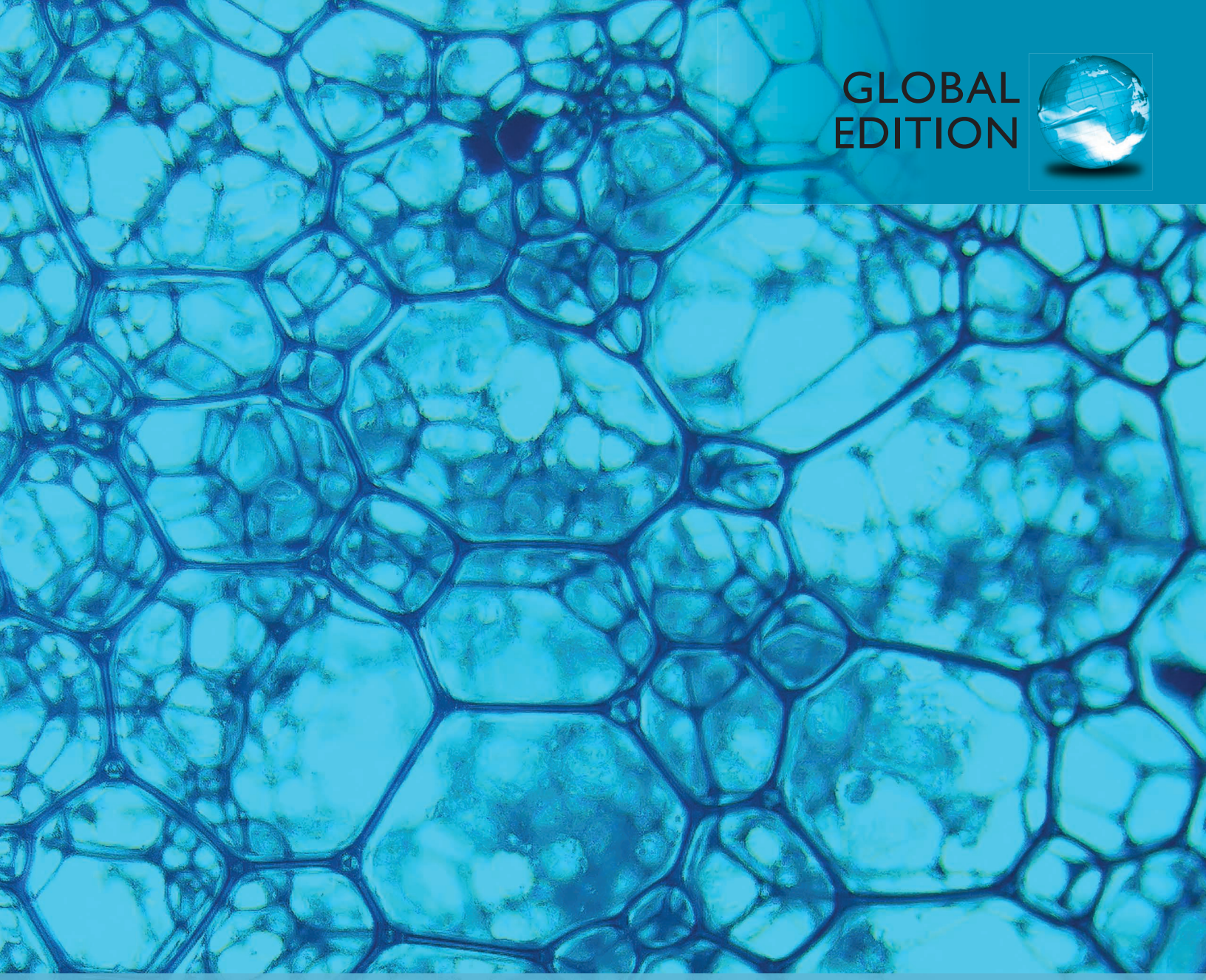

GLOBAL EDITION

General, Organic, and Biological Chemistry

Structures of Life

SIXTH EDITION

Timberlake

General, Organic, and Biological Chemistry

STRUCTURES OF LIFE

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General, Organic, and Biological Chemistry

STRUCTURES OF LIFE

Sixth 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 *General, Organic and Biological Chemistry*, sixth edition, she is also the author of *An Introduction to General, Organic, and Biological Chemistry*, thirteenth edition, with the accompanying *Laboratory Manual*, *Essential Laboratory Manual for General, Organic, and Biological Chemistry*, and *Basic Chemistry*, fifth edition.

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 attends and speaks at chemistry conferences and educational meetings on the teaching methods in chemistry that 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, and cooking.

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-Györgyi

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

—Albert Einstein

Preface

Welcome to the sixth edition of *General, Organic, and Biological Chemistry, Structures of Life*. 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 may interest you
- develop problem-solving skills that lead to your success in chemistry
- promote learning and success in chemistry

New for the Sixth Edition

New and updated features have been added throughout this sixth 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.
- 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 describe successful ways to study and learn chemistry.
- NEW! **Expanded Study Checks in Sample Problems** now contain multiple questions to give students additional self-testing practice.
- NEW! The names and symbols for the newest elements 113, Nihonium, Nh, 115, Moscovium, Mc, 117, Tennessine, Ts, and 118, Oganesson, Og.
- NEW! The **Steps in the Sample Problems** include a worked-out Solution plan for solving the problem.
- NEW! **Table Design** now has cells that highlight and organize related data.
- 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 are now placed in the margin at the beginning of a Section, listing the Key Math Skills and Core Chemistry Skills from the previous chapters, which provide the foundation for learning new chemistry principles in the current chapter.
- UPDATED! **Key Math Skills** review basic math relevant to the chemistry the students are learning throughout the text. A **Key Math Skill Review** at the end of each chapter summarizes and gives additional examples.
- UPDATED! **Core Chemistry Skills** identify the key chemical principles in each chapter that are required for successfully learning chemistry. A **Core Chemistry Skill Review** at the end of each chapter helps reinforce the material and gives additional examples.
- UPDATED! **Analyze the Problem** features included in the Solutions of the Sample Problems strengthen critical-thinking skills and illustrate the breakdown of a word problem into the components required to solve it.
- UPDATED! **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.
- UPDATED! New zoom design highlights macro-to-micro art and captions are now on a gray screen to emphasize the art and text content.
- UPDATED! **Concept Maps** are updated with new design that shows a clearer path linking concept to concept.
- UPDATED! Biochemistry chapters 15, 17, and 19 to 24 have been rewritten to strengthen connections between sections, and include new Study Checks and new Chemistry Links to Health.

Chapter Organization of the Sixth 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 two murders and features the work and career of forensic scientists.
- A new Clinical Update feature describes the forensic evidence that helps to solve the murders and includes Clinical Applications.
- Scientific Method: Thinking Like a Scientist is expanded to include *law* and *theory*.
- An updated Section 1.3 Studying and Learning Chemistry expands the discussion of strategies that improve learning and understanding of content.
- New Section 1.5 Writing Numbers in Scientific Notation is added.
- Key Math Skills are: Identifying Place Values, Using Positive and Negative Numbers in Calculations, Calculating Percentages, Solving Equations, Interpreting Graphs, and Writing Numbers in Scientific Notation.

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

- The Chapter Opener tells the story of a patient with high blood pressure and features the work and career of a registered nurse.
- The Clinical Update describes the patient's status and follow-up visit with his doctor.
- 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.
- Clinical Applications feature questions about measurements, daily values for minerals and vitamins, and equalities and conversion factors for medications.
- The Key Math Skill is: Rounding Off.
- Core Chemistry Skills are: Counting Significant Figures, Using Significant Figures in Calculations, Using Prefixes, Writing Conversion Factors from Equalities, Using Conversion Factors, and Using Density as a Conversion Factor.

Chapter 3, Matter and Energy, classifies matter and states of matter, describes temperature measurement, and discusses energy, specific heat, 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.
- The Clinical Update describes the 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, dental implants, 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 configurations 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. Atomic mass is calculated using the masses of the naturally occurring isotopes and their abundances. Electron arrangements are written using orbital diagrams, electron configurations, and abbreviated electron configurations.

- The Chapter Opener and Clinical Update feature the improvement in crop production by a farmer.
- Atomic number and mass number are used to calculate the number of protons and neutrons in an atom.
- The number of protons and neutrons are used to calculate the mass number and to write the atomic symbol for an isotope.
- 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 Configurations, Using the Periodic Table to Write Electron Configurations, 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 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.
- The 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-90 injections for arthritis pain, and millicuries in a dose of phosphorus-32.
- New art includes the illustration of the organs of the body where medical radioisotopes are used for diagnosis and treatment.
- 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 the chemistry of aspirin and features the work and career of a pharmacy technician.
- The Clinical Update describes several types of compounds at a pharmacy and includes Clinical Applications.
- Section 6.6 is now titled Lewis Structures for Molecules and Polyatomic Ions, and 6.9 is now titled Intermolecular Forces in Compounds.
- New material on polyatomic ions compares the names of *ate* ions and *ite* ions, the charge of sulfate and sulfite, phosphate and phosphite, carbonate and hydrogen carbonate, and the formulas and charges of halogen polyatomic ions with oxygen.
- Core Chemistry Skills are: Writing Positive and Negative Ions, Writing Ionic Formulas, Naming Ionic Compounds, Writing the Names and Formulas for Molecular Compounds, Drawing Lewis Structures, Using Electronegativity, Predicting Shape, Identifying Polarity of Molecules, and Identifying Intermolecular Forces.
- The interchapter problem set, Combining Ideas from Chapters 4 to 6, completes the chapter.

Chapter 7, Chemical Reactions and Quantities, shows students how to balance chemical equations and to recognize the types of chemical reactions: combination, decomposition, single replacement, double replacement , and combustion. Students are introduced to moles and molar masses of compounds, which are used in calculations to determine the mass or number of particles in a given quantity as well as limiting reactants and percent yield. The chapter concludes with a discussion of energy in reactions.

- The Chapter Opener describes the symptoms of heart and pulmonary disease and discusses the career of an exercise physiologist.
- A new Clinical Update, Improving Natalie's Overall Fitness, discusses her test results and suggests exercise to improve oxygen intake.
- A new order of topics begins with Section 7.5 Molar Mass, 7.6 Calculations Using Molar Mass, 7.7 Mole Relationships in Chemical Equations, and 7.8 Mass Calculations for Chemical Reactions, Section 7.9 Limiting Reactants and Percent Yield, and 7.10 Energy in Chemical Reactions.
- New Sample Problems are: Oxidation and Reduction, and Exothermic and Endothermic Reactions.
- New expanded art shows visible evidence of several types of chemical reactions.
- Core Chemistry Skills are: Balancing a Chemical Equation, Classifying Types of Chemical Reactions, Identifying Oxidized and Reduced Substances, Converting Particles to Moles, Calculating Molar Mass, Using Molar Mass as a Conversion Factor, Using Mole–Mole Factors, Converting Grams to Grams, Calculating Quantity of Product from a Limiting Reactant, Calculating Percent Yield, and Using the Heat of Reaction.

Chapter 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, Dalton's, and the Ideal Gas Law. Problem-solving strategies enhance the discussion and calculations with the ideal gas laws.

- The Chapter Opener features the work and career of a respiratory therapist who uses oxygen to treat a child with asthma.
- The Clinical Update describes exercise to manage 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, Using the Ideal Gas Law, Calculating Mass or Volume of a Gas in a Chemical Reaction, and Calculating Partial Pressure.
- The interchapter problem set, Combining Ideas from Chapters 7 and 8, completes the chapter.

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, freezing and boiling points, 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.
- The Clinical Update explains dialysis treatment and electrolyte levels in dialysate fluid.

- A new example of suspensions used to purify water in treatment plants is added.
- New art illustrates the freezing point decrease and boiling point increase for aqueous solutions with increasing number of moles of solute in one kilogram of water.
- Core Chemistry Skills are: Using Solubility Rules, Calculating Concentration, Using Concentration as a Conversion Factor, Calculating the Quantity of a Reactant or Product for a Chemical Reaction in Solution, and Calculating the Boiling Point/Freezing Point of a Solution.

Chapter 10, Reaction Rates and Chemical Equilibrium, looks at the rates of reactions and the equilibrium condition when forward and reverse rates for a reaction become equal. Equilibrium expressions for reactions are written and equilibrium constants are calculated. Le Châtelier's principle is used to evaluate the impact on concentrations when stress is placed on the system.

- The Chapter Opener describes the symptoms of infant respiratory distress syndrome (IRDS) and discusses the career of a neonatal nurse.
- The Clinical Update describes a child with anemia, hemoglobin–oxygen equilibrium, and a diet that is high in iron-containing foods.
- Core Chemistry Skills are: Writing the Equilibrium Expression, Calculating an Equilibrium Constant, Calculating Equilibrium Concentrations, and Using Le Châtelier's Principle.

Chapter 11, Acids and Bases, discusses acids and bases and their strengths, and conjugate acid–base pairs. The dissociation of strong and weak acids and bases is related to their strengths as acids or bases. The dissociation of water leads to the water dissociation expression, K_w, the pH scale, and the calculation of pH. Chemical equations for acids in reactions are balanced and titration of an acid is illustrated. Buffers are discussed along with their role in the blood. The pH of a buffer is calculated.

- The Chapter Opener describes a blood sample for an emergency room patient sent to the clinical laboratory for analysis of blood pH and CO_2 gas and features the work and career of a clinical laboratory technician.
- The Clinical Update describes the symptoms and treatment for acid reflux disease (GERD).
- Key Math Skills are: Calculating pH from $[H_3O^+]$ and Calculating $[H_3O^+]$ from pH.
- Core Chemistry Skills are: Identifying Conjugate Acid–Base Pairs, Calculating $[H_3O^+]$ and $[OH^-]$ in Solutions, Writing Equations for Reactions of Acids and Bases, Calculating Molarity or Volume of an Acid or Base in a Titration, and Calculating the pH of a Buffer.
- The interchapter problem set, Combining Ideas from Chapters 9 to 11, completes the chapter.

Chapter 12, 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.
- The Clinical Update describes the treatment of burns in the hospital and the types of fuels identified in the fire.
- Subsections in 12.4 Solubility and Density and 12.5 Identifying Alkenes and Alkynes are revised for clarity.
- More line-angle formulas for organic structures in Practice Problems have been added.
- Core Chemistry Skills are: Naming and Drawing Alkanes and Writing Equations for Hydrogenation, Hydration, and Polymerization.

Chapter 13, Alcohols, Phenols, Thiols, and Ethers, describes the functional groups and names of alcohols, phenols, thiols, and ethers.

- The new Chapter Opener describes local anesthetics for surgery to repair a torn anterior cruciate ligament (ACL) and features the work and career of a nurse anesthetist.
- The Clinical Update describes some foods added to a diet plan including a comparison of their functional groups.
- New art includes new career photo of a nurse anesthetist, ball-and-stick models added to primary, secondary, and tertiary alcohol structures in Section 13.3 to visualize the classification of alcohols, anesthesia apparatus for delivery of isoflurane, exhausted athlete, and perming hair.
- Chemistry Link to Health "Hand Sanitizers" is revised and "Methanol Poisoning" is moved into "Oxidation of Alcohol in the Body" at the end of Section 13.4.
- Core Chemistry Skills are: Identifying Alcohols, Phenols, and Thiols, Naming Alcohols and Phenols, Writing Equations for the Dehydration of Alcohols, and Writing Equations for the Oxidation of Alcohols.

Chapter 14, Aldehydes and Ketones, discusses the nomenclature, structures, and oxidation and reduction of aldehydes and ketones. The chapter discusses the formation of hemiacetals and acetals.

- The Chapter Opener describes the risk factors for melanoma and discusses the career of a dermatology nurse.
- The Clinical Update discusses melanoma, skin protection, and functional groups of sunscreens.
- New art using line-angle formulas is drawn for separate equations of hemiacetal and acetal formation.
- Sections 14.3 Oxidation and Reduction of Aldehydes and Ketones and 14.4 Addition of Alcohols: Hemiacetals and Acetals are revised for clarity.
- A summary of the Tollens' and Benedict's tests is added to section 14.3.
- Core Chemistry Skills are: Naming Aldehydes and Ketones, and Forming Hemiacetals and Acetals.
- New structures of pamplemousse acetal in grapefruit and rose acetal in perfume are added.
- The interchapter problem set, Combining Ideas from Chapters 12 to 14, completes the chapter.

Chapter 15, 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. The formation of glycosidic bonds in disaccharides and polysaccharides is described.

- The Chapter Opener describes a diabetes patient and her diet and features the work and career of a diabetes nurse.
- The Clinical Update describes a diet and exercise program to lower blood glucose.
- New art accompanies content on tooth decay and use of xylitol, the structures of amino sugars and uronic acids, and hyaluronic acid used as facial fillers.
- New Chemistry Links to Health are: Dental Cavities and Xylitol Gum, and Varied Biological Roles of Carbohydrate Polymers: The Case of Glycosaminoglycans.
- New Study Checks include penicillamine to treat rheumatoid arthritis, and ethambutol to treat tuberculosis.
- Section on Chirality is moved to Chapter 15.
- Core Chemistry Skills are: Identifying Chiral Molecules, Identifying D and L Fischer Projections for Carbohydrates, and Drawing Haworth Structures.

Chapter 16, Carboxylic Acids and Esters, discusses the functional groups and naming of carboxylic acids and esters. Chemical reactions include esterification and acid and base hydrolysis of esters.

- The Chapter Opener describes heart surgery and discusses the work and career of a surgical technician.
- The Clinical Update describes the chemistry and use of liquid bandages.
- More line-angle structures for carboxylic acids and esters have been added.
- New art of ester-containing fruit has been added.
- Core Chemistry Skills are: Naming Carboxylic Acids and Hydrolyzing Esters.

Chapter 17, 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. The role of phospholipids in the lipid bilayer of cell membranes is discussed as well as the lipids that function as steroid hormones.

- The updated Chapter Opener describes a patient with symptoms of familial hypercholesterolemia and features the work and career of a clinical lipid specialist.
- The Clinical Update describes medications a program to and a diet to lower cholesterol.
- New art diagrams include glaucoma and its treatment with a prostaglandin, healthy and nonhealthy livers, and the steroid structure of spironolactone.
- Chemistry Links to Health are: Omega-3 Fatty Acids in Fish Oils and Infant Respiratory Distress Syndrome (IRDS).
- New Chemistry Links to Health are: A Prostaglandin-like Medication for Glaucoma That Also Thickens Eyelashes, and A Steroid Receptor Antagonist That Prevents the Development of Male Sexual Characteristics.
- 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.

Chapter 18, Amines and Amides, emphasizes the nitrogen atom in their functional groups and their names. Properties of amines including classification, boiling point, solubility in water, and use as neurotransmitters are included. Alkaloids are discussed as the naturally occurring amines in plants. Chemical reactions include dissociation and neutralization of amines, amidation, and acid and base hydrolysis of amides.

- The Chapter Opener describes pesticides and pharmaceuticals used on a ranch and discusses the career of an environmental health practitioner.
- The Clinical Update describes the collection of soil and water samples for testing of insecticides and antibiotics.
- New line-angle formulas are drawn for amines, alkaloids, heterocyclic amines, and neurotransmitters.
- Introduction to Section 18.5, Amides is revised.
- Chemistry Link to Health Synthesizing Drugs and Opioids is revised.
- Clinical Applications include novocaine, lidocaine, ritalin, niacin, serotonin, histamine, acetylcholine, dose calculations of pesticides and antibiotics, enrofloxacin, and voltaren.
- Core Chemistry Skills are: Forming Amides and Hydrolyzing Amides.
- The interchapter problem set, Combining Ideas from Chapters 15 to 18, completes the chapter.

