assignments, try to see what general principles and skills they employ. Use the *What's Ahead* feature at the beginning of each chapter to help orient yourself to what is important in each chapter. A single reading of a chapter will generally not be enough for successful learning of chapter concepts and problem-solving skills. You will often need to go over assigned materials more than once. Don't skip the *Give It Some Thought* and *Go Figure* features, *Sample Exercises,* and *Practice Exercises*. These are your guides to whether you are learning the material. They are also good preparation for test-taking. The *Learning Outcomes* and *Key Equations* at the end of the chapter will also help you focus your study.

Keep good lecture notes. Your lecture notes will provide you with a clear and concise record of what your instructor regards as the most important material to learn. Using your lecture notes in conjunction with this text is the best way to determine which material to study.

Skim topics in the text before they are covered in lecture. Reviewing a topic before lecture will make it easier for you to take good notes. First read the *What's Ahead* points and the end-of-chapter *Summary;* then quickly read through the chapter, skipping Sample Exercises and supplemental sections. Paying attention to the titles of sections and subsections gives you a feeling for the scope of topics. Try to avoid thinking that you must learn and understand everything right away.

You need to do a certain amount of preparation before lecture. More than ever, instructors are using the lecture period not simply as a one-way channel of communication from teacher to student. Rather, they expect students to come to class ready to work on problem solving and critical thinking. Coming to class unprepared is not a good idea for any lecture environment, but it certainly is not an option for an active learning classroom if you aim to do well in the course.

After lecture, carefully read the topics covered in class. As you read, pay attention to the concepts presented and to the application of these concepts in the *Sample Exercises*. Once you think you understand a *Sample Exercise,* test your understanding by working the accompanying *Practice Exercise*.

Learn the language of chemistry. As you study chemistry, you will encounter many new words. It is important to pay attention to these words and to know their meanings or the entities to which they refer. Knowing how to identify chemical substances from their names is an important skill; it can help you avoid painful mistakes on examinations. For example, "chlorine" and "chloride" refer to very different things.

Attempt the assigned end-of-chapter exercises. Working the exercises selected by your instructor provides necessary practice in recalling and using the essential ideas of the chapter. You cannot learn merely by observing; you must be a participant. In particular, try to resist checking the *Solutions Manual* (if you have one) until you have made a sincere effort to solve the exercise yourself. If you get stuck on an exercise, however, get help from your instructor, your teaching assistant, or another student. Spending more than 20 minutes on a single exercise is rarely effective unless you know that it is particularly challenging.

Learn to think like a scientist. This book is written by scientists who love chemistry. We encourage you to develop your critical thinking skills by taking advantage of features in this new edition, such as exercises that focus on conceptual learning, and the *Design an Experiment* exercises.

Use online resources. Some things are more easily learned by discovery, and others are best shown in three dimensions. If your instructor has included MasteringChemistry™ with your book, take advantage of the unique tools it provides to get the most out of your time in chemistry.

The bottom line is to work hard, study effectively, and use the tools available to you, including this textbook. We want to help you learn more about the world of chemistry and why chemistry is the central science. If you really learn chemistry, you can be the life of the party, impress your friends and parents, and . . . well, also pass the course with a good grade.

Tips for AP Chemistry Exam Success

Ed Waterman, Rocky Mountain High School

The Content and Nature of the AP Exam in Chemistry

The Advanced Placement Examination in Chemistry is a comprehensive evaluation of knowledge of all areas of general chemistry at the first year college level. It consists of two equally weighted 90 minute sessions. Section I contains 60 multiple-choice questions worth 50% of the total score. Three long and four short free-response questions, counting for another 50%, compose Section II. Use of calculators is allowed only on the free-response section. A periodic table similar to the one found on the end paper of this text, and a list of pertinent formulas and equations is available for the entire exam.

Pearson Education also publishes *Pearson Education Test Prep: For AP® Chemistry*, a companion test prep workbook to accompany *Chemistry: The Central Science, AP Edition*. Thoroughly revised and redesigned, the Pearson Test Prep for AP Workbook correlates to the current AP Chemistry Curriculum Framework (CF). The test prep workbook contains concise content summaries of chapters from *Chemistry: The Central Science* that are relevant to the AP Chemistry Exam, test-taking tips, hundreds of multiple-choice and free-response practice questions, two complete practice exams with scoring guidelines, answers and detailed explanations of all questions. It also presents a review of spectroscopy, including mass spectrometry, photoelectron spectroscopy and UV-visible spectrophotometry. To order your own copy of the test prep workbook please visit Pearsonschool.com/Advanced.

For more information and published examples of test questions, please refer to the College Board's Advanced Placement website at http://apcentral.collegeboard.com/.

Big Ideas and Learning Objectives

The AP Chemistry Curriculum Framework outlines the content of the course around six Big Ideas and 117 learning objectives. The following outline identifies the important AP Chemistry curriculum topics found in each chapter and section of this text organized by the six Big Ideas. The tables that follow correlate the 117 curriculum learning objectives to the pertinent chapters and sections of *Chemistry: The Central Science*.

Besides mastering content, students should be able to visualize and interpret atomic and molecular models, analyze data for patterns and relationships, predict atomic and molecular properties, justify trends, and select and perform chemical calculations for a variety of chemical systems.

