Science Department
AP Chemistry

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Effective Date: September 2024

Scope and Sequence

Unit	Topic of Study	Duration (Weeks)
1	Atomic Structure & Properties	3
2	Compound Structure & Properties	3
3	Properties of Substances & Mixtures	5
4	Chemical Reactions	4
5	Kinetics	4
6	Thermochemistry	3
7	Equilibrium	4
8	Acids & Bases	5
9	Thermodynamics & Electrochemistry	3

Unit 1
Atomic Structure & Properties
Summary and Rationale
This first unit sets the foundation for the course by examining the atomic theory of matter, the fundamental premise of chemistry. Although atoms represent the foundational level of chemistry, observations of chemical properties are made on collections of atoms. Macroscopic systems involve such large numbers of particles that they require the units of moles to translate between this and the particulate scale. The organization of the periodic table reflects the periodicity of element

properties as a function of atomic number. The electronic structure of an atom can be described by an electron configuration that provides a method for describing the distribution of electrons in an atom or ion. In subsequent units, students will apply their understanding of atomic structure to models and representations of chemical phenomena to explain changes and interactions of chemical substances.

Recommended Pacing

3 weeks (~9-10 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS2-4: Use mathematical representations of Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- How does the structure of an atom determine the properties and behavior of matter?
- How do chemists use quantitative measurements to describe and compare matter at the atomic and macroscopic scales?
- What evidence supports our current understanding of atomic structure?
- How do electron configurations influence chemical and physical properties?
- How do patterns in the periodic table help predict the behavior of elements?
- How do electrostatic forces within atoms explain periodic trends and chemical behavior?
- How can scientists use models and representations to explain phenomena that cannot be directly observed?
- How does the organization of the periodic table reflect underlying atomic structure?
- How can experimental techniques such as mass spectrometry and photoelectron spectroscopy provide evidence about the composition and structure of atoms?
- Why is the mole an essential tool for understanding and communicating quantitative relationships in chemistry?

Unit Enduring Understandings:

- Atomic structure provides the foundation for understanding all chemical behavior and interactions.
- The properties of elements are determined by the arrangement of electrons within atoms.
- The periodic table organizes elements according to predictable patterns that arise from atomic structure.
- Periodic trends can be used to explain and predict the physical and chemical properties of elements.
- Quantitative relationships, including the mole concept, connect the microscopic world of atoms to the macroscopic world of measurable substances.
- Scientific models and representations are essential tools for describing and explaining atomic structure and behavior.
- Experimental evidence drives the development, refinement, and validation of atomic theories and models.
- Electrostatic attractions and repulsions govern many observable properties and behaviors of atoms.
- Isotopes of an element differ in mass while maintaining the same chemical identity.
- Electron configurations provide a systematic way to explain and predict elemental properties.
- The composition and structure of matter can be determined through analysis of experimental data.
- Understanding atomic structure and properties provides the conceptual foundation for chemical bonding, molecular structure, chemical reactions, and all subsequent topics in chemistry.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 1.1 – Moles and Molar Mass

- Explain the quantitative relationship between the mole and Avogadro's number.
- Calculate molar mass using the periodic table.
- Convert between mass, moles, and number of particles.
- Use the mole concept to connect macroscopic measurements to particulate quantities.

Topic 1.2 – Mass Spectroscopy of Elements

- Interpret mass spectra to identify isotopes of an element.
- Determine the relative abundance of isotopes using mass spectral data.
- Calculate average atomic mass from isotopic abundance data.
- Explain how mass spectrometry provides evidence for isotopic composition.

Topic 1.3 – Elemental Composition of Pure Substances

- Determine the percent composition of compounds.
- Calculate empirical formulas from composition data.
- Derive molecular formulas from empirical formulas and molar mass information.
- Use quantitative data to determine the composition of pure substances.

Topic 1.4 – Composition of Mixtures

- Distinguish between pure substances and mixtures.
- Analyze quantitative composition data for mixtures.
- Determine the composition of a mixture using experimental evidence.
- Relate mixture composition to measurable properties.

Topic 1.5 – Atomic Structure and Electron Configuration

- Describe the structure of atoms in terms of protons, neutrons, and electrons.
- Explain how electron configurations represent the organization of electrons within atoms.
- Predict electron configurations for atoms and ions.
- Relate electron arrangement to chemical properties.

Topic 1.6 – Photoelectron Spectroscopy

- Interpret photoelectron spectra to determine electron arrangement.
- Relate spectral peaks to electron energy levels and subshells.
- Use photoelectron spectroscopy data to support electron configuration models.
- Compare atomic structures using spectroscopic evidence.

Topic 1.7 – Periodic Trends

- Explain periodic trends using atomic structure and electron configuration.
- Predict atomic radius, ionization energy, electron affinity, and electronegativity trends.
- Relate effective nuclear charge to observed periodic properties.
- Use periodic trends to compare elements and predict behavior.

Topic 1.8 – Valence Electrons and Ionic Compounds

- Identify valence electrons using electron configurations and periodic position.
- Predict common ionic charges based on electron arrangement.
- Explain the formation of ions through electron transfer.
- Relate valence electron patterns to chemical behavior and compound formation.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-

Modifications and accommodations must be aligned to students' IEPs and uphold expectations of the plan lawfully.

● Allow additional time for skill mastery.
● Provide small group/ individualized instruction.
● Allow use of assistive technology.
● Anticipate needs; pre-teach if needed.
● Have student repeat directions to check for understanding.
● Highlight text/ visual presentation.
● Modify assessment/assignment content, format, length (benchmarks, tests and quizzes) .

ML-

● Provide additional wait time for student responses to questions
● Provide simplification of sentence structure and repetition of questions/sentences exactly as stated before trying to rephrase.
● Speak clearly, using a normal tone and rate of speed, or slightly slower.
● Use directed reading activities. Ensure preview of text before assigned/read, provide pre-reading

Gifted and Talented-

● Advance, accelerate, or compact content
● Support abstract and advanced higher-level thinking through differentiated questioning
● Allowance for adapting of content for individual student interests
● Provide assignments geared to development in areas of affect, creativity, cognition, and research skills

504-

Modifications and accommodations must be aligned to the 504 plan and uphold expectations of the plan lawfully.
- Provide additional time for in-class assignments and assessments
- Allow for computer with voice output, spelling and grammar checker
- Offer individual help throughout the lesson
- Modify readings and primary source documents

At Risk-
- Provide small group instruction for identified areas for growth
- Allow for alternate pathways for completion of assignments.
- Provide additional wait time for student responses to questions
- Pair oral instruction with visuals
- Utilize manipulatives

For a full list of Accommodations and Modifications, please click here.