Chapter 19, Amino Acids and Proteins, discusses amino acids, formation of peptide bonds and the primary, secondary, tertiary, and quaternary structural levels of proteins. The ionized structures of amino acids are drawn at physiological pH.

- 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 hematology nurse.
- A new Clinical Update discusses the diagnosis of sickle-cell anemia using electrophoresis and its treatment.
- The protein structure sections are reorganized as: 19.2 Proteins: Primary Structure; 19.3 Proteins: Secondary Structure; and 19.4 Proteins: Tertiary and Quaternary Structures.
- Chemistry Links to Health are: Essential Amino Acids and Complete Proteins, Protein Secondary Structures and Alzheimer's Disease, and Sickle-Cell Anemia.
- New Chemistry Links to Health are: Cystinuria, and Keratoconus.
- New art includes normal cornea, cornea with keratoconus, collagen fibers in keratoconus, and insoluble fiber formation in sickle-cell anemia.

- New Sample Problems are: 19.3 Identifying a Tripeptide and 19.4 Drawing a Peptide.
- Core Chemistry Skills are: Drawing the Structure for an Amino Acid at Physiological pH and Identifying the Primary, Secondary, Tertiary, and Quaternary Structures of Proteins.

Chapter 20, Enzymes and Vitamins, relates the importance of the three-dimensional shape of proteins to their function as enzymes. The shape of an enzyme and its substrate are factors in enzyme regulation. End products of an enzyme-catalyzed sequence can increase or decrease the rate of an enzyme-catalyzed reaction. Other regulatory processes include allosteric enzymes, covalent modification and phosphorylation, and zymogens. Proteins change shape and lose function when subjected to pH changes and high temperatures. The important role of water-soluble vitamins as coenzymes is related to enzyme function.

- The Chapter Opener discusses the symptoms of lactose intolerance and describes the career of a physician assistant.
- The Clinical Update describes the hydrogen breath test to confirm lactose intolerance and a diet that is free of lactose and use of Lactaid.
- Chemistry Link to Health is: Isoenzymes as Diagnostic Tools.
- New Chemistry Links to Health are: Fabry Disease and Taking Advantage of Enzyme Inhibition to Treat Cancer: Imatinib.
- New art includes the structure of galactosidase A and enzyme inhibition of imatinib used to treat myeloid leukemia.
- Core Chemistry Skills are: Describing Enzyme Action, Classifying Enzymes, Identifying Factors Affecting Enzyme Activity, and Describing the Role of Cofactors.

Chapter 21, 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.

- The Chapter Opener describes a patient's diagnosis and treatment of breast cancer and discusses the work and career of a histology technician.
- A 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.
- The Chemistry Link to Health Protein Sequencing was moved from Chapter 19 to Chapter 21.
- New Chemistry Links to Health are: Cataracts and Ehlers–Danlos Syndrome.
- Core Chemical Skills are: Writing the Complementary DNA Strand, Writing the mRNA Segment for a DNA Template, and Writing the Amino Acid for an mRNA Codon.
- The interchapter problem set, Combining Ideas from Chapters 19 to 21, completes the chapter.

Chapter 22, Metabolic Pathways for Carbohydrates, describes the stages of metabolism and the digestion of carbohydrates, our most important fuel. The breakdown of glucose to pyruvate is described using glycolysis, which is followed under aerobic conditions by the decarboxylation of pyruvate to acetyl CoA. The synthesis of glycogen and the synthesis of glucose from noncarbohydrate sources are discussed.

- The Chapter Opener describes the symptoms of a glycogen storage disease and discusses the career of a hepatology nurse.
- The Clinical Update describes medical treatment of frequent feedings of glucose for von Gierke's disease, in which a child has a defective glucose-6-phosphatase and cannot break down glucose-6-phosphate to glucose.
- Chemistry Link to Health is: Glycogen Storage Diseases (GSDs).
- New Chemistry Links to Health are: Galactosemia and Glucocorticoids, and Steroid-Induced Diabetes.
- Sections 22.4 "Glycolysis: Oxidation of Glucose", 22.6 "Glycogen Synthesis and Degradation", and 22.7 "Gluconeogenesis: Glucose Synthesis" are revised for clarity.
- New art includes diagrams of normal lactose oxidation compared to galactosemia, and the impact of glucocorticoids on glucose metabolism.
- Core Chemistry Skills are: Identifying Important Coenzymes in Metabolism, Identifying the Compounds in Glycolysis, and Identifying the Compounds and Enzymes in Glycogenesis and Glycogenolysis.

Chapter 23, Metabolism and Energy Production, looks at the entry of acetyl CoA into the citric acid cycle and the production of reduced coenzymes for electron transport, oxidative phosphorylation, and the synthesis of ATP. The malate–aspartate shuttle describes the transport of NADH from the cytosol into the mitrochondrial matrix.

- The new Chapter Opener discusses a child with mitochondrial myopathy and discusses the work and career of a physical therapist.
- A new Clinical Update discusses treatment that helps increase a child's functional capacity.
- New Clinical Applications include problems about diseases associated with enzyme deficiencies.
- New material discusses diseases of enzymes in the citric acid cycle such as fumarase deficiency that causes neurological impairment, developmental delay, and seizures.
- Feedback Control, Covalent Modification, and Enzyme Inhibition subsections are expanded to enhance student understanding.

- A new subsection Diseases of the Citric Acid Cycle is added to Section 23.1.
- Section 23.2 Electron Transport and ATP is revised for clarity.
- Chemistry Links to Health are: Toxins: Inhibitors of Electron Transport, Uncouplers of ATP Synthase, and Efficiency of ATP Production.
- Core Chemistry Skills are: Describing the Reactions in the Citric Acid Cycle and Calculating the ATP Produced from Glucose.

Chapter 24, Metabolic Pathways for Lipids and Amino Acids, discusses the digestion of lipids and proteins and the metabolic pathways that convert fatty acids and amino acids into energy. Discussions include the conversion of excess carbohydrates to triacylglycerols in adipose tissue and how the intermediates of the citric acid cycle are converted to nonessential amino acids.

- The Chapter Opener describes a liver profile with elevated levels of liver enzymes for a patient with chronic hepatitis C infection and discusses the career of a public health nurse.
- The Clinical Update describes interferon and ribavirin therapy for hepatitis C.
- New material discusses the digestion of triacylglycerols and dietary fats, lipase deficiency, eruptive xanthomas, calculating ATP from beta oxidation of an unsaturated fatty acid, and ketoacidosis.
- Sections 24.1 Digestion of Triacylglycerols, 24.2 Oxidation of Fatty Acids, and 24.3 ATP and Fatty Acid Oxidation are revised for clarity.
- New art includes xanthomas, ackee fruit, and injection of interferon.
- Chemistry Links to Health are: Diabetes and Ketone Bodies and Phenylketonuria (PKU).
- A new Chemistry Link to Health discusses Jamaican vomiting sickness.
- Clinical Applications include new problems about Jamaican vomiting sickness caused by an inhibitor of acyl CoA dehydrogenase, and inhibitors of beta oxidation.
- Core Chemistry Skills are: Calculating the ATP from Fatty Acid Oxidation (β Oxidation), Describing How Ketone Bodies are Formed, and Distinguishing Anabolic and Catabolic Pathways.
- The interchapter problem set, Combining Ideas from Chapters 22 to 24, completes the chapter.

Acknowledgments

The preparation of a new text is a continuous effort of many people. I am thankful for the support, encouragement, and dedication of many people who put in hours of tireless effort to produce a high-quality book that provides an outstanding learning package. I am thankful for the outstanding contributions of Professor MaryKay Orgill whose updates and clarifications enhanced the content of the biochemistry chapters 15, 17, and 19 to 24. The editorial team at Pearson has done an exceptional job. I want to thank Jeanne Zalesky, Director, Courseware Portfolio Management, and Scott Dustan, Courseware Portfolio Manager, who supported our vision of this sixth edition.

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

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

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

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

Karen Timberlake
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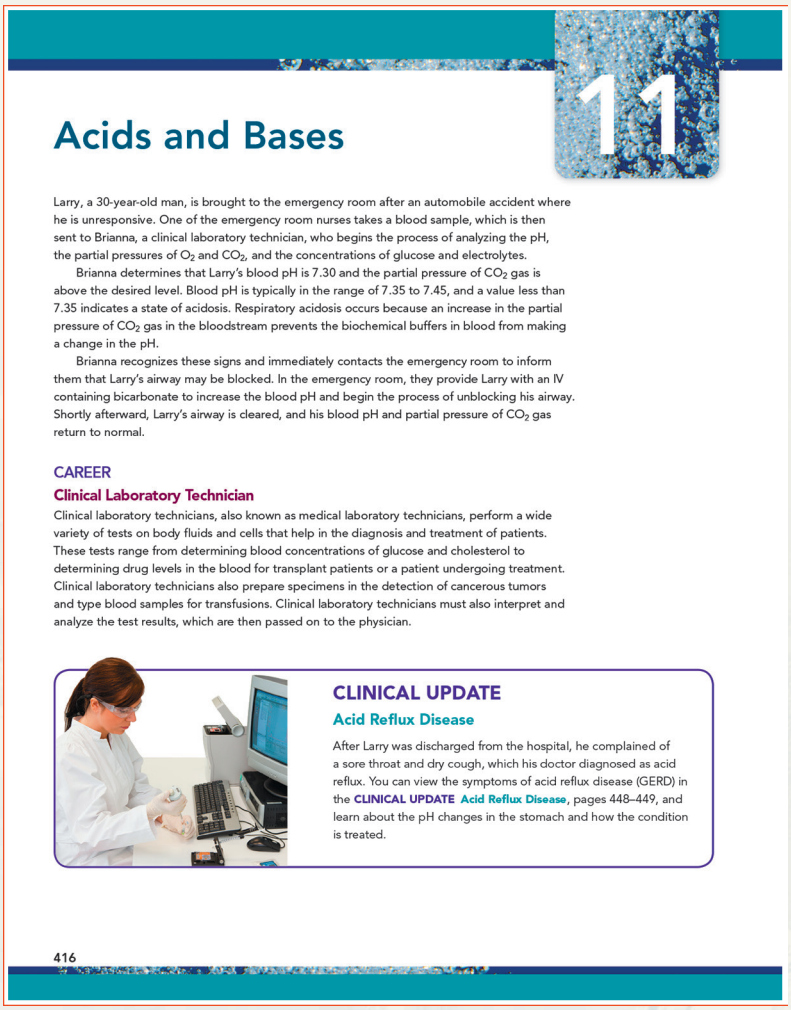
Career Focus Engages Students

Best-selling author Karen Timberlake, joined by new contributing author MaryKay Orgill, connects chemistry to real-world and career applications like no one else. The sixth edition of *General, Organic, and Biological Chemistry: Structures of Life* engages students by helping them see the connections between chemistry, the world around them, and future careers.



11

Acids and Bases

Larry, a 30-year-old man, is brought to the emergency room after an automobile accident where he is unresponsive. One of the emergency room nurses takes a blood sample, which is then sent to Brianna, a clinical laboratory technician, who begins the process of analyzing the pH, the partial pressures of O_2 and CO_2, and the concentrations of glucose and electrolytes.

Brianna determines that Larry's blood pH is 7.30 and the partial pressure of CO_2 gas is above the desired level. Blood pH is typically in the range of 7.35 to 7.45, and a value less than 7.35 indicates a state of acidosis. Respiratory acidosis occurs because an increase in the partial pressure of CO_2 gas in the bloodstream prevents the biochemical buffers in blood from making a change in the pH.

Brianna recognizes these signs and immediately contacts the emergency room to inform them that Larry's airway may be blocked. In the emergency room, they provide Larry with an IV containing bicarbonate to increase the blood pH and begin the process of unblocking his airway. Shortly afterward, Larry's airway is cleared, and his blood pH and partial pressure of CO_2 gas return to normal.

CAREER

Clinical Laboratory Technician

Clinical laboratory technicians, also known as medical laboratory technicians, perform a wide variety of tests on body fluids and cells that help in the diagnosis and treatment of patients. These tests range from determining blood concentrations of glucose and cholesterol to determining drug levels in the blood for transplant patients or a patient undergoing treatment. Clinical laboratory technicians also prepare specimens in the detection of cancerous tumors and type blood samples for transfusions. Clinical laboratory technicians must also interpret and analyze the test results, which are then passed on to the physician.

CLINICAL UPDATE

Acid Reflux Disease

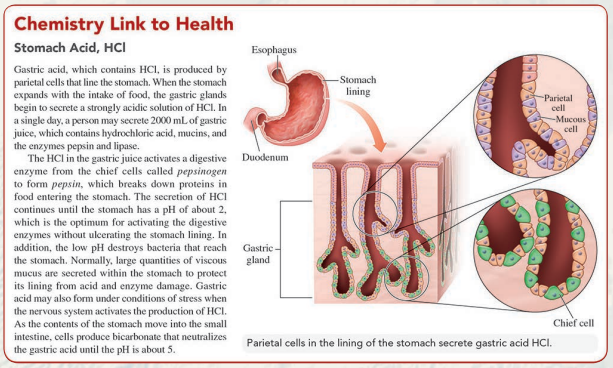
After Larry was discharged from the hospital, he complained of a sore throat and dry cough, which his doctor diagnosed as acid reflux. You can view the symptoms of acid reflux disease (GERD) in the **CLINICAL UPDATE** **Acid Reflux Disease**, pages 448–449, and learn about the pH changes in the stomach and how the condition is treated.

416

Chapter Openers emphasize **clinical connections** by showing students relevant, engaging, and topical examples of how health professionals use chemistry everyday in their careers.

Clinical Updates added at the end of each chapter continue the story of the chapter opener and describe the follow-up treatment, helping students see the connections to the chemistry learned in the chapter.

Chemistry Links to Health and **Chemistry Links to the Environment** apply chemical concepts to health and medical topics as well as topics in the environment, such as bone density, weight loss and weight gain, alcohol abuse, kidney dialysis, dental cavities and xylitol gum, hyperglycemia and hypoglycemia, Alzheimer's disease, sickle-cell anemia, cancer, cataracts, galactosemia, and steroid-induced diabetes, illustrating the importance of understanding chemistry in real-life situations.



Chemistry Link to Health

Stomach Acid, HCl

Gastric acid, which contains HCl, is produced by parietal cells that line the stomach. When the stomach expands with the intake of food, the gastric glands begin to secrete a strongly acidic solution of HCl. In a single day, a person may secrete 2000 mL of gastric juice, which contains hydrochloric acid, mucins, and the enzymes pepsin and lipase.

The HCl in the gastric juice activates a digestive enzyme from the chief cells called *pepsinogen* to form *pepsin*, which breaks down proteins in food entering the stomach. The secretion of HCl continues until the stomach has a pH of about 2, which is the optimum for activating the digestive enzymes without ulcerating the stomach lining. In addition, the low pH destroys bacteria that reach the stomach. Normally, large quantities of viscous mucus are secreted within the stomach to protect its lining from acid and enzyme damage. Gastric acid may also form under conditions of stress when the nervous system activates the production of HCl. As the contents of the stomach move into the small intestine, cells produce bicarbonate that neutralizes the gastric acid until the pH is about 5.

Parietal cells in the lining of the stomach secrete gastric acid HCl.

Builds Students' Critical Thinking

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

in $[H_3O^+]$ and a decrease in $[OH^-]$, which makes an acidic solution. If base is added, $[OH^-]$ increases and $[H_3O^+]$ decreases, which gives a basic solution. However, for any aqueous solution, whether it is neutral, acidic, or basic, the product $[H_3O^+][OH^-]$ is equal to K_w (1.0×10^{-14} at 25 °C) (see TABLE 11.6).

TABLE 11.6 Examples of $[H_3O^+]$ and $[OH^-]$ in Neutral, Acidic, and Basic Solutions

Type of Solution	$[H_3O^+]$	$[OH^-]$	K_w (25 °C)
Neutral	1.0×10^{-7} M	1.0×10^{-7} M	1.0×10^{-14}
Acidic	1.0×10^{-2} M	1.0×10^{-12} M	1.0×10^{-14}
Acidic	2.5×10^{-5} M	4.0×10^{-10} M	1.0×10^{-14}
Basic	1.0×10^{-8} M	1.0×10^{-6} M	1.0×10^{-14}
Basic	5.0×10^{-11} M	2.0×10^{-4} M	1.0×10^{-14}

TEST
Try Practice Problems 11.35 and 11.36

Using the K_w to Calculate $[H_3O^+]$ and $[OH^-]$ in a Solution

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

If we know the $[H_3O^+]$ of a solution, we can use the K_w to calculate $[OH^-]$. If we know the $[OH^-]$ of a solution, we can calculate $[H_3O^+]$ from their relationship in the K_w, as shown in Sample Problem 11.6.

$$K_w = [H_3O^+][OH^-]$$

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

▶SAMPLE PROBLEM 11.6 Calculating the $[H_3O^+]$ of a Solution

CORE CHEMISTRY SKILL
Calculating $[H_3O^+]$ and $[OH^-]$ in Solutions

TRY IT FIRST

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

SOLUTION

STEP 1 State the given and needed quantities.

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

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

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

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

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

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

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

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

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

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

NEW! Test feature found in the margin throughout each chapter encourages students to solve related Practice Problems to practice retrieval of content for exams.

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

NEW! Engage feature asks students to think about what they are reading and immediately assess their understanding by answering the Engage question, which is related to the topic. With regular self-assessment, students connect new concepts to prior knowledge to help them retrieve that content during exams.

and Problem-Solving Skills

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.

CORE CHEMISTRY SKILL
Calculating Molarity or Volume of an Acid or Base in a Titration

ENGAGE
Why do you need to use a balanced equation for a neutralization problem?

▶SAMPLE PROBLEM 11.12 Titration of an Acid

TRY IT FIRST

If 16.3 mL of a 0.185 M $Sr(OH)_2$ solution is used to titrate the HCl in a 25.0-mL (0.0250 L) sample of gastric juice, what is the molarity of the HCl solution?

$$2HCl(aq) + Sr(OH)_2(aq) \longrightarrow 2H_2O(l) + SrCl_2(aq)$$

SOLUTION

STEP 1 State the given and needed quantities and concentrations.

	Given	Need	Connect
ANALYZE THE PROBLEM	25.0 mL (0.0250 L) of HCl solution, 16.3 mL of 0.185 M $Sr(OH)_2$ solution	molarity of the HCl solution	molarity, mole–mole factor
	Neutralization Equation		
	$2HCl(aq) + Sr(OH)_2(aq) \longrightarrow 2H_2O(l) + SrCl_2(aq)$		

STEP 2 Write a plan to calculate the molarity.

mL of $Sr(OH)_2$ solution → Metric factor → L of $Sr(OH)_2$ solution → Molarity → moles of $Sr(OH)_2$ → Mole–mole factor → moles of HCl → Divide by liters → molarity of HCl solution

STEP 3 State equalities and conversion factors, including concentrations.

$$\frac{1000 \text{ mL of } Sr(OH)_2 \text{ solution}}{1000 \text{ mL } Sr(OH)_2 \text{ solution}} = \frac{1 \text{ L of } Sr(OH)_2 \text{ solution}}{1 \text{ L } Sr(OH)_2 \text{ solution}} \quad \text{and} \quad \frac{1 \text{ L } Sr(OH)_2 \text{ solution}}{1000 \text{ mL } Sr(OH)_2 \text{ solution}}$$

$$\frac{0.185 \text{ mole of } Sr(OH)_2}{0.185 \text{ mole } Sr(OH)_2} = \frac{1 \text{ L of } Sr(OH)_2 \text{ solution}}{1 \text{ L } Sr(OH)_2 \text{ solution}} \quad \text{and} \quad \frac{1 \text{ L } Sr(OH)_2 \text{ solution}}{0.185 \text{ mole } Sr(OH)_2}$$

$$\frac{2 \text{ moles of HCl}}{2 \text{ moles HCl}} = \frac{1 \text{ mole of } Sr(OH)_2}{1 \text{ mole } Sr(OH)_2} \quad \text{and} \quad \frac{1 \text{ mole } Sr(OH)_2}{2 \text{ moles HCl}}$$

STEP 4 Set up the problem to calculate the needed quantity.

$$16.3 \text{ mL } Sr(OH)_2 \text{ solution} \times \frac{1 \text{ L } Sr(OH)_2 \text{ solution}}{1000 \text{ mL } Sr(OH)_2 \text{ solution}} \times \frac{0.185 \text{ mole } Sr(OH)_2}{1 \text{ L } Sr(OH)_2 \text{ solution}} \times \frac{2 \text{ moles HCl}}{1 \text{ mole } Sr(OH)_2} = 0.006\,03 \text{ mole of HCl}$$

$$\text{molarity of HCl solution} = \frac{0.006\,03 \text{ mole HCl}}{0.0250 \text{ L HCl solution}} = 0.241 \text{ M HCl solution}$$

INTERACTIVE VIDEO
Acid–Base Titration

STUDY CHECK 11.12

What is the molarity of an HCl solution if 28.6 mL of a 0.175 M NaOH solution is needed to titrate a 25.0-mL sample of the HCl solution?