AP Chemistry Curriculum Framework Correlated to *Chemistry: The Central Science* Table of Contents

Big Idea 1. All matter is composed of atoms.

The content for Big Idea 1 is found primarily in Chapters 1, 2, 3, 6, and 7 of *Chemistry: The Central Science*.

Chapter 1. Matter and Measurement

1.1 The Study of Chemistry
Elements, atoms, molecules

1.2 Classification of Matter
Gas, liquid, solid, pure substance, elements, symbols, compounds, mixtures

1.3 Properties of Matter
Physical properties, chemical properties, physical change, chemical change, separation of mixtures, filtration, distillation, chromatography

1.5 Units of Measurement

1.6 Dimensional Analysis

Chapter 2. Atoms, Molecules, and Ions

2.1 The Atomic Theory of Matter
Atoms, law of constant composition, law of conservation of mass, law of multiple proportions, Dalton's atomic theory

2.3 The Modern View of Atomic Structure
Nucleus, electrons, structure of the atom, atomic mass unit, electrical charges of subatomic particles, atomic number, mass number, isotopes, Coulomb's law, mass spectrometry

2.6 Molecules and Molecular Compounds
Molecules, chemical formulas, molecular formulas, empirical formulas, structural formulas

2.7 Ions and Ionic Compounds
Ion, cation, anion, polyatomic ions, ionic charges, ionic compounds

Chapter 3. Stoichiometry: Calculations with Chemical Formulas and Equations

3.3 Formula weights
Molar mass, percentage composition

3.4 Avogadro's Number and the Mole
Moles, Avogadro's number, molar mass, interconverting mass, moles, and number of particles

3.5 Empirical Formulas from Analysis
Calculation of empirical and molecular formulas, combustion analysis

Chapter 6. Electronic Structure of Atoms

6.2 Quantized Energy and Photons
Quantum, photoelectric effect

6.5 Quantum Mechanics and Atomic Orbitals
Quantum mechanical model, orbitals, electron shell, subshell

6.6 Representations of Orbitals
Shell model, orbitals designated s, p, d, and f, relative energies, relative distance from the nucleus, probability distributions, electron density

6.8 Electron Configurations
Electron configuration, orbital diagram, core electrons, valence electrons

6.9 Electron Configurations and the Periodic Table
Representative elements, transition elements, f-block elements

Chapter 7. Periodic Properties of the Elements

7.2 Effective nuclear charge
Effective nuclear charge, screening effect, valence electrons, inner core electrons, trends in effective nuclear charge

7.3 Sizes of Ions
Atomic radius, ionic radius, trends in atomic and ionic radii, isoelectronic series

7.4 Ionization energy
First ionization energy, successive ionization energies, trends in ionization energies, shells, subshells and trends, electron configurations of ions

7.6 Metals, Nonmetals, and Metalloids
Metals, metallic character, metallic properties, nonmetals, nonmetal properties, metalloids, group trends

Big Idea 2. Bonding and intermolecular forces explain the chemical and physical properties of matter.

The content for Big Idea 2 is found primarily in Chapters 8, 9, 10, 11, 12 and 13 of *Chemistry: The Central Science*.

Chapter 8. Basic Concepts of Chemical Bonding

8.1 Lewis Symbols and the Octet Rule
Lewis electron-dot symbols, octet rule

8.2 Ionic Bonding
Electron transfer, lattice energy, Coulomb's law, energies of ionic bond formation, s- and p-block electron configurations, transition metal ions

8.3 Covalent Bonding
Lewis structures, multiple bonds

8.4 Bond Polarity and Electronegativity
Bond polarity, polar and nonpolar bonds, electron density, polar molecules, dipoles, differentiating covalent and ionic bonding

8.5 Drawing Lewis Structures
Determining Lewis structures, formal charge

8.6 Resonance Structures
Resonance structures, delocalized electrons, depiction of resonance structures

8.7 Exceptions to the Octet Rule
Odd electrons, six electrons, expanded octets

8.8 Strengths and Lengths of Covalent Bonds
Average bond enthalpies of single and multiple bonds, bond lengths

Chapter 9. Molecular Geometry and Bonding Theories

9.1 Molecular Shapes
Linear, bent, trigonal planar, tetrahedral, trigonal pyramidal, bond angles

9.2 The VSEPR Model
Valence shell electron pair repulsion, bonding pair, electron domain, nonbonding pair, molecular geometry, electron domain geometry, expanded valence shells, T-shaped, trigonal bipyramidal, see-saw, octahedral

9.3 Molecular Shape and Polarity
Bond dipole, polar molecules, electron densities in molecules

9.5 Hybrid Orbitals
sp, sp^2, and sp^3 hybridization, orbital overlap, multiple bonds, sigma and pi bonds, delocalized electrons

Chapter 10. Gases

10.2 Pressure
Standard atmospheric pressure, atmospheres, torr,

10.3 The Gas Laws
Boyle's law (pressure-volume), Charles's law (temperature-volume), Boyle's law and Charles law plots, absolute zero, Avogadro's law

10.4 The Ideal-Gas Equation
Ideal gas, ideal-gas constant, calculations using ideal gas law

10.5 Further Applications of the Ideal-Gas Equation
Calculations of gas density, molar mass, and volumes in chemical reactions