Career Readiness, Life Literacies, and Key Skills Practices (June 2020)

Please select all standards that apply to this unit of study:

- ☐ Act as a responsible and contributing citizen and employee.
- ☑ Apply appropriate academic and technical skills.
- ☐ Attend to personal health and financial well being.
- ☑ Communicate clearly and effectively and with reason.
- ☑ Consider the environmental, social and economics impacts of decisions.
- ☐ Demonstrate creativity and innovation.
- ☑ Employ valid and reliable research strategies.
- ☑ Utilize critical thinking to make sense of problems and persevere in solving them.
- ☐ Model integrity, ethical leadership, and effective management.
- ☑ Plan education and career paths aligned to personal goals.
- ☑ Use technology to enhance productivity.
- ☑ Work productively in teams while using cultural global competence.

Unit 2

Compound Structure & Properties

Summary and Rationale

In Unit 2, students apply their knowledge of atomic structure at the particulate level and connect it to the macroscopic properties of a substance. Both the chemical and physical properties of materials can be explained by the structure and arrangement of atoms, ions, or molecules and the forces between them. These forces, called chemical bonds, are distinct from typical intermolecular interactions. Electronegativity can be used to make predictions about the type of bonding present between two atoms. In subsequent units, students will use the periodic table and atomic properties to predict the type of bonding present between two atoms based on position.

Recommended Pacing

3 weeks (~12-13 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS2-4: Use mathematical representations of Coulomb's law to describe and predict electrostatic forces between charged particles.
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with particle motion and the relative position of particles.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- How does the structure of a compound determine its physical and chemical properties?
- How do electrostatic forces govern the formation and stability of chemical bonds?
- How can electronegativity be used to predict the type of bonding between atoms?
- Why do ionic, covalent, and metallic substances exhibit different properties?
- How do Lewis structures help explain the arrangement of electrons in compounds?
- How can resonance and formal charge be used to evaluate and predict molecular structure?
- How does molecular geometry influence the behavior and properties of substances?
- Why are some molecules polar while others are nonpolar?
- How do models help chemists visualize and explain structures that cannot be directly observed?
- How do particle-level interactions explain macroscopic properties such as conductivity, melting point, and strength?
- How can Coulombic attractions and repulsions be used to explain trends in bonding and compound stability?

Unit Enduring Understandings:

- The physical and chemical properties of substances arise from the arrangement of atoms and the forces between them.
- Chemical bonding results from electrostatic attractions between positively and negatively charged particles.
- Electronegativity differences help determine whether a bond is ionic, polar covalent, nonpolar covalent, or metallic.

- The strength and stability of a bond are determined by the balance of attractive and repulsive forces between particles.
- Lewis structures provide models for predicting bonding patterns, electron distribution, and molecular behavior.
- Resonance structures and formal charge are useful tools for describing electron distribution in molecules and ions.
- Molecular geometry influences polarity, reactivity, and many observable properties of substances.
- Coulomb's law helps explain bond energy, bond length, lattice energy, and the stability of compounds.
- The three-dimensional arrangement of atoms within a substance determines many of its macroscopic properties.
- Models and representations are essential tools for communicating and predicting chemical behavior.
- The structure of matter at the atomic and molecular level provides the foundation for understanding all subsequent topics in chemistry.
- Patterns in bonding and structure can be used to predict the properties and behavior of unfamiliar substances.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 2.1 – Types of Chemical Bonds

- Explain how electronegativity trends influence bond type.
- Distinguish between nonpolar covalent, polar covalent, ionic, and metallic bonding.
- Explain how differences in electronegativity affect bond polarity.
- Relate the properties of elements and compounds to their bonding.

Topic 2.2 – Intramolecular Force and Potential Energy

- Interpret potential energy versus internuclear distance graphs.
- Identify equilibrium bond length and bond energy.
- Explain how bond order affects bond length and bond strength.
- Use Coulomb's law to explain the strength of ionic interactions.
- Explain how ionic charge and ionic size influence attraction.

Topic 2.3 – Structure of Ionic Solids

- Describe the three-dimensional arrangement of ions in an ionic solid.
- Explain how attractive and repulsive forces influence ionic crystal structure.
- Represent ionic solids using particulate diagrams.
- Relate ionic charge and size to the strength of ionic interactions.

Topic 2.4 – Structure of Metals and Alloys

- Describe metallic bonding using the sea-of-electrons model.
- Represent the arrangement of positive metal ions and delocalized electrons.
- Distinguish between substitutional and interstitial alloys.
- Explain how differences in atomic size influence alloy structure.

Topic 2.5 – Lewis Diagrams

- Determine the total number of valence electrons in a molecule or polyatomic ion.
- Construct Lewis diagrams using established principles.
- Identify bonding pairs and lone pairs of electrons.
- Apply the octet rule when constructing Lewis diagrams.
- Represent covalent bonds using lines and electron pairs.

Topic 2.6 – Resonance and Formal Charge

- Identify when multiple equivalent Lewis structures can be drawn for a molecule or polyatomic ion.
- Represent resonance structures using Lewis diagrams.
- Explain why resonance structures are needed to accurately represent molecular structure and properties.
- Calculate formal charges for atoms in a Lewis diagram.
- Use formal charge and the octet rule to determine the most appropriate Lewis structure.
- Recognize the limitations of Lewis structures, including molecules with an odd number of valence electrons.

Topic 2.7 – VSEPR and Hybridization

- Use VSEPR theory to predict electron-pair arrangements and molecular geometries.
- Identify molecular shapes and predict approximate bond angles.
- Distinguish between electron geometry and molecular geometry.
- Determine the effect of lone pairs on molecular shape and bond angles.
- Predict whether a molecule has a net dipole moment based on bond polarity and molecular geometry.
- Compare bond lengths and bond energies based on bond order.
- Identify hybridization of central atoms (sp, sp^2, and sp^3).
- Distinguish between sigma and pi bonds.
- Explain how orbital overlap contributes to covalent bond formation.
- Explain how pi bonds restrict rotation and can lead to geometric isomers.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-

Modifications and accommodations must be aligned to students' IEPs and uphold expectations of the plan lawfully.

- Allow additional time for skill mastery.
- Provide small group/ individualized instruction.
- Allow use of assistive technology.
- Anticipate needs; pre-teach if needed.
- Have student repeat directions to check for understanding.
- Highlight text/ visual presentation.
- Modify assessment/assignment content, format, length (benchmarks, tests and quizzes) .

ML-

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Gifted and Talented-

- Advance, accelerate, or compact content
- Support abstract and advanced higher-level thinking through differentiated questioning
- Allowance for adapting of content for individual student interests
- Provide assignments geared to development in areas of affect, creativity, cognition, and research skills

504-

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- Modify readings and primary source documents

At Risk-

- Provide small group instruction for identified areas for growth
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- Provide additional wait time for student responses to questions
- Pair oral instruction with visuals
- Utilize manipulatives

For a full list of Accommodations and Modifications, please click here.