TEST
Try Practice Problems 11.61 to 11.66

ANSWER

0.200 M HCl solution

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 provides steps for successful problem solving within the Sample Problem.

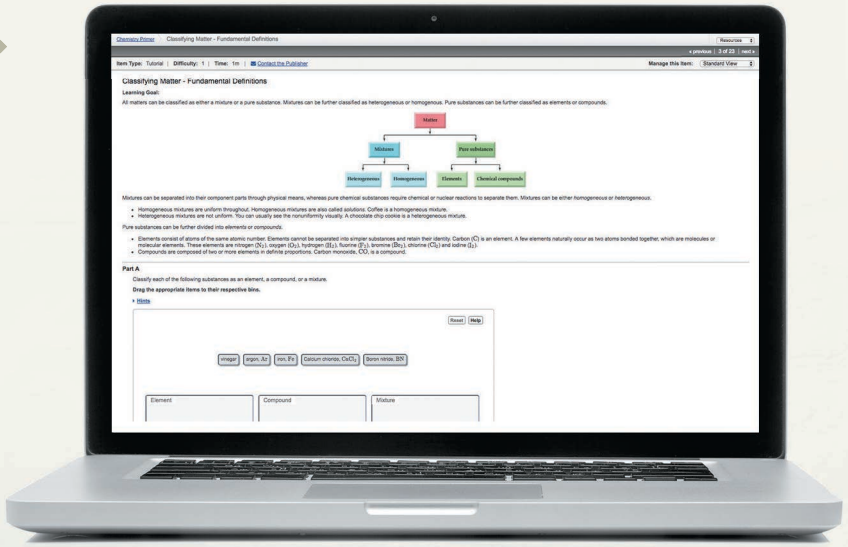
Continuous Learning
Before, During, and After Class

BEFORE CLASS

NEW! Mastering Chemistry Primer tutorials are 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 primer is offered as a prebuilt assignment that is automatically generated with all chemistry courses.



with Mastering Chemistry

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Learning Catalytics generates class discussion, guides your lecture, and promotes peer-to-peer learning with real-time analytics.

MasteringChemistry™ 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:

- 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.
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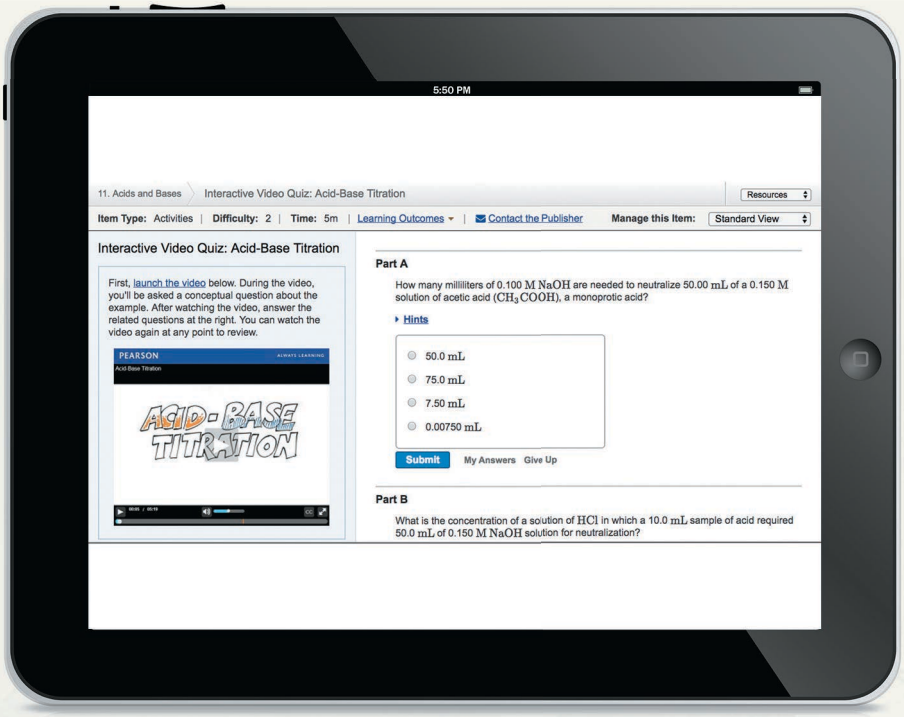
Mastering Chemistry

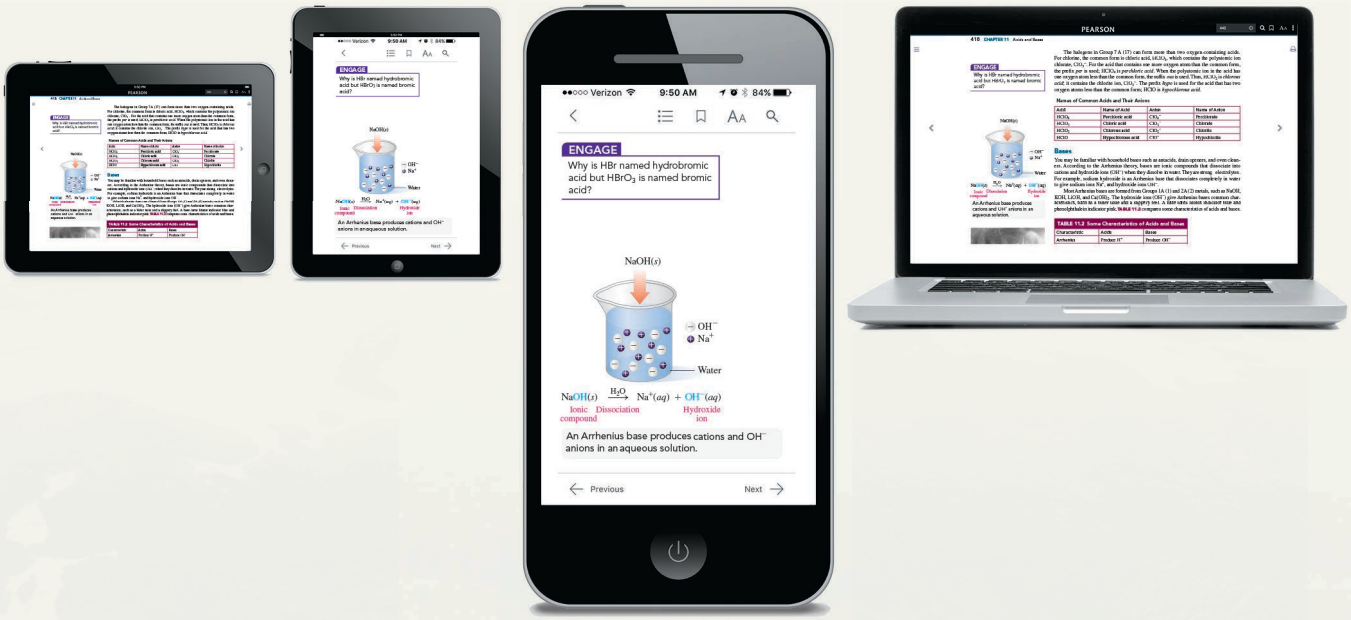
AFTER CLASS



TEN NEW! Interactive Videos indicated by boxes in the margins, have been created. These videos give students an opportunity to connect what they just learned by showing how chemistry works in real life and introducing a bit of humor into chemical problem solving and demonstrations. **Sample Calculations** walk students through the most challenging chemistry problems and provide a successful strategy on how to approach problem solving. Topics include: Using Conversion Factors, Mass Calculations for Reactions, Concentration of Solutions, and Acid–Base Titration.

MasteringChemistry™ 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. To provide additional scaffolding for students moving from **Tutorial Problems** to End-of-Chapter Problems, we created New! **Enhanced End-of-Chapter Problems** that now contain specific wrong-answer feedback.

Pearson eText



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Instructor and Student Supplements

General, Organic, and Biological Chemistry: Structures of Life, sixth 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	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 automatically graded assignments in one place, while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions. http://www.masteringchemistry.com.
Mastering™ Chemistry with Pearson eText		✓	Supplement for Students	The sixth edition of *General, Organic, and Biological Chemistry: Structures of Life* features a Pearson eText within Mastering™ Chemistry. In conjunction with Mastering™ assessment capabilities, new **Interactive Videos** will improve student engagement and knowledge retention. Additionally, the Pearson eText offers students the power to create notes, highlight text in different colors, create bookmarks, zoom, and view single or multiple pages.
Laboratory Manual by Karen Timberlake (9780321811851)	✓		Supplement for Students	This best-selling lab manual coordinates 35 experiments with the topics in *General, Organic, and Biological Chemistry: Structures of Life*, sixth 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—Download Only (9781292275673)		✓	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 (9781292275659)		✓	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 available are downloadable files of the Instructor's Solutions Manual. Visit the Pearson catalog page for Timberlake's *General, Organic, Biological Chemistry: Structures of Life*, sixth edition, at www.pearsonglobaleditions.com to download available instructor supplements.
TestGen Test Bank—Download Only (9781292275666)		✓	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 (9780321812858)		✓	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

1 Chemistry in Our Lives

A call came in to 911 from a man who arrived home from work to find his wife, Gloria, lying on the floor of their living room. When the police arrived, they pronounced the woman dead. 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. At the morgue, the victim's height was measured as 1.573 m, and her mass was 40.5 kg.

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, a forensic scientist, uses scientific procedures and chemical tests to examine the evidence from law enforcement agencies. She analyzes blood, stomach contents, and the unknown liquid from the first victim's home, as well as the fingerprints on the glass. She also looks for the presence of drugs, poisons, and alcohol. She will also match the characteristics of the bullet casings to the weapon that was found at the second crime scene.

CAREER

Forensic Scientist

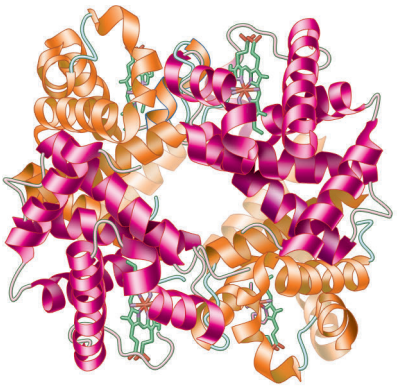
Most forensic scientists work in crime laboratories that are part of city or county legal systems where they analyze bodily fluids and tissue samples collected by crime scene investigators. In analyzing these samples, forensic scientists identify the presence or absence of specific chemicals within the 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. To identify these substances, a variety of 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 54, 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 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 forensic scientist, the nurse, the dietitian, the chemical engineer, or the agricultural scientist, chemistry plays a central role in understanding problems and assessing possible solutions.

Chemistry

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

Chemicals

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

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

TABLE 1.1 Chemicals Commonly Used in Toothpaste

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

PRACTICE PROBLEMS

1.1 Chemistry and Chemicals

In every chapter, odd-numbered exercises in the *Practice Problems* are paired with even-numbered exercises. The answers for the 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?

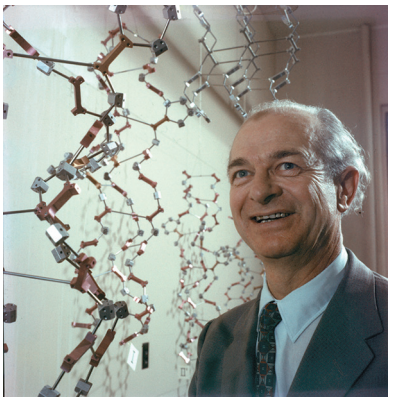
1.6 Read the labels on products used to wash your dishes. What are the names of some chemicals contained in those products?

1.2 Scientific Method: Thinking Like a Scientist

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

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.

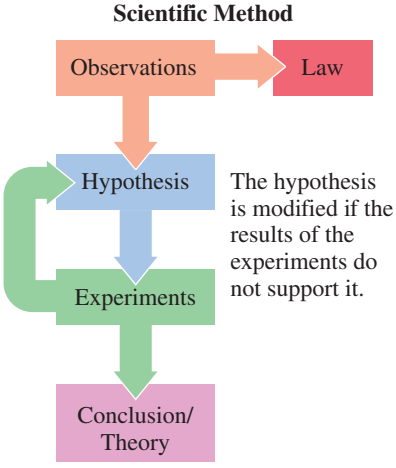


Linus Pauling won the Nobel Prize in Chemistry in 1954.

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 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 about whether the hypothesis is *true* or *false*. When experiments give consistent results, the hypothesis may be stated to be true. Even then, the hypothesis continues to be tested and, based on new experimental results, may need to be modified or replaced. If many additional experiments by a group of scientists continue to support the hypothesis, it may become a *scientific theory*, which gives an explanation for the initial observations.



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

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.

d. When I drink decaffeinated coffee, I sleep better at night.
e. I am going to drink only decaffeinated coffee.
f. I sleep better at night because I stopped drinking caffeinated drinks.

ANSWER

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

TEST
Try Practice Problems 1.7 to 1.10

PRACTICE PROBLEMS

1.2 Scientific Method: Thinking Like a Scientist

1.7 Identify each activity, **a** to **f**, as an observation, a hypothesis, an experiment, or a conclusion.

At a popular restaurant, where Chang is the head chef, the following occurred:

a. Chang determined that sales of the house salad had dropped.
b. Chang decided that the house salad needed a new dressing.
c. In a taste test, Chang prepared four bowls of sliced cucumber, each with a new dressing: sesame seed, olive oil and balsamic vinegar, creamy Italian, and blue cheese.
d. Tasters rated the sesame seed salad dressing as the favorite.
e. After two weeks, Chang noted that the orders for the house salad with the new sesame seed dressing had doubled.
f. Chang decided that the sesame seed dressing improved the sales of the house salad because the sesame seed dressing enhanced the taste.

Customers rated the sesame seed dressing as the best.

1.8 Identify each activity, **a** to **f**, as an observation, a hypothesis, an experiment, or a conclusion.

Lucia wants to develop a process for dyeing shirts so that the color will not fade when the shirt is washed. She proceeds with the following activities:

a. Lucia notices that the dye in a design fades when the shirt is washed.
b. Lucia decides that the dye needs something to help it combine with the fabric.
c. She places a spot of dye on each of four shirts and then places each one separately in water, salt water, vinegar, and baking soda and water.
d. After one hour, all the shirts are removed and washed with a detergent.
e. Lucia notices that the dye has faded on the shirts in water, salt water, and baking soda, whereas the dye did not fade on the shirt soaked in vinegar.
f. Lucia thinks that the vinegar binds with the dye so it does not fade when the shirt is washed.

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

Tips for Using New Study Habits for Successful Learning

1. **Do not keep rereading text or notes.** Reading the same material over and over will make that material seem familiar but does not mean that you have learned it. You need to test yourself to find out what you do and do not know.
2. **Ask yourself questions as you read.** Asking yourself questions as you read requires you to interact continually with new material. 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
	Reading the chapter many times
Retesting a few days later	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. Bill, who reads the chapter four times.
b. Jennifer, who reads the chapter two times and works all the problems at the end of each Section.
c. Mark, who reads the chapter the night before the exam.

SOLUTION

b. Jennifer, who reads the chapter two times and works all the problems at the end of each Section 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 are two more ways that Jennifer could improve her retrieval of information?

ANSWER

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

Features in This Text That Help You Study and Learn Chemistry

This text has been designed with study features to 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. At the beginning of each Section, a *Learning Goal* describes the topics to learn. *Review* icons in the margins refer to Key Math Skills or Core Chemistry Skills from previous chapters that relate to new material in the chapter. *Key Terms* are bolded when they first appear in the text and are summarized at the end of each chapter. They are also listed and defined in the comprehensive *Glossary and Index*, which appears at the end of the text. *Key Math Skills* and *Core Chemistry Skills* that are critical to learning chemistry are indicated by icons in the margin, and summarized at the end of each chapter.

Before you begin reading, obtain an overview of a chapter by reviewing the topics in Looking Ahead. As you prepare to read a Section of the chapter, look at the Section title, and turn it into a question. Asking yourself questions about new topics builds new connections to material you have already learned. For example, for Section 1.1, "Chemistry and Chemicals," you could ask, "What is chemistry?" or "What are chemicals?" At the beginning of each Section, a *Learning Goal* states what you need to understand. As you read the text, you will see *Engage* questions in the margin, which remind you to pause your reading and test yourself with a question related to the material.

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

REVIEW

KEY MATH SKILL

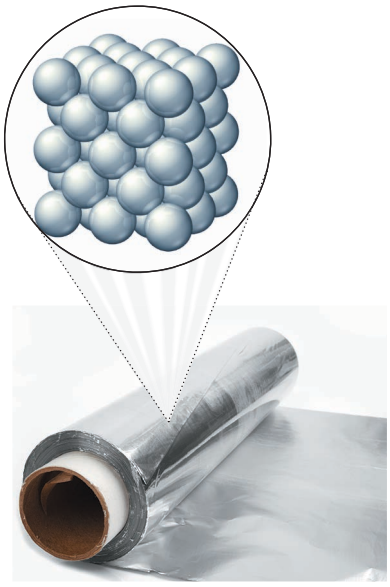
CORE CHEMISTRY SKILL

ENGAGE

TRY IT FIRST

ANALYZE THE PROBLEM	Given	Need	Connect

TEST



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

INTERACTIVE VIDEO

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*.

Studying in a group can be beneficial to learning.

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 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

▶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
e. highlighting the key ideas in the text

ANSWER

b and **d**

TEST

Try Practice Problems 1.11 to 1.14

PRACTICE PROBLEMS

1.3 Studying and Learning Chemistry

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

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

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

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

1.4 Key Math Skills for Chemistry

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

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

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

Identify the place values for each of the following:

a. the victim's height of 1.573 m
b. the victim's mass of 40.5 kg

ANSWER

a.

Digit	Place Value
1	ones
5	tenths
7	hundredths
3	thousandths

b.

Digit	Place Value
4	tens
0	ones
5	tenths

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 is usually 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 (+).

$2 \times 3 = 6$ The + sign (+6) is understood.

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

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.

$12 - (\mathbf{+5}) = 12 \mathbf{-} \mathbf{5} = 7$

$-12 - (\mathbf{-5}) = -12 \mathbf{+} \mathbf{5} = -7$

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		Multiplication and Division	
Example 1:	$15 - 8 + 2 =$	**Example 3:**	$2 \times (-3) =$
Solution:	15 − 8 + 2 = 9	**Solution:**	2 × 3 +/− = −6
Example 2:	$4 + (-10) - 5 =$	**Example 4:**	$\frac{8 \times 3}{4} =$
Solution:	4 + 10 +/− − 5 = −11	**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. Sarah's analysis of the bullet showed that it 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 supporting 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 from both sides.

