GLOBAL EDITION

Chemistry

An Introduction to General, Organic, and Biological Chemistry

THIRTEENTH EDITION

Timberlake

Pearson

CHEMISTRY

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An Introduction to General, Organic, and Biological Chemistry

Thirteenth Edition

Global Edition

Karen Timberlake

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About the Author

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 *An Introduction to General, Organic and Biological Chemistry*, thirteenth edition, she is also the author of *General, Organic, and Biological Chemistry*, fifth edition, with the accompanying *Study Guide and Selected Solutions Manual*, *Laboratory Manual* and *Essentials Laboratory Manual*, and *Basic Chemistry*, fifth edition, with the accompanying *Study Guide and Selected Solutions 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 the 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, which has demonstrated her excellence over time. 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.

When Professor Timberlake is not writing textbooks, she and her husband relax by playing tennis, ballroom dancing, traveling, trying new restaurants, cooking, and taking care of their grandchildren, Daniel and Emily.

DEDICATION

I dedicate this book to

- My husband, Bill, for his patience, loving support, and preparation of late meals
- My 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 me and put purpose in my writing

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-Gyorgyi

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

—Albert Einstein

Preface

Welcome to the thirteenth edition of *An Introduction to General, Organic, and Biological Chemistry.* This chemistry text was written and designed to help you prepare for a career in a health-related profession, such as nursing, dietetics, respiratory therapy, and environmental and agricultural science. This text assumes no prior knowledge of chemistry. My 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 its role in health and the environment. 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 my 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, I 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 Thirteenth Edition

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

- NEW AND UPDATED! **Chapter Openers** provide engaging clinical stories in the health profession and introduce the chemical concepts in each chapter.
- NEW! **Clinical Updates** added at the end of each chapter continue the story of the chapter opener and describe the follow-up treatment.
- NEW! **Engage** feature in the margin asks students to think about the paragraph they are reading and to test their understanding by answering the Engage question, which is related to the topic.
- NEW! **Try It First** 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! **Clinical Applications** added to Practice Problems show the relevance between the chemistry content and medicine and health.
- NEW! **Strategies for Learning Chemistry** are added that utilize successful ways to study and learn chemistry.
- NEW! **TEST** feature added in the margin encourages students to solve related Practice Problems to practice retrieval of content for exams.
- NEW! **Interactive Videos** give students the experience of step-by-step problem solving for problems from the text.
- NEW! **Review** topics placed in the margin at the beginning of a section 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! **Solution Guides** are now included in selected Sample Problems.
- 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! **Practice 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 and develop critical thinking by integrating topics from two or more previous chapters.

Chapter Organization of the Thirteenth Edition

In each textbook I write, I 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 tells the story of a murder and features the work and career of forensic scientists.
- A new Clinical Update feature describes the forensic evidence that helps to solve the murder and includes Clinical Applications.
- "Scientific Method: Thinking Like a Scientist" is expanded to include *law* and *theory*.
- Writing Numbers in Scientific Notation is now a new Section.
- An updated Section titled Studying and Learning Chemistry expands the discussion of strategies that improve learning and understanding of content.
- 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.
- A new Clinical Update describes the patient's status and follow-up visit with his doctor.
- New photos, including an endoscope, propranolol tablets, cough syrup, people exercising, a urine dipstick, and a pint of blood, are added to improve visual introduction to clinical applications of chemistry. Previous art is updated to improve clarity.
- 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.
- New Clinical Applications feature questions about measurements, daily values for minerals and vitamins, equalities and conversion factors for medications.
- New material illustrates how to count significant figures in equalities and in conversion factors used in a problem setup.
- 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, energy in nutrition, and changes of state. 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.
- A new Clinical Update describes the new diet prepared with a dietitian for weight loss.
- 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, and energy values for food.
- Core Chemistry Skills are: Identifying Physical and Chemical Changes, Converting between Temperature Scales, Using Energy Units, Using the Heat Equation, and Calculating Heat for Change of State.
- 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 added to the periodic table. Electron arrangements are written for atoms and the trends in periodic properties are described. Atomic numbers and mass numbers are determined for isotopes. The most abundant isotope of an element is determined by its atomic mass.

- The Chapter Opener and Follow Up feature the work and career of a farmer.
- A new Clinical Update describes the improvement in crop production by the 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.
- The trends in periodic properties are described for valence electrons, atomic size, ionization energy, and metallic character.
- Core Chemistry Skills are: Counting Protons and Neutrons, Writing Atomic Symbols for Isotopes, Writing Electron Arrangements, Identifying Trends in Periodic Properties, and Drawing Lewis Symbols.

Chapter 5, 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 new chapter opener describes a patient with possible coronary heart disease who undergoes a nuclear stress test and features the work and career of a radiation technologist.
- A new Clinical Update discusses the results of cardiac imaging using the radioisotope Tl-201.
- Sample Problems and Practice Problems use nursing and medical examples, including phosphorus-32 for the treatment of leukemia, titanium seeds containing a radioactive isotope implanted in the body to treat cancer, yttrium injections for arthritis pain, and millicuries in a dose of phosphorus-32.
- Core Chemistry Skills are: Writing Nuclear Equations and Using Half-Lives.

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 aspirin as a molecular compound and features the work and career of a pharmacy technician.
- A new Clinical Update describes several types of compounds at a pharmacy and includes Clinical Applications.
- Section 6.6 is now titled "Lewis Structures for Molecules," 6.7 is "Electronegativity and Bond Polarity," 6.8 is "Shapes of Molecules," and 6.9 is "Polarity of Molecules and Intermolecular Forces."
- The term Lewis structure has replaced the term electron-dot formula.
- Updated material on polyatomic ions compares the names of *ate* ions and *ite* ions, the charge of carbonate and hydrogen carbonate, and the formulas and charges of halogen polyatomic ions with oxygen.
- A new art comparing the particles and bonding of ionic compounds and molecular compounds has been added.
- A new flowchart for naming chemical compounds in Section 6.5 shows naming patterns for ionic and molecular compounds.
- Core Chemistry Skills are: Writing Positive and Negative Ions, Writing Ionic Formulas, Naming Ionic Compounds, Writing the Names and Formulas for Molecular Compounds, Drawing Lewis Structures, Using Electronegativity, Predicting Shape, and Identifying Polarity of Molecules and Intermolecular Forces.
- The interchapter problem set, Combining Ideas from Chapters 4 to 6, completes the chapter.

Chapter 7, Chemical Quantities and Reactions, 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 given quantity of an element or a substance. Students learn to balance chemical equations and to recognize the types of chemical reactions: combination, decomposition, single replacement, double replacement, and combustion. Chapter discussion includes Oxidation–Reduction Reactions using real-life examples, including biological reactions, Mole Relationships in Chemical Equations, Mass Calculations for Chemical Reactions, and Energy in Chemical Reactions, which discusses activation energy and energy changes in exothermic and endothermic reactions.

- The chapter opener describes the symptoms of pulmonary emphysema and discusses the career of an exercise physiologist.
- A new Clinical Update explains the treatment for interstitial lung disease.
- Sample Problems and Challenge Problems use nursing and medical examples.
- New expanded art shows visible evidence of a chemical reaction.
- Core Chemistry Skills are: Converting Particles to Moles, Calculating Molar Mass, Using Molar Mass as a Conversion Factor, Balancing a Chemical Equation, Classifying Types of Chemical Reactions, Identifying Oxidized and Reduced Substances, Using Mole–Mole Factors, and Converting Grams to Grams.

Chapter 8, Gases, discusses the properties of gases and calculates changes in gases using the gas laws: Boyle's, Charles's, Gay-Lussac's, Avogadro's, and Dalton's. Problem-solving strategies enhance the discussion and calculations with gas laws.

- The chapter opener features the work and career of a respiratory therapist.
- New Clinical Update describes exercise to prevent exercise-induced asthma. Clinical Applications are related to lung volume and gas laws.
- Sample Problems and Challenge Problems use nursing and medical examples, including, calculating the volume of oxygen gas delivered through a face mask during oxygen therapy, preparing a heliox breathing mixture for a scuba diver, and home oxygen tanks.
- Core Chemistry Skills are: Using the Gas Laws and Calculating Partial Pressure.

Chapter 9, 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 of dilutions and titrations. Properties of solutions, osmosis in the body, 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.

- A new Clinical Update explains dialysis treatment and electrolyte levels in dialysate fluid.
- Art updates include gout and intravenous solutions.
- Table 9.6 on electrolytes in intravenous solutions is expanded.
- Core Chemistry Skills are: Using Solubility Rules, Calculating Concentration, and Using Concentration as a Conversion Factor.
- The interchapter problem set, Combining Ideas from Chapters 7 to 9, completes the chapter.

Chapter 10, Acids and Bases and Equilibrium, discusses acids and bases 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. The reactions of acids and bases with metals, carbonates, and bicarbonates are discussed. 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 chapter opener describes an accident victim with respiratory acidosis and the work and career of a clinical laboratory technician.
- A Clinical Update discusses the symptoms and treatment for acid reflux disease.
- The section "Acid–Base Equilibrium" includes Le Châtelier's principle.
- Clinical Applications include calculating $[OH^-]$ or $[H_3O^+]$ of body fluids, foods, blood plasma, and the pH of body fluids.
- Key Math Skills are: Calculating pH from $[H_3O^+]$ and Calculating $[H_3O^+]$ from pH.
- New Core Chemistry Skills are: Identifying Conjugate Acid–Base Pairs, Using Le Chatelier's Principle, Calculating $[H_3O^+]$ and $[OH^-]$ in Solutions, Writing Equations for Reactions of Acids and Bases, and Calculating Molarity or Volume of an Acid or Base in a Titration.

Chapter 11, Introduction to Organic Chemistry: Hydrocarbons, compares inorganic and organic compounds, and describes the structures and naming of alkanes, alkenes including cis–trans isomers, alkynes, and aromatic compounds.

- The chapter opener describes a fire victim and the search for traces of accelerants and fuel at the arson scene and features the work and career of a firefighter/emergency medical technician.
- A new Clinical Update describes the treatment of burns in the hospital and the types of fuels identified in the fire.
- Wedge–dash models have been added to the representations of methane and ethane.
- Line-angle formulas are now included in Table 11.2 IUPAC Names and Formulas of the First Ten Alkanes.
- Core Chemistry Skills are: Naming and Drawing Alkanes and Writing Equations for Hydrogenation and Hydration.

Chapter 12, Alcohols, Thiols, Ethers, Aldehydes, and Ketones, describes the functional groups and names of alcohols, thiols, ethers, aldehydes, and ketones. The solubility of alcohols, phenols, aldehydes, and ketones in water is discussed.

- A new chapter opener describes the risk factors for melanoma and discusses work and career of a dermatology nurse.
- A new Clinical Update discusses melanoma, skin protection, and functional groups of sunscreens.
- A table Solubility of Selected Aldehydes and Ketones has been updated.
- New material on antiseptics is added.
- The oxidation of methanol in the body is included in the Chemistry Link to Health "Oxidation of Alcohol in the Body."
- Core Chemistry Skills are: Identifying Functional Groups, Naming Alcohols and Phenols, Naming Aldehydes and Ketones, Writing Equations for the Dehydration of Alcohols, and Writing Equations for the Oxidation of Alcohols.
- The interchapter problem set, Combining Ideas from Chapters 10 to 12, completes the chapter.

Chapter 13, Carbohydrates, describes the carbohydrate molecules monosaccharides, disaccharides, and polysaccharides and their formation by photosynthesis. Monosaccharides are classified as aldo or keto pentoses or hexoses. Chiral molecules are discussed along with Fischer projections and D and L notations. Chiral objects are modeled using gumdrops and toothpicks. Carbohydrates used as sweeteners are described and carbohydrates used in blood typing are discussed. The formation of glycosidic bonds in disaccharides and polysaccharides is described.

- A chapter opener describes a diabetes patient and her diet and features the work and career of a diabetes nurse.
- A new Clinical Update describes a diet to lower blood glucose.
- Chiral molecules are discussed and Fischer projections are drawn.
- A new Sample Problem identifies chiral carbons in glycerol and ibuprofen.
- New art shows that insulin needed for the metabolism of glucose is produced in the pancreas.
- Examples of chiral molecules in nature are included to Chemistry Link to Health, "Enantiomers in Biological Systems."
- New Clinical Applications include psicose in foods, lyxose in bacterial glycolipids, xylose in absorption tests, and tagatose in fruit.

- New art shows the rotation of groups on carbon 5 for the Haworth structures of glucose and galactose.
- Drawing Haworth Structures is updated.
- The Chemistry Link to Health "Blood Types and Carbohydrates" has updated structures of the saccharides that determine each blood type.
- Core Chemistry Skills are: Identifying Chiral Molecules, Identifying D and L Fischer Projections, and Drawing Haworth Structures.

Chapter 14, Carboxylic Acids, Esters, Amines, and Amides, discusses the functional groups and naming of carboxylic acids, esters, amines, and amides. Chemical reactions include esterification, amidation, and acid and base hydrolysis of esters and amides.

- A chapter opener describes pesticides and pharmaceuticals used on a ranch and discusses the career of an environmental health practitioner.
- A new Clinical Update describes an insecticide used to spray animals.
- Line-angle structures for carboxylic acids are added to Table 14.1.
- Core Chemistry Skills are: Naming Carboxylic Acids, Hydrolyzing Esters, and Forming Amides.

Chapter 15, Lipids, discusses fatty acids and the formation of ester bonds in triacylglycerols and glycerophospholipids. Chemical properties of fatty acids and their melting points along with the hydrogenation of unsaturated triacylglycerols are discussed. Steroids, such as cholesterol and bile salts, are described. Chemistry Links to Health include "Converting Unsaturated Fats to Saturated Fats: Hydrogenation." The role of phospholipids in the lipid bilayer of cell membranes is discussed as well as the lipids that function as steroid hormones.

- A new chapter opener describes a patient with symptoms of familial hypercholesterolemia and features the work and career of a clinical lipid specialist.
- A new Clinical Update describes a program to lower cholesterol.
- New notation for number of carbon atoms and double bonds in a fatty acid is added.
- New art of unsaturated fatty acids with cis and trans double bonds is added.
- New art of normal and damaged myelin sheath shows deterioration in multiple sclerosis.
- New art of the gallbladder and the bile duct where gallstones pass causing obstruction and pain.
- Core Chemistry Skills are: Identifying Fatty Acids, Drawing Structures for Triacylglycerols, Drawing the Products for the Hydrogenation, Hydrolysis, and Saponification of a Triacylglycerol, and Identifying the Steroid Nucleus.
- The interchapter problem set, Combining Ideas from Chapters 13 to 15, completes the chapter.

Chapter 16, Amino Acids, Proteins, and Enzymes, discusses amino acids, formation of peptide bonds and proteins, structural levels of proteins, enzymes, and enzyme action. The structures of amino acids are drawn at physiological pH. Enzymes are discussed as biological catalysts, along with the impact of inhibitors and denaturation on enzyme action.

- A new chapter opener discusses the symptoms of sickle-cell anemia in a child, the mutation in amino acids that causes the crescent shape of abnormal red blood cells, and the career of a physician assistant.
- The use of electrophoresis to diagnose sickle-cell anemia was added to Chemistry Link to Health "Sickle-Cell Anemia."
- Abbreviations for amino acid names use three letters as well as one letter.
- New ribbon models of beta-amyloid proteins in normal brain and an Alzheimer's brain are added to Chemistry Link to Health "Protein Secondary Structures and Alzheimer's Disease".
- Diagrams illustrate enzyme action and the effect of competitive and noncompetitive inhibitors on enzyme structure.
- Core Chemistry Skills are: Drawing the Structure for an Amino Acid at Physiological pH, Identifying the Primary, Secondary, Tertiary, and Quaternary Structures of Proteins, and Describing Enzyme Action.

Chapter 17, Nucleic Acids and Protein Synthesis, describes the nucleic acids and their importance as biomolecules that store and direct information for the synthesis of cellular components. The role of complementary base pairing is discussed in both DNA replication and the formation of mRNA during protein synthesis. The role of RNA is discussed in the relationship of the genetic code to the sequence of amino acids in a protein. Mutations describe ways in which the nucleotide sequences are altered in genetic diseases.

- A new chapter opener describes a patient's diagnosis and treatment of breast cancer and discusses the work and career of a histology technician.
- A new Clinical Update describes estrogen-positive tumors, the impact of the altered genes BRCA1 and BRCA2 on the estrogen receptor, and medications to suppress tumor growth.
- A new Section discusses recombinant DNA, polymerase chain reaction, and DNA fingerprinting.
- New art illustrates point mutation, deletion mutation, and insertion mutation.
- Core Chemistry Skills are: Writing the Complementary DNA Strand, Writing the mRNA Segment for a DNA Template, and Writing the Amino Acid for an mRNA Codon.

Chapter 18, Metabolic Pathways and ATP Production, describes the metabolic pathways of biomolecules from the digestion of foodstuffs to the synthesis of ATP. The stages of

catabolism and the digestion of carbohydrates along with the coenzymes required in metabolic pathways are described. The breakdown of glucose to pyruvate is described using glycolysis, which is followed by the decarboxylation of pyruvate to acetyl CoA and the entry of acetyl CoA into the citric acid cycle. Electron transport, oxidative phosphorylation, and the synthesis of ATP is described. The oxidation of lipids and the degradation of amino acids are also discussed.

- A new chapter opener describes elevated levels of liver enzymes for a patient with chromic hepatitis C infection and discusses the career of a public health nurse.
- A new Clinical Update describes interferon and ribavirin therapy for hepatitis C.
- Updated art for glycolysis, the citric acid cycle, and electron transport is added.
- The values of ATP produced from the metabolism of glucose, fatty acids, and amino acids is calculated using the updated values of 2.5 ATP for NADH and 1.5 ATP for $FADH_2$.
- Core Chemistry Skills are: Identifying the Compounds in Glycolysis, Describing the Reactions in the Citric Acid Cycle, Calculating the ATP Produced from Glucose, and Calculating the ATP from Fatty Acid Oxidation (β Oxidation).
- The interchapter problem set, Combining Ideas from Chapters 16 to 18, completes the chapter.