Career Readiness, Life Literacies, and Key Skills Practices (June 2020)

Please select all standards that apply to this unit of study:

- ☐ Act as a responsible and contributing citizen and employee.
- ☑ Apply appropriate academic and technical skills.
- ☐ Attend to personal health and financial well being.
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- ☐ Demonstrate creativity and innovation.
- ☑ Employ valid and reliable research strategies.
- ☑ Utilize critical thinking to make sense of problems and persevere in solving them.
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- ☑ Plan education and career paths aligned to personal goals.
- ☑ Use technology to enhance productivity.
- ☑ Work productively in teams while using cultural global competence.

Unit 3

Properties of Substances and Mixtures

Summary and Rationale

Transformations of matter can be observed in ways that are generally categorized as either a chemical or physical change. The shapes of the particles involved and the space between them are key factors in determining the nature of physical changes. The properties of solids, liquids, and gases reflect the relative orderliness of the arrangement of particles in those states, their relative freedom of motion, and the nature and strength of the interactions between them. There is a relationship between the macroscopic properties of solids, liquids, and gases, as well as the structure of the constituent particles of those materials on the molecular and atomic scale. In subsequent units, students will explore chemical transformations of matter.

Recommended Pacing

5 weeks (~14-15 class periods - per AP recommendations in the CED)
Exam weight: 18-22%

Standards

HS-PS1-3: Plan and conduct investigations to compare the structure of substances and infer the strength of electrical forces between particles.
HS-PS2-6: Communicate scientific and technical information about why molecular-level structure is important in the functioning of designed materials.
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with particle motion and the relative position of particles.
HS-PS3-1: Create a computational model to calculate changes in energy within a system.
HS-PS4-1: Use mathematical representations to support claims regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-3: Evaluate claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- How do intermolecular forces influence the physical properties of substances?
- How can particle-level interactions explain the behavior of solids, liquids, and gases?
- How do energy and motion affect the phases and properties of matter?
- Why do gases behave predictably under some conditions but not others?
- How can the behavior of solutions be explained by interactions between solute and solvent particles?
- How can differences in particle interactions be used to separate mixtures?
- Why are some substances soluble in certain solvents but not in others?
- How does electromagnetic radiation interact with matter?
- How can spectroscopic techniques be used to identify substances and determine concentration?

- How do particle-level models help explain macroscopic observations?

Unit Enduring Understandings:

- The properties of matter arise from interactions between particles.
- Intermolecular forces play a major role in determining physical properties such as boiling point, melting point, vapor pressure, and solubility.
- The arrangement and motion of particles determine whether a substance exists as a solid, liquid, or gas.
- Energy influences particle motion and the physical state of matter.
- Gas behavior can be explained and predicted using mathematical models based on particle motion.
- Solutions form when favorable interactions exist between solute and solvent particles.
- Differences in intermolecular forces can be exploited to separate mixtures and purify substances.
- Solubility depends on the relative strengths of interactions among particles.
- Electromagnetic radiation interacts with matter in predictable ways and can be used to gather information about substances.
- Spectroscopic techniques provide evidence about molecular structure, concentration, and composition.
- Models and mathematical relationships allow chemists to predict and explain the properties of substances and mixtures.
- Structure, energy, and particle interactions together determine the observable behavior of matter.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 3.1 – Intermolecular and Interparticle Forces

- Identify and compare intermolecular and interparticle forces.
- Explain how intermolecular forces affect physical properties.
- Predict relative strengths of intermolecular attractions.

Topic 3.2 – Properties of Solids

- Relate particle arrangement to the properties of solids.
- Compare ionic, molecular, metallic, and network covalent solids.
- Explain how bonding influences solid structure and behavior.

Topic 3.3 – Solids, Liquids, and Gases

- Describe particle motion and arrangement in each phase.
- Explain phase-dependent properties using particle models.
- Relate intermolecular forces to phase changes.

Topic 3.4 – Ideal Gas Law

- Use the Ideal Gas Law to solve quantitative problems.
- Explain relationships among pressure, volume, temperature, and moles.
- Interpret gas behavior using mathematical models.

Topic 3.5 – Kinetic Molecular Theory

- Describe the assumptions of Kinetic Molecular Theory.
- Relate temperature to average kinetic energy.
- Explain gas behavior at the particle level.

Topic 3.6 – Deviation from Ideal Gas Law
- Explain why real gases deviate from ideal behavior.
- Predict conditions under which deviations occur.
- Analyze the effects of particle volume and intermolecular attractions on gas behavior.

Topic 3.7 – Solutions and Mixtures
- Explain how solutions form.
- Describe solution composition quantitatively using concentration measurements.
- Relate intermolecular forces to solution formation.

Topic 3.8 – Representations of Solutions
- Interpret particulate representations of solutions.
- Relate symbolic, particulate, and mathematical representations.
- Explain concentration using molecular-level models.

Topic 3.9 – Separation of Solutions and Mixtures
- Explain how intermolecular forces influence separation techniques.
- Analyze the effectiveness of filtration, distillation, and chromatography.
- Predict separation outcomes based on particle interactions.

Topic 3.10 – Solubility
- Explain factors affecting solubility.
- Apply the principle of "like dissolves like."
- Relate solubility to intermolecular forces and particle interactions.

Topic 3.11 – Spectroscopy and the Electromagnetic Spectrum
- Describe regions of the electromagnetic spectrum.
- Relate electromagnetic radiation to energy transitions in matter.
- Explain how spectroscopy provides information about substances.

Topic 3.12 – Photoelectric Effect (Properties of Photons)
- Explain the particle nature of light.
- Relate photon energy to frequency and wavelength.
- Use evidence from the photoelectric effect to support models of light.

Topic 3.13 – Beer-Lambert Law
- Explain the relationship between absorbance and concentration.
- Analyze spectroscopic data using the Beer-Lambert Law.
- Use calibration data to determine concentrations of unknown solutions.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

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504-

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- ☑ Communicate clearly and effectively and with reason.
- ☑ Consider the environmental, social and economics impacts of decisions.
- ☐ Demonstrate creativity and innovation.
- ☑ Employ valid and reliable research strategies.
- ☑ Utilize critical thinking to make sense of problems and persevere in solving them.
- ☐ Model integrity, ethical leadership, and effective management.
- ☑ Plan education and career paths aligned to personal goals.

- ☑ Use technology to enhance productivity.
- ☑ Work productively in teams while using cultural global competence.

Unit 4

Chemical Reactions

Summary and Rationale

This unit explores chemical transformations of matter by building on the physical transformations studied in Unit 3. Chemical changes involve the making and breaking of chemical bonds. Many properties of a chemical system can be understood using the concepts of varying strengths of chemical bonds and weaker intermolecular interactions. When chemical changes occur, the new substances formed have properties that are distinguishable from the initial substance or substances. Chemical reactions are the primary means by which transformations in matter occur. Chemical equations are a representation of the rearrangement of atoms that occur during a chemical reaction. In subsequent units, students will explore rates at which chemical changes occur.