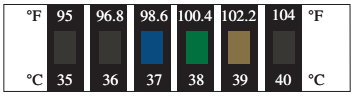
If you eliminate a symbol or number by adding, you need to add that same symbol or number to both sides.

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

$$P_1V_1 = P_2V_2$$

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

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

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

STUDY CHECK 1.6

Solve each of the following equations for m:

a. heat $= m \times \Delta T \times SH$ **b.** $D = \frac{m}{V}$

TEST
Try Practice Problems 1.21 and 1.22

ANSWER

a. $m = \frac{\text{heat}}{\Delta T \times SH}$ **b.** $m = D \times V$

Interpreting Graphs

KEY MATH SKILL
Interpreting Graphs

A graph is a diagram that 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

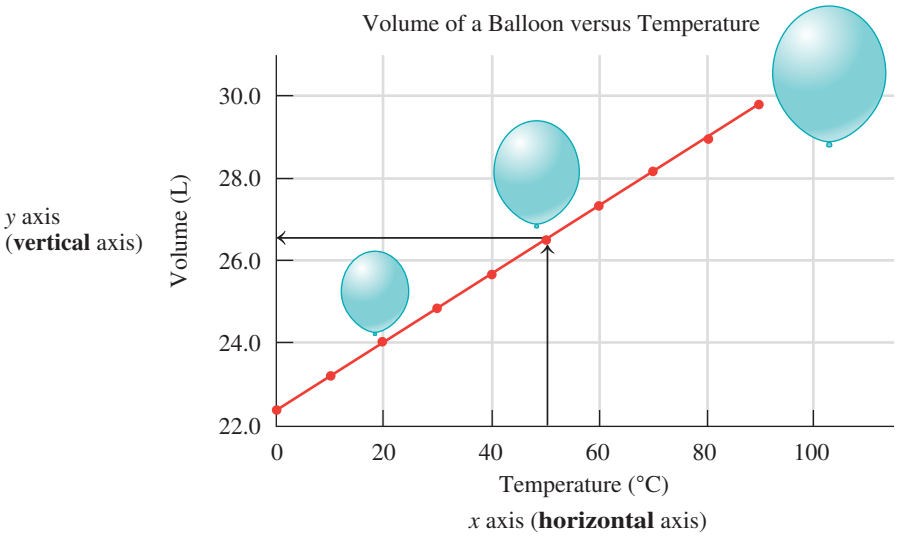
Look at the title. What does it tell us about the graph? The title indicates that the volume of a balloon was measured at different temperatures.

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.

Horizontal Axis

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



ENGAGE

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

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.

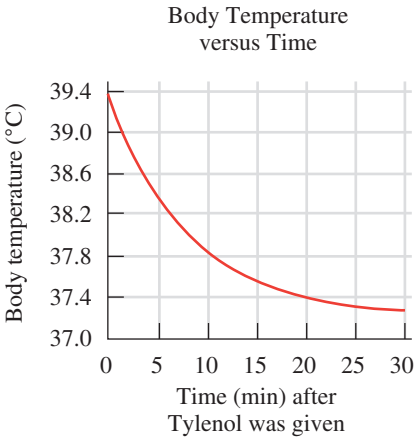
Interpreting the Graph

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 for the temperature to decrease from 39.4 °C to 38.0 °C?
c. What was the decrease, in degrees Celsius, between 5 min and 20 min?

ANSWER

a. 37.6 °C **b.** 8 min **c.** 0.9 °C

TEST

Try Practice Problems 1.23 to 1.26

PRACTICE PROBLEMS

1.4 Key Math Skills for Chemistry

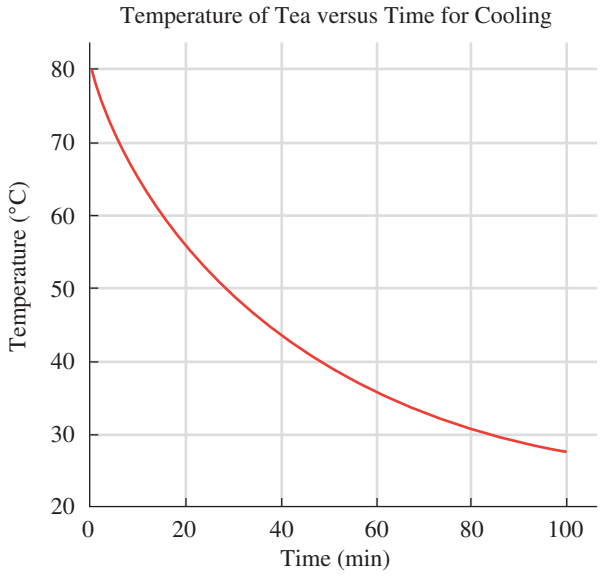
1.15 What is the place value for the bold digit?
- **a.** 7.32**8**8
- **b.** **1**6.1234
- **c.** 4**6**75.99

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.** $15 - (-8) =$ ____
- **b.** $-8 + (-22) =$ ____
- **c.** $4 \times (-2) + 6 =$ ____

1.18 Evaluate each of the following:
- **a.** $-11 - (-9) =$ _____
- **b.** $34 + (-55) =$ _____
- **c.** $\dfrac{-56}{8} =$ _____

Use the following graph for problems 1.19 and 1.20:



1.19
- **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?

1.20
- **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 the tea after 20 min?
- **d.** How many minutes were needed to reach a temperature of 45 °C?

1.21 Solve each of the following for a:
- **a.** $4a + 4 = 40$
- **b.** $\dfrac{a}{6} = 7$

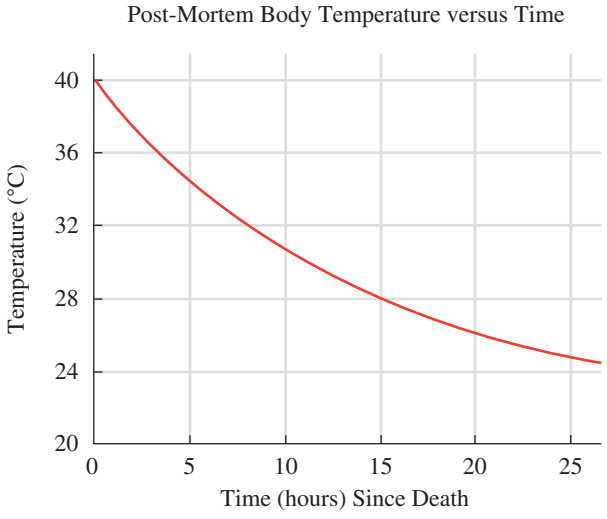
1.22 Solve each of the following for b:
- **a.** $2b + 7 = b + 10$
- **b.** $3b - 4 = 24 - b$

Clinical Applications

1.23
- **a.** A clinic had 25 patients on Friday morning. If 21 patients were given flu shots, what percentage of the patients received flu shots? Express your answer to the ones place.
- **b.** An alloy contains 56 g of pure silver and 22 g of pure copper. What is the percentage of silver in the alloy? Express your answer to the ones place.
- **c.** A collection of coins contains 11 nickels, 5 quarters, and 7 dimes. What is the percentage of dimes in the collection? Express your answer to the ones place.

1.24
- **a.** At a local hospital, 35 babies were born in May. 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.

Use the following graph for problems 1.25 and 1.26:



1.25
- **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?

1.26
- **a.** What is measured on the horizontal axis?
- **b.** What is the range of values on the horizontal axis?
- **c.** How many hours were needed to reach a temperature of 28 °C?
- **d.** The coroner measured Gloria's body temperature at 9 P.M. as 34 °C. What was the time of her death?

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*.

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

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, 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.

KEY MATH SKILL

Writing Numbers in Scientific Notation

ENGAGE

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

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

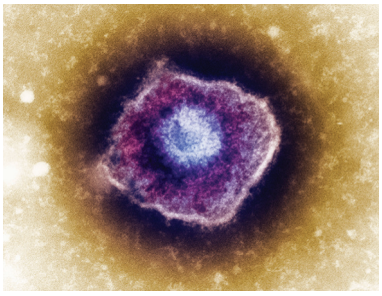
In another example, 0.000 86 is written in scientific notation as 8.6×10^{-4}. The coefficient, 8.6, is obtained by moving the decimal point to the right. Because the decimal point is moved four places to the right, the power of 10 is a negative 4, written as 10^{-4}. When a number less than 1 is written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

ENGAGE

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

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

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.



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

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
1000	$10 \times 10 \times 10$	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	$\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{1000}$	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}	

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

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 **c.** 0.007 30 **d.** 978×10^5

ANSWER

a. 4.25×10^5 **b.** 8.6×10^{-7} **c.** 7.30×10^{-3} **d.** 9.78×10^7

TEST

Try Practice Problems 1.27 and 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 $\times$ 10, and use the power of 10 as an exponent.

ENGAGE

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

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 (2nd F) and the SCI key. The scientific notation appears in the calculator display as a coefficient and the power of 10.

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

Calculator display

PRACTICE PROBLEMS

1.5 Writing Numbers in Scientific Notation

1.27 Write each of the following in scientific notation:

a. 55 000 **b.** 480 **c.** 0.000 005
d. 0.000 14 **e.** 0.0072 **f.** 670 000

1.28 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

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

a. 7.2×10^3 or 8.2×10^2 **b.** 4.5×10^{-4} or 3.2×10^{-2}
c. 1×10^4 or 1×10^{-4} **d.** 0.000 52 or 6.8×10^{-2}

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

a. 4.9×10^{-3} or 5.5×10^{-9} **b.** 1250 or 3.4×10^2
c. 0.000 000 4 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.

Sarah 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

1.31 Identify each of the following comments in the police report as an observation, a hypothesis, an experiment, or a conclusion:

a. Gloria may have had a heart attack.
b. Test results indicate that Gloria was poisoned.
c. The liquid in the glass was analyzed.
d. The antifreeze in the pantry was the same color as the liquid in the glass.

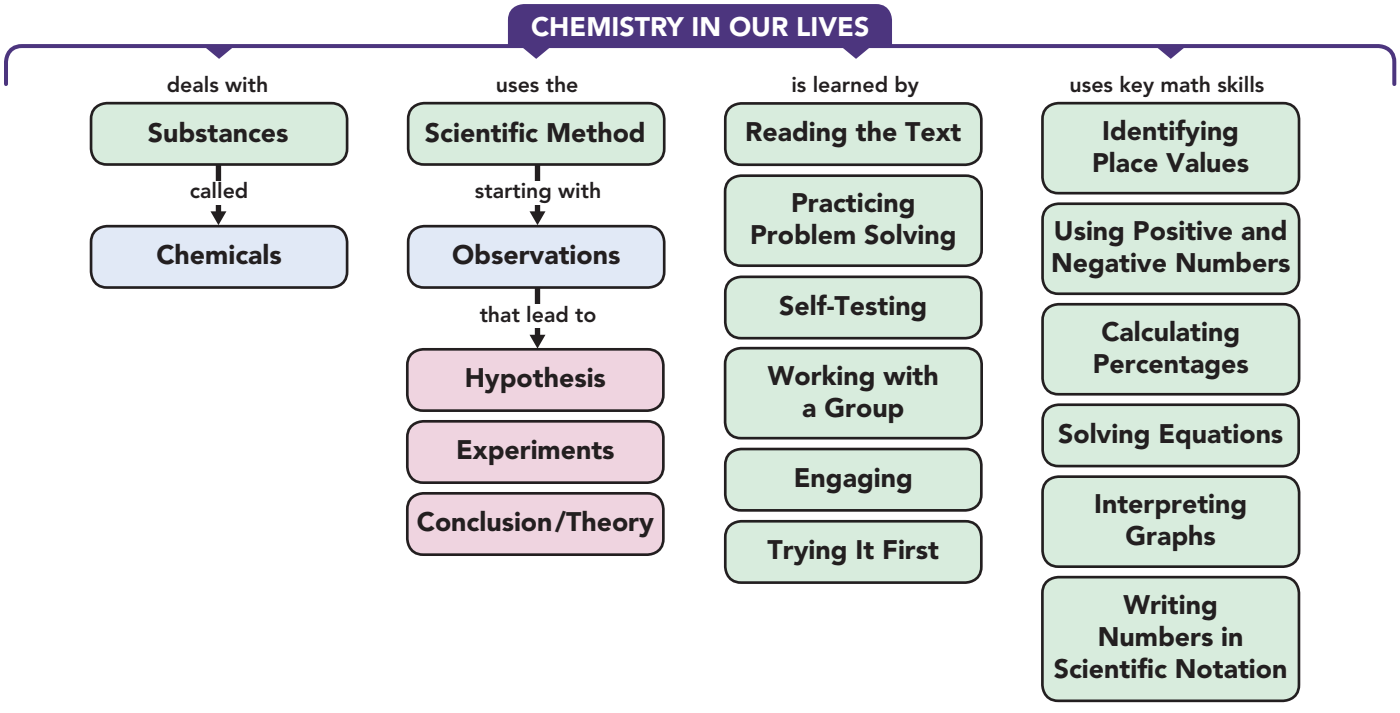
1.32 Identify each of the following comments in the police report as an observation, a hypothesis, an experiment, or a conclusion:

a. Gloria may have committed suicide.
b. Sarah ran blood tests to identify any toxic substances.
c. The temperature of Gloria's body was 34 °C.
d. The fingerprints found on the glass were determined to be her husband's.

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

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

CONCEPT MAP



CHAPTER REVIEW

1.1 Chemistry and Chemicals

LEARNING GOAL Define the term chemistry, and identify chemicals.

- Chemistry is the study of the composition, structure, properties, and reactions of matter.
- A chemical 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*, *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: $\dfrac{6 \text{ white socks}}{24 \text{ total socks}} \times 100\% = 25\%$ 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 from both sides.
- If you eliminate a number or symbol by adding, add that same number or symbol to both sides.
- 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:

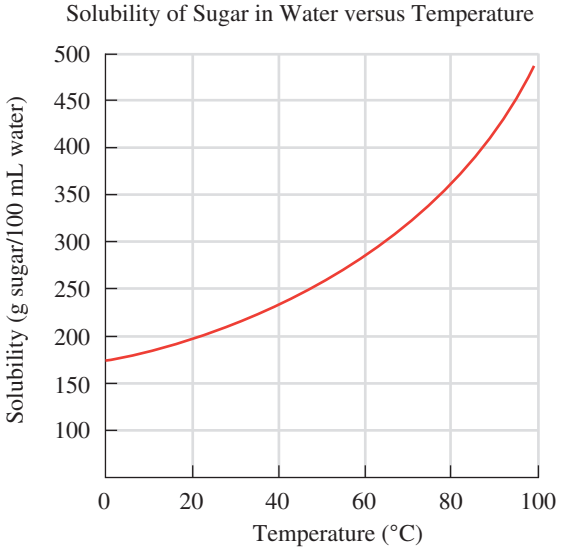
$$3(12) - 8 = 28$$
$$36 - 8 = 28$$
$$28 = 28$$

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:



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.

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

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

1.37 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)

1.38 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)

1.39 For each of the following, indicate if the answer has a positive or negative sign: (1.4)

a. Two negative numbers are multiplied.
b. A larger positive number is added to a smaller negative number.

1.40 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.

Clinical Applications

1.41 Classify each of the following statements as an observation or a hypothesis: (1.2)

a. The athlete's resting heart rate was 54 beats/min.
b. An elderly patient presented with wheezing and shortness of breath.
c. The nurse thinks that the patient's shortness of breath, persistent coughing, and wheezing is due to a chest infection.

1.42 Classify each of the following statements as an observation or a hypothesis: (1.2)

a. Analysis of 10 ceramic dishes showed that four dishes contained lead levels that exceeded federal safety standards.
b. Marble statues undergo corrosion in acid rain.
c. A child with a high fever and a rash may have chickenpox.

ADDITIONAL PRACTICE PROBLEMS

1.43 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

1.44 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

1.45 Which of the following will help you develop a successful study plan? (1.3)

a. skipping class and just reading the text
b. working the Sample Problems as you go through a chapter
c. self-testing
d. reading through the chapter, but working the problems later

1.46 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

1.47 Evaluate each of the following: (1.4)

a. $-65 - (-7) =$ _____ **b.** $\dfrac{165}{-15} =$ _____

c. $8 - 36 =$ _____

1.48 Evaluate each of the following: (1.4)

a. $8 \times (-19) =$ _____ **b.** $+7 + (-68) =$ _____

c. $\dfrac{-160}{-40} =$ _____

1.49 A bag of gumdrops contains 16 orange gumdrops, 6 yellow gumdrops, and 18 pink gumdrops. (1.4)

a. What is the percentage of yellow gumdrops? Express your answer to the ones place.
b. What is the percentage of pink gumdrops? Express your answer to the ones place.

1.50 On the first chemistry test, 12 students got As, 18 students got Bs, and 20 students got Cs. (1.4)

a. What is the percentage of students who received Bs? Express your answer to the ones place.
b. What is the percentage of students who received Cs? Express your answer to the ones place.

1.51 Express each of the following numbers in scientific notation: (1.4)

a. 43000 **b.** 620
c. 0.0000089 **d.** 0.00037

1.52 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

Clinical Applications

1.53 Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion: (1.2)

a. A patient has a high fever and a rash on her back.
b. A nurse tells a patient that her baby who gets sick after drinking milk may be lactose intolerant.
c. Numerous studies have shown that omega-3 fatty acids lower triglyceride levels.

1.54 Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion: (1.2)

a. Every spring, you have congestion and a runny nose.
b. An overweight patient decides to exercise more to lose weight.
c. Many research studies have linked obesity to heart disease.

1.55 How will each of the following increase your chance of success in chemistry? (1.3)
- **a.** self-testing
- **b.** forming a study group
- **c.** reading an assignment before class

1.56 How will each of the following decrease your chance of success in chemistry? (1.3)
- **a.** studying only the night before an exam
- **b.** not going to class
- **c.** not practicing the problems in the text

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.

1.57 Classify each of the following as an observation, a hypothesis, an experiment, or a conclusion: (1.2)
- **a.** If I pour salt on to the icy driveway, the rate at which the ice melts will increase.
- **b.** There is ice on the driveway.
- **c.** In the presence of salt, ice will melt at a faster rate.
- **d.** The section of the icy driveway where I poured salt melted faster than the untreated section.

1.58 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.

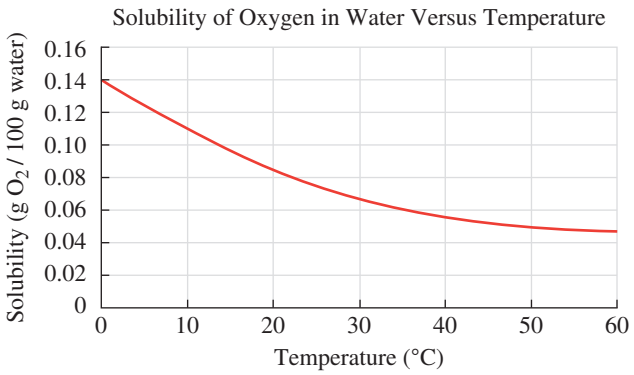
1.59 Solve each of the following for a: (1.4)

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

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

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

Use the following graph for problems 1.61 and 1.62:



1.61
- **a.** What does the title indicate about the graph? (1.4)
- **b.** What is measured on the horizontal axis?
- **c.** What is the range of values on the vertical axis?
- **d.** Does the solubility of oxygen increase or decrease with an increase in temperature?