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

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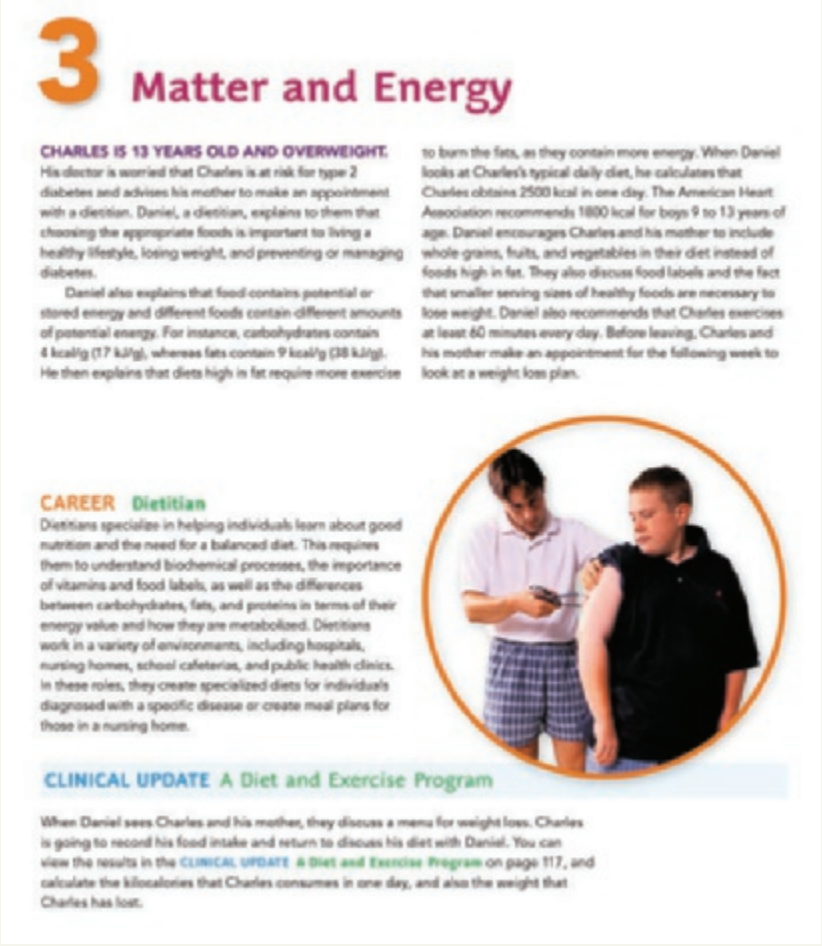
Instructor and Student Supplements

Chemistry: An Introduction to General, Organic, and Biological Chemistry, thirteenth 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
Mastering™ Chemistry (www.masteringchemistry.com)		✓	Supplement for Students and Instructors	This product includes all of the resources of Mastering™ Chemistry. Mastering™ Chemistry from Pearson is the leading online homework, tutorial, and assessment system, designed to improve results by engaging students with powerful content. Instructors ensure students arrive ready to learn by assigning educationally effective content and encourage critical thinking and retention with in-class resources such as Learning Catalytics™. Students can further master concepts through traditional and adaptive homework assignments that provide hints and answer specific feedback. The Mastering™ gradebook records scores for all assignments in one place, while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions. http://www.masteringchemistry.com.
Pearson eText		✓	Supplement for Students	The thirteenth edition of *Chemistry: An Introduction to General, Organic, and Biological Chemistry* features a Pearson eText within Mastering. In conjunction with Mastering assessment capabilities, new **Interactive Videos and 3D animations** will improve student engagement and knowledge retention. Each chapter contains a balance of interactive animations, videos, sample calculations, and self-assessments / quizzes. Icons in the margins throughout the text signify that there is a new **Interactive Video** or animation located within Mastering™ Chemistry for *Chemistry: An Introduction to General, Organic, and Biological Chemistry*, thirteenth edition.
Laboratory Manual by Karen Timberlake (9780321811851)	✓		Supplement for Students	This best-selling lab manual coordinates 35 experiments with the topics in *Chemistry: An Introduction to General, Organic, and Biological Chemistry*, thirteenth edition, uses laboratory investigations to explore chemical concepts, develop skills of manipulating equipment, reporting data, solving problems, making calculations, and drawing conclusions.
Instructor's Solutions Manual		✓	Supplement for Instructors	Prepared by Mark Quirie, the Instructor's Solutions Manual highlights chapter topics, and includes answers and solutions for all Practice Problems in the text.
Instructor Resource Materials–Download Only		✓	Supplement 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 visit the Pearson Education catalog page for Timberlake's *Chemistry: An Introduction to General, Organic, Biological Chemistry*, thirteenth edition, at www.pearsonglobaleditions.com/timberlake to download available instructor supplements.
TestGen Test Bank-Download Only		✓	Supplement for Instructors	Prepared by William Timberlake, this resource includes more than 1600 questions in multiple-choice, matching, true/false, and short-answer format.
Online Instructor Manual for Laboratory Manual		✓	Supplement for Instructors	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.pearsonglobaleditions.com/timberlake.

Career Focus Engages Students

Best-selling author Karen Timberlake connects chemistry to real-world and career applications like no one else. The 13th edition of *Chemistry: An Introduction to General, Organic, and Biological Chemistry* engages students by helping them to see the connections between chemistry, the world around them, and future careers.



3 Matter and Energy

CHARLES IS 13 YEARS OLD AND OVERWEIGHT. His doctor is worried that Charles is at risk for type 2 diabetes and advises his mother to make an appointment with a dietitian. Daniel, a dietitian, explains to them that choosing the appropriate foods is important to living a healthy lifestyle, losing weight, and preventing or managing diabetes.

Daniel also explains that food contains potential or stored energy and different foods contain different amounts of potential energy. For instance, carbohydrates contain 4 kcal/g (17 kJ/g), whereas fats contain 9 kcal/g (38 kJ/g). He then explains that diets high in fat require more exercise to burn the fats, as they contain more energy. When Daniel looks at Charles's typical daily diet, he calculates that Charles obtains 2500 kcal in one day. The American Heart Association recommends 1800 kcal for boys 9 to 13 years of age. Daniel encourages Charles and his mother to include whole grains, fruits, and vegetables in their diet instead of foods high in fat. They also discuss food labels and the fact that smaller serving sizes of healthy foods are necessary to lose weight. Daniel also recommends that Charles exercises at least 60 minutes every day. Before leaving, Charles and his mother make an appointment for the following week to look at a weight loss plan.

CAREER Dietitian

Dietitians specialize in helping individuals learn about good nutrition and the need for a balanced diet. This requires them to understand biochemical processes, the importance of vitamins and food labels, as well as the differences between carbohydrates, fats, and proteins in terms of their energy value and how they are metabolized. Dietitians work in a variety of environments, including hospitals, nursing homes, school cafeterias, and public health clinics. In these roles, they create specialized diets for individuals diagnosed with a specific disease or create meal plans for those in a nursing home.

CLINICAL UPDATE A Diet and Exercise Program

When Daniel sees Charles and his mother, they discuss a menu for weight loss. Charles is going to record his food intake and return to discuss his diet with Daniel. You can view the results in the CLINICAL UPDATE A Diet and Exercise Program on page 117, and calculate the kilocalories that Charles consumes in one day, and also the weight that Charles has lost.

Chapter Openers emphasize clinical connections by showing students relevant, engaging, topical examples of how health professionals use chemistry everyday. Clinical Updates at the end of each chapter relate the chemistry the student learns in the chapter to expand the clinical content in the Chapter Opener and include clinical applications.

Chemistry Links to Health, woven throughout each chapter, apply chemical concepts to topics in health and medicine such as weight loss and weight gain, alcohol abuse, blood buffers, and kidney dialysis, illustrating the importance of understanding chemistry in real-life situations.

CHEMISTRY LINK TO HEALTH

Breathing Mixtures

The air we breathe is composed mostly of the gases oxygen (21%) and nitrogen (79%). The homogeneous breathing mixtures used by scuba divers differ from the air we breathe depending on the depth of the dive. Nitrox is a mixture of oxygen and nitrogen, but with more oxygen gas (up to 32%) and less nitrogen gas (68%) than air. A breathing mixture with less nitrogen gas decreases the risk of *nitrogen narcosis* associated with breathing regular air while diving. Heliox contains oxygen and helium, which is typically used for diving to more than 200 ft. By replacing nitrogen with helium, nitrogen narcosis does not occur. However, at dive depths over 300 ft, helium is associated with severe shaking and a drop in body temperature.

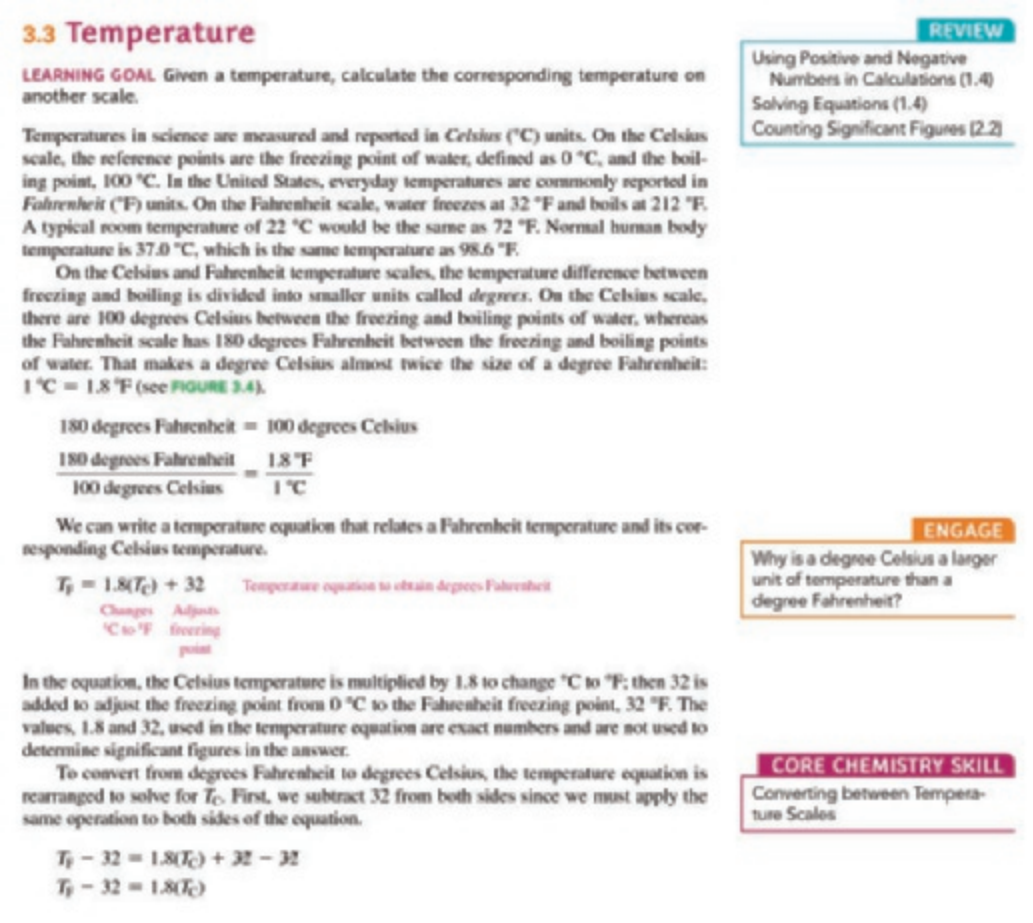
A breathing mixture used for dives over 400 ft is trimix, which contains oxygen, helium, and some nitrogen. The addition of some nitrogen lessens the problem of shaking that comes with breathing high levels of helium. Heliox and trimix are used only by professional, military, or other highly trained divers.

In hospitals, heliox may be used as a treatment for respiratory disorders and lung constriction in adults and premature infants. Heliox is less dense than air, which reduces the effort of breathing and helps distribute the oxygen gas to the tissues.

A nitrox mixture is used to fill scuba tanks.

Builds Students' Critical-Thinking and Problem-Solving Skills

One of Karen Timberlake's goals is to help students to become critical thinkers. Color-coded tips found throughout each chapter are designed to provide guidance and to encourage students to really think about what they are reading, helping to develop important critical-thinking skills.



3.3 Temperature

LEARNING GOAL Given a temperature, calculate the corresponding temperature on another scale.

Temperatures in science are measured and reported in *Celsius* (°C) units. On the Celsius scale, the reference points are the freezing point of water, defined as 0 °C, and the boiling point, 100 °C. In the United States, everyday temperatures are commonly reported in *Fahrenheit* (°F) units. On the Fahrenheit scale, water freezes at 32 °F and boils at 212 °F. A typical room temperature of 22 °C would be the same as 72 °F. Normal human body temperature is 37.0 °C, which is the same temperature as 98.6 °F.

On the Celsius and Fahrenheit temperature scales, the temperature difference between freezing and boiling is divided into smaller units called *degrees*. On the Celsius scale, there are 100 degrees Celsius between the freezing and boiling points of water, whereas the Fahrenheit scale has 180 degrees Fahrenheit between the freezing and boiling points of water. That makes a degree Celsius almost twice the size of a degree Fahrenheit: 1 °C = 1.8 °F (see FIGURE 3.4).

$$180 \text{ degrees Fahrenheit} = 100 \text{ degrees Celsius}$$

$$\frac{180 \text{ degrees Fahrenheit}}{100 \text{ degrees Celsius}} = \frac{1.8 \text{ °F}}{1 \text{ °C}}$$

We can write a temperature equation that relates a Fahrenheit temperature and its corresponding Celsius temperature.

$$T_F = 1.8(T_C) + 32$$

Temperature equation to obtain degrees Fahrenheit

Changes °C to °F; Adjusts freezing point

In the equation, the Celsius temperature is multiplied by 1.8 to change °C to °F; then 32 is added to adjust the freezing point from 0 °C to the Fahrenheit freezing point, 32 °F. The values, 1.8 and 32, used in the temperature equation are exact numbers and are not used to determine significant figures in the answer.

To convert from degrees Fahrenheit to degrees Celsius, the temperature equation is rearranged to solve for T_C. First, we subtract 32 from both sides since we must apply the same operation to both sides of the equation.

$$T_F - 32 = 1.8(T_C) + 32 - 32$$
$$T_F - 32 = 1.8(T_C)$$

REVIEW

Using Positive and Negative Numbers in Calculations (1.4)
Solving Equations (1.4)
Counting Significant Figures (2.2)

ENGAGE

Why is a degree Celsius a larger unit of temperature than a degree Fahrenheit?

CORE CHEMISTRY SKILL

Converting between Temperature Scales

NEW! Review Feature lists the core chemistry skills and key math skills from previous chapters which provide the foundation for learning the new chemistry principles in the current chapter.

NEW! Engage Feature asks students to think about the paragraph they are reading and immediately test their understanding by answering the Engage question, which is related to the topic. Students connect new concepts to prior knowledge to increase retrieval of content.

UPDATED! Core Chemistry Skills found throughout the chapter identify the fundamental chemistry concepts that students need to understand in the current chapter.

Four NEW problem solving features enhance Karen Timberlake's unmatched problem-solving strategies and help students deepen their understanding of content while improving their problem-solving skills.

NEW! Try It First 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! Solution Guide provides **STEPS** for successful Problem Solving within the Sample Problem.

SAMPLE PROBLEM 3.7 Using Specific Heat

TRY IT FIRST

During surgery or when a patient has suffered a cardiac arrest or stroke, lowering the body temperature will reduce the amount of oxygen needed by the body. Some methods used to lower body temperature include cooled saline solution, cool water blankets, or cooling caps worn on the head. How many kilojoules are lost when the body temperature of a surgery patient with a blood volume of 5500 mL is cooled from 38.5 °C to 33.2 °C? (Assume that the specific heat and density of blood are the same as for water.)

A cooling cap lowers the body temperature to reduce the oxygen required by the tissues.

SOLUTION GUIDE

STEP 1 State the given and needed quantities.

	Given	Need	Connect
ANALYZE THE PROBLEM	5500 mL of blood = 5500 g of blood, cooled from 38.5 °C to 33.2 °C	kilojoules removed	heat equation, specific heat of water

STEP 2 Calculate the temperature change (ΔT).

$$\Delta T = 38.5\,^{\circ}\text{C} - 33.2\,^{\circ}\text{C} = 5.3\,^{\circ}\text{C}$$

STEP 3 Write the heat equation and needed conversion factors.

$$\text{Heat} = m \times \Delta T \times SH$$

$$SH_{water} = \frac{4.184\ \text{J}}{\text{g}\,^{\circ}\text{C}} \qquad \frac{4.184\ \text{J}}{\text{g}\,^{\circ}\text{C}} \text{ and } \frac{\text{g}\,^{\circ}\text{C}}{4.184\ \text{J}}$$

$$1\ \text{kJ} = 1000\ \text{J} \qquad \frac{1000\ \text{J}}{1\ \text{kJ}} \text{ and } \frac{1\ \text{kJ}}{1000\ \text{J}}$$

STEP 4 Substitute in the given values and calculate the heat, making sure units cancel.

$$\text{Heat} = 5500\ \text{g} \times 5.3\,^{\circ}\text{C} \times \frac{4.184\ \text{J}}{\text{g}\,^{\circ}\text{C}} \times \frac{1\ \text{kJ}}{1000\ \text{J}} = 120\ \text{kJ}$$

(Two SFs) (Two SFs) (Four SFs, Exact) (Exact) (Two SFs)

STUDY CHECK 3.7

Some cooking pans have a layer of copper on the bottom. How many kilojoules are needed to raise the temperature of 125 g of copper from 22 °C to 325 °C (see Table 3.11)?

ANSWER

14.6 kJ

The copper on a pan conducts heat rapidly to the food in the pan.

TEST

Try Practice Problems 3.39 to 3.42

NEW! Test Feature added in the margin encourages students to solve related Practice Problems to practice retrieval of content for exams.

Continuous Learning
Before, During, and After Class

BEFor E CLASS

Chemistry Primer

NEW! **Chemistry Primer** is a series of tutorials focused on remediating students taking their first college chemistry course. Topics include math in the context of chemistry, chemical skills and literacy, as well as some basics of balancing chemical equations, mole–mole factors, and mass–mass calculations—all of which were chosen based on extensive surveys of chemistry professors across the country.

The main body of each item in the primer offers diagnostic questions designed to help students recognize that they need help. If they struggle, the primer offers extensive formative help in the hint structure via wrong answer feedback, instructional videos, and step-wise worked examples that provide scaffolding to build up students' understanding as needed. The primer is offered as a pre-built assignment that is automatically generated with all chemistry courses.

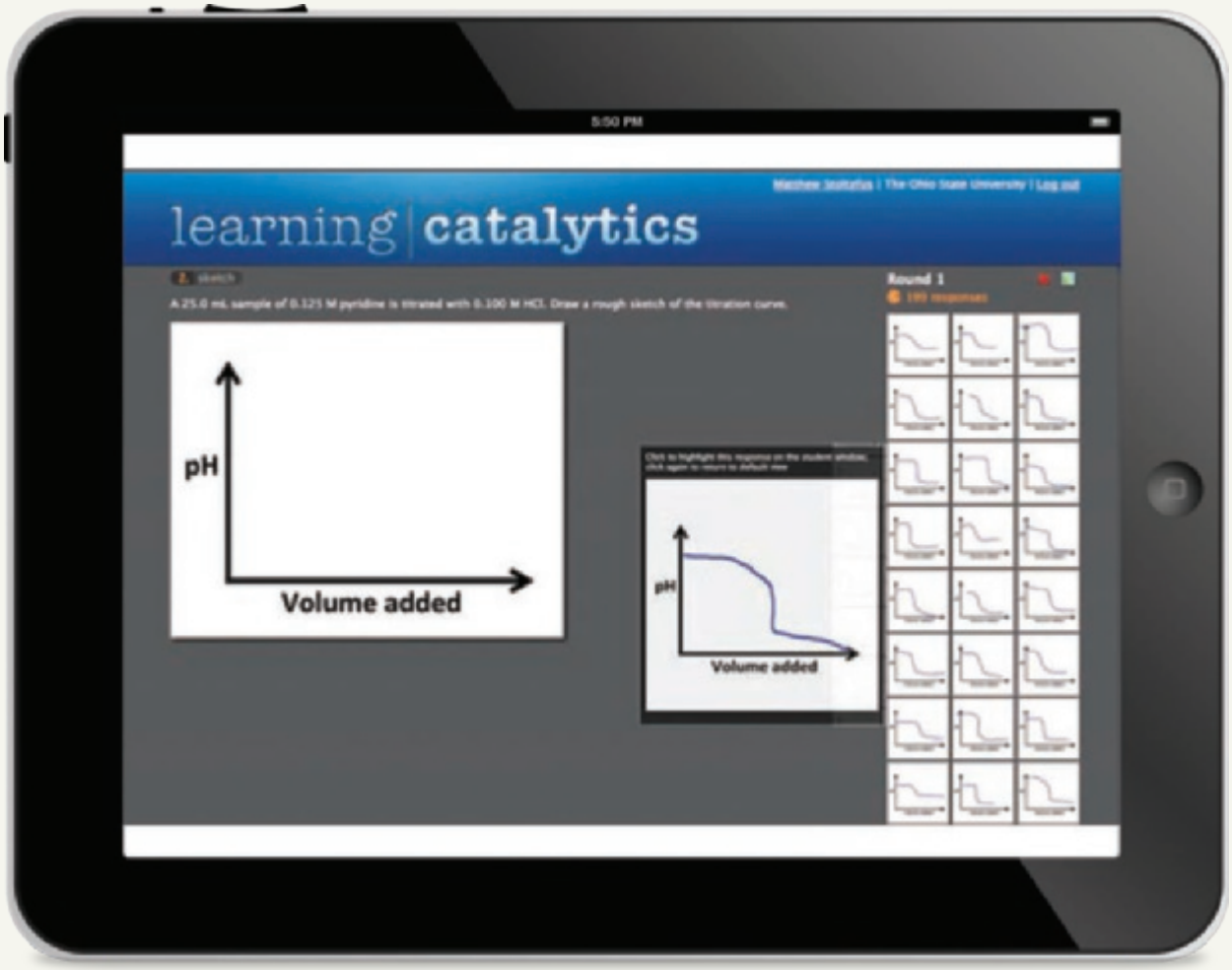
with Mastering™ Chemistry

During C LASS

Learning Catalytics

Learning Catalytics generates class discussion, guides your lecture, and promotes peer-to-peer learning with real-time analytics. Mastering™ Chemistry with eText now provides Learning Catalytics—an interactive student response tool that uses students' smartphones, tablets, or laptops to engage them in more sophisticated tasks and thinking. Instructors can:

- **NEW!** Upload a full PowerPoint® deck for easy creation of slide questions.
- Help students develop critical thinking skills.
- Monitor responses to find out where students are struggling
- Rely on real-time data to adjust teaching strategies.
- Automatically group students for discussion, teamwork, and peer-to-peer learning.