Recommended Pacing

4 weeks (~14-15 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS1-2: Construct and revise explanations for the outcomes of chemical reactions based on valence electrons, periodic trends, and patterns of chemical properties.
HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during chemical reactions.
HS-PS1-3: Plan and conduct investigations to compare structures of substances and infer the strength of electrical forces between particles.
HS-PS3-1: Create computational models to calculate changes in energy within a system.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- How can chemical reactions be represented and interpreted at the macroscopic, particulate, and symbolic levels?
- What evidence indicates that a chemical reaction has occurred?
- How can patterns in chemical behavior be used to predict the products of reactions?
- How does the conservation of mass govern chemical change?
- How can quantitative relationships be used to predict the amounts of reactants and products in a reaction?
- How can laboratory data be used to determine chemical composition and reaction outcomes?
- Why do some reactants limit the amount of product that can be formed?
- How can stoichiometric relationships be used to solve real-world chemical problems?
- How are chemical equations used as models for physical changes occurring at the particle level?
- How can experimental results be used to evaluate the efficiency of a chemical process?

Unit Enduring Understandings:

- Chemical reactions involve the rearrangement of atoms into new substances.
- Balanced chemical equations provide symbolic representations of conservation of mass during chemical change.
- The identity and properties of products can be predicted using patterns in chemical behavior and periodic trends.
- Quantitative relationships among reactants and products are governed by stoichiometric ratios.
- Atoms are neither created nor destroyed during ordinary chemical reactions.
- Limiting reactants determine the maximum amount of product that can be formed.
- Experimental data can be analyzed to determine reaction efficiency and chemical composition.
- Particulate models help explain observable changes during chemical reactions.
- Mathematical reasoning is essential for describing and predicting chemical processes.
- Chemical reactions can be represented and analyzed using multiple forms of evidence and models.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 4.1 – Introduction for Reactions

- Represent chemical reactions using balanced chemical equations.
- Relate symbolic representations to particulate-level changes.
- Explain chemical changes using particle models.

Topic 4.2 – Net Ionic Equations

- Distinguish between complete ionic and net ionic equations.

- Identify spectator ions in aqueous reactions.
- Represent reactions using net ionic equations.

Topic 4.3 – Representation of Physical and Chemical Changes

- Differentiate between physical and chemical changes.
- Interpret particulate diagrams of chemical processes.
- Connect observable evidence to molecular-level changes.

Topic 4.4 – Physical and Chemical Changes Laboratory

- Analyze laboratory data to identify chemical and physical changes.
- Use evidence from observations to support conclusions.
- Communicate experimental findings using scientific reasoning.

Topic 4.5 – Stoichiometry

- Use balanced equations to determine quantitative relationships among substances.
- Calculate moles of reactants and products involved in reactions.
- Apply mole ratios to chemical reaction problems.

Topic 4.6 – Introduction to Titration

- Explain the purpose of titration as an analytical technique.
- Determine unknown concentrations using titration data.
- Apply stoichiometric relationships to solution chemistry.

Topic 4.7 – Types of Chemical Reactions

- Classify reactions based on observable and chemical patterns.
- Predict likely products of common reaction types.
- Explain reactions using particle-level models.

Topic 4.8 – Introduction to Acid-Base Reactions

- Identify acids and bases involved in chemical reactions.
- Predict products of acid-base neutralization reactions.
- Represent acid-base reactions symbolically and conceptually.

Topic 4.9 – Oxidation-Reduction (Redox) Reactions

- Determine oxidation numbers of elements in compounds and ions.
- Identify oxidation and reduction processes.
- Explain electron transfer in redox reactions.

Topic 4.10 – Introduction to Electrochemistry

- Relate redox reactions to electron flow.
- Explain the relationship between oxidation, reduction, and electrical energy.
- Interpret representations of electrochemical processes.

Topic 4.11 – Reaction Stoichiometry

- Solve complex stoichiometric problems involving multiple substances.
- Analyze quantitative relationships in chemical reactions.
- Apply stoichiometric reasoning to experimental data.

Topic 4.12 – Limiting Reactant and Reaction Yields

- Identify the limiting reactant in a chemical reaction.
- Calculate theoretical yield.
- Determine percent yield using experimental data.

- Evaluate factors that influence reaction efficiency.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-
Modifications and accommodations must be aligned to students' IEPs and uphold expectations of the plan lawfully.
● Allow additional time for skill mastery.
● Provide small group/ individualized instruction.
● Allow use of assistive technology.
● Anticipate needs; pre-teach if needed.
● Have student repeat directions to check for understanding.
● Highlight text/ visual presentation.
● Modify assessment/assignment content, format, length (benchmarks, tests and quizzes) .
ML-
● Provide additional wait time for student responses to questions
● Provide simplification of sentence structure and repetition of questions/sentences exactly as stated before trying to rephrase.
● Speak clearly, using a normal tone and rate of speed, or slightly slower.
● Use directed reading activities. Ensure preview of text before assigned/read, provide pre-reading
Gifted and Talented-
● Advance, accelerate, or compact content
● Support abstract and advanced higher-level thinking through differentiated questioning
● Allowance for adapting of content for individual student interests
● Provide assignments geared to development in areas of affect, creativity, cognition, and research skills
504-
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● Allow for computer with voice output, spelling and grammar checker
● Offer individual help throughout the lesson
● Modify readings and primary source documents
At Risk-
● Provide small group instruction for identified areas for growth
● Allow for alternate pathways for completion of assignments.
● Provide additional wait time for student responses to questions
● Pair oral instruction with visuals
● Utilize manipulatives

For a full list of Accommodations and Modifications, please click here.

Career Readiness, Life Literacies, and Key Skills Practices (June 2020)

Please select all standards that apply to this unit of study:

- ☐ Act as a responsible and contributing citizen and employee.
- ☑ Apply appropriate academic and technical skills.
- ☐ Attend to personal health and financial well being.

- ☑ Communicate clearly and effectively and with reason.
- ☑ Consider the environmental, social and economics impacts of decisions.
- ☐ Demonstrate creativity and innovation.
- ☑ Employ valid and reliable research strategies.
- ☑ Utilize critical thinking to make sense of problems and persevere in solving them.
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- ☑ Use technology to enhance productivity.
- ☑ Work productively in teams while using cultural global competence.

Unit 5

Kinetics

Summary and Rationale

Unit 4 focused on chemical changes; in Unit 5 students will develop an understanding of the rates at which chemical changes occur and the factors that influence the rates. Those factors include the concentration of reactants, temperature, catalysts, and other environmental factors. Chemical changes are represented by chemical reactions, and the rates of chemical reactions are determined by the details of the molecular collisions. Rates of change in chemical reactions are observable and measurable. When measuring rates of change, students are measuring the concentration of reactant or product species as a function of time. These chemical processes may be observed in a variety of ways and often involve changes in energy as well. In subsequent units, students will describe the role of energy in changes in matter.