10.6 Gas Mixtures and Partial Pressures
Partial pressure, Dalton's law, water vapor pressure

10.7 The Kinetic-Molecular Theory of Gases
Summary of KMT, molecular collisions, molecular origin of gas properties, molecular speed distributions (Maxwell-Boltzmann), temperature as average kinetic energy

10.9 Real Gases: Deviations from Ideal Behavior
Real vs. ideal gases, effect of intermolecular forces, structure of particles

Chapter 11. Liquids and Intermolecular Forces

11.1 A Molecular Comparison of Gases, Liquids and Solids
Properties of the states of matter, particle explanations

11.2 Intermolecular Forces
Dispersion forces, polarizability, dipole-dipole forces, hydrogen bonding, ion-dipole forces, relative strengths of forces, explanation of molecular properties, solution formation

11.3 Select Properties of Liquids
Viscosity, surface tension, capillary action

11.4 Phase Changes
Energetics of phase changes, heat of fusion, heat of vaporization, heat of sublimation, heating curves, critical temperature and pressure

11.5 Vapor Pressure
Dynamic equilibrium, vapor pressure, volatility, distributions of kinetic energy, boiling point, vapor pressure plots

Chapter 12. Solids and Modern Materials

12.1 Classification of Solids
Metallic, ionic, covalent-network and molecular solids, atomic and molecular explanations, polymers

12.2 Structures of Solids
Crystals, crystalline solids, amorphous solids

12.3 Metallic Solids
Metallic solids, alloys, substitutional and interstitial alloys

12.4 Metallic Bonding
Electron-sea model, delocalized electrons, thermal and electrical conductivity, malleability and ductility

12.5 Ionic Solids
Ionic crystals, ionic interactions, atomic explanation of properties, brittleness, melting points, boiling points

12.6 Molecular Solids
Molecules, intermolecular forces, structural explanation of properties

12.7 Covalent-network solids
Diamond, graphite, semiconductors, doping, p-type, n-type, atomic explanations of properties

Chapter 13. Properties of Solutions

13.1 The Solution Process
Energetics of solution formation, spontaneous processes, entropy, effect of intermolecular forces, solvation, hydration, particle depictions

13.2 Saturated Solutions and Solubility
Crystallization, solubility, saturated, unsaturated, supersaturated

13.3 Factors Affecting Solubility
Miscible, immiscible, solute-solvent interactions, molecular structure, energetics, like dissolves like, pressure effects, temperature effects

13.4 Expressing Solution Concentration
Molarity, particle views, calculations involving molarity

13.6 Colloids
Energetics of colloidal dispersions, Tyndall effect, hydrophilic, hydrophobic, examples of colloids

Big Idea 3. Chemical reactions involve the rearrangement of atoms and describe how matter changes.

The content for Big Idea 3 is found primarily in Chapters 3, 4, 16, and 20 of *Chemistry: The Central Science*.

Chapter 3. Stoichiometry: Calculations with Chemical Formulas and Equations

3.1 Chemical Equations
Chemical equations, reactants, products, balancing equations, coefficients

3.2. Some Simple Patterns of Chemical Reactivity
Combination (synthesis), decomposition, combustion

3.6. Quantitative Information from Balanced Equations
Stoichiometry, using equations to interconvert mass, moles, and number of particles

3.7 Limiting reactants
Limiting reatcatnt, theoretical yield, actual yield, percentage theoretical yield

Chapter 4. Reactions in Aqueous Solution

4.1 General Properties of Aqueous Solutions
Molecules in water, non-electrolytes, ions in solution, strong electrolytes, weak electrolytes, chemical equilibrium

4.2 Precipitation Reactions
Precipitate, solubility, solubility guidelines, molecular (complete) equations, ionic equations, net ionic equations, spectator ions, writing net ionic equations

4.3 Acids, Bases, and Neutralization Reactions
Acids, proton donors, monoprotoc acids, diprotic acids, bases, proton acceptors, hydroxides, strong and weak acids and bases, strong acids and bases as strong electrolytes, neutralization reactions, salts

4.4 Oxidation–Reduction reactions
Oxidation, reduction, redox reactions, oxidation numbers, determining oxidation numbers, displacement reactions, activity series

4.5 Concentrations of Solutions
Molarity, calculating molarity, interconverting molarity, moles, and solution volume, dilution, preparing solution concentrations

4.6 Solution Stoichiometry and Chemical Analysis
Titration, standard solution, equivalence point, titration calculations, mass relations in a neutralization reaction

Chapter 5. Thermochemistry

5.2 The First Law of Thermodynamics
Energy diagrams, exothermic and endothermic reactions, temperature change, energy from foods and fuels

Chapter 16. Acid–Base Equilibria

16.2 Brønsted–Lowry Acids and Bases
Hydronium ion, proton transfer reactions, Brønsted–Lowry acid, Brønsted–Lowry base, conjugate acid–base pairs, relative strengths of acids and bases

Chapter 20. Electrochemistry

20.1 Oxidation States and Oxidation–Reduction Reactions
Electron transfer reactions, gain of electrons, loss of electrons

20.2 Balancing Redox Equations
Half reactions, half reaction method, redox titrations

20.3 Voltaic Cells
Voltaic (galvanic) cell, anode, cathode, salt bridge, direction of electron flow

20.4 Cell Potentials under Standard Conditions
Cell potential, electromotive force, standard emf, standard reduction potential, standard hydrogen electrode, calculating cell potentials

20.5 Free Energy and Redox Reactions
Relationship of free energy (ΔG) to cell potential, Faraday's constant, predicting the direction of the reaction

20.7 Batteries and Fuel Cells
Electrical energy from batteries, lead-acid, alkaline, nickel–cadmium, nickel–metal hydride, lithium-ion, hydrogen fuel cells

20.9 Electrolysis
Electrolytic cell, stoichiometry and redox reactions, calculating electrons transferred, mass, current, time and charge, electrolysis of water, electroplating

Big Idea 4. Molecular dynamics and collisions determine the rates of chemical reactions.