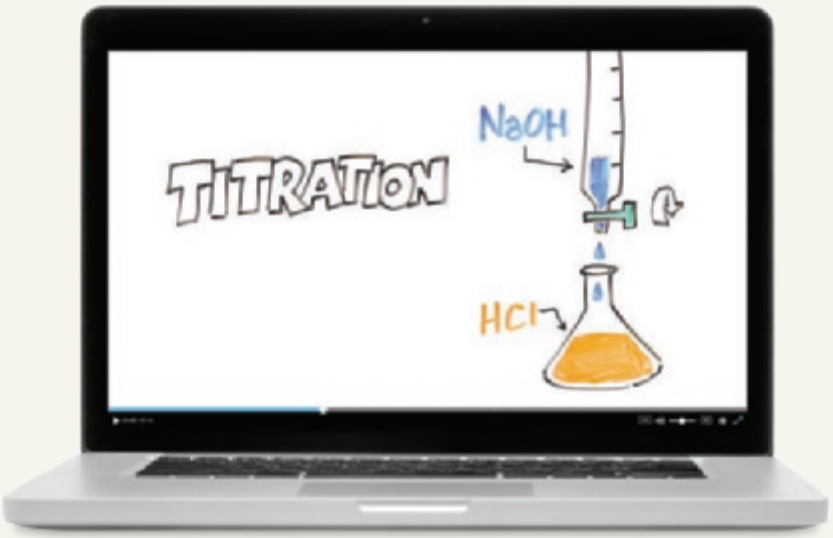


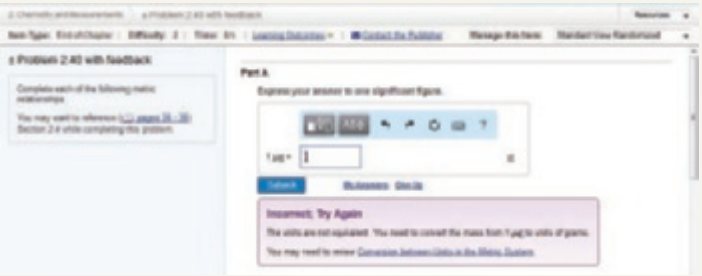
Mastering™ Chemistry

AFTEr C LASS

NEW! **Interactive Videos** clarify and reinforce important concepts such as solving equations, conversion factors, solutions, and more. Sample Calculations now correspond to a key concept/ topic in most chapters, giving 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.

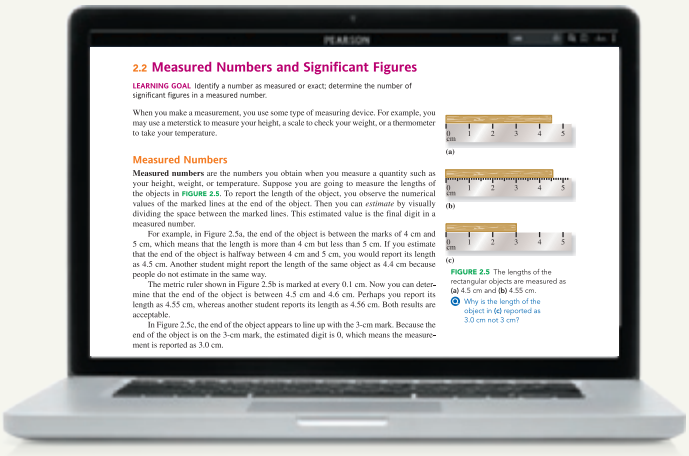
Mastering™ Chemistry offers a wide variety of problems, ranging from multi-step tutorials with extensive hints and feedback to multiple-choice End-of-Chapter Problems and Test Bank questions.





Wrong-answer feedback supports students moving from Tutorial Problems to End-of-Chapter Problems.

Pearson eText



Pearson eText

- Seamlessly integrated videos and activities allow students to watch and practice key concepts within the eText learning experience.
- Study Check Questions allow students to interact in Pearson eText with the questions which follow each Sample Problem. With one click, these activities are brought to life, allowing students to study on their own and test their understanding in real-time. These interactives help students extinguish misconceptions and enhance their problem-solving skills.

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1 Chemistry in Our Lives

A CALL CAME IN TO 911 FROM A MAN WHO arrived home from work to find his wife lying on the floor of their home. When the police arrived, they prounouced the woman dead. 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, the police found a half-empty bottle of antifreeze, which contains the toxic compound ethylene glycol. 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 analyzes 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, analyzes 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.

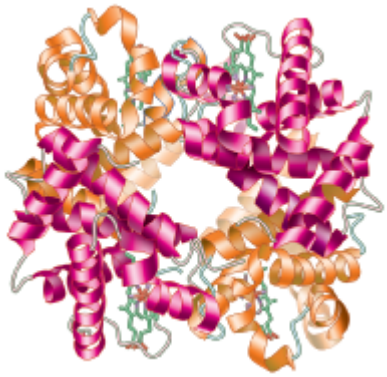
CAREER Forensic Scientist

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 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.

CLINICAL UPDATE Forensic Evidence Helps Solve the Crime

In the forensic laboratory, Sarah analyzes the victim's stomach contents and blood for toxic compounds. You can view the results of the tests on the forensic evidence in the **CLINICAL UPDATE Forensic Evidence Helps Solve the Crime**, page 49, and determine if the victim ingested a toxic level of ethylene glycol (antifreeze).

LOOKING AHEAD



In the blood, hemoglobin transports oxygen to the tissues and carbon dioxide to the lungs.

Antacid tablets undergo a chemical reaction when dropped into water.

ENGAGE

Why is water a chemical?

Toothpaste is a combination of many chemicals.

TEST

Try Practice Problems 1.1 to 1.6

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 what hemoglobin does in the blood or how aspirin relieves a headache. Just like you, chemists are curious about the world we live in.

What does hemoglobin do in the body? Hemoglobin consists of four polypeptide chains, each containing a heme group with an iron atom that binds to oxygen (O_2) in the lungs. From the lungs, hemoglobin transports oxygen to the tissues of the body where it is used to provide energy. Once the oxygen is released, hemoglobin binds to carbon dioxide (CO_2) for transport to the lungs where it is released.

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 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 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. 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. 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 with fluoride
Methyl salicylate	Gives toothpaste a pleasant wintergreen flavor

PRACTICE 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 *Practice Problems* are paired with even-numbered exercises. The answers for the magenta, odd-numbered *Practice Problems* are given at the end of each chapter.

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?

Clinical 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?

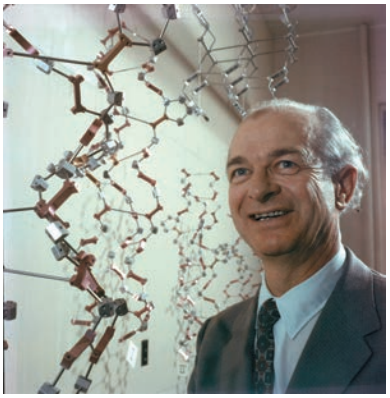
1.6 Name the key components of each of the following:
a. vinegar **b.** alcohol disinfectant pads

1.2 Scientific Method: Thinking Like a Scientist

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

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 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.

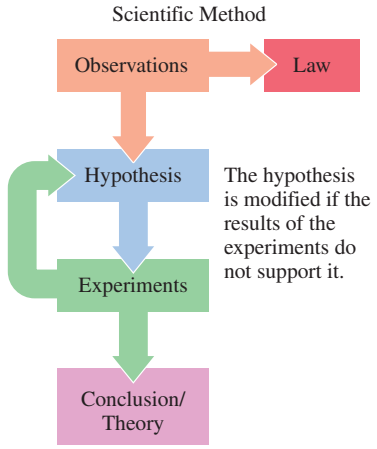


Linus Pauling won the Nobel Prize in Chemistry in 1954.

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.

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



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

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 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 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 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.

ENGAGE

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?

Nurses make observations in the hospital.

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.

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

STUDY CHECK 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.

ANSWER

a. observation **b.** experiment **c.** hypothesis

TEST

Try Practice Problems 1.7 to 1.10

PRACTICE PROBLEMS

1.2 Scientific Method: Thinking Like a Scientist

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

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:

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. 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.

1.8 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.

Clinical 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 something 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 evaluation of study habits depends on their value in helping 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 that we can retrieve. This can be accomplished by developing study habits that involve a lot of practice testing ourselves on how 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 how to differentiate 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. In the long run, you retain and retrieve more information, making your study for exams less stressful.

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. For example, you might ask yourself how the new material is related to previous material, which helps you make connections. 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.
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

Why is self-testing helpful for learning new concepts?

SAMPLE PROBLEM 1.2 Strategies for Learning Chemistry

TRY IT FIRST

Predict which student will obtain the best exam score.

a. A student who reads the chapter four times.
b. A student who reads the chapter two times and works all the problems at the end of each Section.
c. A student who reads the chapter the night before the exam.

SOLUTION

b. A student who reads the chapter two times and works all the problems at the end of each Section has interacted with the content in the chapter using self-testing to make connections between concepts and practicing retrieving information learned previously.

STUDY CHECK 1.2

What is another way that student **b** in Sample Problem 1.2 could improve his or her retrieval of information?

ANSWER

Student **b** in Sample Problem 1.2 could also wait two or three days and practice working the problems in each Section again to determine how much he or she has learned. Retesting strengthens connections between new and previously learned information for longer lasting memory and more efficient retrieval.

Features in This Text That Help You Study and Learn 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.

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 each Section, a *Learning Goal* states what you need to understand and a *Review* box lists the Key Math Skills and Core Chemistry Skills from previous chapters that relate to new material in the chapter. As you read the text, you will see *Engage* features in the margin, which remind you to pause your reading and test yourself with a question related to the material.

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. The *Analyze the Problem* feature includes *Given*, the information you have; *Need*, what you have to accomplish; and *Connect*, how you proceed. It is helpful to try to work a problem first because it helps you link what you know to what you need to learn. This process will help you develop successful problem-solving techniques. Many Sample Problems include a *Solution Guide* that shows the steps you can use for problem solving. Work the associated *Study Check* 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

KEY MATH SKILL

CORE CHEMISTRY SKILL

REVIEW

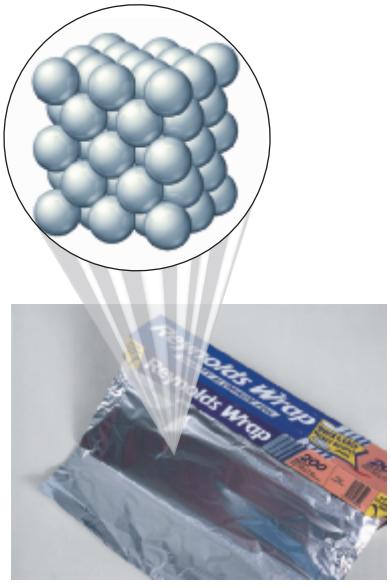
ENGAGE

What is the purpose of an Engage question?

TRY IT FIRST

ANALYZE THE PROBLEM	Given	Need	Connect
	165 lb	kilograms	conversion factor

TEST



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

INTERACTIVE VIDEO

Section, *Test* suggestions remind you to solve the indicated Practice Problems as you study. The *Clinical Applications* in the Practice Problems relate the content to health and medicine. 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. *Answers* to all of the odd-numbered problems complete the chapter allowing you to 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.

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.

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 *Test* problems as I read each Section
_____ answering the *Engage* questions
_____ trying to work the *Sample Problem* before looking at the *Solution*
_____ working the *Practice Problems* at the end of each Section and checking answers
_____ 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

Studying in a group can be beneficial to learning.

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. self-testing during and after reading each Section
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

Your success in chemistry can be improved by:

b. going to the professor's office hours
c. self-testing during and after reading each Section
e. trying to work the Sample Problem before looking at the Solution
f. retesting on new information a few days later

STUDY CHECK 1.3

Which of the following will help you learn chemistry?

a. skipping review sessions
b. working problems as you read a Section
c. staying up all night before an exam
d. reading the assignment before class

ANSWER

b and **d**

TEST

Try Practice Problems 1.11 to 1.14

PRACTICE PROBLEMS

1.3 Studying and Learning Chemistry

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

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

1.12 What are three safety precautions you can take while working in the laboratory?

1.13 A student in your class asks you for advice on learning chemistry. In what order would you give the bits of advice mentioned below:
a. Work on the Q&A for each section and check the answers at the end.
b. Read the chapter before the class lecture.
c. Be an active learner during the class lecture.
d. Review key core chemistry skills.

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.

KEY MATH SKILL

Identifying Place Values

Identifying Place Values

For any number, we can identify the *place value* for each of the digits in that number. These place values have names such as the ones place (first place to the left of the decimal point) or the tens place (second place to the left of the decimal point). A premature baby has a mass of 2518 g. We can indicate the place values for the number 2518 as follows:

Digit	Place Value
2	thousands
5	hundreds
1	tens
8	ones

ENGAGE

In the number 8.034, how do you know the 0 is in the tenths place?

We also identify place values such as the tenths place (first place to the right of the decimal point) and the hundredths place (second place to the right of the decimal point). A silver coin has a mass of 6.407 g. We can indicate the place values for the number 6.407 as follows:

Digit	Place Value
6	ones
4	ten**ths**
0	hundred**ths**
7	thousand**ths**

Note that place values ending with the suffix *ths* refer to the decimal places to the right of the decimal point.

SAMPLE PROBLEM 1.4 Identifying Place Values

TRY IT FIRST

A bullet found at a crime scene has a mass of 15.24 g. What are the place values for each of the digits in the mass of the bullet?

SOLUTION

Digit	Place Value
1	tens
5	ones
2	tenths
4	hundredths

STUDY CHECK 1.4

A bullet found at a crime scene contains 0.925 g of lead. What are the place values for each of the digits in the mass of the lead?

ANSWER

Digit	Place Value
9	tenths
2	hundredths
5	thousandths

TEST

Try Practice Problems 1.15 and 1.16

Using Positive and Negative Numbers in Calculations

KEY MATH SKILL

Using Positive and Negative Numbers in Calculations

A *positive number* is any number that is greater than zero and has a positive sign (+). Often the positive sign is understood and not written in front of the number. For example, the number +8 can also be written as 8. A *negative number* is any number that is less than zero and is written with a negative sign (−). For example, a negative eight is written as −8.

Multiplication and Division of Positive and Negative Numbers

When two positive numbers or two negative numbers are multiplied, the answer is positive (+).

$$2 \times 3 = +6$$
$$(-2) \times (-3) = +6$$

When a positive number and a negative number are multiplied, the answer is negative (−).

$$2 \times (-3) = -6$$
$$(-2) \times 3 = -6$$

The rules for the division of positive and negative numbers are the same as the rules for multiplication. When two positive numbers or two negative numbers are divided, the answer is positive (+).

$$\frac{6}{3} = 2 \qquad \frac{-6}{-3} = 2$$

When a positive number and a negative number are divided, the answer is negative (−).

$$\frac{-6}{3} = -2 \qquad \frac{6}{-3} = -2$$

Addition of Positive and Negative Numbers

When positive numbers are added, the sign of the answer is positive.

$3 + 4 = 7$ The + sign (+7) is understood.

When negative numbers are added, the sign of the answer is negative.

$(-3) + (-4) = -7$

When a positive number and a negative number are added, the smaller number is subtracted from the larger number, and the result has the same sign as the larger number.

$12 + (-15) = -3$

ENGAGE

Why does $(-5) + 4 = -1$, whereas $(-5) + (-4) = -9$?

Subtraction of Positive and Negative Numbers

When two numbers are subtracted, change the sign of the number to be subtracted and follow the rules for addition shown above.

$$12 - (+5) = 12 - 5 = 7$$
$$12 - (-5) = 12 + 5 = 17$$
$$-12 - (-5) = -12 + 5 = -7$$
$$-12 - (+5) = -12 - 5 = -17$$

TEST

Try Practice Problems 1.17 and 1.18

Calculator Operations

On your calculator, there are four keys that are used for basic mathematical operations. The change sign [+/−] key is used to change the sign of a number.

To practice these basic calculations on the calculator, work through the problem going from the left to the right doing the operations in the order they occur. If your calculator has a change sign [+/−] key, a negative number is entered by pressing the number and then pressing the change sign [+/−] key. At the end, press the equals [=] key or ANS or ENTER.

Addition and Subtraction

Example 1: $15 - 8 + 2 =$

Solution: 15 [−] 8 [+] 2 [=] 9

Example 2: $4 + (-10) - 5 =$

Solution: 4 [+] 10 [+/−] [−] 5 [=] −11

Multiplication and Division

Example 3: $2 \times (-3) =$

Solution: 2 [×] 3 [+/−] [=] −6

Example 4: $\frac{8 \times 3}{4} =$

Solution: 8 [×] 3 [÷] 4 [=] 6

KEY MATH SKILL

Calculating Percentages

ENGAGE

Why is the value of 100% used in the calculation of a percentage?