Recommended Pacing

4 weeks (~13-14 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS1-5: Apply scientific principles and evidence to explain how changing temperature or concentration affects the rate at which a reaction occurs.
HS-PS1-2: Construct and revise explanations for the outcome of chemical reactions based on atomic interactions, periodic trends, and patterns of chemical properties.
HS-PS3-1: Create computational models to calculate changes in energy within a system.
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of particle motion and the relative position of particles.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- What factors determine the rate at which a chemical reaction occurs?
- How does collision theory explain reaction rates at the particulate level?
- How do concentration, temperature, surface area, and catalysts influence reaction rate?
- How can reaction rates be measured and analyzed experimentally?
- How can mathematical models be used to describe chemical kinetics?
- What information can be obtained from rate laws and reaction orders?
- How do reaction mechanisms explain the sequence of events occurring during a chemical reaction?
- How does the rate-determining step influence the overall reaction rate?
- How do catalysts alter reaction pathways?
- How do energy changes influence the rate and progress of chemical reactions?
- How can experimental evidence be used to support or refute a proposed reaction mechanism?

Unit Enduring Understandings:

- Chemical reactions occur through collisions between particles.
- Only collisions with sufficient energy and proper orientation lead to successful reactions.
- Reaction rate depends on the frequency and effectiveness of particle collisions.
- Temperature, concentration, and surface area influence reaction rates by affecting collision frequency and energy.
- Catalysts increase reaction rate by providing alternative reaction pathways with lower activation energies.
- Reaction rates can be measured experimentally and described quantitatively.
- Rate laws describe the relationship between reactant concentration and reaction rate.
- Experimental data can be used to determine reaction order and assess reaction mechanisms.
- Chemical reactions often occur through a sequence of elementary steps rather than a single event.
- The slowest step in a reaction mechanism frequently determines the overall reaction rate.
- Energy diagrams provide evidence about activation energy, intermediates, and reaction pathways.
- Models and mathematical relationships help chemists predict and explain reaction behavior.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 5.1 – Reaction Rates

- Define and calculate reaction rate.
- Represent reaction rates using experimental data.
- Relate changes in reactant and product concentrations to reaction progress.
- Interpret graphical representations of reaction rate data.

Topic 5.2 – Introduction to Rate Law

- Explain the relationship between rate and reactant concentration.
- Determine rate laws using experimental observations.
- Interpret the meaning of reaction orders.
- Use rate laws to calculate reaction rates.

Topic 5.3 – Concentration Changes Over Time

- Analyze concentration-versus-time data.
- Interpret graphical representations of reaction progress.
- Relate concentration changes to reaction rates.
- Evaluate how reaction rates change throughout a reaction.

Topic 5.4 – Elementary Reactions

- Distinguish between overall reactions and elementary reactions.
- Interpret molecularity in elementary steps.
- Determine rate laws for elementary reactions.
- Relate particle collisions to elementary processes.

Topic 5.5 – Collision Model

- Apply collision theory to explain reaction rates.
- Explain the importance of collision frequency and orientation.
- Predict how changes in reaction conditions affect collision effectiveness.
- Relate successful collisions to activation energy.

Topic 5.6 – Reaction Energy Profile

- Interpret potential energy diagrams.
- Identify activation energy, intermediates, and transition states.
- Explain how energy changes influence reaction rate.
- Compare energy profiles for different reactions.

Topic 5.7 – Introduction to Reaction Mechanisms

- Describe reaction mechanisms as sequences of elementary steps.
- Identify intermediates in reaction pathways.
- Relate mechanisms to observable reaction behavior.
- Evaluate whether a mechanism is consistent with an overall reaction.

Topic 5.8 – Reaction Mechanism and Rate Law

- Determine whether a proposed mechanism supports an experimentally determined rate law.
- Identify the rate-determining step.
- Relate slow steps to overall reaction rate.
- Use evidence to support mechanism selection.

Topic 5.9 – Steady-State Approximation

- Analyze reaction mechanisms involving intermediates.

- Explain how intermediate concentrations affect reaction behavior.
- Apply reasoning to complex reaction pathways.
- Connect mechanistic models with experimental observations.

Topic 5.10 – Multistep Reaction Energy Profile

- Construct and interpret multistep energy diagrams.
- Identify transition states and intermediates.
- Compare activation energies for individual reaction steps.
- Relate energy profiles to reaction mechanisms.

Topic 5.11 – Catalysis

- Explain how catalysts affect reaction rate.
- Describe catalytic reaction pathways.
- Compare catalyzed and uncatalyzed reactions.
- Interpret energy diagrams involving catalysts.
- Evaluate the role of catalysts in chemical and biological systems.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-

Modifications and accommodations must be aligned to students' IEPs and uphold expectations of the plan lawfully.

● Allow additional time for skill mastery.
● Provide small group/ individualized instruction.
● Allow use of assistive technology.
● Anticipate needs; pre-teach if needed.
● Have student repeat directions to check for understanding.
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ML-

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● Speak clearly, using a normal tone and rate of speed, or slightly slower.
● Use directed reading activities. Ensure preview of text before assigned/read, provide pre-reading

Gifted and Talented-

● Advance, accelerate, or compact content
● Support abstract and advanced higher-level thinking through differentiated questioning
● Allowance for adapting of content for individual student interests
● Provide assignments geared to development in areas of affect, creativity, cognition, and research skills

504-

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● Offer individual help throughout the lesson
● Modify readings and primary source documents

At Risk-

- Provide small group instruction for identified areas for growth
- Allow for alternate pathways for completion of assignments.
- Provide additional wait time for student responses to questions
- Pair oral instruction with visuals
- Utilize manipulatives

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- ☑ Use technology to enhance productivity.
- ☑ Work productively in teams while using cultural global competence.

Unit 6

Thermochemistry

Summary and Rationale

The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter. The availability or disposition of energy plays a role in virtually all observed chemical processes. Thermochemistry provides tools for understanding this key role, particularly the conservation of energy, including energy transfer in the forms of heat and work. Chemical bonding is central to chemistry. A key concept to know is that the breaking of a chemical bond inherently requires an energy input, and because bond formation is the reverse process, it will release energy. In subsequent units, the application of thermodynamics will determine the favorability of a reaction occurring.

Recommended Pacing

3 weeks (~10-11 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- How is energy transferred and conserved during physical and chemical processes?
- What causes a chemical reaction or physical change to be endothermic or exothermic?
- How can changes in energy be measured experimentally?
- How do particle interactions and motion explain thermal energy?
- How can models be used to explain and predict energy changes in chemical systems?
- How is energy stored within chemical bonds?
- How do changes in bond energy determine whether energy is absorbed or released?
- How can calorimetry be used to quantify energy transfer?
- How can Hess's Law be used to determine energy changes that cannot be measured directly?
- How do scientists use energy diagrams to represent chemical processes?
- How does the transfer of thermal energy affect systems and surroundings?
- How do energy considerations help chemists predict and explain chemical behavior?