The content for Big Idea 4 is found primarily in Chapter 14 of *Chemistry: The Central Science*.

Chapter 14. Chemical Kinetics

14.1 Factors that Affect Reaction Rates
Effects of temperature, physical state, concentration and catalysts

14.2 Reaction Rates
Reaction rate as change in concentration per time, graphical representations of rate, rate, and stoichiometry

14.3 Concentration and Rate Laws
Initial rate, spectroscopic measurement of rates, rate law, rate constant, reaction order, rate constant units, method of initial rate

14.4 The Change of Concentration with Time
Integrated rate law, zeroth, first and second order reactions, graphical representations, half-life, radioactive decay

14.5 Temperature and Rate
The collision model, orientation factor, activation energy, activated complex, transition state, energy profile and reaction rate, graphical representations, Arrhenius equation (qualitative),

14.6 Reaction Mechanisms
Mechanisms, elementary reaction, unimolecular, bimolecular and termolecular reactions, overall equation from elementary steps, intermediate, rate-determining step, mechanism and rate-determining step

14.7 Catalysis
Catalyst, homogeneous and heterogeneous catalysis, effect of catalyst on energy profile, surface catalyst, acid–base catalysts, enzymes, active site, substrate, lock-and-key model

Big Idea 5. Thermodynamics describes the role energy plays in physical and chemical changes.

The content for Big Idea 5 is found primarily in Chapters 5 and 19 of *Chemistry: The Central Science*.

Chapter 5. Thermochemistry

1.4 The Nature of Energy
Energy, work, heat, kinetic energy, potential energy

5.1 The Nature of Chemical Energy
Coulomb's law, electrostatic potential energy, energy stored in chemical bonds measurement of energy, joules, calories, force, work and heat

5.2 The First Law of Thermodynamics
System, surroundings internal energy (ΔE), relating ΔE to work and heat, exothermic, endothermic

5.3 Enthalpy
Enthalpy, pressure-volume work ($P\Delta V$), enthalpy change

5.4 Enthalpies of Reaction
Enthalpy of reaction (ΔH), thermochemical equation, enthalpy diagram, signs of ΔH, relating heats to stoichiometry

5.5 Calorimetry
Constant pressure calorimetry, calorimeter, heat capacity, molar heat capacity, specific heat capacity, calculating heats

5.6 Hess's Law
Heats added and subtracted like chemical equations

5.7 Enthalpies of Formation
Standard enthalpy of formation ($\Delta H_f f$), formation reaction, using ΔH_f to calculate enthalpies of reaction, enthalpy diagrams

5.8 Bond Enthalpies
Bond enthalpies, average bond enthalpies, bond breaking, bond forming, using bond enthalpies to calculate enthalpies of reaction
5.9 Foods and Fuels
Combustion of natural gas, fossil fuels, petroleum, coal, sugars and fats, renewable energy sources

Chapter 19. Chemical Thermodynamics

19.1 Spontaneous Processes
Spontaneous process, direction and extent of a reaction, reversible and irreversible processes
19.2 Entropy and the Second Law ofThermodynamics
Entropy (S), randomness, change in entropy (ΔS), ΔS for phase changes, second law of thermodynamics
19.3 Molecular Interpretation of Entropy
Translational, vibrational and rotational energy, entropy and phase, third law of thermodynamics
19.4 Entropy Change in Chemical Reactions
Standard molar entropies, entropy and temperature, molecular complexity
19.5 Gibbs Free Energy
Free energy (ΔG), free energy and equilibrium, $\Delta G = \Delta H - T\Delta S$, standard free energy of formation
19.6 Free Energy and Temperature
Temperature and spontaneous processes, phase changes
19.7 Free Energy and the Equilibrium Constant
Standard and nonstandard conditions, relationship between ΔG and K

Big Idea 6. Equilibrium represents a balance between enthalpy and entropy for reversible physical and chemical changes.

The content for Big Idea 6 is found primarily in Chapters 15, 16, and 17 of *Chemistry: The Central Science*.