Calculating Percentages

To determine a percentage, divide the parts by the total (whole) and multiply by 100%. For example, if an aspirin tablet contains 325 mg of aspirin (active ingredient) and the tablet has a mass of 545 mg, what is the percentage of aspirin in the tablet?

$$\frac{325 \text{ mg aspirin}}{545 \text{ mg tablet}} \times 100\% = 59.6\% \text{ aspirin}$$

When a value is described as a percentage (%), it represents the number of parts of an item in 100 of those items. If the percentage of red balls is 5, it means there are 5 red balls in every 100 balls. If the percentage of green balls is 50, there are 50 green balls in every 100 balls.

$$5\% \text{ red balls} = \frac{5 \text{ red balls}}{100 \text{ balls}} \qquad 50\% \text{ green balls} = \frac{50 \text{ green balls}}{100 \text{ balls}}$$

A bullet casing at a crime scene is marked as evidence.

SAMPLE PROBLEM 1.5 Calculating a Percentage

TRY IT FIRST

A bullet found at a crime scene may be used as evidence in a trial if the percentage of metals is a match to the composition of metals in a bullet from the suspect's ammunition. If a bullet found at a crime scene contains 13.9 g of lead, 0.3 g of tin, and 0.9 g of antimony, what is the percentage of each metal in the bullet? Express your answers to the ones place.

SOLUTION

$$\text{Total mass} = 13.9 \text{ g} + 0.3 \text{ g} + 0.9 \text{ g} = 15.1 \text{ g}$$

Percentage of lead

$$\frac{13.9 \text{ g}}{15.1 \text{ g}} \times 100\% = 92\% \text{ lead}$$

Percentage of tin

$$\frac{0.3 \text{ g}}{15.1 \text{ g}} \times 100\% = 2\% \text{ tin}$$

Percentage of antimony

$$\frac{0.9 \text{ g}}{15.1 \text{ g}} \times 100\% = 6\% \text{ antimony}$$

STUDY CHECK 1.5

A bullet seized from the suspect's ammunition has a composition of lead 11.6 g, tin 0.5 g, and antimony 0.4 g.

a. What is the percentage of each metal in the bullet? Express your answers to the ones place.
b. Could the bullet removed from the suspect's ammunition be considered as evidence that the suspect was at the crime scene mentioned in Sample Problem 1.5?

ANSWER

a. The bullet from the suspect's ammunition is lead 93%, tin 4%, and antimony 3%.
b. The composition of this bullet does not match the bullet from the crime scene and cannot be used as evidence.

TEST

Try Practice Problems 1.19 and 1.20

Solving Equations

KEY MATH SKILL

Solving Equations

In chemistry, we use equations that express the relationship between certain variables. Let's look at how we would solve for x in the following equation:

$$2x + 8 = 14$$

Our overall goal is to rearrange the items in the equation to obtain x on one side.

ENGAGE

Why is the number 8 subtracted from both sides of this equation?

1. *Place all like terms on one side.* The numbers 8 and 14 are like terms. To remove the 8 from the left side of the equation, we subtract 8. To keep a balance, we need to subtract 8 from the 14 on the other side.

$$\begin{aligned} 2x + \cancel{8} - \cancel{8} &= 14 - 8 \\ 2x &= 6 \end{aligned}$$

2. *Isolate the variable you need to solve for.* In this problem, we obtain x by dividing both sides of the equation by 2. The value of x is the result when 6 is divided by 2.

$$\begin{aligned} \frac{\cancel{2}x}{\cancel{2}} &= \frac{6}{2} \\ x &= 3 \end{aligned}$$

3. *Check your answer.* Check your answer by substituting your value for x back into the original equation.

$$\begin{aligned} 2(3) + 8 &= 14 \\ 6 + 8 &= 14 \\ 14 &= 14 \end{aligned}$$ Your answer $x = 3$ is correct.

Summary: To solve an equation for a particular variable, be sure you perform the same mathematical operations on *both* sides of the equation.

If you eliminate a symbol or number by subtracting, you need to subtract that same symbol or number on the opposite side.

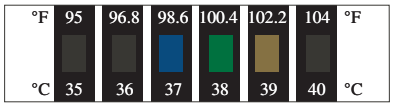
If you eliminate a symbol or number by adding, you need to add that same symbol or number on the opposite side.

If you cancel a symbol or number by dividing, you need to divide both sides by that same symbol or number.

If you cancel a symbol or number by multiplying, you need to multiply both sides by that same symbol or number.

When we work with temperature, we may need to convert between degrees Celsius and degrees Fahrenheit using the following equation:

$$T_F = 1.8(T_C) + 32$$



A plastic strip thermometer changes color to indicate body temperature.

To obtain the equation for converting degrees Fahrenheit to degrees Celsius, we subtract 32 from both sides.

$$T_F = 1.8(T_C) + 32$$
$$T_F - 32 = 1.8(T_C) + \cancel{32} - \cancel{32}$$
$$T_F - 32 = 1.8(T_C)$$

To obtain T_C by itself, we divide both sides by 1.8.

$$\frac{T_F - 32}{1.8} = \frac{\cancel{1.8}(T_C)}{\cancel{1.8}} = T_C$$

SAMPLE PROBLEM 1.6 Solving Equations

TRY IT FIRST

Solve the following equation for V_2:

$$P_1V_1 = P_2V_2$$

INTERACTIVE VIDEO
Solving Equations

SOLUTION

$$P_1V_1 = P_2V_2$$

ENGAGE
Why is the numerator divided by P_2 on both sides of the equation?

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

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

STUDY CHECK 1.6

Solve the following equation for m:

$$\text{heat} = m \times \Delta T \times SH$$

ANSWER

$$m = \frac{\text{heat}}{\Delta T \times SH}$$

TEST
Try Practice Problems 1.21 and 1.22

Interpreting Graphs

KEY MATH SKILL
Interpreting Graphs

A graph represents the relationship between two variables. These quantities are plotted along two perpendicular axes, which are the x axis (horizontal) and y axis (vertical).

Example

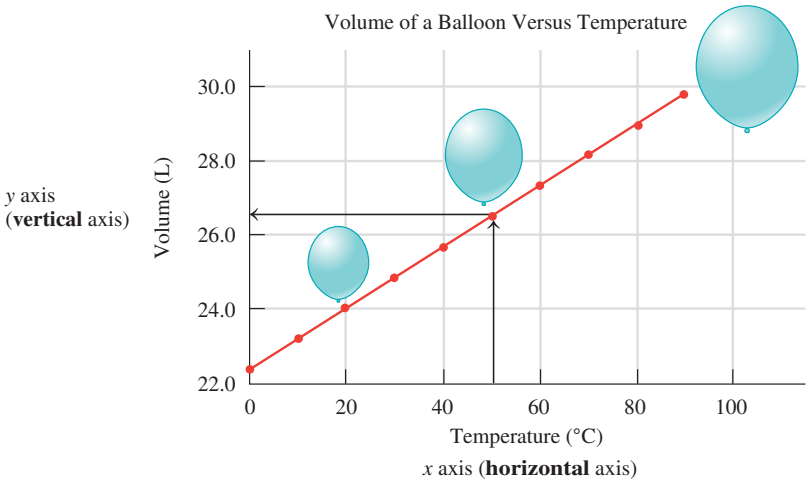
In the graph Volume of a Balloon Versus Temperature, the volume of a gas in a balloon is plotted against its temperature.

Title

Look at the title. What does it tell us about the graph? The title indicates that the volume of a balloon was measured at different temperatures.

Vertical Axis

Look at the label and the numbers on the vertical (y) axis. The label indicates that the volume of the balloon was measured in liters (L). The numbers, which are chosen to include the low and high measurements of the volume of the gas, are evenly spaced from 22.0 L to 30.0 L.



ENGAGE

Why are the numbers on the vertical and horizontal axes placed at regular intervals?

Horizontal Axis

The label on the horizontal (x) axis indicates that the temperature of the balloon was measured in degrees Celsius (°C). The numbers are measurements of the Celsius temperature, which are evenly spaced from 0 °C to 100 °C.

Points on the Graph

Each point on the graph represents a volume in liters that was measured at a specific temperature. When these points are connected, a line is obtained.

Interpreting the Graph

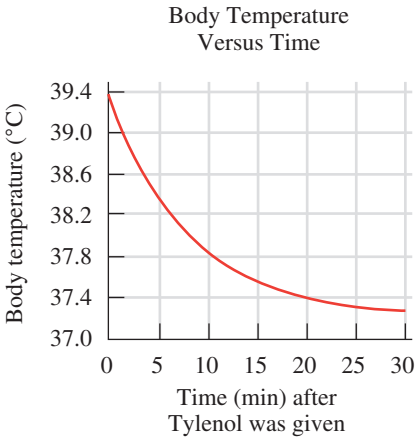
From the graph, we see that the volume of the gas increases as the temperature of the gas increases. This is called a *direct relationship*. Now we use the graph to determine the volume at various temperatures. For example, suppose we want to know the volume of the gas at 50 °C. We would start by finding 50 °C on the x axis and then drawing a line up to the plotted line. From there, we would draw a horizontal line that intersects the y axis and read the volume value where the line crosses the y axis as shown on the graph above.

SAMPLE PROBLEM 1.7 Interpreting a Graph

TRY IT FIRST

A nurse administers Tylenol to lower a child's fever. The graph shows the body temperature of the child plotted against time.

a. What is measured on the vertical axis?
b. What is the range of values on the vertical axis?
c. What is measured on the horizontal axis?
d. What is the range of values on the horizontal axis?



SOLUTION

a. body temperature, in degrees Celsius
b. 37.0 °C to 39.4 °C
c. time, in minutes, after Tylenol was given
d. 0 min to 30 min

STUDY CHECK 1.7

a. Using the graph in Sample Problem 1.7, what was the child's temperature 15 min after Tylenol was given?
b. How many minutes elapsed before the temperature decreased to 38.0 °C?

ANSWER

a. 37.6 °C **b.** 8 min

TEST

Try Practice Problems 1.23 and 1.24

PRACTICE PROBLEMS

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.

1.15 What is the place value for the bold digit?
- **a.** 7.0**9**84
- **b.** **2**6.2860
- **c.** **8**5.5258

1.16 What is the place value for the bold digit?
- **a.** 97.**5**689
- **b.** 3**7**5.88
- **c.** 46.1**0**00

1.17 Evaluate each of the following
- **a.** $20 - (-10) =$
- **b.** $-6 + (-38) =$
- **c.** $2 \times (-7) + 14 =$

1.18 Evaluate each of the following
- **a.** $-17 - (-12) =$
- **b.** $19 + (-86) =$
- **c.** $\dfrac{-78}{6} =$

Clinical Applications

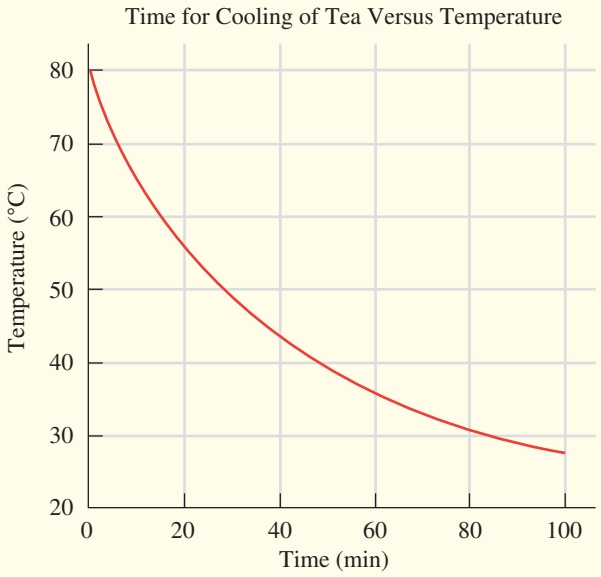
1.19
- **a.** A cargo comprises 80 kg of wheat and 20 kg of cotton. What is the percentage of cotton by weight in the cargo?
- **b.** A ship contains 400 tons of wheat and 100 tons of cotton. What is the percentage of wheat by weight on the ship?
- **c.** Which contains a higher percentage of wheat?

1.20
- **a.** At a local hospital, 35 babies were born. If 22 were boys, what percentage of the newborns were boys? Express your answer to the ones place.
- **b.** An alloy contains 67 g of pure gold and 35 g of pure zinc. What is the percentage of zinc in the alloy? Express your answer to the ones place.
- **c.** A collection of coins contains 15 pennies, 14 dimes, and 6 quarters. What is the percentage of pennies in the collection? Express your answer to the ones place.

1.21 Solve each of the following for 'a':
- **a.** $5a + 10 = 60$
- **b.** $\dfrac{a}{8} = 6$

1.22 Solve each of the following for b:
- **a.** $2b + 7 = b + 10$
- **b.** $3b - 4 = 24 - b$

Use the following graph for problems 1.23 and 1.24:



1.23
- **a.** What does the title indicate about the graph?
- **b.** What is measured on the vertical axis?
- **c.** What is the range of values on the vertical axis?
- **d.** Does the temperature increase or decrease with an increase in time?

1.24
- **a.** What is measured on the horizontal axis?
- **b.** What is the range of values on the horizontal axis?
- **c.** What is the temperature of tea after 20 min?
- **d.** How many minutes did it take for the tea to reach a temperature below 30 °C?

1.5 Writing Numbers in Scientific Notation

LEARNING GOAL Write a number in scientific notation.

In chemistry, we often work with numbers that are very large and very small. We might measure something as tiny as the width of a human hair, which is about 0.000 008 m. Or perhaps we want to count the number of hairs on the average human scalp, which is about 100 000 hairs. In this text, we add spaces between sets of three digits when it helps make the places easier to count. However, we will see that it is more convenient to write large and small numbers in *scientific notation*.

A number written in **scientific notation** has two parts: a coefficient and a power of 10. For example, the number 2400 is written in scientific notation as 2.4×10^3. The coefficient, 2.4,

Humans have an average of 1×10^5 hairs on their scalps. Each hair is about 8×10^{-6} m wide.

Standard Number	Scientific Notation
0.000 008 m	8×10^{-6} m
100 000 hairs	1×10^5 hairs

KEY MATH SKILL

Writing Numbers in Scientific Notation

is obtained by moving the decimal point to the left to give a number that is at least 1 but less than 10. Because we moved the decimal point three places to the left, the power of 10 is a positive 3, which is written as 10^3. When a number greater than 1 is converted to scientific notation, the power of 10 is positive.

Standard Number		Scientific Notation		
2400.	=	2.4	×	10^3
← 3 places		Coefficient		Power of 10

ENGAGE

Why is 530 000 written as 5.3×10^5 in scientific notation?

In another example, 0.000 86 is written in scientific notation as 8.6×10^{-4}. The coefficient, 8.6, is obtained by moving the decimal point to the right. Because the decimal point is moved four places to the right, the power of 10 is a negative 4, written as 10^{-4}. When a number less than 1 is written in scientific notation, the power of 10 is negative.

Standard Number		Scientific Notation		
0.00086	=	8.6	×	10^{-4}
4 places →		Coefficient		Power of 10

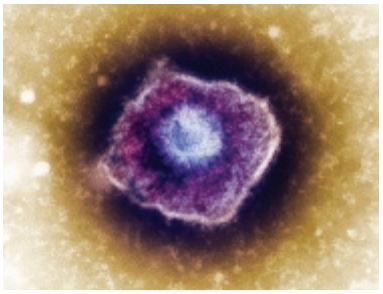
ENGAGE

Why is 0.000 053 written as 5.3×10^{-5} in scientific notation?

TABLE 1.2 gives some examples of numbers written as positive and negative powers of 10. The powers of 10 are a way of keeping track of the decimal point in the number. **TABLE 1.3** gives several examples of writing measurements in scientific notation.

TABLE 1.2 Some Powers of 10

Standard Number	Multiples of 10	Scientific Notation	
10 000	$10 \times 10 \times 10 \times 10$	1×10^4	Some positive powers of 10
1 000	$10 \times 10 \times 10$	1×10^3	
100	10×10	1×10^2	
10	10	1×10^1	
1	0	1×10^0	
0.1	$\frac{1}{10}$	1×10^{-1}	Some negative powers of 10
0.01	$\frac{1}{10} \times \frac{1}{10} = \frac{1}{100}$	1×10^{-2}	
0.001	$\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{1\,000}$	1×10^{-3}	
0.0001	$\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{10\,000}$	1×10^{-4}	



A chickenpox virus has a diameter of 3×10^{-7} m.

TABLE 1.3 Some Measurements Written as Standard Numbers and in Scientific Notation

Measured Quantity	Standard Number	Scientific Notation
Volume of gasoline used in the United States each year	550 000 000 000 L	5.5×10^{11} L
Diameter of Earth	12 800 000 m	1.28×10^{7} m
Average volume of blood pumped in 1 day	8500 L	8.5×10^{3} L
Time for light to travel from the Sun to Earth	500 s	5×10^{2} s
Mass of a typical human	68 kg	6.8×10^{1} kg
Mass of stirrup bone in ear	0.003 g	3×10^{-3} g
Diameter of a chickenpox (*Varicella zoster*) virus	0.000 000 3 m	3×10^{-7} m
Mass of bacterium (mycoplasma)	0.000 000 000 000 000 000 1 kg	1×10^{-19} kg

SAMPLE PROBLEM 1.8 Writing a Number in Scientific Notation

TRY IT FIRST

Write each of the following in scientific notation:

a. 3500 **b.** 0.000 016

SOLUTION GUIDE

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

a. 3500

STEP 1 Move the decimal point to obtain a coefficient that is at least 1 but less than 10. For a number greater than 1, the decimal point is moved to the left three places to give a coefficient of 3.5.

STEP 2 Express the number of places moved as a power of 10. Moving the decimal point three places to the left gives a power of 3, written as 10^{3}.

STEP 3 Write the product of the coefficient multiplied by the power of 10. 3.5×10^{3}

b. 0.000 016

STEP 1 Move the decimal point to obtain a coefficient that is at least 1 but less than 10. For a number less than 1, the decimal point is moved to the right five places to give a coefficient of 1.6.

STEP 2 Express the number of places moved as a power of 10. Moving the decimal point five places to the right gives a power of negative 5, written as 10^{-5}.

STEP 3 Write the product of the coefficient multiplied by the power of 10. 1.6×10^{-5}

STUDY CHECK 1.8

Write each of the following in scientific notation:

a. 425 000 **b.** 0.000 000 86

ANSWER

a. 4.25×10^{5} **b.** 8.6×10^{-7}

TEST

Try Practice Problems 1.25 to 1.28

Scientific Notation and Calculators

You can enter a number in scientific notation on many calculators using the EE or EXP key. After you enter the coefficient, press the EE or EXP key and enter the power 10. To enter a negative power of 10, press the +/− key or the (−) key, depending on your calculator.

Number to Enter	Procedure	Calculator Display
4×10^{6}	4 EE or EXP 6	4 06 or 4^{06} or 4E06
2.5×10^{-4}	2.5 EE or EXP +/− 4	2.5−04 or 2.5^{-04} or 2.5E−04

When a calculator answer appears in scientific notation, the coefficient is shown as a number that is at least 1 but less than 10, followed by a space or E and the power of 10. To express this display in scientific notation, write the coefficient value, write × 10, and use the power of 10 as an exponent.

Calculator Display	Expressed in Scientific Notation
7.52 04 or 7.52^{04} or 7.52E04	7.52×10^{4}
5.8−02 or 5.8^{-02} or 5.8E−02	5.8×10^{-2}

On many calculators, a number is converted into scientific notation using the appropriate keys. For example, the number 0.000 52 is entered, followed by pressing the 2nd or 3rd function key and the SCI key. The scientific notation appears in the calculator display as a coefficient and the power of 10.

0.000 52 [2nd or 3rd function key] [SCI] = 5.2−04 or 5.2^{-04} or 5.2E−04 = 5.2×10^{-4}

Calculator display

ENGAGE

Describe how you enter a number in scientific notation on your calculator.