1.62
- **a.** At what temperature does oxygen have a solubility of 0.06 g/100 g water? (1.4 and 1.5)
- **b.** Write the scientific notation for the solubility of oxygen in water at 0°C.
- **c.** According to the graph, if the highest (total) solubility of oxygen in water is 0.14 g/100 g water, what percentage of oxygen remains when the solubility decreases to 0.07 g/100 g water?

ANSWERS

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 **a**, **c**, and **e**

1.15 **a.** thousandths **b.** ones **c.** hundreds

1.17 **a.** 23 **b.** −30 **c.** −2

1.19 **a.** 84% **b.** 72% **c.** 30%

1.21 **a.** 9 **b.** 42

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.** This graph shows the relationship between body temperature and time since death.
- **b.** temperature, in °C
- **c.** 20 °C to 40 °C
- **d.** decrease

1.27 **a.** 5.5×10^4 **b.** 4.8×10^2 **c.** 5×10^{-6} **d.** 1.4×10^{-4} **e.** 7.2×10^{-3} **f.** 6.7×10^5

1.29 **a.** 7.2×10^3 **b.** 3.2×10^{-2} **c.** 1×10^4 **d.** 6.8×10^{-2}

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

1.33 27% ethylene glycol

1.35 No. All of the ingredients are chemicals.

1.37 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.

1.39 **a.** positive **b.** positive

1.41 **a.** observation **b.** observation **c.** hypothesis

1.43 **b** and **c**

1.45 **b** and **c**

1.47 **a.** -58 **b.** -11 **c.** -28

1.49 **a.** 15% **b.** 45%

1.51 **a.** 4.3×10^{4} **b.** 6.2×10^{2}
c. 8.9×10^{-6} **d.** 3.7×10^{-4}

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

1.55 **a.** Self-testing allows you to check on what you understand.
b. Forming a study group can motivate you to study, fill in gaps, and correct misunderstandings by teaching and learning together.
c. Reading the assignment before class prepares you to learn new material.

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

1.59 **a.** 10 **b.** -36

1.61 **a.** The graph presents the relationship between the solubility of oxygen in water and temperature.
b. Temperature (°C)
c. 0 to 0.16 g of O_2/100 g of water
d. decrease

2

Chemistry and Measurements

During the past few months, Greg has had 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 164 lb, height 5 ft 8 in., 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, or 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. 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 complains to his doctor that he is feeling tired. He has a blood test to determine if his iron level is low. You can see the results of Greg's blood serum iron level in the **CLINICAL UPDATE Greg's Visit with His Doctor**, page 88, and determine if Greg should be given an iron supplement.

2.1 Units of Measurement

LEARNING GOAL Write the names and abbreviations for the metric and 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**.

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.

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

$$1\ L = 1000\ mL \qquad 1\ L = 1.06\ qt \qquad 946\ mL = 1\ qt$$

LOOKING AHEAD

Your weight on a bathroom scale is a measurement.

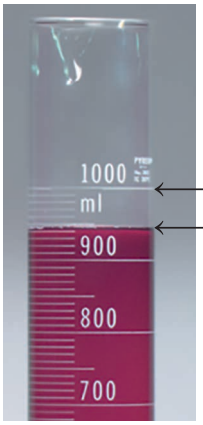


FIGURE 2.1 ▶ In the metric system, volume is based on the liter.

How many milliliters are in 1 quart?

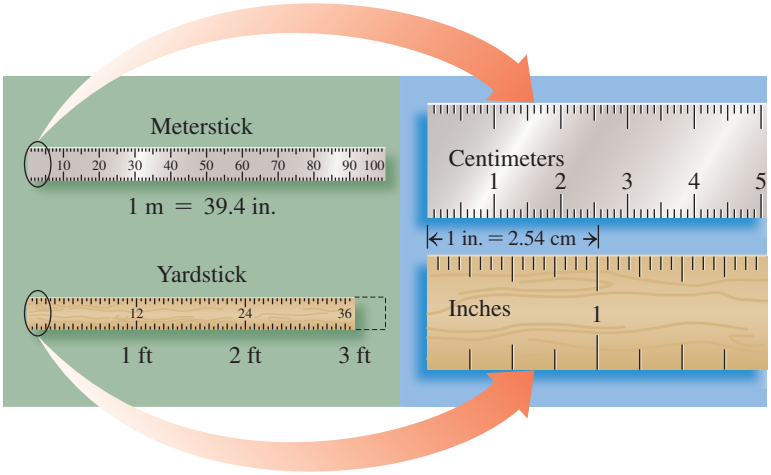


FIGURE 2.2 ▶ Length in the metric system (SI) is based on the meter, which is slightly longer than a yard.

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 m = 100 cm 1 m = 39.4 in. 1 m = 1.09 yd 2.54 cm = 1 in.

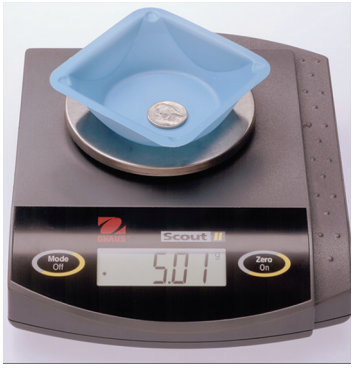


FIGURE 2.3 ▶ On an electronic balance, the digital readout gives the mass of a nickel, which is 5.01 g.

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 kg = 1000 g 1 kg = 2.20 lb 454 g = 1 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**).

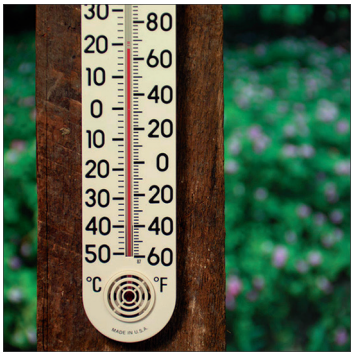


FIGURE 2.4 ▶ A thermometer is used to determine temperature.

What kinds of temperature readings have you made today?

Temperature

Temperature tells us how hot something is, tells us 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 day = 24 h 1 h = 60 min 1 min = 60 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 names and types of measurements for an infant that is 54.6 cm long with a mass of 5.2 kg.

ANSWER

A centimeter (cm) is a unit of length. A kilogram (kg) is a unit of mass.

TEST

Try Practice Problems 2.1 to 2.8

PRACTICE PROBLEMS

2.1 Units of Measurement

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 the type of measurement indicated for each of the following quantities:
a. 4.8 m **b.** 325 g **c.** 1.5 mL
d. 4.8×10^2 s **e.** 28 °C

2.6 State the name of the unit and the type of measurement indicated for each of the following quantities:
a. 0.8 L **b.** 3.6 cm **c.** 4 kg
d. 3.5 h **e.** 373 K

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.

REVIEW
Writing Numbers in Scientific Notation (1.5)

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.

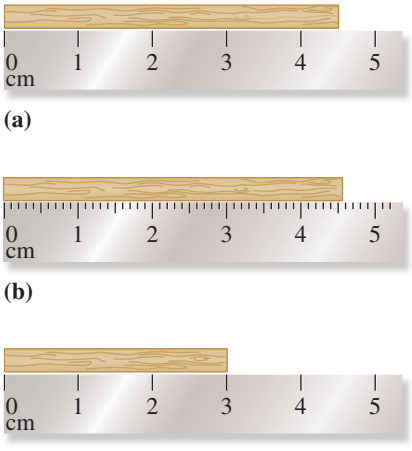


FIGURE 2.5 ▶ The lengths of the rectangular objects are measured as **(a)** 4.5 cm and **(b)** 4.55 cm.

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

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.

Significant Figures

CORE CHEMISTRY SKILL
Counting 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.

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

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.

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

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 want 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**.

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

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

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 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
d. 85 600 s

ANSWER

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

TEST

Try Practice Problems 2.17 to 2.22

PRACTICE PROBLEMS

2.2 Measured Numbers and Significant Figures

2.9 How many significant figures are in each of the following?

a. 11.005 g **b.** 0.000 32 m
c. 36 000 000 km **d.** 1.80×10^4 kg
e. 0.8250 L **f.** 30.0 °C

2.10 How many significant figures are in each of the following?

a. 20.60 mL **b.** 1036.48 kg
c. 4.00 m **d.** 20.8 °C
e. 60 800 000 g **f.** 5.0×10^{-3} L

2.11 In which of the following pairs do both numbers contain the same number of significant figures?

a. 11.0 m and 11.00 m
b. 0.0250 m and 0.205 m
c. 0.000 12 s and 12 000 s
d. 250.0 L and 2.5×10^{-2} 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 3.80×10^5 L

2.13 Indicate if the zeros are significant in each of the following measurements:

a. 0.0038 m **b.** 5.04 cm
c. 800. L **d.** 3.0×10^{-3} kg
e. 85 000 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. 5000 L **b.** 30 000 g
c. 100 000 m **d.** 0.000 25 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. A patient has a mass of 67.5 kg.
b. A patient is given 2 tablets of medication.
c. In the metric system, 1 L is equal to 1000 mL.
d. The distance from Denver, Colorado, to Houston, Texas, is 1720 km.

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 pairs of numbers:

a. 5 pizzas and 50.0 g of cheese
b. 6 nickels and 16 g of nickel
c. 3 onions and 3 lb of onions
d. 5 miles and 5 cars

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.

REVIEW

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

2.3 Significant Figures in Calculations

LEARNING GOAL Give the correct number of significant figures for a calculated answer.

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.

Rounding Off

KEY MATH SKILL
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 m	×	3.58 m	=	19.7616	=	19.8 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 10.072 rounded off to three significant figures equal to 10.1?

▶SAMPLE PROBLEM 2.3 Rounding Off

TRY IT FIRST

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

a. 35.7823 m **b.** 0.002 621 7 L **c.** 3.8268×10^3 g **d.** 8 s

SOLUTION

a. 35.8 m **b.** 0.002 62 L **c.** 3.83×10^3 g **d.** 8.00 s

STUDY CHECK 2.3

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

ANSWER

a. 36 m **b.** 0.0026 L **c.** 3.8×10^3 g **d.** 8.0 s

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:

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

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

ENGAGE

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

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.

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.

Three SFs		Calculator display		Final answer, two zeros added to give three SFs
$\frac{8.00}{2.00}$	=	4.	=	4.00
Three SFs				

▶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

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.

Three SFs Two SFs
a. 56.8 × 0.37

Four SFs Three SFs
b. $\frac{(2.075)\,(0.585)}{(8.42)\,(0.0245)}$
Three SFs Three SFs

Three SFs
c. $\frac{25.0}{5.00}$
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 with measured numbers and give each answer with the correct number of decimal places:

a. 104 + 7.8 + 40 **b.** 153.247 − 14.82

SOLUTION

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

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

a.
```
  104   Ones place
  7.8   Tenths place
+ 40    Tens place
```

b.
```
  153.247   Thousandths place
− 14.82     Hundredths place
```

STEP 2 Perform the indicated calculation.

a. 151.8 (Calculator display)

b. 138.427 (Calculator display)

STEP 3 Round off (or add zeros) to give the same number of decimal places as the measured number having the fewest decimal places.

a. 150 Rounded off to the tens place
b. 138.43 Rounded off to the hundredths place

STUDY CHECK 2.5

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

a. 82.45 + 1.245 + 0.000 56
b. 4.259 − 3.8

ANSWER

a. 83.70 **b.** 0.5

TEST

Try Practice Problems 2.29 and 2.30

PRACTICE PROBLEMS

2.3 Significant Figures in Calculations

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 + 8.057
b. 23.45 + 104.1 + 0.025
c. 145.675 − 24.2
d. 1.08 − 0.585
e. 2300 + 196.11
f. 145.111 − 22.9 + 34.49

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

a. 5.08 + 25.1
b. 85.66 + 104.10 + 0.025
c. 24.568 − 14.25
d. 0.2654 − 0.2585
e. 66.77 + 17 − 0.33
f. 460 − 33.77

2.4 Prefixes and Equalities

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

TABLE 2.4 Daily Values (DV) 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

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 (FDA) 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 2.5 Metric and SI Prefixes

Prefix	Symbol	Numerical Value	Scientific Notation	Equality
Prefixes That Increase the Size of the Unit				
peta	P	1 000 000 000 000 000	10^{15}	$1\ \text{Pg} = 1 \times 10^{15}\ \text{g}$ $1\ \text{g} = 1 \times 10^{-15}\ \text{Pg}$
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}	$1\ \text{ps} = 1 \times 10^{-12}\ \text{s}$ $1\ \text{s} = 1 \times 10^{12}\ \text{ps}$
femto	f	0.000 000 000 000 001	10^{-15}	$1\ \text{fs} = 1 \times 10^{-15}\ \text{s}$ $1\ \text{s} = 1 \times 10^{15}\ \text{fs}$

*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.

CORE CHEMISTRY SKILL

Using Prefixes

TEST

Try Practice Problems 2.31 to 2.38

ENGAGE

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

▶ 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

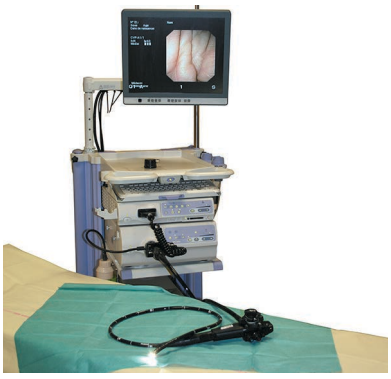
a. 1 m = 1000 mm **b.** 1 cm = 10 mm

STUDY CHECK 2.6

a. What is the relationship between millimeters and micrometers?
b. What is the relationship between liters and centiliters?

ANSWER

a. 1 mm = 1000 μm (mcm) **b.** 1 L = 100 cL



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

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

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

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

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

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**.

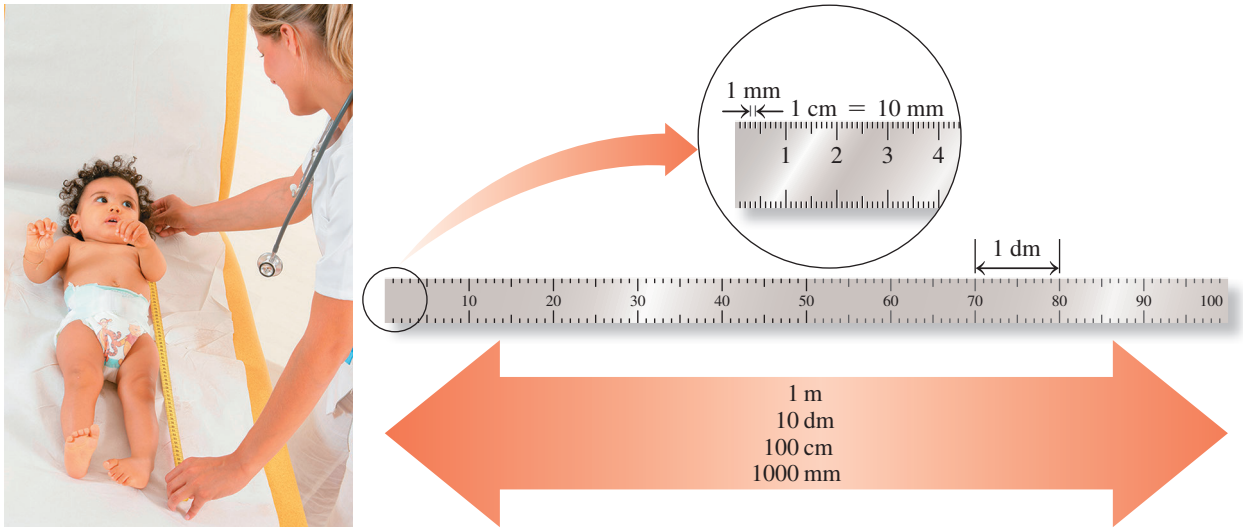


FIGURE 2.6 ▶ The metric length of 1 m is the same length as 10 dm, 100 cm, or 1000 mm.
How many millimeters (mm) are in 1 centimeter (cm)?

ENGAGE

Why can the relationship of centimeters and meters be written as 1 m = 100 cm or 0.01 m = 1 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.

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

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

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.

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

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**.

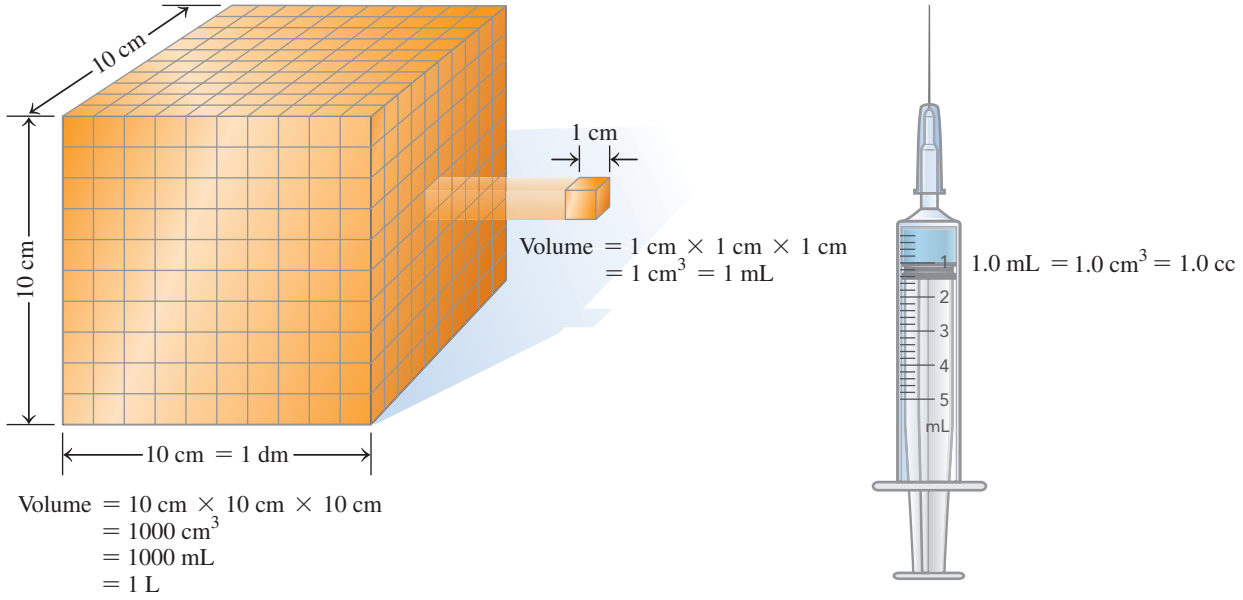


FIGURE 2.8 ▶ A cube measuring 10 cm on each side has a volume of 1000 cm^3 or 1 L; a cube measuring 1 cm on each side has a volume of 1 cm^3 (cc) or 1 mL.

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:

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

TEST

Try Practice Problems 2.39 to 2.42

PRACTICE PROBLEMS

2.4 Prefixes and Equalities

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.** femtosecond

2.33 Write the complete name for each of the following units:
a. cL **b.** kg **c.** ms **d.** Pm

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 m = _____ cm **b.** 1 m = _____ nm
c. 1 mm = _____ m **d.** 1 L = _____ mL

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 is the larger unit?
a. milligram or kilogram **b.** milliliter or microliter
c. m or km **d.** kL or dL
e. nanometer or picometer

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

REVIEW
Calculating Percentages (1.4)

CORE CHEMISTRY SKILL
Writing Conversion Factors from Equalities

TEST
Try Practice Problems 2.43 and 2.44

2.5 Writing Conversion Factors

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

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 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.

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

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

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 definition between two metric units or between two U.S. system units are exact. 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.

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 $\frac{1\text{ m}}{100\text{ cm}}$

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.

ENGAGE

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

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.

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?

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 price of onions in dollars per pound 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.

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

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

The price of onions is $1.24 per pound.

