

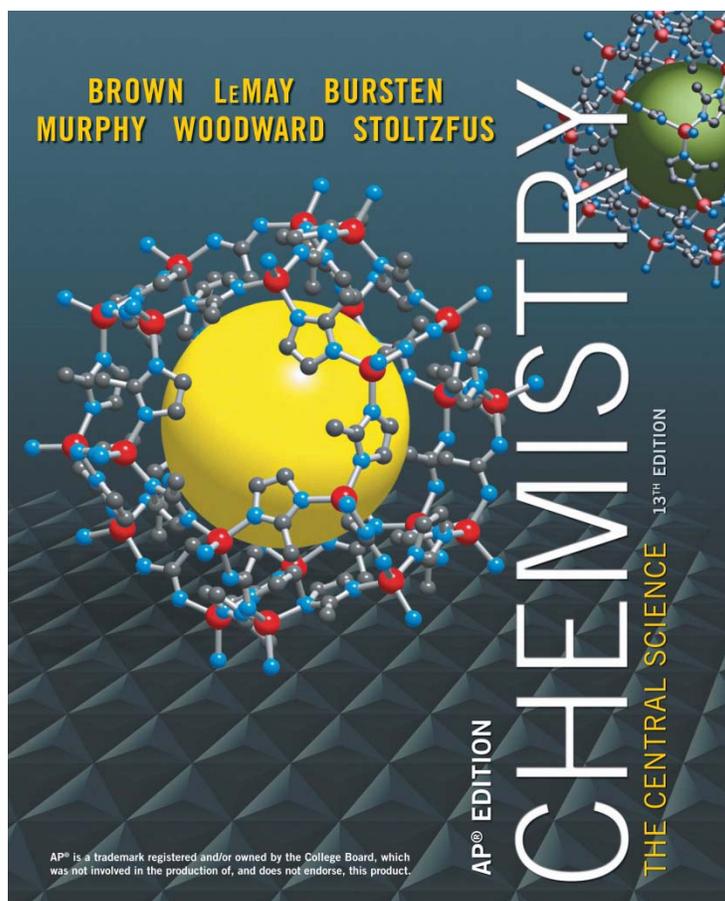
A Correlation of

# Chemistry

## The Central Science

13<sup>th</sup> Edition, AP<sup>®</sup> Edition, ©2015

Brown • LeMay • Bursten • Murphy • Woodward • Stoltzfus



To the

# Advanced Placement Chemistry Topics

ALWAYS LEARNING

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## Advice for Learning and Studying Chemistry

Learning chemistry requires both the assimilation of many concepts and the development of analytical skills. In this text, we have provided you with numerous tools to help you succeed in both tasks. If you are going to succeed in your chemistry course, you will have to develop good study habits. Science courses, and chemistry in particular, make different demands on your learning skills than do other types of courses. We offer the following tips for success in your study of chemistry:

**Don't fall behind!** As the course moves along, new topics will build on material already presented. If you don't keep up in your reading and problem solving, you will find it much harder to follow the discussions on current topics. Experienced teachers know that students who read the relevant sections of the text *before* coming to a class learn more from the class and retain greater recall. "Cramming" just before an exam has been shown to be an ineffective way to study any subject, chemistry included. So now you know. How important to you, in this competitive world, is a good grade in chemistry?

**Focus your study.** The amount of information you will be expected to learn can sometimes seem overwhelming. It is essential to recognize those concepts and skills that are particularly important. Pay attention to what your teacher is emphasizing. As you work through the *Sample Exercises* and homework 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 simply not be enough for successful learning of chapter concepts and problem-solving skills. You will 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*. They 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 should help you focus your study.

**Keep good notes.** Your notes will provide you with a clear and concise record of what your teacher 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 class.** Reviewing a topic before class 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 class.** More than ever, teachers are using the class 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 environment, but it certainly is not an option for an active learning classroom if you aim to do well in the course.

**After class, 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 teacher 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 *Student 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 teacher 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 new features in this 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 teacher 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 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 and a list of pertinent formulas and equations is available for the entire exam.