PRACTICE PROBLEMS

1.5 Writing Numbers in Scientific Notation

LEARNING GOAL Write a number in scientific notation.

1.25 Write each of the following in scientific notation:

a. 67 000 **b.** 520 **c.** 0.000 0081
d. 0.000 27 **e.** 0.0094 **f.** 490 000

1.26 Write each of the following in scientific notation:

a. 180 000 000 **b.** 0.000 06 **c.** 750
d. 0.15 **e.** 0.024 **f.** 1500

1.27 Which number in each of the following pairs is larger?

a. 6.1×10^{4} or 4.2×10^{2}
b. 3.7×10^{-6} or 5.8×10^{-3}
c. 7×10^{-8} or 7×10^{8}
d. 0.000 69 or 8.3×10^{-1}

1.28 Which number in each of the following pairs is smaller?

a. 0.9×10^{-3} or 5.5×10^{-9}
b. 1250 or 3.4×10^{2}
c. 0.5×10^{3} or 5.0×10^{2}
d. 2.50×10^{2} or 4×10^{5}

CLINICAL UPDATE Forensic Evidence Helps Solve the Crime

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.

Clinical Applications

1.29 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.

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

CONCEPT MAP

CHEMISTRY IN OUR LIVES

- deals with
  - **Substances**
  - called
  - **Chemicals**
- uses the
  - **Scientific Method**
  - starting with
  - **Observations**
  - that lead to
  - **Hypothesis**
  - **Experiments**
  - **Conclusion/Theory**
- is learned by
  - **Reading the Text**
  - **Practicing Problem Solving**
  - **Self-Testing**
  - **Working with a Group**
  - **Engaging**
  - **Trying It First**
- uses key math skills
  - **Identifying Place Values**
  - **Using Positive and Negative Numbers**
  - **Calculating Percentages**
  - **Solving Equations**
  - **Interpreting Graphs**
  - **Writing Numbers in Scientific Notation**

CHAPTER REVIEW

1.1 Chemistry and Chemicals

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

- Chemistry is the study of the composition, structure, properties, and reactions of matter.
- A chemical is any substance that always has the same composition and properties wherever it is found.

1.2 Scientific Method: Thinking Like a Scientist

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

- The scientific method is a process of explaining natural phenomena beginning with making observations, forming a hypothesis, and performing experiments.
- After repeated successful experiments, a hypothesis may become a theory.

1.3 Studying and Learning Chemistry

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

- A plan for learning chemistry utilizes the features in the text that help develop a successful approach to learning chemistry.
- By using the *Learning Goals*, *Reviews*, *Analyze the Problems*, and *Try It First* in the chapter and working the *Sample Problems*, *Study Checks*, and the *Practice Problems* at the end of each Section, you can successfully learn the concepts of chemistry.

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.

- Solving chemistry problems involves a number of math skills: identifying place values, using positive and negative numbers, calculating percentages, solving equations, and interpreting graphs.

1.5 Writing Numbers in Scientific Notation

LEARNING GOAL Write a number in scientific notation.

- A number written in scientific notation has two parts, a coefficient and a power of 10.
- When a number greater than 1 is converted to scientific notation, the power of 10 is positive.
- When a number less than 1 is written in scientific notation, the power of 10 is negative.

KEY TERMS

chemical A substance that has the same composition and properties wherever it is found.

chemistry The study of the composition, structure, properties, and reactions of matter.

conclusion An explanation of an observation that has been validated by repeated experiments that support a hypothesis.

experiment A procedure that tests the validity of a hypothesis.

hypothesis An unverified explanation of a natural phenomenon.

observation Information determined by noting and recording a natural phenomenon.

scientific method The process of making observations, proposing a hypothesis, and testing the hypothesis; after repeated experiments validate the hypothesis, it may become a theory.

scientific notation A form of writing large and small numbers using a coefficient that is at least 1 but less than 10, followed by a power of 10.

theory An explanation for an observation supported by additional experiments that confirm the hypothesis.

KEY MATH SKILLS

The chapter Section containing each Key Math Skill is shown in parentheses at the end of each heading.

Identifying Place Values (1.4)

- The place value identifies the numerical value of each digit in a number.

Example: Identify the place value for each of the digits in the number 456.78.

Answer:

Digit	Place Value
4	hundreds
5	tens
6	ones
7	tenths
8	hundredths

Using Positive and Negative Numbers in Calculations (1.4)

- A *positive number* is any number that is greater than zero and has a positive sign (+). A *negative number* is any number that is less than zero and is written with a negative sign (−).
- When two positive numbers are added, multiplied, or divided, the answer is positive.
- When two negative numbers are multiplied or divided, the answer is positive. When two negative numbers are added, the answer is negative.
- When a positive and a negative number are multiplied or divided, the answer is negative.
- When a positive and a negative number are added, the smaller number is subtracted from the larger number and the result has the same sign as the larger number.
- When two numbers are subtracted, change the sign of the number to be subtracted then follow the rules for addition.

Example: Evaluate each of the following:

a. $-8 - 14 =$ _____ **b.** $6 \times (-3) =$ _____

Answer: **a.** -22 **b.** -18

Calculating Percentages (1.4)

- A percentage is the part divided by the total (whole) multiplied by 100%.

Example: A drawer contains 6 white socks and 18 black socks. What is the percentage of white socks?

Answer: $\frac{6 \text{ white socks}}{24 \text{ total socks}} \times 100\% = 25\%$ white socks

Solving Equations (1.4)

An equation in chemistry often contains an unknown. To rearrange an equation to obtain the unknown factor by itself, you keep it balanced by performing matching mathematical operations on both sides of the equation.

- If you eliminate a number or symbol by subtracting, subtract that same number or symbol on the opposite side.
- If you eliminate a number or symbol by adding, add that same number or symbol on the opposite side.
- If you cancel a number or symbol by dividing, divide both sides by that same number or symbol.
- If you cancel a number or symbol by multiplying, multiply both sides by that same number or symbol.

Example: Solve the equation for a: $3a - 8 = 28$

Answer:

Add 8 to both sides

$$3a - \cancel{8} + \cancel{8} = 28 + 8$$
$$3a = 36$$

Divide both sides by 3

$$\frac{\cancel{3}a}{\cancel{3}} = \frac{36}{3}$$
$$a = 12$$

Check:

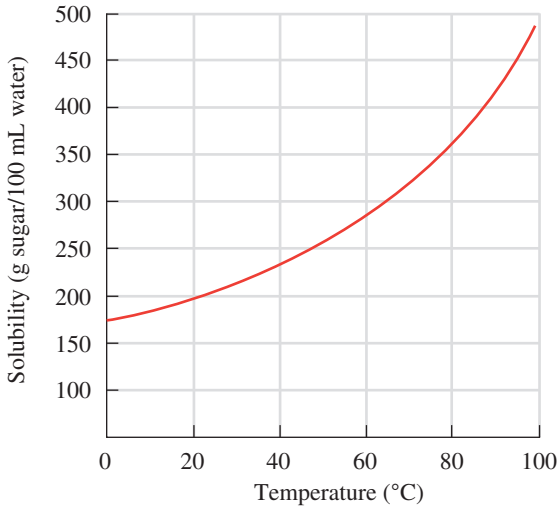
$$3(12) - 8 = 28$$
$$36 - 8 = 28$$
$$28 = 28$$

Your answer $a = 12$ is correct.

Interpreting Graphs (1.4)

- A graph represents the relationship between two variables.
- The quantities are plotted along two perpendicular axes, which are the x axis (horizontal) and y axis (vertical).
- The title indicates the components of the x and y axes.
- Numbers on the x and y axes show the range of values of the variables.
- The graph shows the relationship between the component on the y axis and that on the x axis.

Example: Solubility of Sugar in Water Versus Temperature



a. Does the amount of sugar that dissolves in 100 mL of water increase or decrease when the temperature increases?

b. How many grams of sugar dissolve in 100 mL of water at 70 °C?

c. At what temperature (°C) will 275 g of sugar dissolve in 100 mL of water?

Answer: **a.** increase

b. 320 g

c. 55 °C

Writing Numbers in Scientific Notation (1.5)

- A number written in scientific notation consists of a coefficient and a power of 10.

A number is written in scientific notation by:

- Moving the decimal point to obtain a coefficient that is at least 1 but less than 10.
- Expressing the number of places moved as a power of 10. The power of 10 is positive if the decimal point is moved to the left, negative if the decimal point is moved to the right.

Example: Write the number 28 000 in scientific notation.

Answer: Moving the decimal point four places to the left gives a coefficient of 2.8 and a positive power of 10, 10^4. The number 28 000 written in scientific notation is 2.8×10^4.

UNDERSTANDING THE CONCEPTS

The chapter Sections to review are shown in parentheses at the end of each problem.

1.31 A "chemical-free" shampoo includes the following ingredients: water, cocamide, glycerin, and citric acid. Is the shampoo truly "chemical-free"? (1.1)

1.32 A "chemical-free" sunscreen includes the following ingredients: titanium dioxide, vitamin E, and vitamin C. Is the sunscreen truly "chemical-free"? (1.1)

1.33 According to Sherlock Holmes, "One must follow the rules of scientific inquiry, gathering, observing, and testing data, then formulating, modifying, and rejecting hypotheses, until only one remains." Did Holmes use the scientific method? Why or why not? (1.2)

1.34 In *A Scandal in Bohemia*, Sherlock Holmes receives a mysterious note. He states, "I have no data yet. It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts." What do you think Holmes meant? (1.2)

Sherlock Holmes is a fictional detective in novels written by Arthur Conan Doyle.

1.35 Classify each of the following statements as an observation (O) or a hypothesis (H)
- **a.** At boiling point, water is converted into steam.
- **b.** If temperature is related to metabolic activity in animals, decreasing the ambient temperature will result in decrease in metabolism.
- **c.** Tomato plant grows well when exposed to more sunlight.

1.36 Classify each of the following statements as an observation (O) or a hypothesis (H): (1.2)
- **a.** Analysis of a sample of 100 toys indicated that 5% contained lead.
- **b.** Reduced CO_2 emission can help reduce global warming.
- **c.** A child with fever higher than 40 °C is likely to suffer damage to brain function.

Clinical Applications

1.37 For each of the following, indicate if the answer has a positive or negative sign: (1.4)
- **a.** Three negative numbers are added.
- **b.** Two negative numbers are multiplied, and then divided by a positive number.

1.38 For each of the following, indicate if the answer has a positive or negative sign: (1.4)
- **a.** A negative number is divided by a positive number.
- **b.** Two negative numbers are added.

ADDITIONAL PRACTICE PROBLEMS

1.39 Select the correct phrase(s) to complete the following statement: If experimental results do not support your hypothesis, you should: (1.2)
- **a.** pretend that the experimental results support your hypothesis
- **b.** modify your hypothesis
- **c.** do more experiments

1.40 Select the correct phrase(s) to complete the following statement: A hypothesis is confirmed when: (1.2)
- **a.** one experiment proves the hypothesis
- **b.** many experiments validate the hypothesis
- **c.** you think your hypothesis is correct

1.41 Select the correct phrases to complete the following statement: If experimental results do not support your hypothesis, you should… (1.2)
- **a.** try to verify the experimental parameters again and see if there is any error
- **b.** discuss with your classmate and see if there is something wrong
- **c.** consult with your professor
- **d.** do more experiments

1.42 Which of the following will help you develop a successful study plan? (1.3)
- **a.** studying all night before the exam
- **b.** forming a study group and discussing the problems together
- **c.** working problems in a notebook for easy reference
- **d.** highlighting important ideas in the text

1.43 What should you do if your study group is unable to settle an argument in chemistry? (1.3)
- **a.** simply insist your own opinion further
- **b.** search for an answer on the web
- **c.** go through the textbook again
- **d.** do experiments on your own
- **e.** consult with the course coordinator

1.44 Evaluate each of the following: (1.4)
- **a.** $-95 - (-11) =$ _____
- **b.** $\dfrac{152}{-19} =$ _____
- **c.** $4 - 56 =$ _____

1.45 Evaluate each of the following
- **a.** $6 \times (-9)$
- **b.** $+7 + (-81)$
- **c.** $\dfrac{-120}{-40}$

1.46 Evaluate each of the following:
- **a.** $-67 - (-8)$
- **b.** $\dfrac{135}{-15}$
- **c.** $6 - 39$

1.47 Write each of the following in scientific notation: (1.5)
- **a.** 120 000
- **b.** 0.000 000 34
- **c.** 0.066
- **d.** 2700

1.48 Write each of the following in scientific notation: (1.5)
- **a.** 0.0042
- **b.** 310
- **c.** 890 000 000
- **d.** 0.000 000 056

Clinical Applications

1.49 Use scientific notation to express each of the following numbers: (1.5)
- **a.** 1200 000
- **b.** 0.000 000 44
- **c.** 0.066
- **c.** 1000 000

1.50 Express each of the following numbers in scientific notation: (1.4)
- **a.** 0.0064.
- **b.** 290000.
- **c.** 650 000 000.
- **d.** 0.000 000 004 2.

CHALLENGE PROBLEMS

The following problems are related to the topics in this chapter. However, they do not all follow the chapter order, and they require you to combine concepts and skills from several Sections. These problems will help you increase your critical thinking skills and prepare for your next exam.

1.51 Classify each of the following as an observation, a hypothesis, an experiment, or a conclusion: (1.2)
- **a.** The bicycle tire is flat.
- **b.** If I add air to the bicycle tire, it will expand to the proper size.
- **c.** When I added air to the bicycle tire, it was still flat.
- **d.** The bicycle tire has a leak in it.

1.52 Classify each of the following as an observation, a hypothesis, an experiment, or a conclusion: (1.2)
- **a.** A big log in the fire does not burn well.
- **b.** If I chop the log into smaller wood pieces, it will burn better.
- **c.** The small wood pieces burn brighter and make a hotter fire.
- **d.** The small wood pieces are used up faster than burning the big log.

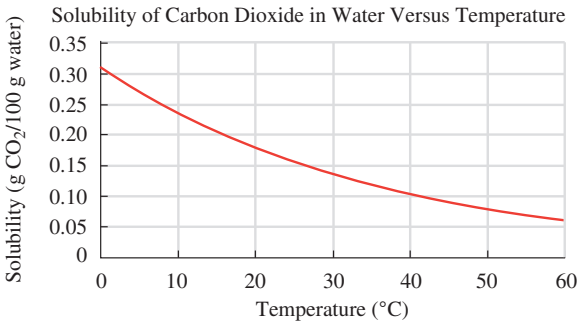
1.53 Solve each of the following for a: (1.4)

a. $4a - 5 = 35$ **b.** $\frac{3a}{6} = -18$

1.54 Solve each of the following for z: (1.4)

a. $7z - (-11) = 39$ **b.** $-8z \times 5 = -80$

Use the following graph for problems 1.55 and 1.56:



1.55 **a.** What does the title indicate about the graph? (1.4)
b. What is measured on the vertical axis?
c. What is the range of values on the vertical axis?
d. Does the solubility of carbon dioxide increase or decrease with an increase in temperature?

1.56 **a.** What is measured on the horizontal axis? (1.4)
b. What is the range of values on the horizontal axis?
c. What is the solubility of carbon dioxide in water at 25 °C?
d. At what temperature does carbon dioxide have a solubility of 0.20 g/100 g water?

ANSWERS

Answers to Selected Practice Problems

1.1 **a.** Chemistry is the study of the composition, structure, properties, and reactions of matter.
b. A chemical is a substance that has the same composition and properties wherever it is found.

1.3 Many chemicals are listed on a vitamin bottle such as vitamin A, vitamin B_3, vitamin B_{12}, vitamin C, and folic acid.

1.5 Typical items found in a medicine cabinet and some of the chemicals they contain are as follows:

Antacid tablets: calcium carbonate, cellulose, starch, stearic acid, silicon dioxide

Mouthwash: water, alcohol, thymol, glycerol, sodium benzoate, benzoic acid

Cough suppressant: menthol, beta-carotene, sucrose, glucose

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

1.9 **a.** observation **b.** hypothesis
c. experiment **d.** experiment

1.11 There are several things you can do that will help you successfully learn chemistry: forming a study group, retesting, doing *Try It First* before reading the Solution, checking *Review*, working *Sample Problems* and *Study Checks*, working *Practice Problems* and checking *Answers*, reading the assignment ahead of class, and keeping a problem notebook.

1.13 **b., c., d., a.**

1.15 **a.** hundredths. **b.** ones. **c.** tens.

1.17 **a.** 30 **b.** −44 **c.** 0

1.19 **a.** 20% cotton **b.** 80% wheat
c. Both have the same percentage of wheat.

1.21 **a.** $a = 10$ **b.** $a = 48$

1.23 **a.** The graph shows the relationship between the temperature of a cup of tea and time.
b. temperature, in °C
c. 20 °C to 80 °C
d. decrease

1.25 **a.** 6.7×10^4. **b.** 5.2×10^2. **c.** 8.1×10^{-6}.
d. 2.7×10^{-4}. **e.** 9.4×10^{-3}. **f.** 4.9×10^5.

1.27 **a.** 6.1×10^4 **b.** 5.8×10^{-3}
c. 7×10^8 **d.** 8.3×10^{-1}

1.29 27% ethylene glycol

1.31 No. All of the ingredients are chemicals.

1.33 Yes. Sherlock's investigation includes making observations (gathering data), formulating a hypothesis, testing the hypothesis, and modifying it until one of the hypotheses is validated.

1.35 **a.** O **b.** H **c.** O

1.37 **a.** negative **b.** positive

1.39 **b** and **c**

1.41 **a, d**

1.43 **c** and **e**.

1.45 **a.** −54 **b.** −74 **c.** +3

1.47 **a.** 1.2×10^5 **b.** 3.4×10^{-7}
c. 6.6×10^{-2} **d.** 2.7×10^3

1.49 **a.** 1.2×10^6. **b.** 4.4×10^{-7}.
c. 6.6×10^{-2}. **d.** 1.0×10^6.

1.51 **a.** observation **b.** hypothesis
c. experiment **d.** conclusion

1.53 **a.** 10 **b.** –36

1.55 **a.** The graph shows the relationship between the solubility of carbon dioxide in water and temperature.
b. solubility of carbon dioxide (g CO_2/100 g water)
c. 0 to 0.35 g of CO_2/100 g of water
d. decrease

2 Chemistry and Measurements

DURING THE PAST FEW MONTHS, GREG experienced an increased number of headaches, dizzy spells, and nausea. He goes to his doctor's office where Sandra, the registered nurse, completes the initial part of his exam by recording several measurements: weight 74.5 kg, height 171 cm, temperature 37.2 °C, and blood pressure 155/95. Normal blood pressure is 120/80 or lower.

When Greg sees his doctor, he is diagnosed with high blood pressure (hypertension). The doctor prescribes 80 mg of Inderal (propranolol), which is available in 40.-mg tablets. Inderal is a beta blocker, which relaxes the muscles of the heart. It is used to treat hypertension, angina (chest pain), arrhythmia, and migraine headaches.

Two weeks later, Greg visits his doctor again, who determines that Greg's blood pressure is now 152/90. The doctor increases the dosage of Inderal to 160 mg. The registered nurse, Sandra, informs Greg that he needs to increase his daily dosage from two tablets to four tablets.

CAREER Registered Nurse

In addition to assisting physicians, registered nurses work to promote patient health and prevent and treat disease. They provide patient care and help patients cope with illness. They take measurements such as a patient's weight, height, temperature, and blood pressure; make conversions; and calculate drug dosage rates. Registered nurses also maintain detailed medical records of patient symptoms and prescribed medications.