Equality	Conversion Factors	Significant Figures or Exact
1 lb = $1.24	$\frac{\$1.24}{1\text{ lb}}$ and $\frac{1\text{ lb}}{\$1.24}$	The $1.24 is measured: It has three significant figures. The 1 lb is exact.

TEST

Try Practice Problems 2.45 and 2.46

Conversion Factors from Dosage Problems

Equalities stated within dosage problems for medications can also be written as conversion factors. Keflex (cephalexin), an antibiotic used for respiratory and ear infections, is available in 250-mg capsules. Vitamin C, an antioxidant, is available in 500-mg tablets. These dosage relationships can be used to write equalities from which two conversion factors can be derived.

One capsule contains 250 mg of Keflex.

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.

Vitamin C is an antioxidant needed by the body.

One tablet contains 500 mg of vitamin C.

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

Conversion Factors from a Percentage, ppm, and ppb

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 in the factor must be the same.

ENGAGE

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

Equality	Conversion Factors	Significant Figures or Exact
100 kg of body mass = 18 kg of body fat	$\frac{\text{18 kg body fat}}{\text{100 kg body mass}}$ and $\frac{\text{100 kg body mass}}{\text{18 kg body fat}}$	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.

When scientists want to indicate very small ratios, they use numerical relationships called *parts per million* (ppm) or *parts per billion* (ppb). The ratio of parts per million is the same as the milligrams of a substance per kilogram (mg/kg). The ratio of parts per billion equals the micrograms per kilogram (μg/kg, mcg/kg).

Ratio	Units
parts per million (ppm)	milligrams per kilogram (mg/kg)
parts per billion (ppb)	micrograms per kilogram (μg/kg, mcg/kg)

For example, the maximum amount of lead that is allowed by the FDA in glazed pottery bowls is 2 ppm, which is 2 mg/kg.

Equality	Conversion Factors	Significant Figures or Exact
1 kg of glaze = 2 mg of lead	$\frac{\text{2 mg lead}}{\text{1 kg glaze}}$ and $\frac{\text{1 kg glaze}}{\text{2 mg lead}}$	The 2 mg is measured: It has one significant figure. The 1 kg is exact.

▶ 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.
c. The U.S. Environmental Protection Agency (EPA) has set the maximum level for mercury in tuna at 0.5 ppm.

Propranolol is used to lower high blood pressure.

SOLUTION

a.

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

b.

Equality	Conversion Factors	Significant Figures or Exact
100 g of salmon = 1.9 g of omega-3 fatty acids	$\frac{1.9 \text{ g omega-3 fatty acids}}{100 \text{ g salmon}}$ 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.

c.

Equality	Conversion Factors	Significant Figures or Exact
1 kg of tuna = 0.5 mg of mercury	$\frac{0.5 \text{ mg mercury}}{1 \text{ kg tuna}}$ and $\frac{1 \text{ kg tuna}}{0.5 \text{ mg mercury}}$	The 0.5 mg is measured: It has one significant figure. The 1 kg is exact.

The maximum amount of mercury allowed in tuna is 0.5 ppm.

STUDY CHECK 2.7

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

a. Levsin (hyoscyamine), used to treat stomach and bladder problems, is available as drops with 0.125 mg of Levsin per 1 mL of solution.
b. The EPA has set the maximum level of cadmium in rice as 0.4 ppm.

ANSWER

a. 1 mL of solution = 0.125 mg of Levsin

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

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

b. 1 kg of rice = 0.4 mg of cadmium

$$\frac{0.4 \text{ mg cadmium}}{1 \text{ kg rice}} \text{ and } \frac{1 \text{ kg rice}}{0.4 \text{ mg cadmium}}$$

The 0.4 mg is measured: It has one significant figure. The 1 kg is exact.

TEST

Try Practice Problems 2.47 to 2.54

PRACTICE PROBLEMS

2.5 Writing Conversion Factors

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
e. millimeters and decimeters

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. liters and deciliters
e. grams and picograms

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.
e. One minute is 60 s.

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. There are 7 days in 1 week.
d. One deciliter contains 100 mL.
e. 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.** The pesticide level in plums was 29 ppb.
- **e.** 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.** The nitrate level in well water was 32 ppm.
- **c.** Gold jewelry contains 58% gold by mass.
- **d.** The price of a liter of milk is $1.65.
- **e.** A metric ton is 1000 kg.

Clinical Applications

2.51 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 calcium supplement contains 630 mg of calcium per tablet.
- **b.** The Daily Value (DV) for vitamin C is 60 mg.
- **c.** The label on a bottle reads 50 mg of atenolol per tablet.
- **d.** A low-dose aspirin contains 81 mg of aspirin per tablet.

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?

SOLUTION

STEP 1 **State the given and needed quantities.**

ANALYZE THE PROBLEM	Given	Need	Connect
	164 lb	kilograms	U.S.–metric conversion factor

STEP 2 **Write a plan to convert the given unit to the needed unit.**

pounds → U.S.–Metric factor → kilograms

STEP 3 **State the equalities and conversion factors.**

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

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

STEP 4 **Set up the problem to cancel units and calculate the answer.** Write the given, 164 lb, and multiply by the conversion factor that has lb in the denominator (bottom number) to cancel lb in the given.

Unit for answer goes here

$$164\ \cancel{\text{lb}} \times \frac{1\text{ kg}}{2.20\ \cancel{\text{lb}}} = 74.5\text{ kg}$$

Given | Conversion factor | Answer

The given unit lb cancels out and the needed unit kg is in the numerator. *The unit you want in the final answer is the one that remains after all the other units have canceled out.* This is a helpful way to check that you set up a problem properly.

$$\cancel{\text{lb}} \times \frac{\text{kg}}{\cancel{\text{lb}}} = \text{kg}$$ Unit needed for answer

The calculator display gives the numerical answer, which is adjusted to give a final answer with the proper number of significant figures (SFs). The value of 74.5 combined with the unit, kg, gives the final answer of 74.5 kg.

Exact

$$164 \times \frac{1}{2.20} = 164 \div 2.20 = 74.54545454 = 74.5$$

Three SFs | Three SFs | Calculator display | Three SFs (rounded off)

STUDY CHECK 2.8

a. A total of 2500 mL of a boric acid antiseptic solution is prepared from boric acid concentrate. How many quarts of boric acid have been prepared?

b. A vial contains 65 mg of phenobarbital per 1 mL of solution. How many milliliters are needed for an order of 40. mg of phenobarbital?

ANSWER

a. 2.6 qt **b.** 0.62 mL

ENGAGE

When you convert one unit to another, how do you know which unit of the conversion factor to place in the denominator?

INTERACTIVE VIDEO

Conversion Factors

TEST

Try Practice Problems 2.55 and 2.56

Using Two or More Conversion Factors

In problem solving, two or more conversion factors are often needed to complete the change of units. In setting up these problems, one factor follows the other. Each factor is arranged to cancel the preceding unit until the needed unit is obtained. Once the problem is set up to cancel units properly, the calculations can be done without writing intermediate results. In this text, when two or more conversion factors are required, the final answer will be based on obtaining a final calculator display and rounding off (or adding zeros) to give the correct number of significant figures as shown in Sample Problem 2.9.

CORE CHEMISTRY SKILL

Using Conversion Factors

▶ SAMPLE PROBLEM 2.9 Using Two Conversion Factors

TRY IT FIRST

Greg has been diagnosed with diminished thyroid function. His doctor prescribes a dosage of 0.150 mg of Synthroid to be taken once a day. If tablets in stock contain 75 mcg of Synthroid, how many tablets are required to provide the prescribed medication?

ENGAGE

How can two conversion factors be utilized in a problem setup?

SOLUTION

STEP 1 **State the given and needed quantities.**

ANALYZE THE PROBLEM	Given	Need	Connect
	0.150 mg of Synthroid	number of tablets	metric conversion factor, clinical conversion factor

STEP 2 **Write a plan to convert the given unit to the needed unit.**

milligrams → (Metric factor) → micrograms → (Clinical factor) → number of tablets

STEP 3 **State the equalities and conversion factors.**

$$\frac{1000\text{ mcg}}{1\text{ mg}} \text{ and } \frac{1\text{ mg}}{1000\text{ mcg}} \qquad (1\text{ mg} = 1000\text{ mcg})$$

$$\frac{75\text{ mcg Synthroid}}{1\text{ tablet}} \text{ and } \frac{1\text{ tablet}}{75\text{ mcg Synthroid}} \qquad (1\text{ tablet} = 75\text{ mcg of Synthroid})$$

STEP 4 **Set up the problem to cancel units and calculate the answer.** The problem can be set up using the metric factor to cancel milligrams, and then the clinical factor to obtain the number of tablets as the final unit.

$$0.150\ \cancel{\text{mg Synthroid}} \times \frac{1000\ \cancel{\text{mcg}}}{1\ \cancel{\text{mg}}} \times \frac{1\text{ tablet}}{75\ \cancel{\text{mcg Synthroid}}} = 2\text{ tablets}$$

Three SFs; Exact; Exact; Two SFs

One teaspoon of cough syrup is measured for a patient.

STUDY CHECK 2.9

a. A bottle contains 120 mL of cough syrup. If one teaspoon (5 mL) is given four times a day, how many days will elapse before a refill is needed?

b. A patient is given a solution containing 0.625 g of calcium carbonate. If the calcium carbonate solution contains 1250 mg per 5 mL, how many milliliters of the solution were given to the patient?

TEST

Try Practice Problems 2.57 to 2.60

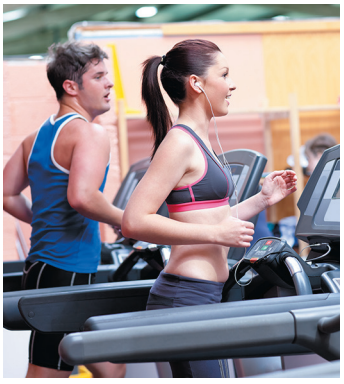
ANSWER

a. 6 days **b.** 2.5 mL

▶ SAMPLE PROBLEM 2.10 Using a Percentage as a Conversion Factor

TRY IT FIRST

A person who exercises regularly has 16% body fat by mass. If this person weighs 155 lb, what is the mass, in kilograms, of body fat?



Exercising regularly helps reduce body fat.

SOLUTION

STEP 1 **State the given and needed quantities.**

ANALYZE THE PROBLEM	Given	Need	Connect
	155 lb body weight	kilograms of body fat	U.S.–metric conversion factor, percentage conversion factor

STEP 2 **Write a plan to convert the given unit to the needed unit.**

pounds of body weight → (U.S.–Metric factor) → kilograms of body mass → (Percentage factor) → kilograms of body fat

STEP 3 **State the equalities and conversion factors.**

1 kg of body mass = 2.20 lb of body weight			100 kg of body mass = 16 kg of body fat		
$\frac{2.20\text{ lb body weight}}{1\text{ kg body mass}}$	and	$\frac{1\text{ kg body mass}}{2.20\text{ lb body weight}}$	$\frac{16\text{ kg body fat}}{100\text{ kg body mass}}$	and	$\frac{100\text{ kg body mass}}{16\text{ kg body fat}}$

STEP 4 **Set up the problem to cancel units and calculate the answer.**

		Exact		Two SFs		
155 ~~lb body weight~~	×	$\frac{1\text{ ~~kg body mass~~}}{2.20\text{ ~~lb body weight~~}}$	×	$\frac{16\text{ kg body fat}}{100\text{ ~~kg body mass~~}}$	=	11 kg of body fat
Three SFs		Three SFs		Exact		Two SFs

STUDY CHECK 2.10

a. A package contains 1.33 lb of ground round. If it contains 15% fat, how many grams of fat are in the ground round?

b. A cream contains 4.0% (by mass) lidocaine to relieve back pain. If a patient uses 12 grams of cream, how many milligrams of lidocaine are used?

ANSWER

a. 91 g of fat **b.** 480 mg

TEST

Try Practice Problems 2.61 to 2.66

Chemistry Link to Health

Toxicology and Risk–Benefit Assessment

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

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

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

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

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

TABLE 2.8 lists some LD_{50} values and compares substances in order of increasing toxicity.

TABLE 2.8 Some LD_{50} Values for Substances Tested in Rats

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

PRACTICE PROBLEMS

2.6 Problem Solving Using Unit Conversion

2.55 Perform each of the following conversions using metric conversion factors:

a. 44.2 mL to liters
b. 8.65 m to nanometers
c. 5.2×10^{8} g to megagrams
d. 0.72 ks to milliseconds

2.56 Perform each of the following conversions using metric conversion factors:

a. 4.82×10^{-5} L to picoliters
b. 575.2 dm to kilometers
c. 5×10^{-4} kg to micrograms
d. 6.4×10^{10} ps to seconds

2.57 Perform each of the following conversions using metric and U.S. conversion factors:

a. 3.428 lb to kilograms
b. 1.6 m to inches
c. 4.2 L to quarts
d. 0.672 ft to millimeters

2.58 Perform each of the following conversions using metric and U.S. conversion factors:

a. 0.21 lb to grams
b. 11.6 in. to centimeters
c. 0.15 qt to milliliters
d. 35.41 kg to pounds

2.59 Use metric conversion factors to solve each of the following problems:

a. If a student is 175 cm tall, how tall is the student in meters?
b. A cooler has a volume of 5000 mL. What is the capacity of the cooler in liters?
c. A hummingbird has a mass of 0.0055 kg. What is the mass, in grams, of the hummingbird?
d. A balloon has a volume of 3500 cm^3. What is the volume in liters?

2.60 Use metric conversion factors to solve each of the following problems:

a. The Daily Value (DV) for phosphorus is 800 mg. How many grams of phosphorus are recommended?
b. A glass of orange juice contains 3.2 dL of juice. How many milliliters of orange juice are in the glass?
c. A package of chocolate instant pudding contains 2840 mg of sodium. How many grams of sodium are in the pudding?
d. A jar contains 0.29 kg of olives. How many grams of olives are in the jar?

2.61 Solve each of the following problems using one or more conversion factors:

a. A container holds 0.500 qt of liquid. How many milliliters of lemonade will it hold?
b. What is the mass, in kilograms, of a person who weighs 175 lb?
c. An athlete has 15% body fat by mass. What is the weight of fat, in pounds, of a 74-kg athlete?
d. A plant fertilizer contains 15% nitrogen (N) by mass. In a container of soluble plant food, there are 10.0 oz of fertilizer. How many grams of nitrogen are in the container?

Agricultural fertilizers applied to a field provide nitrogen for plant growth.

2.62 Solve each of the following problems using one or more conversion factors:

a. Wine is 12% alcohol by volume. How many milliliters of alcohol are in a 0.750-L bottle of wine?
b. Blueberry high-fiber muffins contain 51% dietary fiber by mass. If a package with a net weight of 12 oz contains six muffins, how many grams of fiber are in each muffin?
c. A jar of crunchy peanut butter contains 1.43 kg of peanut butter. If you use 8.0% of the peanut butter for a sandwich, how many ounces of peanut butter did you take out of the container?
d. In a candy factory, the nutty chocolate bars contain 22.0% pecans by mass. If 5.0 kg of pecans were used for candy last Tuesday, how many pounds of nutty chocolate bars were made?

Clinical Applications

2.63 Using conversion factors, solve each of the following clinical problems:

a. You have used 250 L of distilled water for a dialysis patient. How many gallons of water is that?
b. A patient needs 0.024 g of a sulfa drug. There are 8-mg tablets in stock. How many tablets should be given?
c. The daily dose of ampicillin for the treatment of an ear infection is 115 mg/kg of body weight. What is the daily dose for a 34-lb child?
d. You need 4.0 oz of a steroid ointment. How many grams of ointment does the pharmacist need to prepare?

2.64 Using conversion factors, solve each of the following clinical problems:

a. The physician has ordered 1.0 g of tetracycline to be given every six hours to a patient. If your stock on hand is 500-mg tablets, how many will you need for one day's treatment?
b. An intramuscular medication is given at 5.00 mg/kg of body weight. What is the dose for a 180-lb patient?
c. A physician has ordered 0.50 mg of atropine, intramuscularly. If atropine were available as 0.10 mg/mL of solution, how many milliliters would you need to give?
d. During surgery, a patient receives 5.0 pt of plasma. How many milliliters of plasma were given?

2.65 Using conversion factors, solve each of the following clinical problems:

a. A nurse practitioner prepares 500. mL of an IV of normal saline solution to be delivered at a rate of 80. mL/h. What is the infusion time, in hours, to deliver 500. mL?
b. A nurse practitioner orders Medrol to be given 1.5 mg/kg of body weight. Medrol is an anti-inflammatory administered as an intramuscular injection. If a child weighs 72.6 lb and the available stock of Medrol is 20. mg/mL, how many milliliters does the nurse administer to the child?

2.66 Using conversion factors, solve each of the following clinical problems:

a. A nurse practitioner prepares an injection of promethazine, an antihistamine used to treat allergic rhinitis. If the stock bottle is labeled 25 mg/mL and the order is a dose of 12.5 mg, how many milliliters will the nurse draw up in the syringe?
b. You are to give ampicillin 25 mg/kg to a child with a mass of 67 lb. If stock on hand is 250 mg/capsule, how many capsules should be given?

2.7 Density

LEARNING GOAL Calculate the density of a substance; use the density to calculate the mass or volume of a substance.

The mass and volume of any object can be measured. If we compare the mass of the object to its volume, we obtain a relationship called **density**.

$$\text{Density} = \frac{\text{mass of substance}}{\text{volume of substance}}$$

Every substance has a unique density, which distinguishes it from other substances. For example, lead has a density of 11.3 g/mL, whereas cork has a density of 0.26 g/mL. From these densities, we can predict if these substances will sink or float in water. *If an object is less dense than a liquid, the object floats when placed in the liquid.* If a substance, such as cork, is less dense than water, it will float. However, a lead object sinks because its density is greater than that of water (see **FIGURE 2.10**).

ENGAGE

If a piece of iron sinks in water, how does its density compare to that of water?

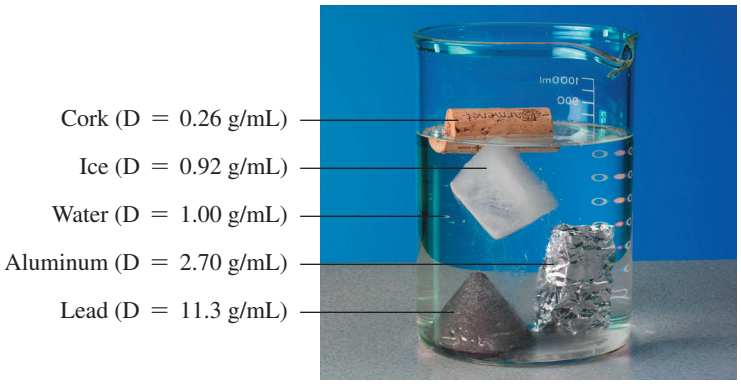


FIGURE 2.10 ▶ Objects that sink in water are more dense than water; objects that float are less dense.

Why does an ice cube float and a piece of aluminum sink?

Density is used in chemistry in many ways. If we calculate the density of a pure metal as 10.5 g/mL, then we could identify it as silver, but not gold or aluminum. Metals such as gold and silver have higher densities, whereas gases have low densities. In the metric system, the densities of solids and liquids are usually expressed as grams per cubic centimeter (g/cm^3) or grams per milliliter (g/mL). The densities of gases are usually stated as grams per liter (g/L). **TABLE 2.9** gives the densities of some common substances.