Pearson Education also publishes *Pearson Education Test Prep Workbook for AP<sup>®</sup> Chemistry*, a companion workbook to accompany *Chemistry: The Central Science*, AP<sup>®</sup> Edition. Thoroughly revised and redesigned, the 2015 Test Prep Workbook for AP<sup>®</sup> Chemistry correlates to the new AP<sup>®</sup> Chemistry Curriculum Framework (CF) which launched in the 2013-2014 school year. The test prep workbook contains concise content summaries of chapters 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](http://Pearsonschool.com/Advanced) or call 1-800-848-9500.

For more information and published examples of recent exams, 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 their trends and select and perform chemical calculations for a variety of chemical systems.

## AP Chemistry Curriculum Topics 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*.

### 1. Introduction: Matter and Measurement

**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.

### 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.

## 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.

## 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.

## 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.

**7.5 Electron Affinities** Electron affinity as energy, trends, anomalies.

**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 physical and chemical 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, 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 of Covalent Bonds.** Bond enthalpy, bond breaking, bond forming, calculations using bond enthalpies, bond lengths.

## 9. Molecular Geometry and Bonding Theory

**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.

## 10. Gases

**10.2 Pressure.** Standard atmospheric pressure, atmospheres, torr.

**10.3 The Gas Laws.** Boyle's law (pressure-volume), Charles law (temperature-volume), Boyles 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.

## 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.

## 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.

## 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.

**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 reactant, 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, monoprotic 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 ( $\Delta G$ ) 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 collisions determine the rates of chemical reactions.** The content for Big Idea 4 is found primarily in Chapter 14 of *Chemistry: The Central Science*.

## 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 chemical and physical changes.** The content in Big Idea 5 is found primarily in Chapters 5 and 19 of *Chemistry: The Central Science*.

## 5. Thermochemistry

**5.1 The Nature of Energy.** Energy, work, kinetic energy, potential energy, Coulomb's law, electrostatic potential energy, measurement of energy, joules, calories, system, surroundings, force, work and heat.

**5.2 The First Law of Thermodynamics.** Internal energy ( $\Delta E$ ), relating  $\Delta E$  to work and heat, exothermic, endothermic.

**5.3 Enthalpy.** Enthalpy, pressure-volume work ( $P\Delta V$ ).

**5.4 Enthalpies of Reaction.** Enthalpy of reaction ( $\Delta H$ ), thermochemical equation, enthalpy diagram, signs of  $\Delta H$ , 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 ( $\Delta H_f^\circ$ ), formation reaction, using  $\Delta H_f^\circ$  to calculate enthalpies of reaction, enthalpy diagrams.

**5.8 Foods and Fuels.** Combustion of natural gas, fossil fuels, petroleum, coal, sugars and fats, renewable energy sources.

## 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 of Thermodynamics.** Entropy ( $S$ ), randomness, change in entropy ( $\Delta S$ ),  $\Delta S$  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 ( $\Delta G$ ), 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  $\Delta G$  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.

## 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 Topics correlated to *Chemistry: The Central Science*, Thirteenth Edition, AP<sup>®</sup> Edition

### BIG IDEA 1. All matter is composed of atoms.

Learning Objective	Science Practice	Chapter/Section
1.1 Use atomic molecular theory to explain that the element mass ratio in any pure compound is always identical.	6.1	1.2
1.2 Use mass data to quantitatively identify or infer the compositions of pure substances and mixtures.	2.2	2.1, 2.4
1.3 Use calculations of mass data to determine the identity or purity of a substance.	2.2, 6.1	1.6
1.4 Interconvert the number of particles, moles, mass, and volume of substances, both qualitatively and quantitatively.	7.1	3.4

	<b>Learning Objective</b>	<b>Science Practice</b>	<b>Chapter/Section</b>
1.5	Use data to explain electron distributions in atoms or ions.	1.5, 6.2	6.8, 6.9
1.6	Analyze data of electron energies for patterns and relationships.	5.1	6.8 TPWB
1.7	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 TPWB
1.8	Analyze measured energies and explain electron configurations using Coulomb's law.	6.2	6.8 TPWB
1.9	Explain trends in atomic properties using the shell model or location on the periodic table.	6.4	7.2, 7.3, 7.4
1.10	Use experimental evidence to explain 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 of 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	Use mass spectral data to identify elements and isotopes.	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	
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 TPWB
1.17	Use both symbols and particle drawings to quantitatively and qualitatively express the law of conservation of mass.	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 physical and chemical properties of matter.**