CLINICAL UPDATE Greg's Visit with His Doctor

A few weeks later, Greg complained to his doctor that he was feeling tired. He had a blood test to determine if his iron level was low. You can see the results of Greg's blood serum iron level in the **CLINICAL UPDATE Greg's Visit with His Doctor**, page 82, and determine if Greg should be given an iron supplement.

LOOKING AHEAD

2.1 Units of Measurement

LEARNING GOAL Write the names and abbreviations for the metric or SI units used in measurements of volume, length, mass, temperature, and time.

Think about your day. You probably took some measurements. Perhaps you checked your weight by stepping on a bathroom scale. If you made rice for dinner, you added two cups of water to one cup of rice. If you did not feel well, you may have taken your temperature. Whenever you take a measurement, you use a measuring device such as a scale, a measuring cup, or a thermometer.

Scientists and health professionals throughout the world use the **metric system** of measurement. It is also the common measuring system in all but a few countries in the world. The **International System of Units (SI)**, or Système International, is the official system of measurement throughout the world except for the United States. In chemistry, we use metric units and SI units for volume, length, mass, temperature, and time, as listed in **TABLE 2.1**.

Your weight on a bathroom scale is a measurement.

TABLE 2.1 Units of Measurement and Their Abbreviations

Measurement	Metric	SI
Volume	liter (L)	cubic meter (m^3)
Length	meter (m)	meter (m)
Mass	gram (g)	kilogram (kg)
Temperature	degree Celsius (°C)	kelvin (K)
Time	second (s)	second (s)

Suppose you walked 1.3 mi to campus today, carrying a backpack that weighs 26 lb. The temperature was 72 °F. Perhaps you weigh 128 lb and your height is 65 in. These measurements and units may seem familiar to you because they are stated in the U.S. system of measurement. However, in chemistry, we use the *metric system* in making our measurements. Using the metric system, you walked 2.1 km to campus, carrying a backpack that has a mass of 12 kg, when the temperature was 22 °C. You have a mass of 58.0 kg and a height of 1.7 m.

There are many measurements in everyday life.

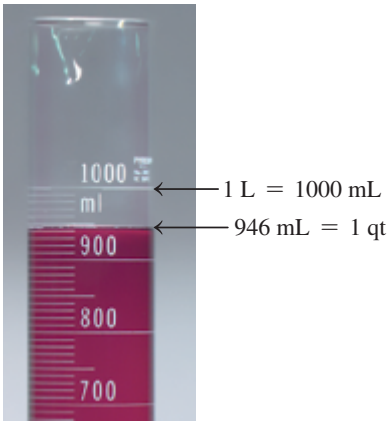


FIGURE 2.1 In the metric system, volume is based on the liter.

How many milliliters are in 1 quart?

Volume

Volume (*V*) is the amount of space a substance occupies. The metric unit for volume is the **liter (L)**, which is slightly larger than a quart (qt). In a laboratory or a hospital, chemists work with metric units of volume that are smaller and more convenient, such as the **milliliter (mL)**. There are 1000 mL in 1 L. (See **FIGURE 2.1**.) Some relationships between units for volume are

1 L = 1000 mL 1 L = 1.06 qt 946 mL = 1 qt

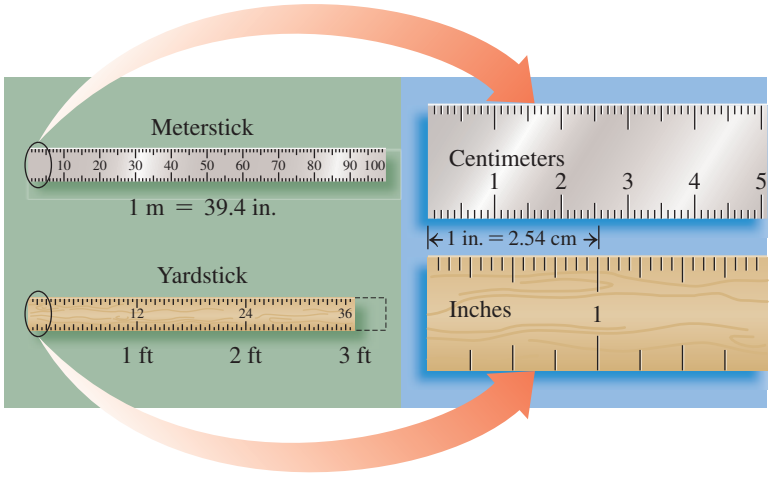


FIGURE 2.2 Length in the metric (SI) system is based on the meter, which is slightly longer than a yard.

How many centimeters are in a length of 1 inch?

Length

The metric and SI unit of length is the **meter (m)**. The **centimeter (cm)**, a smaller unit of length, is commonly used in chemistry and is about equal to the width of your little finger (see **FIGURE 2.2**). Some relationships between units for length are

$$1\text{ m} = 100\text{ cm} \qquad 1\text{ m} = 39.4\text{ in.} \qquad 1\text{ m} = 1.09\text{ yd} \qquad 2.54\text{ cm} = 1\text{ in.}$$

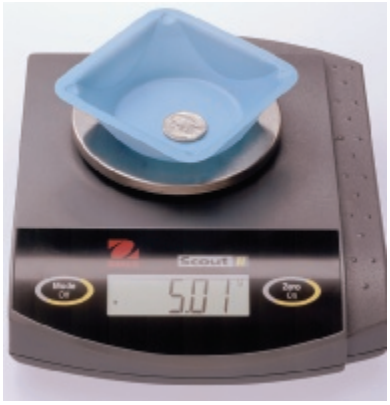


FIGURE 2.3 On an electronic balance, the digital readout gives the mass of a nickel, which is 5.01 g.

What is the mass of 10 nickels?

Mass

The **mass** of an object is a measure of the quantity of material it contains. The SI unit of mass, the **kilogram (kg)**, is used for larger masses such as body mass. In the metric system, the unit for mass is the **gram (g)**, which is used for smaller masses. There are 1000 g in 1 kg. One pound (lb) is equal to 454 g. Some relationships between units for mass are

$$1\text{ kg} = 1000\text{ g} \qquad 1\text{ kg} = 2.20\text{ lb} \qquad 454\text{ g} = 1\text{ lb}$$

You may be more familiar with the term *weight* than with mass. Weight is a measure of the gravitational pull on an object. On Earth, an astronaut with a mass of 75.0 kg has a weight of 165 lb. On the Moon where the gravitational pull is one-sixth that of Earth, the astronaut has a weight of 27.5 lb. However, the mass of the astronaut is the same as on Earth, 75.0 kg. Scientists measure mass rather than weight because mass does not depend on gravity.

In a chemistry laboratory, an electronic balance is used to measure the mass in grams of a substance (see **FIGURE 2.3**).

FIGURE 2.4 A thermometer is used to determine temperature.

What kinds of temperature readings have you made today?

Temperature

Temperature tells us how hot something is, how cold it is outside, or helps us determine if we have a fever (see **FIGURE 2.4**). In the metric system, temperature is measured using Celsius temperature. On the **Celsius (°C) temperature scale**, water freezes at 0 °C and boils at 100 °C, whereas on the Fahrenheit (°F) scale, water freezes at 32 °F and boils at 212 °F. In the SI system, temperature is measured using the **Kelvin (K) temperature scale** on which the lowest possible temperature is 0 K. A unit on the Kelvin scale is called a kelvin (K) and is not written with a degree sign.

A stopwatch is used to measure the time of a race.

Time

We typically measure time in units such as years (yr), days, hours (h), minutes (min), or seconds (s). Of these, the SI and metric unit of time is the **second (s)**. The standard now used to determine a second is an atomic clock. Some relationships between units for time are

$$1\text{ day} = 24\text{ h} \qquad 1\text{ h} = 60\text{ min} \qquad 1\text{ min} = 60\text{ s}$$

SAMPLE PROBLEM 2.1 Units of Measurement

TRY IT FIRST

On a typical day, a nurse encounters several situations involving measurement. State the name and type of measurement indicated by the units in each of the following:

a. A patient has a temperature of 38.5 °C.
b. A physician orders 1.5 g of cefuroxime for injection.
c. A physician orders 1 L of a sodium chloride solution to be given intravenously.
d. A medication is to be given to a patient every 4 h.

SOLUTION

a. A degree Celsius is a unit of temperature.
b. A gram is a unit of mass.
c. A liter is a unit of volume.
d. An hour is a unit of time.

STUDY CHECK 2.1

State the name and type of measurement indicated by an infant that is 32.5 cm long.

ANSWER

A centimeter is a unit of length.

TEST

Try Practice Problems 2.1 to 2.8

PRACTICE PROBLEMS

2.1 Units of Measurement

LEARNING GOAL Write the names and abbreviations for the metric or SI units used in measurements of volume, length, mass, temperature, and time.

2.1 Write the abbreviation for each of the following:
a. gram **b.** degree Celsius
c. liter **d.** pound
e. second

2.2 Write the abbreviation for each of the following:
a. kilogram **b.** kelvin
c. quart **d.** meter
e. centimeter

2.3 State the type of measurement in each of the following statements:
a. I put 12 L of gasoline in my gas tank.
b. My friend is 170 cm tall.
c. Earth is 385 000 km away from the Moon.
d. The horse won the race by 1.2 s.

2.4 State the type of measurement in each of the following statements:
a. I rode my bicycle 15 km today.
b. My dog weighs 12 kg.
c. It is hot today. It is 30 °C.
d. I added 2 L of water to my fish tank.

2.5 State the name of the unit and their use of measurement for each of the following quantities.
a. 3.4 cm **b.** 500 mg **c.** 2.0 L
d. 60 s **e.** 300 K

2.6 Arrange the following in descending order:
a. 10 cm **b.** 1 m **c.** 100 mm
d. 1 km

Clinical Applications

2.7 On a typical day, medical personnel may encounter several situations involving measurement. State the name and type of measurement indicated by the units in each of the following:
a. The clotting time for a blood sample is 12 s.
b. A premature baby weighs 2.0 kg.
c. An antacid tablet contains 1.0 g of calcium carbonate.
d. An infant has a temperature of 39.2 °C.

2.8 On a typical day, medical personnel may encounter several situations involving measurement. State the name and type of measurement indicated by the units in each of the following:
a. During open-heart surgery, the temperature of a patient is lowered to 29 °C.
b. The circulation time of a red blood cell through the body is 20 s.
c. A patient with a persistent cough is given 10. mL of cough syrup.
d. The amount of iron in the red blood cells of the body is 2.5 g.

2.2 Measured Numbers and Significant Figures

LEARNING GOAL Identify a number as measured or exact; determine the number of significant figures in a measured number.

When you make a measurement, you use some type of measuring device. For example, you may use a meterstick to measure your height, a scale to check your weight, or a thermometer to take your temperature.

Measured Numbers

Measured numbers are the numbers you obtain when you measure a quantity such as your height, weight, or temperature. Suppose you are going to measure the lengths of the objects in **FIGURE 2.5**. To report the length of the object, you observe the numerical values of the marked lines at the end of the object. Then you can *estimate* by visually dividing the space between the marked lines. This estimated value is the final digit in a measured number.

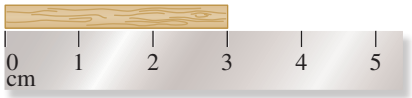
For example, in Figure 2.5a, the end of the object is between the marks of 4 cm and 5 cm, which means that the length is more than 4 cm but less than 5 cm. If you estimate that the end of the object is halfway between 4 cm and 5 cm, you would report its length as 4.5 cm. Another student might report the length of the same object as 4.4 cm because people do not estimate in the same way.

The metric ruler shown in Figure 2.5b is marked at every 0.1 cm. Now you can determine that the end of the object is between 4.5 cm and 4.6 cm. Perhaps you report its length as 4.55 cm, whereas another student reports its length as 4.56 cm. Both results are acceptable.

In Figure 2.5c, the end of the object appears to line up with the 3-cm mark. Because the end of the object is on the 3-cm mark, the estimated digit is 0, which means the measurement is reported as 3.0 cm.

(a)

(b)



(c)

FIGURE 2.5 The lengths of the rectangular objects are measured as **(a)** 4.5 cm and **(b)** 4.55 cm.

Why is the length of the object in **(c)** reported as 3.0 cm not 3 cm?

Significant Figures

In a measured number, the **significant figures (SFs)** are all the digits including the estimated digit. Nonzero numbers are always counted as significant figures. However, a zero may or may not be a significant figure depending on its position in a number. **TABLE 2.2** gives the rules and examples of counting significant figures.

CORE CHEMISTRY SKILL
Counting Significant Figures

TABLE 2.2 Significant Figures in Measured Numbers

Rule	Measured Number	Number of Significant Figures
1. A number is a *significant figure* if it is		
a. not a zero	4.5 g 122.35 m	2 5
b. a zero between nonzero digits	205 °C 5.008 kg	3 4
c. a zero at the end of a decimal number	50. L 16.00 mL	2 4
d. in the coefficient of a number written in scientific notation	4.8×10^5 m 5.70×10^{-3} g	2 3
2. A zero is *not significant* if it is		
a. at the beginning of a decimal number	0.0004 s 0.075 cm	1 2
b. used as a placeholder in a large number without a decimal point	850 000 m 1 250 000 g	2 3

TEST
Try Practice Problems 2.9 to 2.12

ENGAGE

Why is the zero in the coefficient of 3.20×10^4 cm a significant figure?

TEST

Try Practice Problems 2.13 to 2.16

Significant Zeros and Scientific Notation

In this text, we will place a decimal point after a significant zero at the end of a number. For example, if a measurement is written as 500. g, the decimal point after the second zero indicates that *both zeros* are significant. To show this more clearly, we can write it as 5.00×10^2 g. When the first zero in the measurement 300 m is a significant zero, but the second zero is not, the measurement is written as 3.0×10^2 m. We will assume that all zeros at the end of large standard numbers without a decimal point are not significant. Therefore, we write 400 000 g as 4×10^5 g, which has only one significant figure.

Exact Numbers

Exact numbers *are those numbers obtained by counting items or using a definition that compares two units in the same measuring system.* Suppose a friend asks you how many classes you are taking. You would answer by counting the number of classes in your schedule. Suppose you are asked to state the number of seconds in one minute. Without using any measuring device, you would give the definition: There are 60 s in 1 min. *Exact numbers are not measured, do not have a limited number of significant figures, and do not affect the number of significant figures in a calculated answer.* For more examples of exact numbers, see **TABLE 2.3**.

The number of baseballs is counted, which means 2 is an exact number.

TABLE 2.3 Examples of Some Exact Numbers

Counted Numbers	Defined Equalities	
Items	Metric System	U.S. System
8 doughnuts	1 L = 1000 mL	1 ft = 12 in.
2 baseballs	1 m = 100 cm	1 qt = 4 cups
5 capsules	1 kg = 1000 g	1 lb = 16 oz

For example, a mass of 42.2 g and a length of 5.0×10^{-3} cm are measured numbers because they are obtained using measuring tools. There are three SFs in 42.2 g because all nonzero digits are always significant. There are two SFs in 5.0×10^{-3} cm because all the digits in the coefficient of a number written in scientific notation are significant. However, a quantity of three eggs is an exact number that is obtained by counting. In the equality 1 kg = 1000 g, the masses of 1 kg and 1000 g are both exact numbers because this equality is a definition in the metric system.

SAMPLE PROBLEM 2.2 Measured and Exact Numbers

TRY IT FIRST

Identify each of the following numbers as measured or exact and give the number of significant figures (SFs) in each of the measured numbers:

a. 0.170 L
b. 4 knives
c. 6.3×10^{-6} s
d. 1 m = 100 cm

SOLUTION

a. measured; three SFs
b. exact
c. measured; two SFs
d. exact

STUDY CHECK 2.2

Identify each of the following numbers as measured or exact and give the number of significant figures (SFs) in each of the measured numbers:

a. 0.020 80 kg
b. 5.06×10^4 h
c. 4 chemistry books

ANSWER

a. measured; four SFs
b. measured; three SFs
c. exact

TEST

Try Practice Problems 2.17 to 2.22

PRACTICE PROBLEMS

2.2 Measured Numbers and Significant Figures

LEARNING GOAL Identify a number as measured or exact; determine the number of significant figures in a measured number.

2.9 How many significant figures are there in each of the following?
a. 28.003 g **b.** 0.000057 m
c. 890000000 km **d.** 4.50×10^6 kg
e. 0.7005 L **f.** 19.0 °C

2.10 How many significant figures are in each of the following?
a. 3.1416 m **b.** 59600700 g
c. 300. K **d.** 120.5 °C
e. 10.102 g

2.11 In which of the following pairs do both numbers contain the same number of significant figures?
a. 51.00 kg and 510000 kg
b. 0.825 m and 0.00825 m
c. 0.000073 s and 7.30×10^4 s
d. 480.0 L and 0.0480 L

2.12 In which of the following pairs do both numbers contain the same number of significant figures?
a. 0.005 75 g and 5.75×10^{-3} g
b. 405 K and 405.0 K
c. 150 000 s and 1.50×10^4 s
d. 3.8×10^{-2} L and 3.0×10^5 L

2.13 Indicate if the zeros are significant in each of the following measurements.
a. 1.008 m **b.** 3000 L
c. 28700 cm **d.** 5.6×10^{-5}
e. 9670000 g

2.14 Indicate if the zeros are significant in each of the following measurements:
a. 20.05 °C **b.** 5.00 m
c. 0.000 02 g **d.** 120 000 yr
e. 8.05×10^2 L

2.15 Write each of the following in scientific notation with two significant figures:
a. 8537 L **b.** 31 000 g
c. 160 000 m **d.** 0.0001 20 cm

2.16 Write each of the following in scientific notation with two significant figures:
a. 5 100 000 g **b.** 26 000 s
c. 40 000 m **d.** 0.000 820 kg

2.17 Identify the numbers in each of the following statements as measured or exact:
a. My chemistry book weighs 8 lb.
b. There are 12 red roses in this bouquet.
c. In metric system, 1 m is equal to 100 cm.
d. There are 20 types of cakes in this bakery.

2.18 Identify the numbers in each of the following statements as measured or exact:
a. There are 31 students in the laboratory.
b. The oldest known flower lived 1.20×10^8 yr ago.
c. The largest gem ever found, an aquamarine, has a mass of 104 kg.
d. A laboratory test shows a blood cholesterol level of 184 mg/dL.

2.19 Identify the measured number(s), if any, in each of the following pairs of numbers:
a. 3 hamburgers and 6 oz of hamburger
b. 1 table and 4 chairs
c. 0.75 lb of grapes and 350 g of butter
d. 60 s = 1 min

2.20 Identify the exact number(s), if any, in each of the following statements:
a. Density of water is 1 g/mL.
b. 1 g of water is equal to 1 cm^3
c. 1 g of water can fill the container.
d. 1 qt of milk contains 700 mL water.

Clinical Applications

2.21 Identify each of the following as measured or exact and give the number of significant figures (SFs) in each measured number:
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.
d. In November, 23 babies were born in a hospital.

2.22 Identify each of the following as measured or exact and give the number of significant figures (SFs) in each measured number:
a. An adult with the flu has a temperature of 103.5 °F.
b. A blister (push-through) pack of prednisone contains 21 tablets.
c. The time for a nerve impulse to travel from the feet to the brain is 0.46 s.
d. A brain contains 1.20×10^{10} neurons.