TABLE 2.9 Densities of Some Common Substances

Solids (at 25 °C)	Density (g/mL)	Liquids (at 25 °C)	Density (g/mL)	Gases (at 0 °C)	Density (g/L)
Cork	0.26	Gasoline	0.74	Hydrogen	0.090
Body fat	0.909	Ethanol	0.79	Helium	0.179
Ice (at 0 °C)	0.92	Olive oil	0.92	Methane	0.714
Muscle	1.06	Water (at 4 °C)	1.00	Neon	0.902
Sugar	1.59	Urine	1.003–1.030	Nitrogen	1.25
Bone	1.80	Plasma (blood)	1.03	Air (dry)	1.29
Salt (NaCl)	2.16	Milk	1.04	Oxygen	1.43
Aluminum	2.70	Blood	1.06	Carbon dioxide	1.96
Iron	7.86	Mercury	13.6		
Copper	8.92				
Silver	10.5				
Lead	11.3				
Gold	19.3				

Calculating Density

We can calculate the density of a substance from its mass and volume as shown in Sample Problem 2.11.

▶SAMPLE PROBLEM 2.11 Calculating Density

TRY IT FIRST

High-density lipoprotein (HDL) is a type of cholesterol, sometimes called "good cholesterol," that is measured in a routine blood test. If a 0.258-g sample of HDL has a volume of 0.215 mL, what is the density, in grams per milliliter, of the HDL sample?

SOLUTION

STEP 1 **State the given and needed quantities.**

ANALYZE THE PROBLEM	Given	Need	Connect
	0.258 g of HDL, 0.215 mL	density (g/mL) of HDL	density expression

STEP 2 **Write the density expression.**

$$\text{Density} = \frac{\text{mass of substance}}{\text{volume of substance}}$$

STEP 3 **Express mass in grams and volume in milliliters.**

Mass of HDL sample = 0.258 g
Volume of HDL sample = 0.215 mL

STEP 4 **Substitute mass and volume into the density expression and calculate the density.**

$$\text{Density} = \frac{\overset{\text{Three SFs}}{0.258\text{ g}}}{\underset{\text{Three SFs}}{0.215\text{ mL}}} = \frac{1.20\text{ g}}{1\text{ mL}} = \underset{\text{Three SFs}}{1.20\text{ g/mL}}$$

STUDY CHECK 2.11

a. Low-density lipoprotein (LDL), sometimes called "bad cholesterol," is also measured in a routine blood test. If a 0.380-g sample of LDL has a volume of 0.362 mL, what is the density, in grams per milliliter, of the LDL sample?

b. Osteoporosis is a condition in which bone deteriorates to cause a decreased bone mass. If a bone sample has a mass of 2.15 g and a volume of 1.40 cm^3, what is its density in grams per cubic centimeter?

TEST

Try Practice Problems 2.67 to 2.70

ANSWER

a. 1.05 g/mL **b.** 1.54 g/cm^3

Density of Solids Using Volume Displacement

The volume of a solid can be determined by volume displacement. When a solid is completely submerged in water, it displaces a volume that is equal to the volume of the solid. In **FIGURE 2.11**, the water level rises from 35.5 mL to 45.0 mL after the zinc object is added. This means that 9.5 mL of water is displaced and that the volume of the object is 9.5 mL.

The density of the zinc is calculated using volume displacement as follows:

$$\text{Density} = \frac{\overset{\text{Four SFs}}{68.60 \text{ g Zn}}}{\underset{\text{Two SFs}}{9.5 \text{ mL}}} = \underset{\text{Two SFs}}{7.2 \text{ g/mL}}$$

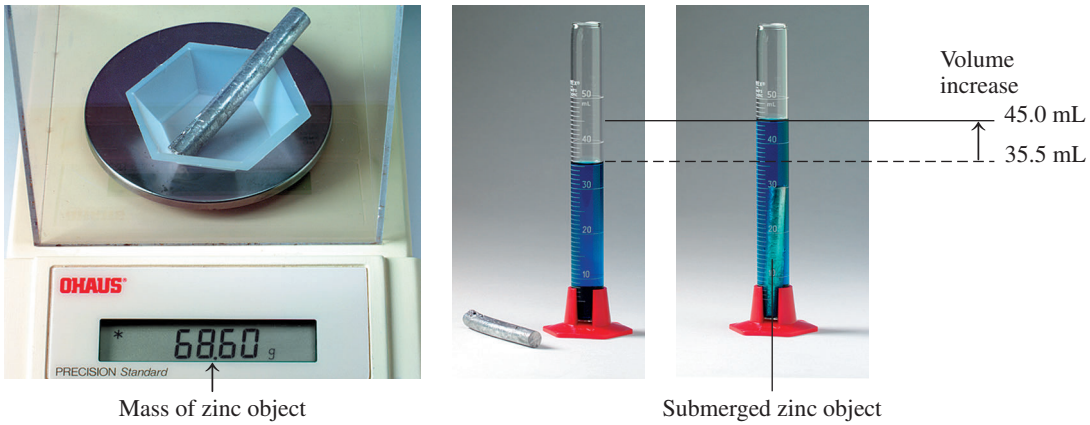


FIGURE 2.11 ▶ The density of a solid can be determined by volume displacement because a submerged object displaces a volume of water equal to its own volume.

How is the volume of the zinc object determined?

Problem Solving Using Density

Density can be used as a conversion factor. For example, if the volume and the density of a sample are known, the mass in grams of the sample can be calculated as shown in Sample Problem 2.12.

CORE CHEMISTRY SKILL
Using Density as a Conversion Factor

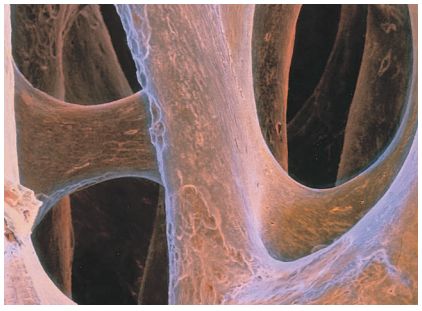
Chemistry Link to Health

Bone Density

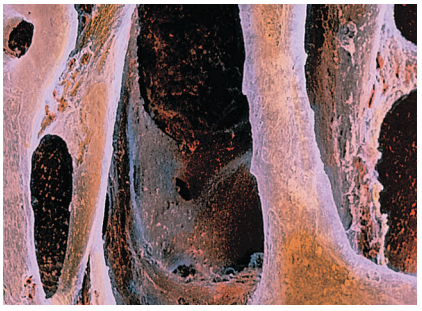
Our bones' density is a measure of their health and strength. Our bones are constantly gaining and losing calcium, magnesium, and phosphate. In childhood, bones form at a faster rate than they break down. As we age, bone breakdown occurs more rapidly than new bone forms. As bone loss increases, bones begin to thin, causing a decrease in mass and density. Thinner bones lack strength, which increases the risk of fracture. Hormonal changes, disease, and certain medications can also contribute to the bone thinning. Eventually, a condition of severe bone thinning known as *osteoporosis*, may occur. *Scanning electron micrographs* (SEMs) show **(a)** normal bone and **(b)** bone with osteoporosis due to loss of bone minerals.

Bone density is often determined by passing low-dose X-rays through the narrow part at the top of the femur (hip) and the spine **(c)**. These locations are where fractures are more likely to occur, especially as we age. Bones with high density will block more of the X-rays compared to bones that are less dense. The results of a bone density test are compared to a healthy young adult as well as to other people of the same age.

Recommendations to improve bone strength include calcium and vitamin D supplements. Weight-bearing exercise such as walking and lifting weights can also improve muscle strength, which in turn increases bone strength.

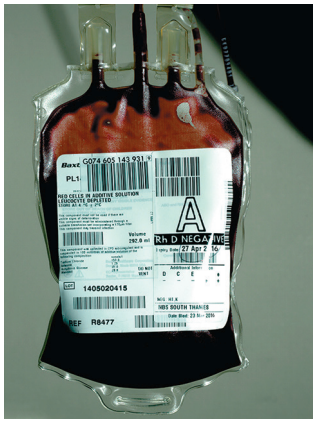


(a) Normal bone



(b) Bone with osteoporosis

(c) Viewing a low-dose X-ray of the spine



1 pt of blood contains 473 mL.

▶SAMPLE PROBLEM 2.12 Problem Solving Using Density

TRY IT FIRST

Greg has a blood volume of 5.9 qt. If the density of blood is 1.06 g/mL, what is the mass, in grams, of Greg's blood?

SOLUTION

STEP 1 State the given and needed quantities.

ANALYZE THE PROBLEM	Given	Need	Connect
	5.9 qt of blood	grams of blood	U.S.–metric conversion factor, density conversion factor

STEP 2 Write a plan to calculate the needed quantity.

quarts → U.S.–Metric factor → milliliters → Density factor → grams

STEP 3 Write the equalities and their conversion factors including density.

$$1\text{ qt} = 946\text{ mL} \qquad \frac{946\text{ mL}}{1\text{ qt}} \text{ and } \frac{1\text{ qt}}{946\text{ mL}}$$

$$1\text{ mL of blood} = 1.06\text{ g of blood} \qquad \frac{1.06\text{ g blood}}{1\text{ mL blood}} \text{ and } \frac{1\text{ mL blood}}{1.06\text{ g blood}}$$

STEP 4 Set up the problem to calculate the needed quantity.

	Three SFs	Three SFs	
$5.9\ \cancel{\text{qt blood}} \times$	$\frac{946\ \cancel{\text{mL}}}{1\ \cancel{\text{qt}}} \times$	$\frac{1.06\text{ g blood}}{1\ \cancel{\text{mL blood}}} =$	5900 g of blood
Two SFs	Exact	Exact	Two SFs

STUDY CHECK 2.12

a. During surgery, a patient receives 3.0 pt of blood. How many kilograms of blood (density = 1.06 g/mL) were needed for the transfusion?

b. A woman receives 1280 g of type A blood. If the blood has a density of 1.06 g/mL, how many liters of blood did she receive?

TEST

Try Practice Problems 2.71 to 2.76

ANSWER

a. 1.5 kg **b.** 1.21 L

Specific Gravity

Specific gravity (sp gr) is a relationship between the density of a substance and the density of water. Specific gravity is calculated by dividing the density of a sample by the density of water, which is 1.00 g/mL at 4 °C. A substance with a specific gravity of 1.00 has the same density as water (1.00 g/mL).

$$\text{Specific gravity} = \frac{\text{density of sample}}{\text{density of water}}$$

TEST

Try Practice Problems 2.77 and 2.78

Specific gravity is one of the few unitless values you will encounter in chemistry. The specific gravity of urine helps evaluate the water balance in the body and the substances in

the urine. In **FIGURE 2.12**, a hydrometer is used to measure the specific gravity of urine. The normal range of specific gravity for urine is 1.003 to 1.030. The specific gravity can decrease with *type 2 diabetes* and kidney disease. Increased specific gravity may occur with dehydration, kidney infection, and liver disease. In a clinic or hospital, a dipstick containing chemical pads is used to evaluate specific gravity.

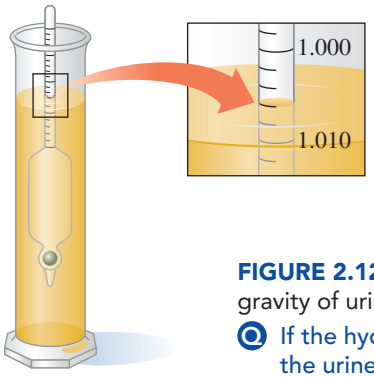


FIGURE 2.12 ▶ A hydrometer is used to measure the specific gravity of urine, which, for adults, is 1.003 to 1.030.

If the hydrometer reading is 1.006, what is the density of the urine?

A dipstick is used to measure the specific gravity of a urine sample.

PRACTICE PROBLEMS

2.7 Density

2.67 Determine the density (g/mL) for each of the following:

a. A 20.0-mL sample of a salt solution has a mass of 24.0 g.

b. A cube of butter weighs 0.250 lb and has a volume of 130.3 mL.

c. A gem has a mass of 4.50 g. When the gem is placed in a graduated cylinder containing 12.00 mL of water, the water level rises to 13.45 mL.

d. A 3.00-mL sample of a medication has a mass of 3.85 g.

2.68 Determine the density (g/mL) for each of the following:

a. The fluid in a car battery has a volume of 125 mL and a mass of 155 g.

b. A plastic material weighs 2.68 lb and has a volume of 3.5 L.

c. A 4.000-mL urine sample from a person suffering from diabetes mellitus has a mass of 4.004 g.

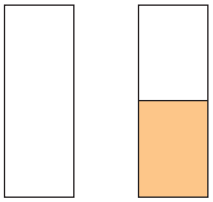
d. A solid object has a mass of 1.65 lb and a volume of 170 mL.

2.69 What is the density (g/mL) of each of the following samples?

a. A lightweight head on a golf club is made of titanium. The volume of a sample of titanium is 114 cm^3, and the mass is 514.1 g.

Lightweight heads on golf clubs are made of titanium.

b. A syrup is added to an empty container with a mass of 115.25 g. When 0.100 pt of syrup is added, the total mass of the container and syrup is 182.48 g.



115.25 g **182.48 g**

c. A block of aluminum metal has a volume of 3.15 L and a mass of 8.51 kg.

2.70 What is the density (g/mL) of each of the following samples?

a. An ebony carving has a mass of 275 g and a volume of 207 cm^3.

b. A 14.3-cm^3 sample of tin has a mass of 0.104 kg.

c. A bottle of acetone (fingernail polish remover) contains 55.0 mL of acetone with a mass of 43.5 g.

2.71 Use the density values in Table 2.9 to solve each of the following problems:

a. How many liters of ethanol contain 1.50 kg of ethanol?

b. How many grams of mercury are present in a barometer that holds 6.5 mL of mercury?

c. A sculptor has prepared a mold for casting a silver figure. The figure has a volume of 225 cm^3. How many ounces of silver are needed in the preparation of the silver figure?

2.72 Use the density values in Table 2.9 to solve each of the following problems:

a. A graduated cylinder contains 18.0 mL of water. What is the new water level, in milliliters, after 35.6 g of silver metal is submerged in the water?

b. A thermometer containing 8.3 g of mercury has broken. What volume, in milliliters, of mercury spilled?

c. A fish tank holds 35 gal of water. How many kilograms of water are in the fish tank?

2.73 Use the density values in Table 2.9 to solve each of the following problems:

a. What is the mass, in grams, of a cube of copper that has a volume of 74.1 cm^3?

b. How many kilograms of gasoline fill a 12.0-gal gas tank?

c. What is the volume, in cubic centimeters, of an ice cube that has a mass of 27 g?

2.74 Use the density values in Table 2.9 to solve each of the following problems:

a. If a bottle of olive oil contains 1.2 kg of olive oil, what is the volume, in milliliters, of the olive oil?

b. A cannon ball made of iron has a volume of 115 cm^3. What is the mass, in kilograms, of the cannon ball?

c. A balloon filled with helium has a volume of 7.3 L. What is the mass, in grams, of helium in the balloon?

2.75 In an old trunk, you find a piece of metal that you think may be aluminum, silver, or lead. You take it to a lab, where you find it has a mass of 217 g and a volume of 19.2 cm^3. Using Table 2.9, what is the metal you found?

2.76 Suppose you have two 100-mL graduated cylinders. In each cylinder, there is 40.0 mL of water. You also have two cubes: one is lead, and the other is aluminum. Each cube measures 2.0 cm on each side. After you carefully lower each cube into the water of its own cylinder, what will the new water level be in each of the cylinders? Use Table 2.9 for density values.

Clinical Applications

2.77 Solve each of the following problems:

a. A urine sample has a density of 1.030 g/mL. What is the specific gravity of the sample?

b. A 20.0-mL sample of a glucose IV solution has a mass of 20.6 g. What is the density of the glucose solution?

c. The specific gravity of a vegetable oil is 0.92. What is the mass, in grams, of 750 mL of vegetable oil?

d. A bottle containing 325 g of cleaning solution is used to clean hospital equipment. If the cleaning solution has a specific gravity of 0.850, what volume, in milliliters, of solution was used?

2.78 Solve each of the following problems:

a. A glucose solution has a density of 1.02 g/mL. What is its specific gravity?

b. A 0.200-mL sample of very-low-density lipoprotein (VLDL) has a mass of 190 mg. What is the density of the VLDL?

c. Butter has a specific gravity of 0.86. What is the mass, in grams, of 2.15 L of butter?

d. A 5.000-mL urine sample has a mass of 5.025 g. If the normal range for the specific gravity of urine is 1.003 to 1.030, would the specific gravity of this urine sample indicate that the patient could have type 2 diabetes?

CLINICAL UPDATE Greg's Visit with His Doctor

On Greg's visit to his doctor, he complains of feeling tired. Sandra, the registered nurse, withdraws 8.0 mL of blood, which is sent to the lab and tested for iron. When the iron level is low, a person may have fatigue and decreased immunity.

The normal range for serum iron in men is 80 to 160 mcg/dL. Greg's iron test shows a blood serum iron level of 42 mcg/dL, which indicates that Greg has *iron-deficiency anemia*. His doctor orders an iron supplement. One tablet of the iron supplement contains 50 mg of iron.

Clinical Applications

2.79 **a.** Write an equality and two conversion factors for Greg's serum iron level.

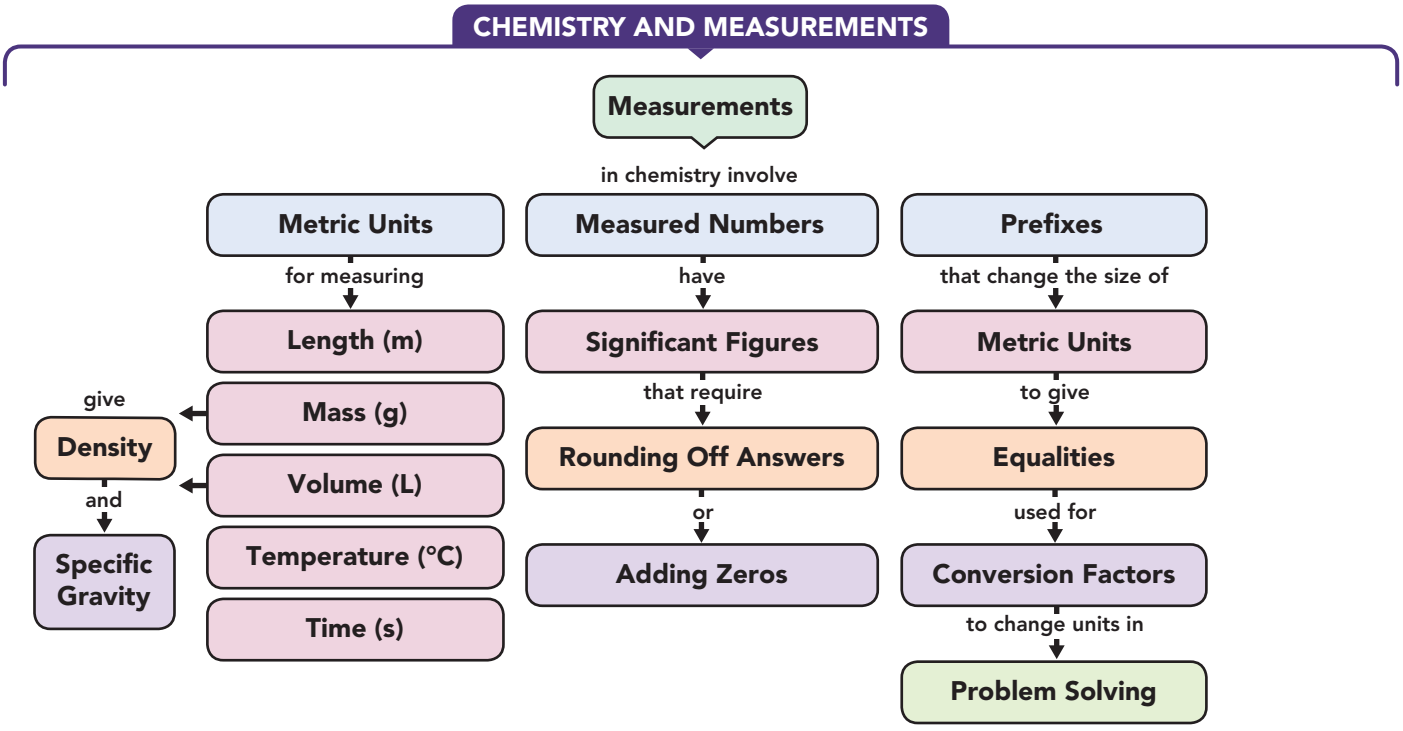
b. How many micrograms of iron were in the 8.0-mL sample of Greg's blood?