	<b>Learning Objective</b>	<b>Science Practice</b>	<b>Chapter/Section</b>
2.1	Predict and explain properties based on chemical formulas and particle views.	6.4, 7.1	8.2, 8.3, 8.4
2.2	Explain the strengths of acids and bases using molecular structure, intermolecular forces, and solution equilibrium.	7.2	16.2, 16.6, 16.9, 16.10
2.3	Use particulate models to explain differences between solids and liquids.	6.4, 7.1	11.1 to 11.7
2.4	Use KMT and intermolecular forces to predict the macroscopic properties of real and ideal gases.	1.4, 6.4	10.1, 10.2, 10.3, 10.7, 10.9
2.5	Use particle representations to explain the effect of changes in the macroscopic properties of gases.	1.3, 6.4, 7.2	10.3, 10.4
2.6	Calculate temperature, pressure, volume and moles for an ideal gas.	2.2, 2.3	10.3, 10.4, 10.5, 10.6
2.7	Use intermolecular forces to explain how solutes separate by chromatography.	6.2	13.3 TPWB
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	13.3 TPWB
2.11	Use London dispersion forces to predict properties and explain trends for non-polar substances.	6.2, 6.4	11.2

	Learning Objective	Science Practice	Chapter/Section
2.12	Analyze data for real gases to identify deviations from ideal behavior and explain 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	Using particle views, qualitatively apply Coulomb's law to explain how the solubility of ionic compounds is affected by interactions of ions, and attractions between ions and solvents.	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 to show intermolecular forces and entropy.	1.4, 6.2	13.2, 13.3
2.16	Use the strengths and types of intermolecular forces to explain the properties of molecules such as phase, vapor pressure, viscosity, melting point and boiling point.	6.2	11.3
2.17	Predict the type of bonding in a binary compound based on electronegativity of the elements and position on the periodic table.	6.4	8.3, 8.4
2.18	Use location of atoms on the periodic table to rank and explain bond polarity.	6.1	8.4
2.19	Use particle views of ionic compounds to explain the effect of microscopic structure on macroscopic properties such as boiling point, solubility, hardness, brittleness, low volatility, and 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	Use Lewis diagrams and VSEPR to predict geometry, hybridization, and polarity of molecules.	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	12.1 TPWB
2.23	Create a visual representation of an ionic solid showing its structure and particle interactions.	1.1	12.5
2.24	Use a visual representation of an ionic solid to explain its structure and particle interactions.	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	Use the electron sea model to explain the macroscopic properties of metals and alloys.	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	Use a visual representation of a metallic solid to explain its structure and particle interactions.	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	Use a visual representation of a covalent solid to explain its structure and particle interactions.	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	Use a visual representation of a molecular solid to explain its structure and particle interactions.	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