2.3 Significant Figures in Calculations

REVIEW
Identifying Place Values (1.4)
Using Positive and Negative Numbers in Calculations (1.4)

LEARNING GOAL Adjust calculated answers to give the correct number of significant figures.

In the sciences, we measure many things: the length of a bacterium, the volume of a gas sample, the temperature of a reaction mixture, or the mass of iron in a sample. The number of significant figures in measured numbers determines the number of significant figures in the calculated answer.

Using a calculator will help you perform calculations faster. However, calculators cannot think for you. It is up to you to enter the numbers correctly, press the correct function keys, and give the answer with the correct number of significant figures.

KEY MATH SKILL
Rounding Off

Rounding Off

Suppose you decide to buy carpeting for a room that has a length of 5.52 m and a width of 3.58 m. To determine how much carpeting you need, you would calculate the area of the room by multiplying 5.52 times 3.58 on your calculator. The calculator shows the number 19.7616 in its display. Because each of the original measurements has only three significant figures, the calculator display (19.7616) is *rounded off* to three significant figures, 19.8.

$$5.52 \times 3.58 = 19.7616 = 19.8\ \text{m}^2$$

Three SFs	Three SFs	Calculator display	Final answer, rounded off to three SFs

Therefore, you can order carpeting that will cover an area of 19.8 m^2.

Each time you use a calculator, it is important to look at the original measurements and determine the number of significant figures that can be used for the answer. You can use the following rules to round off the numbers shown in a calculator display.

A technician uses a calculator in the laboratory.

Rules for Rounding Off

1. If the first digit to be dropped is *4 or less*, then it and all following digits are simply dropped from the number.
2. If the first digit to be dropped is *5 or greater*, then the last retained digit of the number is increased by 1.

Number to Round Off	Three Significant Figures	Two Significant Figures
8.4234	8.42 (drop 34)	8.4 (drop 234)
14.780	14.8 (drop 80, increase the last retained digit by 1)	15 (drop 780, increase the last retained digit by 1)
3256	3260* (drop 6, increase the last retained digit by 1, add 0) (3.26×10^3)	3300* (drop 56, increase the last retained digit by 1, add 00) (3.3×10^3)

*The value of a large number is retained by using placeholder zeros to replace dropped digits.

ENGAGE
Why is 10.07208 rounded off to three significant figures equal to 10.1?

SAMPLE PROBLEM 2.3 Rounding Off

TRY IT FIRST

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

SOLUTION

a. 35.8 m **b.** 0.002 62 L **c.** 3.83×10^3 g

STUDY CHECK 2.3

Round off each of the numbers in Sample Problem 2.3 to two significant figures.

ANSWER

a. 36 m **b.** 0.0026 L **c.** 3.8×10^3 g

TEST
Try Practice Problems 2.23 to 2.26

Multiplication and Division with Measured Numbers

CORE CHEMISTRY SKILL
Using Significant Figures in Calculations

In multiplication or division, the final answer is written so that it has the same number of significant figures (SFs) as the measurement with the fewest SFs. An example of rounding off a calculator display follows:

Perform the following operations with measured numbers:

$$\frac{2.8 \times 67.40}{34.8} =$$

When the problem has multiple steps, the numbers in the numerator are multiplied and then divided by each of the numbers in the denominator.

2.8 ⊠ 67.40 ÷ 34.8 = 5.422988506 = 5.4

Two SFs | Four SFs | Three SFs | Calculator display | Answer, rounded off to two SFs

Because the calculator display has more digits than the significant figures in the measured numbers allow, we need to round it off. Using the measured number that has the smallest number (two) of significant figures, 2.8, we round off the calculator display to an answer with two SFs.

A calculator is helpful in working problems and doing calculations faster.

Adding Significant Zeros

Sometimes, a calculator display gives a small whole number. For example, suppose the calculator display is 4, but you used measurements that have three significant numbers. Then two significant zeros are *added* to give 4.00 as the correct answer.

$$\frac{8.00}{2.00} = 4. = 4.00$$

Three SFs / Three SFs | Calculator display | Final answer, two zeros added to give three SFs

ENGAGE

Why is the answer for the multiplication of 0.3 × 52.6 written with one significant figure?

SAMPLE PROBLEM 2.4 Significant Figures in Multiplication and Division

TRY IT FIRST

Perform the following calculations with measured numbers. Write each answer with the correct number of significant figures.

a. 56.8 × 0.37 **b.** $\frac{(2.075)\,(0.585)}{(8.42)\,(0.0245)}$ **c.** $\frac{25.0}{5.00}$

SOLUTION GUIDE

ANALYZE THE PROBLEM	Given	Need	Connect
	multiplication and division	answer with SFs	rules for rounding off, adding zeros

STEP 1 Determine the number of significant figures in each measured number.

a. 56.8 × 0.37 (Three SFs, Two SFs) **b.** $\frac{(2.075)\,(0.585)}{(8.42)\,(0.0245)}$ (Four SFs, Three SFs / Three SFs, Three SFs) **c.** $\frac{25.0}{5.00}$ (Three SFs / Three SFs)

STEP 2 Perform the indicated calculation.

a. 21.016 (Calculator display) **b.** 5.884313345 (Calculator display) **c.** 5. (Calculator display)

STEP 3 Round off (or add zeros) to give the same number of significant figures as the measurement having the fewest significant figures.

a. 21 **b.** 5.88 **c.** 5.00

STUDY CHECK 2.4

Perform the following calculations with measured numbers and give the answers with the correct number of significant figures:

a. 45.26 × 0.01088 **b.** 2.6 ÷ 324 **c.** $\frac{4.0 \times 8.00}{16}$

ANSWER

a. 0.4924 **b.** 0.0080 or 8.0×10^{-3} **c.** 2.0

TEST

Try Practice Problems 2.27 and 2.28

Addition and Subtraction with Measured Numbers

In addition or subtraction, the final answer is written so that it has the same number of decimal places as the measurement having the fewest decimal places.

2.045	Thousandths place
⊕ 34.1	Tenths place
36.145	Calculator display
36.1	Answer, rounded off to the tenths place

When numbers are added or subtracted to give an answer ending in zero, the zero does not appear after the decimal point in the calculator display. For example, 14.5 g − 2.5 g = 12.0 g. However, if you do the subtraction on your calculator, the display shows 12. To write the correct answer, a significant zero is written after the decimal point.

ENGAGE

Why is the answer for the addition of 55.2 and 2.506 written with one decimal place?

SAMPLE PROBLEM 2.5 Decimal Places in Addition and Subtraction

TRY IT FIRST

Perform the following calculations and give each answer with the correct number of decimal places:

a. 104.45 mL + 0.838 mL + 46 mL **b.** 153.247 g − 14.82 g

SOLUTION GUIDE

ANALYZE THE PROBLEM	Given	Need	Connect
	addition and subtraction	correct number of decimal places	rules for rounding off

STEP 1 Determine the number of decimal places in each measured number.

a.

104.45 mL	Hundredths place
0.838 mL	Thousandths place
⊕ 46 mL	Ones place

b.

153.247 g	Thousandths place
⊖ 14.82 g	Hundredths place

STEP 2 Perform the indicated calculation.

a. 151.288 (Calculator display)

b. 138.427 (Calculator display)

STEP 3 Round off the answer to give the same number of decimal places as the measurement having the fewest decimal places.

a. 151 mL **b.** 138.43 g

STUDY CHECK 2.5

Perform the following calculations and give each answer with the correct number of decimal places:

a. 82.45 mg + 1.245 mg + 0.000 56 mg **b.** 4.259 L − 3.8 L

TEST

Try Practice Problems 2.29 and 2.30

ANSWER

a. 83.70 mg **b.** 0.5 L

PRACTICE PROBLEMS

2.3 Significant Figures in Calculations

LEARNING GOAL Adjust calculated answers to give the correct number of significant figures.

2.23 Round off each of the following calculator answers to three significant figures:

a. 1.854 kg **b.** 88.2038 L
c. 0.004 738 265 cm **d.** 8807 m
e. 1.832×10^5 s

2.24 Round off each of the calculator answers in problem 2.23 to two significant figures.

2.25 Round off or add zeros to each of the following to three significant figures:

a. 56.855 m **b.** 0.002 282 g
c. 11 527 s **d.** 8.1 L

2.26 Round off or add zeros to each of the following to two significant figures:

a. 3.2805 m **b.** 1.855×10^2 g
c. 0.002 341 mL **d.** 2 L

2.27 Perform each of the following calculations, and give an answer with the correct number of significant figures:

a. 45.7×0.034 **b.** $0.002\,78 \times 5$

c. $\dfrac{34.56}{1.25}$ **d.** $\dfrac{(0.2465)\,(25)}{1.78}$

e. $(2.8 \times 10^4)\,(5.05 \times 10^{-6})$ **f.** $\dfrac{(3.45 \times 10^{-2})\,(1.8 \times 10^5)}{(8 \times 10^3)}$

2.28 Perform each of the following calculations, and give an answer with the correct number of significant figures:

a. 400×185

b. $\dfrac{2.40}{(4)\,(125)}$

c. $0.825 \times 3.6 \times 5.1$

d. $\dfrac{(3.5)\,(0.261)}{(8.24)\,(20.0)}$

e. $\dfrac{(5 \times 10^{-5})\,(1.05 \times 10^4)}{(8.24 \times 10^{-8})}$

f. $\dfrac{(4.25 \times 10^2)\,(2.56 \times 10^{-3})}{(2.245 \times 10^{-3})\,(56.5)}$

2.29 Perform each of the following calculations, and give an answer with the correct number of decimal places:

a. 45.48 cm + 8.057 cm
b. 23.45 g + 104.1 g + 0.025 g
c. 145.675 mL − 24.2 mL
d. 1.08 L − 0.585 L

2.30 Perform each of the following calculations, and give an answer with the correct number of decimal places:

a. $236.02 \div 108.01$
b. 56.8×300
c. $28.7 \div 7$

2.4 Prefixes and Equalities

LEARNING GOAL Use the numerical values of prefixes to write a metric equality.

REVIEW

Writing Numbers in Scientific Notation (1.5)

The special feature of the metric system is that a **prefix** can be placed in front of any unit to increase or decrease its size by some factor of 10. For example, the prefixes *milli* and *micro* are used to make the smaller units, milligram (mg) and microgram (μg).

The U.S. Food and Drug Administration has determined the Daily Values (DV) for nutrients for adults and children age 4 or older. Examples of these recommended Daily Values, some of which use prefixes, are listed in **TABLE 2.4**.

The prefix *centi* is like cents in a dollar. One cent would be a "centidollar" or 0.01 of a dollar. That also means that one dollar is the same as 100 cents. The prefix *deci* is like dimes in a dollar. One dime would be a "decidollar" or 0.1 of a dollar. That also means that one dollar is the same as 10 dimes. **TABLE 2.5** lists some of the metric prefixes, their symbols, and their numerical values.

The relationship of a prefix to a unit can be expressed by replacing the prefix with its numerical value. For example, when the prefix *kilo* in kilometer is replaced with its value of 1000, we find that a kilometer is equal to 1000 m. Other examples follow:

1 **kilo**meter (1 km) = **1000** meters (1000 m = 10^3 m)
1 **kilo**liter (1 kL) = **1000** liters (1000 L = 10^3 L)
1 **kilo**gram (1 kg) = **1000** grams (1000 g = 10^3 g)

TABLE 2.4 Daily Values for Selected Nutrients

Nutrient	Amount Recommended
Calcium	1.0 g
Copper	2 mg
Iodine	150 μg (150 mcg)
Iron	18 mg
Magnesium	400 mg
Niacin	20 mg
Phosphorus	800 mg
Potassium	3.5 g
Selenium	70. μg (70. mcg)
Sodium	2.4 g
Zinc	15 mg

CORE CHEMISTRY SKILL

Using Prefixes

TABLE 2.5 Metric and SI Prefixes

Prefix	Symbol	Numerical Value	Scientific Notation	Equality
Prefixes That Increase the Size of the Unit				
tera	T	1 000 000 000 000	10^{12}	$1\ \text{Ts} = 1 \times 10^{12}\ \text{s}$ $1\ \text{s} = 1 \times 10^{-12}\ \text{Ts}$
giga	G	1 000 000 000	10^{9}	$1\ \text{Gm} = 1 \times 10^{9}\ \text{m}$ $1\ \text{m} = 1 \times 10^{-9}\ \text{Gm}$
mega	M	1 000 000	10^{6}	$1\ \text{Mg} = 1 \times 10^{6}\ \text{g}$ $1\ \text{g} = 1 \times 10^{-6}\ \text{Mg}$
kilo	k	1 000	10^{3}	$1\ \text{km} = 1 \times 10^{3}\ \text{m}$ $1\ \text{m} = 1 \times 10^{-3}\ \text{km}$
Prefixes That Decrease the Size of the Unit				
deci	d	0.1	10^{-1}	$1\ \text{dL} = 1 \times 10^{-1}\ \text{L}$ $1\ \text{L} = 10\ \text{dL}$
centi	c	0.01	10^{-2}	$1\ \text{cm} = 1 \times 10^{-2}\ \text{m}$ $1\ \text{m} = 100\ \text{cm}$
milli	m	0.001	10^{-3}	$1\ \text{ms} = 1 \times 10^{-3}\ \text{s}$ $1\ \text{s} = 1 \times 10^{3}\ \text{ms}$
micro	μ*	0.000 001	10^{-6}	$1\ \mu\text{g} = 1 \times 10^{-6}\ \text{g}$ $1\ \text{g} = 1 \times 10^{6}\ \mu\text{g}$
nano	n	0.000 000 001	10^{-9}	$1\ \text{nm} = 1 \times 10^{-9}\ \text{m}$ $1\ \text{m} = 1 \times 10^{9}\ \text{nm}$
pico	p	0.000 000 000 001	10^{-12}	$1\ \text{ps} = 1 \times 10^{-12}\ \text{s}$ $1\ \text{s} = 1 \times 10^{12}\ \text{ps}$

*In medicine, the abbreviation *mc* for the prefix *micro* is used because the symbol μ may be misread, which could result in a medication error. Thus, 1 μg would be written as 1 mcg.

ENGAGE

Why is 60. mg of vitamin C the same as 0.060 g of vitamin C?

An endoscope has a video camera with a width of 1 mm attached to the end of a thin cable.

SAMPLE PROBLEM 2.6 Prefixes and Equalities

TRY IT FIRST

An endoscopic camera has a width of 1 mm. Complete each of the following equalities involving millimeters:

a. 1 m = _____ mm **b.** 1 cm = _____ mm

SOLUTION

a. 1 m = 1000 mm **b.** 1 cm = 10 mm

STUDY CHECK 2.6

What is the relationship between millimeters and micrometers?

ANSWER

1 mm = 1000 μm (mcm)

Using a retinal camera, an ophthalmologist photographs the retina of an eye.

Measuring Length

An ophthalmologist may measure the diameter of the retina of an eye in centimeters (cm), whereas a surgeon may need to know the length of a nerve in millimeters (mm). When the prefix *centi* is used with the unit meter, it becomes *centimeter*, a length that is one-hundredth of a meter (0.01 m). When the prefix *milli* is used with the unit meter, it becomes *millimeter*, a length that is one-thousandth of a meter (0.001 m). There are 100 cm and 1000 mm in a meter.

If we compare the lengths of a millimeter and a centimeter, we find that 1 mm is 0.1 cm; there are 10 mm in 1 cm. These comparisons are examples of **equalities**, which show the

relationship between two units that measure the same quantity. Examples of equalities between different metric units of length follow:

$$1\text{ m} = 100\text{ cm} = 1 \times 10^2\text{ cm}$$
$$1\text{ m} = 1000\text{ mm} = 1 \times 10^3\text{ mm}$$
$$1\text{ cm} = 10\text{ mm} = 1 \times 10^1\text{ mm}$$

Some metric units for length are compared in **FIGURE 2.6**.

First quantity			Second quantity	
1	m	=	100	cm
↑	↑		↑	↑
Number	+ unit		Number	+ unit

This example of an equality shows the relationship between meters and centimeters.

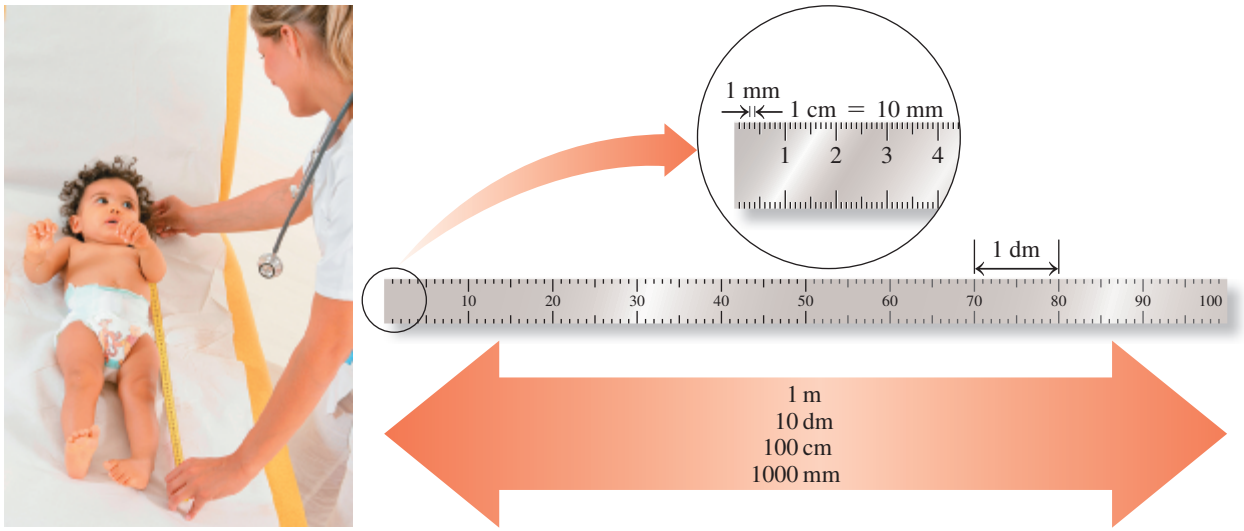


FIGURE 2.6 The metric length of 1 m is the same length as 10 dm, 100 cm, or 1000 mm.
How many millimeters (mm) are in 1 centimeter (cm)?

Measuring Volume

Volumes of 1 L or smaller are common in the health sciences. When a liter is divided into 10 equal portions, each portion is a deciliter (dL). There are 10 dL in 1 L. Laboratory results for bloodwork are often reported in mass per deciliter. **TABLE 2.6** lists normal laboratory test values for some substances in the blood.