2.80 **a.** Write an equality and two conversion factors for one tablet of the iron supplement.

b. How many grams of iron will Greg consume in one week, if he takes two tablets each day?

Each tablet contains 50 mg of iron, which is given for iron supplementation.

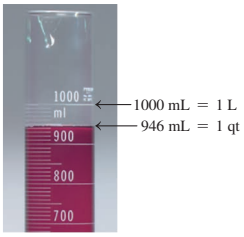
CONCEPT MAP



CHAPTER REVIEW

2.1 Units of Measurement

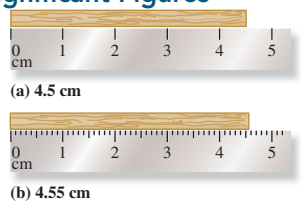
LEARNING GOAL Write the names and abbreviations for the metric and SI units used in measurements of volume, length, mass, temperature, and time.



- In science, physical quantities are described in units of the metric or International System of Units (SI).
- Some important units are liter (L) for volume, meter (m) for length, gram (g) and kilogram (kg) for mass, degree Celsius (°C) and kelvin (K) for temperature, and second (s) for time.

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.



- A measured number is any number obtained by using a measuring device.
- An exact number is obtained by counting items or from a definition; no measuring device is needed.
- Significant figures are the numbers reported in a measurement including the estimated digit.
- Zeros in front of a decimal number or at the end of a nondecimal number are not significant.

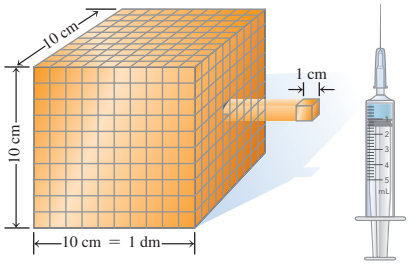
2.3 Significant Figures in Calculations

LEARNING GOAL Give the correct number of significant figures for a calculated answer.

- In multiplication and division, the final answer is written so that it has the same number of significant figures as the measurement with the fewest significant figures.
- In addition and subtraction, the final answer is written so that it has the same number of decimal places as the measurement with the fewest decimal places.

2.4 Prefixes and Equalities

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



- A prefix placed in front of a metric or SI unit changes the size of the unit by factors of 10.
- Prefixes such as *centi*, *milli*, and *micro* provide smaller units; prefixes such as *kilo*, *mega*, and *tera* provide larger units.
- An equality shows the relationship between two units that measure the same quantity of volume, length, mass, or time.
- Examples of metric equalities are 1 L = 1000 mL, 1 m = 100 cm, 1 kg = 1000 g, and 1 min = 60 s.

2.5 Writing Conversion Factors

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

- Conversion factors are used to express a relationship in the form of a fraction.
- Two conversion factors can be written for any relationship in the metric or U.S. system.
- A percentage is written as a conversion factor by expressing matching units as the parts in 100 parts of the whole.

2.6 Problem Solving Using Unit Conversion

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

- Conversion factors are useful when changing a quantity expressed in one unit to a quantity expressed in another unit.
- In the problem-solving process, a given unit is multiplied by one or more conversion factors that cancel units until the needed answer is obtained.

2.7 Density

LEARNING GOAL Calculate the density of a substance; use the density to calculate the mass or volume of a substance.

- The density of a substance is a ratio of its mass to its volume, usually g/mL or g/cm^3.
- The units of density can be used to write conversion factors that convert between the mass and volume of a substance.
- Specific gravity (sp gr) compares the density of a substance to the density of water, 1.00 g/mL.

KEY TERMS

Celsius (°C) temperature scale A temperature scale on which water has a freezing point of 0 °C and a boiling point of 100 °C.

centimeter (cm) A unit of length in the metric system; there are 2.54 cm in 1 in.

conversion factor A ratio in which the numerator and denominator are quantities from an equality or given relationship. For example, the two conversion factors for the equality 1 kg = 2.20 lb are written as

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

cubic centimeter (cm^3, cc) The volume of a cube that has 1-cm sides; 1 cm^3 is equal to 1 mL.

density The relationship of the mass of an object to its volume expressed as grams per cubic centimeter (g/cm^3), grams per milliliter (g/mL), or grams per liter (g/L).

equality A relationship between two units that measure the same quantity.

exact number A number obtained by counting or by definition.

gram (g) The metric unit used in measurements of mass.

International System of Units (SI) The official system of measurement throughout the world, except for the United States, that modifies the metric system.

Kelvin (K) temperature scale A temperature scale on which the lowest possible temperature is 0 K.

kilogram (kg) A metric mass of 1000 g, equal to 2.20 lb. The kilogram is the SI standard unit of mass.

liter (L) The metric unit for volume that is slightly larger than a quart.

mass A measure of the quantity of material in an object.

measured number A number obtained when a quantity is determined by using a measuring device.

meter (m) The metric unit for length that is slightly longer than a yard. The meter is the SI standard unit of length.

metric system A system of measurement used by scientists and in most countries of the world.

milliliter (mL) A metric unit of volume equal to one-thousandth of a liter (0.001 L).

prefix The part of the name of a metric unit that precedes the base unit and specifies the size of the measurement. All prefixes are related on a decimal scale.

second (s) A unit of time used in both the SI and metric systems.

SI See International System of Units (SI).

significant figures (SFs) The numbers recorded in a measurement.

specific gravity (sp gr) A relationship between the density of a substance and the density of water:

$$\text{sp gr} = \frac{\text{density of sample}}{\text{density of water}}$$

temperature An indicator of the hotness or coldness of an object.

volume (*V*) The amount of space occupied by a substance.

KEY MATH SKILL

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

Rounding Off (2.3)

Calculator displays are rounded off to give the correct number of significant figures.

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

One or more significant zeros are added when the calculator display has fewer digits than the needed number of significant figures.

Example: Round off each of the following to three significant figures:

a. 3.608 92 L
b. 0.003 870 298 m
c. 6 g

Answer: **a.** 3.61 L **b.** 0.003 87 m **c.** 6.00 g

CORE CHEMISTRY SKILLS

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

Counting Significant Figures (2.2)

The significant figures (SFs) are all the measured numbers including the last, estimated digit.

- All nonzero digits
- Zeros between nonzero digits
- Zeros within a decimal number
- All digits in a coefficient of a number written in scientific notation

An *exact* number is obtained from counting or a definition and has no effect on the number of significant figures in the final answer.

Example: State the number of significant figures in each of the following:

a. 0.003 045 mm
b. 15 000 m
c. 45.067 kg
d. 5.30×10^3 g
e. 2 cans of soda

Answer: **a.** four SFs **b.** two SFs **c.** five SFs **d.** three SFs **e.** exact

Using Significant Figures in Calculations (2.3)

- In multiplication or division, the final answer is written so that it has the same number of significant figures as the measurement with the fewest SFs.
- 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.

Example: Perform the following calculations using measured numbers, and give answers with the correct number of SFs or decimal places:

a. $4.05 \text{ m} \times 0.6078 \text{ m}$
b. $\dfrac{4.50 \text{ g}}{3.27 \text{ mL}}$
c. $0.758 \text{ g} + 3.10 \text{ g}$
d. $13.538 \text{ km} - 8.6 \text{ km}$

Answer: **a.** 2.46 m^2 **b.** 1.38 g/mL **c.** 3.86 g **d.** 4.9 km

Using Prefixes (2.4)

In the metric and SI systems of units, a prefix attached to any unit increases or decreases its size by some factor of 10.

- 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).

Example: Complete each of the following metric relationships:

a. 1000 m = 1 ____ m **b.** 0.01 g = 1 ____ g

Answer: **a.** 1000 m = 1 km **b.** 0.01 g = 1 cg

Writing Conversion Factors from Equalities (2.5)

- A conversion factor allows you to change from one unit to another.
- Two conversion factors can be written for any equality in the metric, U.S., or metric–U.S. systems of measurement.
- Two conversion factors can be written for a relationship stated within a problem.

Example: Write two conversion factors for the equality: 1 L = 1000 mL.

Answer: $\dfrac{1000 \text{ mL}}{1 \text{ L}}$ and $\dfrac{1 \text{ L}}{1000 \text{ mL}}$

Using Conversion Factors (2.6)

In problem solving, conversion factors are used to cancel the given unit and to provide the needed unit for the answer.

- State the given and needed quantities.
- Write a plan to convert the given unit to the needed unit.
- State the equalities and conversion factors.
- Set up the problem to cancel units and calculate the answer.

Example: A computer chip has a width of 0.75 in. What is the width in millimeters?

Answer: $0.75 \cancel{\text{in.}} \times \dfrac{2.54 \cancel{\text{cm}}}{1 \cancel{\text{in.}}} \times \dfrac{10 \text{ mm}}{1 \cancel{\text{cm}}} = 19 \text{ mm}$

Using Density as a Conversion Factor (2.7)

Density is an equality of mass and volume for a substance, which is written as the *density expression.*

$$\text{Density} = \frac{\text{mass of substance}}{\text{volume of substance}}$$

Density is useful as a conversion factor to convert between mass and volume.

Example: The element tungsten used in light bulb filaments has a density of 19.3 g/cm^3. What is the volume, in cubic centimeters, of 250 g of tungsten?

Answer: $250 \cancel{\text{g}} \times \dfrac{1 \text{ cm}^3}{19.3 \cancel{\text{g}}} = 13 \text{ cm}^3$

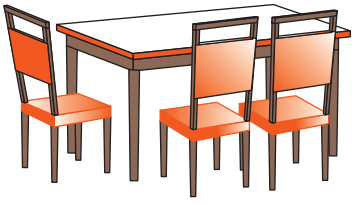
UNDERSTANDING THE CONCEPTS

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

2.81 In which of the following pairs do both numbers contain the same number of significant figures? (2.2)
a. 5100 m and 0.0051 m
b. 8000 kg and 0.080 kg
c. 0.0000 95 s and 95 0000 s
d. 58.0 L and 5.80×10^4 L

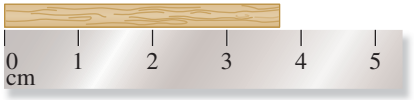
2.82 In which of the following pairs do both numbers contain the same number of significant figures? (2.2)
a. 7.45×10^4 g and 0.0745 g
b. 0.000064 s and 6.4×10^5 s
c. 4.37×10^{-7} m and 43.70 m
d. 258.0 K and 2.58×10^{-8} K

2.83 Indicate if each of the following is answered with an exact number or a measured number: (2.2)

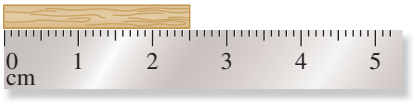


a. number of legs
b. height of table
c. number of chairs at the table
d. area of tabletop

2.84 Measure the length of each of the objects in diagrams **(a)**, **(b)**, and **(c)** using the metric ruler in the figure. Indicate the number of significant figures for each and the estimated digit for each. (2.2)



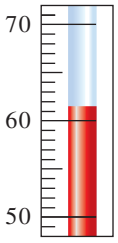
(a)



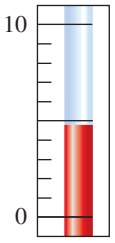
(b)

(c)

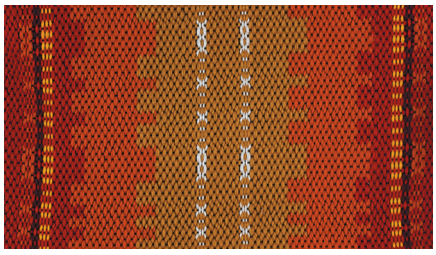
2.85 State the temperature on the Celsius thermometer to the correct number of significant figures: (2.3)



2.86 State the temperature on the Celsius thermometer to the correct number of significant figures: (2.3)



2.87 The length of this rug is 38.4 in. and the width is 24.2 in. (2.3, 2.6)

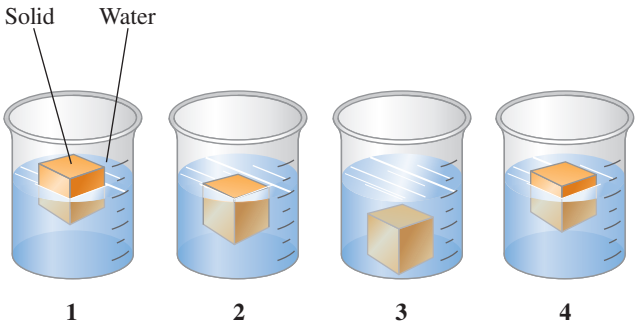


a. What is the length of this rug, in centimeters?
b. What is the width of this rug, in centimeters?
c. How many significant figures are in the length measurement?
d. Calculate the area of the rug, in square centimeters, to the correct number of significant figures. (Area = Length × Width)

2.88 A shipping box has a length of 7.00 in., a width of 6.00 in., and a height of 4.00 in. (2.3, 2.6)

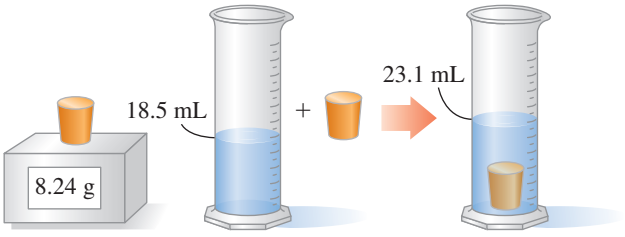
a. What is the length of the box, in centimeters?
b. What is the width of the box, in centimeters?
c. How many significant figures are in the width measurement?
d. Calculate the volume of the box, in cubic centimeters, to the correct number of significant figures. (Volume = Length × Width × Height)

2.89 Each of the following diagrams represents a container of water and a cube. Some cubes float while others sink. Match diagrams **1**, **2**, **3**, or **4** with one of the following descriptions and explain your choices: (2.7)

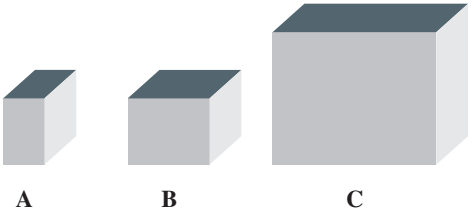


a. The cube has a greater density than water.
b. The cube has a density that is 0.80 g/mL.
c. The cube has a density that is one-half the density of water.
d. The cube has the same density as water.

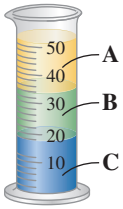
2.90 What is the density of the solid object that is weighed and submerged in water? (2.7)



2.91 Consider the following solids. The solids **A**, **B**, and **C** represent aluminum (D = 2.70 g/mL), gold (D = 19.3 g/mL), and silver (D = 10.5 g/mL). If each has a mass of 10.0 g, what is the identity of each solid? (2.7)



2.92 A graduated cylinder contains three liquids—**A**, **B**, and **C**—that have different densities and do not mix: gasoline (D = 0.74 g/mL), olive oil (D = 0.92 g/mL), and milk (D = 1.04 g/mL). Identify the liquids **A**, **B**, and **C** in the cylinder. (2.7)



2.93 The gray cube has a density of 4.5 g/cm^3. Is the density of the green cube the same, lower than, or higher than that of the gray cube? (2.7)

2.94 The gray cube has a density of 4.5 g/cm^3. Is the density of the green cube the same, lower than, or higher than that of the gray cube? (2.7)

ADDITIONAL PRACTICE PROBLEMS

2.95 Round off or add zeros to the following calculated answers to give a final answer with three significant figures: (2.2)

a. 2.784 kg **b.** 76.016 L

c. 0.006212 cm

2.96 Round off or add zeros to the following calculated answers to give a final answer with three significant figures: (2.2)

a. 58.703 mL **b.** 3×10^{-3} s

c. 0.010 826 g **d.** 1.7484×10^{3} ms

2.97 A chicken and cheese sandwich contains 90 g of chicken, 28.25 g of cheese, and 76.4 g of bread. (2.3, 2.6)

a. What is the total mass, in grams, of the sandwich?

b. What is the total weight, in pounds, of the sandwich?

2.98 A fish company delivers 22 kg of salmon, 5.5 kg of crab, and 3.48 kg of oysters to your seafood restaurant. (2.3, 2.6)

a. What is the total mass, in kilograms, of the seafood?

b. What is the total number of pounds?

2.99 In France, grapes are 1.95 euros per kilogram. What is the cost of grapes, in dollars per pound, if the exchange rate is 1.14 dollars/euro? (2.6)

2.100 In Mexico, avocados are 48 pesos per kilogram. What is the cost, in cents, of an avocado that weighs 0.45 lb if the exchange rate is 18 pesos to the dollar? (2.6)

2.101 Bill's recipe for onion soup calls for 4.0 lb of thinly sliced onions. If an onion has an average mass of 115 g, how many onions does Bill need? (2.6)

2.102 The price of 1 lb of potatoes is $1.75. If all the potatoes sold today at the store bring in $1420, how many kilograms of potatoes did grocery shoppers buy? (2.6)

2.103 There is a new hiking trail that you would like to walk; however, you are uncertain of how long it will take to complete. The total distance is 12,500 ft. If you keep an average pace of 90 m/min, how many minutes will it take you to complete the route? (2.6)

2.104 The distance between two cities is 1700 km. How long will it take, in hours, to drive from one city to the other if your average speed is 63 mi/h? (2.6)

2.105 The water level in a graduated cylinder initially at 215 mL rises to 285 mL after a piece of lead is submerged. What is the mass, in grams, of the lead (see Table 2.9)? (2.7)

2.106 A graduated cylinder contains 160 mL of water. A 17.0-g piece of copper (density = 8.92 g/mL) and a 25.0-g piece of silver (density = 10.5 g/mL) are added. What is the new water level, in milliliters, in the cylinder? (2.7)

2.107 How many milliliters of gasoline have a mass of 1.2 kg (see Table 2.9)? (2.7)

2.108 What is the volume, in quarts, of 3.40 kg of ethanol (see Table 2.9)? (2.7)

Clinical Applications

2.109 The following nutritional information is listed on a food supplement package: (2.6)

Serving size is 250 mL

Protein per serve is 17 g

Energy per serve is 1,550 kJ

a. How many mL of the supplement would the patient need to consume to meet their daily requirement of 62 grams of protein?

b. What would be the total energy consumed in part **a**?

2.110 A dialysis unit requires 75 000 mL of distilled water. How many gallons of water are needed? (2.6)

2.111 To treat a bacterial infection, a doctor orders 4 tablets of amoxicillin per day for 10 days. If each tablet contains 250 mg of amoxicillin, how many ounces of the medication are given in 10 days? (2.6)

2.112 Celeste's diet restricts her intake of protein to 24 g per day. If she eats 1.2 oz of protein, has she exceeded her protein limit for the day? (2.6)

2.113 A doctor orders 5.0 mL of phenobarbital elixir. If the phenobarbital elixir is available as 30. mg per 7.5 mL, how many milligrams is given to the patient? (2.6)

2.114 A doctor orders 2.0 mg of morphine. The vial of morphine on hand is 10. mg/mL. How many milliliters of morphine should you administer to the patient? (2.6)