Unit Enduring Understandings:

- Energy is conserved and can be transferred between systems and surroundings.
- Chemical and physical processes involve measurable energy changes.
- Energy may be released to or absorbed from the surroundings during a process.
- The energy of a system is related to both particle motion and particle interactions.
- The transfer of thermal energy continues until energy is more evenly distributed within a system.
- Chemical bonds store potential energy that can be released or absorbed during reactions.

- The overall energy change of a reaction depends on the relative energies of reactants and products.
- Calorimetry provides a method for measuring energy transfer in chemical and physical processes.
- Mathematical models can be used to quantify and predict energy changes.
- Hess's Law allows energy changes from multiple processes to be related and calculated.
- Energy diagrams provide visual models for understanding chemical processes.
- Understanding energy transfer is essential for explaining and predicting chemical behavior.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 6.1 – Endothermic and Exothermic Processes

- Distinguish between endothermic and exothermic processes.
- Identify energy flow between a system and its surroundings.
- Interpret representations of energy transfer during physical and chemical changes.
- Relate temperature changes to energy flow.

Topic 6.2 – Energy Diagrams

- Interpret energy diagrams for chemical and physical processes.
- Relate potential energy changes to reaction energetics.
- Compare the energy content of reactants and products.
- Explain energy changes using graphical models.

Topic 6.3 – Heat Transfer and Thermal Equilibrium

- Explain how thermal energy is transferred between objects and systems.
- Predict the direction of heat flow.
- Describe thermal equilibrium using particle models.
- Relate temperature changes to energy transfer.

Topic 6.4 – Introduction to Calorimetry

- Use calorimetry data to determine energy changes.
- Calculate heat transferred during physical and chemical processes.
- Interpret experimental calorimetry data.
- Explain assumptions used in calorimetric measurements.

Topic 6.5 – Energy of Phase Changes

- Explain energy changes associated with phase transitions.
- Relate intermolecular forces to phase-change energetics.
- Interpret heating and cooling curves.
- Compare energy requirements for different phase changes.

Topic 6.6 – Introduction to Enthalpy of Reaction

- Define enthalpy change for chemical reactions.

- Determine whether reactions are exothermic or endothermic based on enthalpy.
- Interpret thermochemical equations.
- Relate enthalpy changes to energy transfer.

Topic 6.7 – Bond Enthalpies

- Use bond enthalpy values to estimate reaction enthalpies.
- Relate bond breaking and bond formation to energy changes.
- Explain why bond breaking requires energy and bond formation releases energy.
- Predict reaction energetics using bond enthalpy data.

Topic 6.8 – Enthalpy of Formation

- Interpret standard enthalpy of formation values.
- Calculate reaction enthalpies using formation data.
- Compare relative stabilities of substances using thermodynamic information.
- Apply enthalpy data to chemical systems.

Topic 6.9 – Hess's Law

- Apply Hess's Law to determine enthalpy changes.
- Combine thermochemical equations to calculate overall energy changes.
- Interpret and manipulate thermochemical data.
- Explain why enthalpy is a state function.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-

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Gifted and Talented-

● Advance, accelerate, or compact content
● Support abstract and advanced higher-level thinking through differentiated questioning
● Allowance for adapting of content for individual student interests
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504-

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At Risk-

● Provide small group instruction for identified areas for growth
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● Provide additional wait time for student responses to questions
● Pair oral instruction with visuals
● Utilize manipulatives

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Unit 7

Equilibrium

Summary and Rationale

Chemical equilibrium is a dynamic state in which opposing processes occur at the same rate. In this unit, students learn that any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations. A change in conditions, such as addition of a chemical species, change in temperature, or change in volume, can cause the rate of the forward and reverse reactions to fall out of balance. Le Châtelier's principle provides a means to reason qualitatively about the direction of the shift in an equilibrium system resulting from various possible stresses. The expression for the equilibrium constant, K, is a mathematical expression that describes the equilibrium state associated with a chemical change. An analogous expression for the reaction quotient, Q,

describes a chemical reaction at any point, enabling a comparison to the equilibrium state. The dissolution of a solid in a solvent can also be understood by applying the principles of chemical equilibrium because it is a reversible reaction. The relationships between salt solubility, pH, and free energy will be encountered in subsequent units. Subsequent units will also explore equilibrium constants that arise from acid-base chemistry.

Recommended Pacing

4 weeks (~13-15 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- What does it mean for a chemical system to be at equilibrium?
- How can equilibrium be described and predicted using mathematical models?
- Why do some reactions favor reactants while others favor products?
- How can equilibrium constants be used to determine the extent of a reaction?
- How do changes in concentration, pressure, volume, and temperature affect equilibrium systems?
- How can Le Châtelier's Principle be used to predict the response of a system to stress?
- What is the relationship between the reaction quotient and the equilibrium constant?
- How can particulate models help explain dynamic equilibrium?
- Why does equilibrium not mean that reactions have stopped?
- How can equilibrium principles be applied to industrial and natural processes?
- How can changes in conditions be used to maximize product formation?

- How do energy considerations influence equilibrium behavior?

Unit Enduring Understandings:

- Chemical equilibrium is a dynamic state in which forward and reverse reaction rates are equal.
- At equilibrium, concentrations of reactants and products remain constant but are not necessarily equal.
- Equilibrium systems can be described quantitatively using equilibrium constants.
- The magnitude of an equilibrium constant indicates the relative extent of a reaction.
- Chemical systems respond predictably to disturbances in order to establish a new equilibrium state.
- Changes in concentration, pressure, volume, and temperature may shift the position of equilibrium.
- Le Châtelier's Principle provides a model for predicting how chemical systems respond to stress.
- The reaction quotient can be used to predict the direction a reaction will proceed to reach equilibrium.
- Mathematical models provide evidence for understanding and predicting equilibrium behavior.
- Dynamic equilibrium occurs at both the particulate and macroscopic levels.
- Conditions can be manipulated to favor the formation of desired products.
- Equilibrium concepts are essential for understanding chemical, biological, environmental, and industrial systems.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 7.1 – Introduction to Equilibrium

- Describe dynamic equilibrium at the particulate and macroscopic levels.
- Explain the characteristics of a system at equilibrium.
- Distinguish between static and dynamic equilibrium.
- Relate reaction rates to equilibrium conditions.

Topic 7.2 – Direction of Reversible Reactions

- Determine the direction in which a reaction will proceed.
- Interpret particulate and symbolic representations of reversible reactions.
- Predict changes as a system approaches equilibrium.
- Relate reaction progress to reactant and product concentrations.

Topic 7.3 – Reaction Quotient and Equilibrium Constant

- Calculate reaction quotient (Q) and equilibrium constant (K).
- Compare Q and K to predict reaction direction.
- Explain the significance of equilibrium constant values.
- Relate equilibrium expressions to balanced chemical equations.

Topic 7.4 – Calculating the Equilibrium Constant

- Determine equilibrium constants from experimental data.
- Interpret the magnitude of equilibrium constants.