TABLE 2.6 Some Normal Laboratory Test Values

Substance in Blood	Normal Range
Albumin	3.5–5.4 g/dL
Ammonia	20–70 μg/dL (mcg/dL)
Calcium	8.5–10.5 mg/dL
Cholesterol	105–250 mg/dL
Iron (male)	80–160 μg/dL (mcg/dL)
Protein (total)	6.0–8.5 g/dL

TEST
Try Practice Problems 2.31 to 2.38

When a liter is divided into a thousand parts, each of the smaller volumes is a milliliter (mL). In a 1-L container of physiological saline, there are 1000 mL of solution (see **FIGURE 2.7**). Examples of equalities between different metric units of volume follow:

$$1\text{ L} = 10\text{ dL} = 1 \times 10^1\text{ dL}$$
$$1\text{ L} = 1000\text{ mL} = 1 \times 10^3\text{ mL}$$
$$1\text{ dL} = 100\text{ mL} = 1 \times 10^2\text{ mL}$$
$$1\text{ mL} = 1000\ \mu\text{L (mcL)} = 1 \times 10^3\ \mu\text{L (mcL)}$$

The **cubic centimeter** (abbreviated as **cm^3** or **cc**) is the volume of a cube whose dimensions are 1 cm on each side. A cubic centimeter has the same volume as a milliliter, and the units are often used interchangeably.

$$1\text{ cm}^3 = 1\text{ cc} = 1\text{ mL}$$

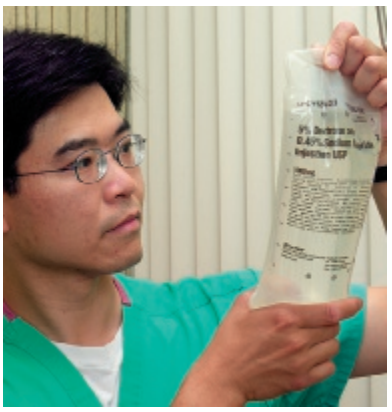


FIGURE 2.7 A plastic intravenous fluid container contains 1000 mL.
How many liters of solution are in the intravenous fluid container?

When you see *1 cm*, you are reading about length; when you see *1 cm*^{3} or *1 cc* or *1 mL*, you are reading about volume. A comparison of units of volume is illustrated in **FIGURE 2.8**.

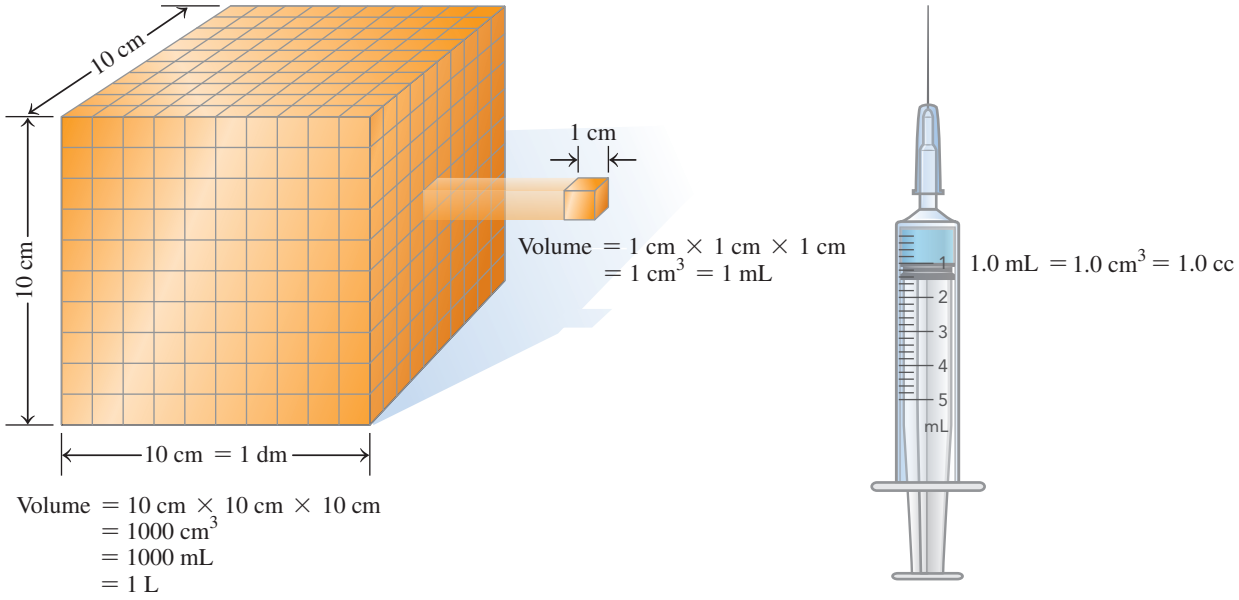


FIGURE 2.8 A cube measuring 10 cm on each side has a volume of 1000 cm^3, or 1 L; a cube measuring 1 cm on each side has a volume of 1 cm^3 (cc) or 1 mL.

What is the relationship between a milliliter (mL) and a cubic centimeter (cm^3)?

Measuring Mass

When you go to the doctor for a physical examination, your mass is recorded in kilograms, whereas the results of your laboratory tests are reported in grams, milligrams (mg), or micrograms (μg or mcg). A kilogram is equal to 1000 g. One gram represents the same mass as 1000 mg, and one mg equals 1000 μg (or 1000 mcg). Examples of equalities between different metric units of mass follow:

$$1\text{ kg} = 1000\text{ g} = 1 \times 10^3\text{ g}$$
$$1\text{ g} = 1000\text{ mg} = 1 \times 10^3\text{ mg}$$
$$1\text{ mg} = 1000\ \mu\text{g (mcg)} = 1 \times 10^3\ \mu\text{g (mcg)}$$

TEST

Try Practice Problems 2.39 to 2.42

PRACTICE PROBLEMS

2.4 Prefixes and Equalities

LEARNING GOAL Use the numerical values of prefixes to write a metric equality.

2.31 Write the abbreviation for each of the following units:
a. milligram **b.** deciliter
c. kilometer **d.** picogram

2.32 Write the abbreviation for each of the following units:
a. gigagram **b.** megameter
c. microliter **d.** nanosecond

2.33 Write the complete name for each of the following units:
a. ps **b.** cm **c.** nm **d.** mL

2.34 Write the complete name for each of the following units:
a. dL **b.** Ts **c.** mcg **d.** pm

2.35 Write the numerical value for each of the following prefixes:
a. centi **b.** tera **c.** milli **d.** deci

2.36 Write the numerical value for each of the following prefixes:
a. giga **b.** micro **c.** mega **d.** nano

2.37 Use a prefix to write the name for each of the following:
a. 0.1 g **b.** 10^{-6} g **c.** 1000 g **d.** 0.01 g

2.38 Use a prefix to write the name for each of the following:
a. 10^9 m **b.** 10^6 m **c.** 0.001 m **d.** 10^{-12} m

2.39 Complete each of the following metric relationships.
a. 1 s = _____ Ts **b.** 1 pm = _____ m
c. 1 cm = _____ m **d.** 1 m = _____ Gm

2.40 Complete each of the following metric relationships:
a. 1 Mg = _____ g **b.** 1 mL = _____ μL
c. 1 g = _____ kg **d.** 1 g = _____ mg

2.41 For each of the following pairs, which has the larger amount?
a. 1000 g or 0.1 kg **b.** 0.5 dL or 60 mL
c. 1000 nm or 10 µm **d.** 2 dm or 0.2 m

2.42 For each of the following pairs, which is the smaller unit?
a. mg or g **b.** centimeter or nanometer
c. millimeter or micrometer **d.** mL or dL
e. centigram or megagram

2.5 Writing Conversion Factors

LEARNING GOAL Write a conversion factor for two units that describe the same quantity.

REVIEW
Calculating Percentages (1.4)

Many problems in chemistry and the health sciences require you to change from one unit to another unit. Suppose you worked 2.0 h on your homework, and someone asked you how many minutes that was. You would answer 120 min. You must have multiplied 2.0 h × 60 min/h because you knew the equality (1 h = 60 min) that related the two units. When you expressed 2.0 h as 120 min, you did not change the amount of time you spent studying. You changed only the unit of measurement used to express the time. *Any equality can be written as fractions called* **conversion factors** *with one of the quantities in the numerator and the other quantity in the denominator*. Two conversion factors are always possible from any equality. Be sure to include the units when you write the conversion factors.

CORE CHEMISTRY SKILL
Writing Conversion Factors from Equalities

TEST
Try Practice Problems 2.43 and 2.44

Two Conversion Factors for the Equality: 1 h = 60 min

$$\frac{\text{Numerator} \longrightarrow}{\text{Denominator} \longrightarrow} \quad \frac{60 \text{ min}}{1 \text{ h}} \quad \text{and} \quad \frac{1 \text{ h}}{60 \text{ min}}$$

These factors are read as "60 minutes per 1 hour" and "1 hour per 60 minutes." The term *per* means "divide." Some common relationships are given in **TABLE 2.7**.

TABLE 2.7 Some Common Equalities

Quantity	Metric (SI)	U.S.	Metric–U.S.
Length	1 km = 1000 m	1 ft = 12 in.	2.54 cm = 1 in. (exact)
	1 m = 1000 mm	1 yd = 3 ft	1 m = 39.4 in.
	1 cm = 10 mm	1 mi = 5280 ft	1 km = 0.621 mi
Volume	1 L = 1000 mL	1 qt = 4 cups	946 mL = 1 qt
	1 dL = 100 mL	1 qt = 2 pt	1 L = 1.06 qt
	1 mL = 1 cm^3	1 gal = 4 qt	473 mL = 1 pt
	1 mL = 1 cc*		5 mL = 1 t (tsp)*
			15 mL = 1 T (tbsp)*
Mass	1 kg = 1000 g	1 lb = 16 oz	1 kg = 2.20 lb
	1 g = 1000 mg		454 g = 1 lb
	1 mg = 1000 mcg*		
Time	1 h = 60 min	1 h = 60 min	
	1 min = 60 s	1 min = 60 s	

*Used in medicine.

The numbers in any equality between two metric units or between two U.S. system units are definitions. Because numbers in a definition are exact, they are not used to determine significant figures. For example, the equality of 1 g = 1000 mg is a definition, which means that both of the numbers 1 and 1000 are exact.

When an equality consists of a metric unit and a U.S. unit, one of the numbers in the equality is obtained by measurement and counts toward the significant figures in the answer. For example, the equality of 1 lb = 454 g is obtained by measuring the grams in exactly 1 lb. In this equality, the measured quantity 454 g has three significant figures, whereas the 1 is exact. An exception is the relationship of 1 in. = 2.54 cm, which has been defined as exact.

TEST
Try Practice Problems 2.45 and 2.46

Metric Conversion Factors

We can write two metric conversion factors for any of the metric relationships. For example, from the equality for meters and centimeters, we can write the following factors:

Metric Equality	Conversion Factors
1 m = 100 cm	$\frac{100 \text{ cm}}{1 \text{ m}}$ and $\frac{1 \text{ m}}{100 \text{ cm}}$

ENGAGE
Why does the equality 1 day = 24 h have two conversion factors?

FIGURE 2.9 In the United States, the contents of many packaged foods are listed in both U.S. and metric units.

What are some advantages of using the metric system?

Both are proper conversion factors for the relationship; one is just the inverse of the other. *The usefulness of conversion factors is enhanced by the fact that we can turn a conversion factor over and use its inverse.* The numbers 100 and 1 in this equality and its conversion factors are both *exact* numbers.

Metric–U.S. System Conversion Factors

Suppose you need to convert from pounds, a unit in the U.S. system, to kilograms in the metric system. A relationship you could use is

$$1 \text{ kg} = 2.20 \text{ lb}$$

The corresponding conversion factors would be

$$\frac{2.20 \text{ lb}}{1 \text{ kg}} \quad \text{and} \quad \frac{1 \text{ kg}}{2.20 \text{ lb}}$$

FIGURE 2.9 illustrates the contents of some packaged foods in both U.S. and metric units.

Equalities and Conversion Factors Stated Within a Problem

An equality may also be stated within a problem that applies only to that problem. For example, the speed of a car in kilometers per hour or the milligrams of vitamin C in a tablet would be specific relationships for that problem only. From each of the following statements, we can write an equality and two conversion factors, and identify each number as exact or give the number of significant figures.

TEST

Try Practice Problems 2.47 to 2.52

The car was traveling at a speed of 85 km/h.

Equality	Conversion Factors	Significant Figures or Exact
85 km = 1 h	$\frac{85 \text{ km}}{1 \text{ h}}$ and $\frac{1 \text{ h}}{85 \text{ km}}$	The 85 km is measured: It has two significant figures. The 1 h is exact.

Vitamin C, an antioxidant needed by the body, is found in fruits such as lemons.

One tablet contains 500 mg of vitamin C.

Equality	Conversion Factors	Significant Figures or Exact
1 tablet = 500 mg of vitamin C	$\frac{500 \text{ mg vitamin C}}{1 \text{ tablet}}$ and $\frac{1 \text{ tablet}}{500 \text{ mg vitamin C}}$	The 500 mg is measured: It has one significant figure. The 1 tablet is exact.

Conversion Factors from a Percentage

A percentage (%) is written as a conversion factor by choosing a unit and expressing the numerical relationship of the parts of this unit to 100 parts of the whole. For example, a person might have 18% body fat by mass. The percentage quantity can be written as 18 mass units of body fat in every 100 mass units of body mass. Different mass units such as grams (g), kilograms (kg), or pounds (lb) can be used, but both units used for the factor must be the same.

Equality	Conversion Factors	Significant Figures or Exact
18 kg of body fat = 100 kg of body mass	$\frac{18 \text{ kg body fat}}{100 \text{ kg body mass}}$ and $\frac{100 \text{ kg body mass}}{18 \text{ kg body fat}}$	The 18 kg is measured: It has two significant figures. The 100 kg is exact.

The thickness of the skin-fold at the abdomen is used to determine the percentage of body fat.

Conversion Factors from Dosage Problems

Equalities stated within dosage problems for medications can also be written as conversion factors. For example, Keflex (cephalexin), an antibiotic used for respiratory and ear

infections, is available in 250-mg capsules. The quantity of Keflex in a capsule can be written as an equality from which two conversion factors are possible.

Equality	Conversion Factors	Significant Figures or Exact
1 capsule = 250 mg of Keflex	$\frac{250\text{ mg Keflex}}{1\text{ capsule}}$ and $\frac{1\text{ capsule}}{250\text{ mg Keflex}}$	The 250 mg is measured: It has two significant figures. The 1 capsule is exact.

Keflex (cephalexin), used to treat respiratory infections, is available in 250-mg capsules.

SAMPLE PROBLEM 2.7 Equalities and Conversion Factors in a Problem

TRY IT FIRST

Write the equality and two conversion factors, and identify each number as exact or give the number of significant figures for each of the following:

a. The medication that Greg takes for his high blood pressure contains 40. mg of propranolol in 1 tablet.

b. Cold-water fish such as salmon contains 1.9% omega-3 fatty acids by mass.

SOLUTION

a. There are 40. mg of propranolol in 1 tablet.

Equality	Conversion Factors	Significant Figures or Exact
1 tablet = 40. mg of propranolol	$\frac{40.\text{ mg propranolol}}{1\text{ tablet}}$ and $\frac{1\text{ tablet}}{40.\text{ mg propranolol}}$	The 40. mg is measured: It has two significant figures. The 1 tablet is exact.

Propranolol is used to lower high blood pressure.

b. Cold-water fish such as salmon contains 1.9% omega-3 fatty acids by mass.

Equality	Conversion Factors	Significant Figures or Exact
1.9 g of omega-3 fatty acids = 100 g of salmon	$\frac{1.9\text{ g omega-3 fatty acids}}{100\text{ g salmon}}$ and $\frac{100\text{ g salmon}}{1.9\text{ g omega-3 fatty acids}}$	The 1.9 g is measured: It has two significant figures. The 100 g is exact.

Salmon contains high levels of omega-3 fatty acids.

STUDY CHECK 2.7

Levsin (hyoscyamine), used to treat stomach and bladder problems, is available as drops with 0.125 mg Levsin per 1 mL of solution. Write the equality and two conversion factors, and identify each number as exact or give the number of significant figures.

ANSWER

0.125 mg of Levsin = 1 mL of solution

$$\frac{0.125\text{ mg Levsin}}{1\text{ mL solution}} \text{ and } \frac{1\text{ mL solution}}{0.125\text{ mg Levsin}}$$

The 0.125 mg is measured: It has three SFs. The 1 mL is exact.

ENGAGE

How is a percentage used to write an equality and two conversion factors?

TEST

Try Practice Problems 2.53 and 2.54

PRACTICE PROBLEMS

2.5 Writing Conversion Factors

LEARNING GOAL Write a conversion factor for two units that describe the same quantity.

2.43 Why can two conversion factors be written for an equality such as 1 m = 100 cm?

2.44 How can you check that you have written the correct conversion factors for an equality?

2.45 Write the equality and two conversion factors for each of the following pairs of units:

a. centimeters and meters
b. nanograms and grams
c. liters and kiloliters
d. seconds and milliseconds

2.46 Write the equality and two conversion factors for each of the following pairs of units:

a. centimeters and inches
b. kilometers and miles
c. pounds and grams
d. quarts and liters

2.47 Write the equality and two conversion factors, and identify the numbers as exact or give the number of significant figures for each of the following:

a. One yard is 3 ft.
b. One kilogram is 2.20 lb.
c. A car goes 27 mi on 1 gal of gas.
d. Sterling silver is 93% silver by mass.

2.48 Write the equality and two conversion factors, and identify the numbers as exact or give the number of significant figures for each of the following:

a. One liter is 1.06 qt.
b. At the store, oranges are $1.29 per lb.
c. One deciliter contains 100 mL.
d. An 18-carat gold ring contains 75% gold by mass.

2.49 Write the equality and two conversion factors, and identify the numbers as exact or give the number of significant figures for each of the following:

a. A bee flies at an average speed of 3.5 m per second.
b. The Daily Value (DV) for potassium is 3.5 g.
c. An automobile traveled 26.0 km on 1 L of gasoline.
d. Silicon makes up 28.2% by mass of Earth's crust.

2.50 Write the equality and two conversion factors, and identify the numbers as exact or give the number of significant figures for each of the following:

a. The Daily Value (DV) for iodine is 150 mcg.
b. Gold jewelry contains 58% gold by mass.
c. The price of a liter of milk is $1.65.
d. A metric ton is 1000 kg.

Clinical Applications

2.51 Write the equality and conversion factors for each of the following statements:

a. An hour has 60 mins.
b. A week has 7 days.
c. A can containing 355 mL of Coke.
d. A bottle of 20 Vitamin C tablets.

2.52 Write the equality and two conversion factors, and identify the numbers as exact or give the number of significant figures for each of the following:

a. The label on a bottle reads 10 mg of furosemide per 1 mL.
b. The Daily Value (DV) for selenium is 70. mcg.
c. An IV of normal saline solution has a flow rate of 85 mL per hour.
d. One capsule of fish oil contains 360 mg of omega-3 fatty acids.

2.53 Write an equality and two conversion factors for each of the following medications:

a. 10 mg of Atarax per 5 mL of Atarax syrup
b. 0.25 g of Lanoxin per 1 tablet of Lanoxin
c. 300 mg of Motrin per 1 tablet of Motrin

2.54 Write an equality and two conversion factors for each of the following medications:

a. 2.5 mg of Coumadin per 1 tablet of Coumadin
b. 100 mg of Clozapine per 1 tablet of Clozapine
c. 1.5 g of Cefuroxime per 1 mL of Cefuroxime

2.6 Problem Solving Using Unit Conversion

LEARNING GOAL Use conversion factors to change from one unit to another.

The process of problem solving in chemistry often requires one or more conversion factors to change a given unit to the needed unit. For the problem, the unit of the given and the unit of the needed are identified. From there, the problem is set up with one or more conversion factors used to convert the given unit to the needed unit as seen in Sample Problem 2.8.

Given unit × one or more conversion factors = needed unit

SAMPLE PROBLEM 2.8 Using Conversion Factors

TRY IT FIRST

Greg's doctor has ordered a PET scan of his heart. In radiological imaging, dosages of pharmaceuticals are based on body mass. If Greg weighs 164 lb, what is his body mass in kilograms?