Chapter 15. Chemical Equilibrium

15.1 The Concept of Equilibrium
Rates of forward and reverse reactions, equilibrium mixtures
15.2 The Equilibrium Constant
Law of mass action, equilibrium constant expression, equilibrium constant (K), K_c, and K_p
15.3 Understanding and Working with Equilibrium Constants
Magnitudes of K, chemical equations and K, stoichiometry and K, calculating K
15.4 Heterogeneous Equilibria
Homogeneous and heterogeneous equilibria and K
15.5 Calculating Equilibrium Constants
K from concentrations, K from initial conditions, ICE tables
15.6 Applications of Equilibrium Constants
Reaction quotient (Q), predicting direction, calculating concentrations
15.7 LeChâtelier's Principle
LeChâtelier's principle, changes in concentration, volume, pressure or temperature, catalysts, optimizing a product

Chapter 16. Acid–Base Equilibria

16.2 Brønsted–Lowry Acids and Bases
Hydronium ion, proton transfer reactions, Brønsted–Lowry acids, Brønsted–Lowry bases, conjugate acid–base pairs, proton acceptor, proton donor, relative acid and base strengths
16.3 The Autoionization of Water
Ion-product constant (K_w), effect of temperature
16.4 The pH Scale
pH, pOH, measuring pH, indicators
16.5 Strong Acids and Bases
Complete ionization, calculating pH
16.6 Weak Acids
Incomplete ionization, acid-dissociation constant (K_a), calculating concentration, K_a and pH, percent ionization, polyprotic acids
16.7 Weak Bases
Base-dissociation constant (K_b), amines as weak bases, calculating pH and pOH
16.8 Relationship Between K_a and K_b
$K_a K_b = K_w$, K's of conjugate acid–base pairs
16.9 Acid–Base Properties of Salt Solutions
Hydrolysis, anions as bases, cations as acids
16.10 Acid–Base Behavior and Chemical Structure
Factors that affect acid strength, oxidation number, electronegativity, oxyacids, carboxylic acids

Chapter 17. Additional Aspects of Aqueous Equilibria

17.1 The Common-Ion Effect
Common ions and equilibrium
17.2 Buffered Solutions
Buffers, buffer composition, buffer action, buffer pH, buffer capacity, buffer calculations
17.3 Acid–base Titrations
Titration curve, pH of equivalence point, weak acid–strong base titrations, pK_a of weak acid from titration data, polyprotic acid titrations, indicators
17.4 Solubility Equilibria
Solubility product constant (K_{sp}), solubility, calculating solubilities
17.5 Factors that Affect Solubility
Common ions, pH

Correlation Guide for AP

AP Chemistry Learning Objectives and Science Practices Correlated to *Chemistry: The Central Science*, Fourteenth Edition, AP® Edition

BIG IDEA 1. All matter is composed of atoms.

Learning Objective	Science Practice	Chapter/Section
1.1 Justify using **atomic molecular theory** that the element mass ratio of any pure compound is always identical.	6.1	1.2
1.2 Identify or infer the quantitative **compositions** of pure substances and mixtures using mass data.	2.2	2.1, 2.4
1.3 Justify the **identity or purity** of a substance using calculations of mass data.	2.2, 6.1	1.7
1.4 Interconvert the number of particles, **moles**, mass, and volume of substances, both qualitatively and quantitatively.	7.1	3.4
1.5 Explain **electron distributions** in atoms or ions using data.	1.5, 6.2	6.8, 6.9
1.6 Analyze data of **electron energies** for patterns and relationships.	5.1	6.8, 6.9 APTP
1.7 Describe atomic electron structure and explain how energies of electrons vary within atomic shells using data from **photoelectron spectroscopy**, ionization energy data, and Coulomb's law.	5.1, 6.2	6.8, 6.9 APTP
1.8 Explain **electron configurations** by using Coulomb's law to analyze measured energies.	6.2	6.9 APTP
1.9 Predict and justify **trends in atomic properties** using the shell model or atomic location on the periodic table.	6.4	7.2, 7.3, 7.4
1.10 Justify with experimental evidence the **arrangement of the periodic table** and apply periodic properties to chemical reactivity.	6.1	7.6, 7.7
1.11 Analyze and identify patterns in data for binary compounds to **predict properties** of related compounds.	3.1, 5.1	8.2, 8.4 T8.1, T8.2, T8.3
1.12 Explain how data sets support either the classical **shell atomic model** or the **quantum mechanical model**.	6.3	6.2, 6.3, 6.4, 6.5, 6.6
1.13 Determine if an **atomic model** is consistent with a given set of data.	5.3	2.1, 2.2, 2.3, 6.3
1.14 Identify elements and isotopes and their masses using **mass spectral data**.	1.4, 1.5	2.4
1.15 Explain why various types of **spectroscopy** are used to measure vibrational and electronic motions of molecules.	4.1	14.3, 6.9 APTP
1.16 Design and interpret an experiment that uses **spectrophotometry** to determine the concentration of a substance in a solution.	4.2, 5.1	14.3, 4.5 APTP
1.17 Express the **law of conservation of mass** quantitatively and qualitatively using both symbols and particle drawings.	1.5	3.1
1.18 Apply conservation of atoms to particle views of **balanced chemical reactions** and physical changes.	1.4	3.1, 3.2
1.19 Design or interpret data from a **gravimetric analysis** experiment to determine the concentration of a substance in solution.	4.2, 5.1	3.6, 3.7
1.20 Design or interpret data from a **titration** experiment to determine the concentration of a substance in solution.	4.2, 5.1	4.5, 4.6

BIG IDEA 2. Bonding and intermolecular forces explain the chemical and physical properties of matter.