- Compare product-favored and reactant-favored systems.
- Evaluate equilibrium conditions quantitatively.

Topic 7.5 – Introduction to Le Châtelier's Principle

- Predict the response of an equilibrium system to external stress.
- Explain shifts in equilibrium using particulate reasoning.
- Relate concentration changes to equilibrium position.
- Describe how systems reestablish equilibrium.

Topic 7.6 – Effects of Temperature Changes

- Predict the effects of temperature on equilibrium systems.
- Explain temperature effects using endothermic and exothermic models.
- Relate temperature changes to equilibrium constant values.
- Analyze how energy influences equilibrium position.

Topic 7.7 – Introduction to Solubility Equilibria

- Describe equilibrium in saturated solutions.
- Explain dissolution and precipitation as equilibrium processes.
- Relate solubility behavior to equilibrium concepts.
- Interpret particulate representations of solution equilibria.

Topic 7.8 – Representations of Equilibrium

- Interpret graphical, symbolic, mathematical, and particulate models of equilibrium.
- Relate multiple representations to equilibrium behavior.
- Analyze equilibrium data from tables and graphs.
- Communicate equilibrium concepts using scientific models.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-

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Gifted and Talented-

● Advance, accelerate, or compact content

● Support abstract and advanced higher-level thinking through differentiated questioning
● Allowance for adapting of content for individual student interests
● Provide assignments geared to development in areas of affect, creativity, cognition, and research skills

504-

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At Risk-

● Provide small group instruction for identified areas for growth
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- ☑ Use technology to enhance productivity.
- ☑ Work productively in teams while using cultural global competence.

Unit 8

Acids & Bases

Summary and Rationale

This unit builds on the content about chemical equilibrium studied in Unit 7. Chemical equilibrium plays an important role in acid-base chemistry and solubility. The proton-exchange reactions of acid-base chemistry are reversible reactions that reach equilibrium quickly, and much of acid-base chemistry can be understood by applying the principles of chemical equilibrium. Most acid-base reactions have either large or small values of K, which means qualitative conclusions regarding equilibrium

state can often be drawn without extensive computations. In the final unit, the equilibrium constant is related to temperature and the difference in Gibbs free energy between the reactants and products.

Recommended Pacing

5 weeks (~14-16 class periods - per AP recommendations in the CED)
Exam weight: 11-15%

Standards

HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- What distinguishes an acid from a base?
- How can the strength of acids and bases be measured and compared?
- How does equilibrium explain the behavior of acids and bases in solution?
- How do acids and bases interact to produce predictable chemical changes?
- How are pH and pOH used to describe chemical systems?
- How can mathematical relationships be used to predict acid-base behavior?
- What factors determine whether an acid or base is considered strong or weak?
- How do buffers resist changes in pH?
- How can titrations be used to determine unknown concentrations?
- How can particulate models explain acid-base processes?
- How do changes in concentration affect acid-base equilibrium systems?
- Why is acid-base chemistry important in biological, environmental, and industrial systems?

Unit Enduring Understandings:

- Acids and bases can be described and classified using multiple models and theories.
- Acid-base reactions involve the transfer of protons and the establishment of equilibrium systems.

- The strength of an acid or base depends on the extent of its dissociation in solution.
- Equilibrium principles govern the behavior of weak acids and weak bases.
- pH and pOH provide quantitative measures of acidity and basicity.
- Mathematical relationships can be used to predict the behavior of acid-base systems.
- Acid-base reactions proceed toward equilibrium and can be represented using equilibrium expressions.
- Buffers help maintain relatively stable pH values when acids or bases are added.
- Titration is an effective analytical method for determining solution concentrations.
- The behavior of acid-base systems can be explained using symbolic, mathematical, and particulate models.
- Changes in system conditions affect acid-base equilibrium in predictable ways.
- Acid-base chemistry has important applications in natural systems, living organisms, and industrial processes.

Evidence of Learning (Assessments)

Assign the Progress Checks from AP Course and Exam Description Resource for each unit.
Each Personal Progress Check contains formative multiple-choice and free-response questions.
The feedback from the Personal Progress Checks shows students the areas where they need to focus.

Objectives (SLO)

Topic 8.1 – Introduction to Acids and Bases

- Identify acids and bases using accepted chemical models.
- Describe the properties of acids and bases.
- Represent acid-base reactions using chemical equations.
- Explain proton transfer in acid-base systems.

Topic 8.2 – pH and pOH of Strong Acids and Bases

- Calculate pH and pOH of strong acid and strong base solutions.
- Relate hydrogen ion and hydroxide ion concentrations to pH.
- Interpret pH as a measure of acidity and basicity.
- Analyze mathematical relationships among pH, pOH, and ion concentration.

Topic 8.3 – Weak Acid and Base Equilibria

- Describe the equilibrium behavior of weak acids and weak bases.
- Interpret acid dissociation and base dissociation constants.
- Compare strengths of acids and bases using equilibrium data.
- Calculate equilibrium concentrations in weak acid-base systems.

Topic 8.4 – Acid-Base Reactions and Buffers

- Explain the formation and function of buffers.
- Predict how buffers respond to the addition of acids or bases.
- Interpret acid-base reactions involving buffer systems.
- Relate equilibrium principles to buffer behavior.

Topic 8.5 – Henderson-Hasselbalch Equation

- Apply the Henderson-Hasselbalch equation to buffer systems.
- Calculate solution pH using buffer data.

- Interpret relationships among pH, pKa, and concentration.
- Analyze the effectiveness of buffer systems.

Topic 8.6 – Acid-Base Titrations

- Interpret titration curves for acids and bases.
- Identify important regions of an acid-base titration.
- Calculate unknown concentrations from titration data.
- Relate titration behavior to acid and base strength.

Topic 8.7 – Properties of Buffers

- Explain factors affecting buffer effectiveness.
- Compare buffer systems quantitatively.
- Predict changes in pH following additions of acids or bases.
- Analyze the limitations of buffer systems.

Topic 8.8 – Environmental and Biological Applications of Acid-Base Chemistry

- Explain the role of acid-base reactions in environmental systems.
- Analyze pH changes in natural and biological contexts.
- Apply acid-base concepts to real-world phenomena.
- Use evidence to explain chemical changes involving acids and bases.

Suggested Resources/Technology Tools

College Board AP Website

Modifications

Special Education-

Modifications and accommodations must be aligned to students' IEPs and uphold expectations of the plan lawfully.

● Allow additional time for skill mastery.
● Provide small group/ individualized instruction.
● Allow use of assistive technology.
● Anticipate needs; pre-teach if needed.
● Have student repeat directions to check for understanding.
● Highlight text/ visual presentation.
● Modify assessment/assignment content, format, length (benchmarks, tests and quizzes) .