Learning Objective	Science Practice	Chapter/Section
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 Use stoichiometry calculations to model laboratory chemical reactions and analyze deviations from the expected results.	2.2, 5.1	3.6, 3.7, 4.6
3.4 Apply stoichiometry calculations to convert 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 Use data from synthesis or decomposition of a compound to confirm the conservation of mass and the law of definite proportions.	2.2, 6.1	3.5
3.7 Use proton-transfer reactions to identify compounds as Brønsted-Lowry acids and bases and conjugate acid-base pairs.	6.1	16.1, 16.2
3.8 Use electron transfer to identify redox reactions.	6.1	3.2, 4.4
3.9 Design or interpret the results of a redox titration experiment.	4.2, 5.1	4.4, 4.6, 4.5 TPWB
3.10 Classify a process as a physical change, a chemical change, or an ambiguous change using macroscopic observations and the formation or breaking of chemical bonds or intermolecular forces.	1.4, 6.1	1.3, 4.2, 4.3, 4.4
3.11 Create symbolic and graphical representations 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 Use half-cell reactions, potentials and Faraday's laws to make quantitative predictions about voltaic (galvanic) or electrolytic reactions.	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 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 TPWB 14.1
4.2 Analyze concentration vs. time data to determine the rate law for a zeroth-, first-, and second-order reaction.	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 Relate the rate law, order and rate constant for an elementary reaction to 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, TPWB 14.5
4.6 Make qualitative predictions about the temperature dependence of reaction rate using an energy profile for an elementary reaction including reactants, transition state and products.	1.4, 6.4	14.5
4.7 Evaluate alternative reaction mechanisms that correspond to rate data and infer the presence or absence of an intermediate.	6.5	14.6
4.8 Use various representations including energy profiles, particle views and chemical equations to describe chemical reactions that occur with and without catalysts.	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 in 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 Use molecular collisions to explain or predict the transfer of heat between systems.	7.1	5.2
5.4 Use conservation of energy to explain energy transfer between systems including 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 Use conservation of energy to explain the quantity of energy change that occurs when two substances of different temperatures interact.	2.2	5.5
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 $P\Delta V$ 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 Use bond energies to calculate or estimate enthalpies of reaction.	2.3, 7.1, 7.2	5.4, 8.8
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 Use chemical bonds and intermolecular forces to classify and justify chemical and physical changes.	5.1	11.1, 11.2
5.11 Use the strengths of intermolecular forces, such as hydrogen bonding and London dispersions, to explain the shape and function of large molecules.	7.2	24.7 to 24.10
5.12 Use particle views and models to predict the signs and relative magnitudes of the entropy changes associated with chemical or physical processes.	1.4	19.2, 19.3, 19.4
5.13 Use the signs of both $\Delta H^\circ$ and $\Delta S^\circ$ and a calculation or estimation of $\Delta G^\circ$ , to predict the favorability of a physical or chemical change.	2.2, 2.3, 6.4	19.5
5.14 Calculate the change in standard Gibbs free energy to determine the favorability of a chemical or physical change.	2.2	19.5
5.15 Explain how nonspontaneous processes, such as those in living systems, can be made favorable by coupling them with spontaneous reactions.	6.2	19.5 & p808, p814
5.16 Use LeChâtelier's principle to predict outcomes for systems in which coupled reactions share a common intermediate.	6.4	15.7
5.17 Use the equilibrium constant for combined reactions to make predictions for systems involving coupled reactions sharing a common intermediate.	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 reversible physical and chemical changes.**

Learning Objective	Science Practice	Chapter/Section
6.1 Use a given a set of experimental observations to explain the reversibility of a chemical, biological or environmental process.	6.2	15.1
6.2 Predict the effects of changing conditions on Q or K of a chemical system.	2.2	15.2, 15.3, 15.4
6.3 Predict the relative rates of the forward and reverse reactions using LeChâtelier's principle and principles of kinetics.	7.2	15.2, 15.7
6.4 Given initial conditions, use Q and K to predict the direction a reaction will proceed toward equilibrium.	2.2, 6.4	15.6

Learning Objective	Science Practice	Chapter/Section
6.5 Calculate the equilibrium constant, $K$ , given the appropriate tabular or graphical data for a system at equilibrium.	2.2	15.5
6.6 Given a set of initial conditions and the equilibrium constant, $K$ , use stoichiometry and the law of mass action to determine qualitatively or quantitatively equilibrium concentrations or partial pressures.	2.2, 6.4	15.5, 15.6
6.7 Given an equilibrium system with a large or small $K$ , determine which chemical species will have relatively large and small concentrations.	2.2, 2.3	15.5, 15.6
6.8 Use LeChâtelier's principle to predict the direction a reaction at equilibrium will proceed as a result of a given change.	1.4, 6.4	15.7
6.9 Design a set of conditions that will optimize a desired result using LeChatelier's principle.	4.2	15.7
6.10 Use LeChâtelier's principle to explain the effect a change will have on $Q$ or $K$ .	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 Contrast pH, percentage ionization, concentrations and the amount of base required to reach an equivalence point when comparing solutions of strong and weak acids.	1.4	16.4, 16.5, 16.6
6.13 Interpret titration data to determine concentration of a weak acid or base and its $pK_a$ or $pK_b$ .	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 + p713
6.15 Calculate or estimate the pH and the concentrations of all species in a mixture of strong acids and 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 Given a mixture of weak and strong acids and bases, identify the chemical reaction and tell 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 Use data to predict the influence of pH and common ions on the relative solubilities of salts.	5.1	17.5
6.24 Use particle representations to explain changes in enthalpy and entropy associated with the dissolution of a salt.	1.4, 7.1	17.5
6.25 Use the relationship between $\Delta G^\circ$ and $K$ ( $\Delta G^\circ = -RT \ln K$ ) to estimate the magnitude of $K$ and the thermodynamic favorability of a process.	2.3	19.7

TPWB: Test Prep Workbook

VC: Visualizing Concepts

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