Learning Objective	Science Practice	Chapter/Section
2.1 Predict properties of substances based on their **chemical formulas** and explain properties using particle views.	6.4, 7.1	8.2, 8.3, 8.4
2.2 Explain the strengths of **acids and bases** using molecular structure, interparticle forces, and solution equilibrium.	7.2	16.2, 16.6, 16.9, 16.10
2.3 Explain differences between **solids and liquids** using particulate models.	6.4, 7.1	11.1 to 11.7
2.4 Predict the macroscopic properties of real and ideal gases using **kinetic molecular theory** and intermolecular forces.	1.4, 6.4	10.1, 10.2, 10.3, 10.7, 10.9
2.5 Explain the effect of changes in the macroscopic **properties of gases** using particle representations.	1.3, 6.4, 7.2	10.3, 10.4
2.6 Calculate temperature, pressure, volume, and moles for **ideal gases**.	2.2, 2.3	10.3, 10.4, 10.5, 10.6

Learning Objective	Science Practice	Chapter/Section
2.7 Explain how solutes separate by **chromatography** using intermolecular forces.	6.2	13.3 APTP
2.8 Draw and interpret particle representations of solutions showing interactions between the **solute and solvent** particles.	1.1, 1.2, 6.4	13.1, 13.2, 13.3
2.9 Create particle views of solutions to interpret **molar concentration**.	1.1, 1.4	13.4, 13.5 VC 4.1–4.5
2.10 Design an experiment to separate substances using filtration, paper **chromatography**, column chromatography, or distillation and explain how substances separate using intermolecular interactions.	4.2, 5.1	APTP 13.3
2.11 Predict properties and explain trends for nonpolar substances Using **London dispersion forces**.	6.2, 6.4	11.2
2.12 Identify and explain deviations from ideal behavior for real gases by analyzing data using molecular interactions.	5.1, 6.5	10.9
2.13 Explain how the structural features of **polar molecules** affect the forces of attraction between them.	1.4, 6.4	11.2, 13.3
2.14 Explain how the **solubility of ionic compounds** is affected by interactions of ions, and attractions between ions and solvents using particle views and the qualitative application of **Coulomb's law**.	1.4, 6.4	13.3 + VC 13.1–13.12
2.15 Explain the **solubility** of ionic solids and molecules in water and other solvents using particle views showing intermolecular forces and entropy.	1.4, 6.2	13.2, 13.3
2.16 Explain properties of molecules such as phase, vapor pressure, viscosity, melting point, and boiling point using the strengths and types of **intermolecular forces**.	6.2	11.3
2.17 Predict the type of bonding in a binary compound based on the **electronegativities** and the locations of the elements on the periodic table.	6.4	8.3, 8.4
2.18 Rank and explain **bond polarity** using location of the bonded atoms on the periodic table.	6.1	8.4
2.19 Explain, using particle views, the effect of microscopic structure on the macroscopic properties of **ionic compounds** such as boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, and conductivity.	1.1, 1.4, 7.1	12.5
2.20 Explain how delocalized electrons affect the macroscopic properties of **metals** such as conductivity, malleability, ductility, and low volatility.	6.2, 7.1	12.3, 12.4
2.21 Predict **geometry, hybridization, and polarity** of molecules using Lewis diagrams.	1.4	9.2, 9.3, 9.4, 9.5
2.22 Design and evaluate an experimental plan to collect and interpret data to deduce the types of **bonding in solids**.	4.2	APTP 12.1
2.23 Create a visual representation of an **ionic solid** showing its structure and particle interactions.	1.1	12.5
2.24 Explain the structure and particle interactions of an **ionic solid** using visual representations.	1.1, 6.2, 7.1	12.5
2.25 Compare properties of **alloys and metals**, identify alloy types and explain properties on the atomic level.	1.4, 7.2	12.3
2.26 Predict and explain the macroscopic properties of **metals and alloys** using the electron sea model	6.4, 7.1	12.3, 12.4
2.27 Create a visual representation of a **metallic solid** showing its structure and particle interactions.	1.1	12.3, 12.4
2.28 Explain the structure and particle interactions of a **metallic solid** using a visual representation.	1.1, 1.2, 6.4	12.3, 12.4
2.29 Create a visual representation of a **covalent solid** showing its structure and particle interactions.	1.1	12.7
2.30 Explain the structure and particle interactions of a **covalent solid** using a visual representation.	1.1, 1.2, 6.4	12.7
2.31 Create a visual representation of a **molecular solid** showing its structure and particle interactions.	1.1	12.6, 12.8
2.32 Explain the structure and particle interactions of a **molecular solid** using a visual representation.	1.1, 1.2, 6.4	12.6, 12.8

BIG IDEA 3. Chemical reactions involve the rearrangement of atoms and describe how matter changes.