ML-

● Provide additional wait time for student responses to questions
● Provide simplification of sentence structure and repetition of questions/sentences exactly as stated before trying to rephrase.
● Speak clearly, using a normal tone and rate of speed, or slightly slower.
● Use directed reading activities. Ensure preview of text before assigned/read, provide pre-reading

Gifted and Talented-

● Advance, accelerate, or compact content
● Support abstract and advanced higher-level thinking through differentiated questioning
● Allowance for adapting of content for individual student interests
● Provide assignments geared to development in areas of affect, creativity, cognition, and research skills

504-

Modifications and accommodations must be aligned to the 504 plan and uphold expectations of the plan lawfully.

● Provide additional time for in-class assignments and assessments

● Allow for computer with voice output, spelling and grammar checker
● Offer individual help throughout the lesson
● Modify readings and primary source documents

At Risk-

● Provide small group instruction for identified areas for growth
● Allow for alternate pathways for completion of assignments.
● Provide additional wait time for student responses to questions
● Pair oral instruction with visuals
● Utilize manipulatives

For a full list of Accommodations and Modifications, please click here.

Career Readiness, Life Literacies, and Key Skills Practices (June 2020)

Please select all standards that apply to this unit of study:

- ☐ Act as a responsible and contributing citizen and employee.
- ☑ Apply appropriate academic and technical skills.
- ☐ Attend to personal health and financial well being.
- ☑ Communicate clearly and effectively and with reason.
- ☑ Consider the environmental, social and economics impacts of decisions.
- ☐ Demonstrate creativity and innovation.
- ☑ Employ valid and reliable research strategies.
- ☑ Utilize critical thinking to make sense of problems and persevere in solving them.
- ☐ Model integrity, ethical leadership, and effective management.
- ☑ Plan education and career paths aligned to personal goals.
- ☑ Use technology to enhance productivity.
- ☐ Work productively in teams while using cultural global competence.

Unit 9

Thermodynamics & Electrochemistry

Summary and Rationale

This unit allows students to connect principles and calculations across Units 1–8. The thermodynamics of a chemical reaction is connected to both the structural aspects of the reaction and the macroscopic outcomes of the reaction. All changes in matter involve some form of energy change. One key determinant of chemical transformations is the change in potential energy that results from changes in electrostatic forces. Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions. Applying the laws of thermodynamics will allow students to describe the essential role of energy and explain and predict the direction of changes in matter.

Recommended Pacing

3 weeks (~10-13 class periods - per AP recommendations in the CED)
Exam weight: 7-9%

Standards

HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
HS-PS2-5: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Interdisciplinary Connections

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

Instructional Focus

Unit Essential Questions:

- What determines whether a chemical process is thermodynamically favorable?
- How do energy and entropy influence the direction of chemical change?
- Why do some reactions occur spontaneously while others do not?
- How can Gibbs free energy be used to predict reaction favorability?
- How are equilibrium and free energy related?
- How does the dispersal of matter and energy affect chemical systems?
- How can chemical reactions be used to produce electrical energy?
- How do electrochemical cells convert chemical energy into electrical energy?
- How can cell potential be used to predict the direction of redox reactions?
- What factors influence the voltage produced by an electrochemical cell?
- How can electricity be used to drive nonspontaneous chemical reactions?
- How can quantitative relationships be used to predict electrochemical outcomes?

Unit Enduring Understandings:

- Energy and matter tend to become more widely dispersed in natural systems.
- The spontaneity of a process depends on the combined effects of enthalpy and entropy.

- Gibbs free energy provides a quantitative measure of thermodynamic favorability.
- Thermodynamic calculations can be used to predict whether chemical processes are favorable.
- A reaction may be thermodynamically favorable even if it proceeds slowly.
- Chemical equilibrium and free energy are fundamentally related.
- Energy changes in chemical systems can be represented mathematically and graphically.
- Redox reactions involve the transfer of electrons and can be harnessed to produce electrical energy.
- Electrochemical cells convert chemical energy into electrical energy through spontaneous redox reactions.
- Cell potential provides a measure of the driving force for electron transfer.
- Electrolysis uses electrical energy to drive nonspontaneous chemical reactions.
- Quantitative models allow chemists to predict energy transfer, electrical work, and reaction behavior.
- Thermodynamics and electrochemistry provide powerful frameworks for understanding and predicting the behavior of chemical systems.

Evidence of Learning (Assessments)

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Objectives (SLO)

Topic 9.1 – Introduction to Entropy

- Explain entropy as a measure of matter and energy dispersal.
- Predict relative entropy values for different physical and chemical systems.
- Relate entropy changes to molecular organization.
- Analyze processes in terms of changes in disorder and dispersal.

Topic 9.2 – Absolute Entropy and Entropy Change

- Calculate entropy changes using thermodynamic data.
- Compare entropy changes among physical and chemical processes.
- Relate phase changes to entropy.
- Apply entropy concepts to reaction analysis.

Topic 9.3 – Gibbs Free Energy and Thermodynamic Favorability

- Calculate Gibbs free energy changes.
- Determine whether a process is thermodynamically favorable.
- Relate enthalpy and entropy to free energy.
- Predict reaction favorability under specified conditions.

Topic 9.4 – Thermodynamic and Kinetic Control

- Distinguish between thermodynamic favorability and reaction rate.
- Explain why favorable reactions may proceed slowly.
- Compare kinetic and thermodynamic considerations in chemical systems.
- Use evidence to evaluate reaction behavior.

Topic 9.5 – Free Energy and Equilibrium

- Relate Gibbs free energy to equilibrium.
- Interpret the significance of equilibrium conditions.
- Predict reaction direction using free energy relationships.
- Connect thermodynamic models to equilibrium concepts.

Topic 9.6 – Coupled Reactions

- Explain how favorable reactions can drive unfavorable processes.
- Analyze energy transfer among coupled chemical reactions.
- Interpret biological and chemical examples of coupled reactions.
- Evaluate reaction systems using free energy concepts.

Topic 9.7 – Galvanic (Voltaic) Cells

- Describe the structure and operation of galvanic cells.
- Identify oxidation and reduction processes within electrochemical cells.
- Explain electron flow and ion movement.
- Relate cell design to energy production.

Topic 9.8 – Cell Potential and Free Energy

- Calculate cell potentials using standard reduction potentials.
- Relate cell potential to reaction favorability.
- Connect electrical work to free energy changes.
- Predict spontaneous redox reactions using electrochemical data.

Topic 9.9 – Electrolysis and Faraday's Law

- Explain how electrolysis drives nonspontaneous reactions.
- Calculate quantities associated with electrolysis.
- Relate charge flow to chemical change.
- Apply Faraday's Law to electrochemical systems.

Topic 9.10 – Electrochemistry Applications

- Analyze practical applications of electrochemistry.
- Explain the operation of batteries and electrolytic systems.
- Evaluate electrochemical technologies using scientific evidence.
- Connect electrochemistry to industrial and environmental processes.

Suggested Resources/Technology Tools

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