Learning Objective	Science Practice	Chapter/Section
3.1 Interpret macroscopic observations of change using symbols, **chemical equations**, and particle views.	1.5, 7.1	4.1, 4.2, 4.3
3.2 Interpret an observed chemical change using a balanced molecular **(complete), ionic or net ionic equation** and justify why each is used in a given situation.	1.5, 7.1	3.2, 4.1, 4.2, 4.3
3.3 Model laboratory chemical reactions and analyze deviations from the expected results using **stoichiometry** calculations.	2.2, 5.1	3.6, 3.7, 4.6

Continued

Learning Objective	Science Practice	Chapter/Section
3.4 Convert, using stoichiometry calculations, measured quantities such as mass, volumes of solutions, or volumes and pressures of gases to other quantities in chemical reactions, including reactions with **limiting reactants** or unreacted products.	2.2, 5.1, 6.4	3.6, 3.7, 4.6
3.5 Design an experiment or analyze data from an experiment involving the **synthesis or decomposition** of a compound to confirm the conservation of mass and the law of definite proportions.	2.1, 2.4	3.5
3.6 Confirm the **conservation of mass and the law of definite proportions** using data from the synthesis or decomposition of a compound.	2.2, 6.1	3.5
3.7 Identify compounds as **Brønsted–Lowry** acids, bases, and conjugate acid–base pairs using proton-transfer reactions.	6.1	16.1, 16.2
3.8 Identify redox reactions from electron transfer.	6.1	3.2, 4.4
3.9 Design and interpret the results of a **redox titration** experiment.	4.2, 5.1	4.4, 4.6, APTP 4.5
3.10 Classify a process as a **physical change, a chemical change**, or an ambiguous change using macroscopic observations and the making and breaking of chemical bonds or intermolecular forces.	1.4, 6.1	1.3, 4.2, 4.3, 4.4
3.11 Create a symbolic and a graphical representation to describe an observed **change in energy** associated with a chemical or physical change.	1.5, 4.4	5.2, 5.3, 5.4
3.12 Make qualitative and quantitative predictions about voltaic (galvanic) and electrolytic reactions using **half-cell reactions** and potentials and Faraday's laws.	2.2, 2.3, 6.4	20.3, 20.9
3.13 Analyze **voltaic** (galvanic) or **electrolytic cell** data to identify properties of redox reactions.	5.1	20.3, 20.9

BIG IDEA 4. Molecular dynamics and collisions determine the rates of chemical reactions.

Learning Objective	Science Practice	Chapter/Section
4.1 Design and interpret an experiment to determine the **factors that affect reaction rate** such as temperature, concentration, and surface area.	4.2, 5.1	14.1 APTP 14.1
4.2 Determine the **rate law** for a zeroth-, first-, and second-order reaction by analyzing **concentration vs. time** data.	5.1	14.3, 14.4
4.3 Determine **half-life** from the rate constant of a first-order reaction.	2.1, 2.2	14.4
4.4 Explain the relationship among the **rate law**, order, and rate constant for an elementary reaction and the frequency and success of molecular collisions.	7.1	14.5, 14.6
4.5 Explain effective and ineffective reactant **collisions** using energy distributions and molecular orientation.	6.2	14.5, APTP 14.5
4.6 Explain the relative temperature dependence of reaction rate using an **energy profile** for an elementary reaction showing reactants, transition state, and products.	1.4, 6.4	14.5
4.7 Evaluate alternative **reaction mechanisms** to match reaction rate data and infer the presence of an intermediate.	6.5	14.6
4.8 Describe chemical reactions that occur with and without catalysts using various representations including **energy profiles**, particle views, and chemical equations.	1.5	14.7
4.9 Explain rate changes due to acid–base, surface, and enzyme **catalysts**, and select appropriate mechanisms with or without catalysts.	6.2, 7.2	14.7

BIG IDEA 5. Thermodynamics describes the role energy plays in physical and chemical changes.

Learning Objective	Science Practice	Chapter/Section
5.1 Create and interpret graphical representations to explain how and why **potential energy varies with distance between atoms** such as in bond order, strength and length in covalent bonds, and the magnitudes of intermolecular forces between polar molecules.	1.1, 1.4, 7.2	9.7
5.2 Explain how **temperature relates to molecular motion** using particle views of moving molecules or kinetic energy distribution (Maxwell-Boltzmann) plots.	1.1, 1.4, 7.1	10.7
5.3 Explain and predict the **transfer of heat** between systems using molecular collisions.	7.1	5.2
5.4 Explain **energy transfer** between systems using the conservation of energy to include the quantity of energy transferred, the direction of energy flow, and the type of energy (heat or work).	1.4, 2.2	5.2, 5.3
5.5 Explain, using the conservation of energy, the **quantity of energy change** that occurs when two substances of different temperatures interact.	2.2	5.5

Learning Objective	Science Practice	Chapter/Section
5.6 Calculate or estimate **energy changes associated with chemical reactions**, heating or cooling a substance, or changing its phase using quantities such as enthalpy of reaction, heat capacity and heat of fusion or vaporization, and relate energy changes to PΔV work.	2.2, 2.3	5.2, 5.3, 11.4
5.7 Design and interpret a constant pressure **calorimetry** experiment to determine change in enthalpy of a chemical or physical process.	4.2, 5.1	5.5
5.8 Calculate or estimate enthalpies of reaction using **bond energies**.	2.3, 7.1, 7.2	5.4, 5.8
5.9 Explain and predict the relative strengths and types of intermolecular forces acting between molecules using molecular **electron density distributions.**	6.4	11.2, 11.3
5.10 Classify and justify **chemical and physical changes** citing changes in chemical bonds and intermolecular forces.	5.1	11.1, 11.2
5.11 Explain the shapes and functions of large molecules using the strengths of intermolecular forces, such as hydrogen bonding and London dispersions.	7.2	24.7 through 24.10
5.12 Predict the signs and relative magnitudes of the **entropy changes** associated with chemical or physical processes using particle views and models.	1.4	19.2, 19.3, 19.4
5.13 Predict the thermodynamic favorability of a physical or chemical change using the signs of both **$\Delta H°$ and $\Delta S°$** and a calculation or estimation of **$\Delta G°$**.	2.2, 2.3, 6.4	19.5
5.14 Calculate the change in standard **Gibbs free energy** to determine the thermodynamic favorability of a chemical or physical change.	2.2	19.5
5.15 Explain how **thermodynamically unfavorable processes**, such as those in living systems, can be made thermodynamically favorable by coupling them with favorable reactions.	6.2	19.5 & pp 836, pp 842
5.16 Make predictions for systems in which coupled reactions share a common intermediate using **LeChatelier's principle**.	6.4	15.7
5.17 Make predictions for systems involving coupled reactions sharing a common intermediate using the **equilibrium constant** for the combined reactions.	6.4	19.7
5.18 Explain how initial conditions can greatly affect product formation for unfavorable reactions using **thermodynamic and kinetic** arguments.	1.3, 7.2	19.7

BIG IDEA 6. Equilibrium represents a balance between enthalpy and entropy for physical and chemical changes.

Learning Objective	Science Practice	Chapter/Section
6.1 Explain the **reversibility** of a chemical, biological, or environmental process, given a set of experimental observations.	6.2	15.1
6.2 Predict the effects of manipulating a chemical equation or set of equations on Q or K of that chemical system.	2.2	15.2, 15.3, 15.4
6.3 Predict the **relative rates** of the forward and reverse reactions using LeChatelier's principle and principles of kinetics.	7.2	15.2, 15.7
6.4 Predict the direction a reaction will proceed toward equilibrium, given initial conditions and considering **Q and K**.	2.2, 6.4	15.6
6.5 Calculate the **equilibrium constant**, K, given the appropriate tabular or graphical data for a system at equibrium.	2.2	15.5
6.6 Calculate or estimate equilibrium concentrations or partial pressures from stoichiometry and the **law of mass action**, given a set of initial conditions and the equilibrium constant, K.	2.2, 6.4	15.5, 15.6
6.7 Determine which chemical species will have relatively large and small concentrations, given an equilibrium system with a **large or small K**.	2.2, 2.3	15.5, 15.6
6.8 Predict the direction a reaction at equilibrium will proceed as a result of a given change using **LeChatelier's principle**.	1.4, 6.4	15.7
6.9 Design a set of conditions that will **optimize a desired result**, such as product yield, using LeChatelier's principle.	4.2	15.7
6.10 Explain the effect a change of conditions will have on Q or K of an equilibrium system using Use **LeChatelier's principle**.	1.4, 7.2	15.7
6.11 Construct a particle representation of a **strong or weak acid** to illustrate which species will have large and small concentrations at equilibrium.	1.1, 1.4, 2.3	16.6
6.12 Compare and contrast properties of **strong and weak acid solutions** including pH, percentage ionization, concentrations and the amount of base required to reach an equivalence.	1.4	16.4, 16.5, 16.6

Continued

Learning Objective	Science Practice	Chapter/Section
6.13 Interpret data for a weak acid or weak base titration to determine the concentration of titrant, the pK_a or pK_b and the equivalence point.	5.1	17.3
6.14 Explain why a neutral solution requires $[H^+] = [OH^-]$ rather than pH = 7, using the **dependence of K_w on temperature**.	2.2, 6.2	16.3, 16.4, pp 737
6.15 **Calculate** or estimate the pH and concentrations of all chemical species in a mixture of strong acids and/or bases.	2.2, 2.3, 6.4	16.5
6.16 Identify a solution as a **weak acid or base**, calculate its pH and the concentration of all species in the solution, and infer its relative strength.	2.2, 6.4	16.6, 16.7
6.17 Determine the chemical reaction that results in a given **mixture of weak and strong acids and bases**, and identify which species are present in large concentrations at equilibrium.	6.4	17.3
6.18 Select an appropriate conjugate acid–base pair to design a **buffer solution** with a target pH and estimate the concentrations needed to achieve a desired buffer capacity.	2.3, 4.2, 6.4	16.2, 17.1, 17.2
6.19 Given the pK_a, predict the **predominant form** of a weak acid in a solution of a given pH.	2.3, 5.1, 6.4	16.9, 17.3
6.20 Identify a **buffer solution** and explain how it behaves upon addition of acid or base.	6.4	17.2
6.21 Predict and rank the **solubilities** of various salts, given their K_{sp} values.	2.2, 2.3, 6.4	17.4, 17.5
6.22 Interpret solubility data of various salts to determine or rank **K_{sp} values**.	2.2, 2.3, 6.4	17.4, 17.5
6.23 Interpret data to predict the influence of **pH and common ions** on the relative solubilities of salts.	5.1	17.5
6.24 Identify and explain changes in enthalpy and entropy associated with the dissolution of a salt using particle representations.	1.4, 7.1	17.5
6.25 Estimate the magnitude of K and the thermodynamic favorability of a process using the **relationship between ΔG° and K** ($\Delta G^\circ = -RT \ln K$).	2.3	19.7

APTP: AP Test Prep

VC: Visualizing Concepts

p: page number

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