Kenilworth Public Schools

Curriculum Guide

Content Area: AP Chemistry
Grade: 11-12
BOE Approved: 4/6/20

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AP Chemistry- 11th – 12th grade Scope and Sequence

Unit 1- Atomic Structure and Properties	Unit 2- Molecular and Ionic Compound Structure and Properties	Unit 3- Intermolecular Forces and Properties	Unit 4- Chemical Reactions	Unit 5- Kinetics	Unit 6- Thermodynamics
Weeks 1-3	Weeks 4-6	Weeks 7-10	Weeks 11-14	Weeks 15-18	Weeks 19-21
Unit Description: 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 that they require moles as a unit of comparison. The periodic table provides information about each element's predictable periodicity as a function of the atomic number. The electronic structure	*Unit Description:* 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	*Unit Description:* 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	*Unit Description:* 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	*Unit Description:* 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	*Unit Description:* 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. Thermodynamics 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

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 and explain changes and interactions of chemical substances.	between two atoms. In subsequent units, students will use the periodic table and the atomic properties to predict the type of bonding present between two atoms based on position.	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	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.	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.	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.
Unit Targets: • Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept. • Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes. • Explain the quantitative relationship between	*Unit Targets:* • Explain the relationship between the type of bonding and the properties of the elements participating in the bond. • Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.	*Unit Targets:* • Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when: a. The molecules are of the same chemical species. b. The molecules are of two different chemical	*Unit Targets:* • Identify evidence of chemical and physical changes in matter. • Represent changes in matter with a balanced chemical or net ionic equation: a. For physical changes. b. For given information about the identity of the reactants and/or products. c. For ions in a	*Unit Targets:* • Explain the relationship between the rate of a chemical reaction and experimental parameters. • Represent experimental data with a consistent rate law expression. • Identify the rate law expression of a chemical reaction using data that show how the concentrations of	*Unit Targets:* • Explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation. • Represent a chemical or physical transformation with an energy diagram. • Explain the relationship between the transfer of thermal energy and molecular

the elemental composition by mass and the empirical formula of a pure substance. • Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture. • Represent the electron configuration of an element or ions of an element using the Aufbau principle. • Explain the relationship between the photoelectron spectrum of an atom or ion and: a. The electron configuration of the species. b. The interactions between the electrons and the nucleus. • Explain the relationship between trends in atomic properties of elements and electronic structure and	• Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions. • Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance. • Represent a molecule with a Lewis diagram. • Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures. • Based on the relationship between Lewis diagrams, VSEPR theory, bond orders,	species. • Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles. • Represent the differences between solid, liquid, and gas phases using a particulate-level model. • Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law. • Explain the relationship between the motion of particles and the macroscopic properties of gases with: a. The kinetic molecular theory (KMT). b. A particulate model.	given chemical reaction. • Represent a given chemical reaction or physical process with a consistent particulate model. • Explain the relationship between macroscopic characteristics and bond interactions for: a. Chemical processes. b. Physical processes. • Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process. • Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion. • Identify a reaction as acid-base, oxidation-reduction, or precipitation. • Identify species as Brønsted-Lowry acids, bases, and/or	reaction species change over time. • Represent an elementary reaction as a rate law expression using stoichiometry • Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions. • Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile. • Identify the components of a reaction mechanism. • Identify the rate law for a reaction from a mechanism in which the first step is rate limiting. • Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting. • Represent the	collisions. • Calculate the heat q absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature. • Explain changes in the heat q absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition. • Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction. • Calculate the enthalpy change of a reaction based on the average bond energies of bonds

periodicity. • Explain the relationship between trends in the reactivity of elements and periodicity.	and bond polarities: a. Explain structural properties of molecules. b. Explain electron properties of molecules.	c. A graphical representation • Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes. • Calculate the number of solute particles, volume, or molarity of solutions. • Using particulate models for mixtures: a. Represent interactions between components. b. Represent concentrations of components. • Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles. • Explain the relationship between a region of the electromagnetic	conjugate acid-base pairs, based on proton-transfer involving those species. • Represent a balanced redox reaction equation using half-reactions	activation energy and overall energy change in a multistep reaction with a reaction energy profile. • Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism.	broken and formed in the reaction. • Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation. • Represent a chemical or physical process as a sequence of steps.

		spectrum and the types of molecular or electronic transitions associated with that region. • Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule. • Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity.			

AP Chemistry- 11th – 12th grade Scope and Sequence

Unit 7- Equilibrium	Unit 8- Acids and Bases	Unit 9- Application of Thermodynamics			
Weeks 22-25	Weeks 26-29	Weeks 30-32			
Unit Description: 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	*Unit Description:* 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	*Unit Description:* This unit allows students to connect principles and calculations across Units 5–8. 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:			

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. Subsequent units will explore equilibrium constants that arise from acid-base chemistry.	often be drawn without extensive computations. 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 that often reaches equilibrium quickly. In the final unit, the equilibrium constant is related to temperature and the difference in Gibbs free energy between the reactants and products.	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.			
Unit Targets: • Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of	*Unit Targets:* • Calculate the values of pH and pOH, based on K_w and the concentration of all species present in a neutral solution of	*Unit Targets:* • Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.			

equilibrium, to experimental observations. • Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions. • Represent the reaction quotient Q_c or Q_p , for a reversible reaction, and the corresponding equilibrium expressions $K_c = Q_c$ or $K_p = Q_p$. • Calculate K_c or K_p based on experimental observations of concentrations or pressures at equilibrium. • Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium. • Represent a multistep process with an	water. • Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base. • Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base. • Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases. • Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components. • Explain the relationship between the strength of an acid or base and the structure of the molecule or ion. • Explain the	• Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process. • Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^o . • Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate. • Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o , and T. • Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes. • Explain the relationship between			

overall equilibrium expression, using the constituent K expressions for each individual reaction. • Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant. • Represent a system undergoing a reversible reaction with a particulate model. • Identify the response of a system at equilibrium to an external stress, using Le Châtelier's principle. • Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium. • Calculate the solubility of a salt based on the value of K_{sp} for the salt. • Identify the solubility	relationship between the predominant form of a weak acid or base in solution at a given pH and the pK_a of the conjugate acid or the pK_b of the conjugate base. • Explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered solution. • Identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer. • Explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution.	the physical components of an electrochemical cell and the overall operational principles of the cell. • Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell. • Explain the relationship between deviations from standard cell conditions and changes in the cell potential. • Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.			

of a salt, and/or the value of K_{sp} for the salt, based on the concentration of a common ion already present in solution. • Identify the qualitative effect of changes in pH on the solubility of a salt. • Explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process.					

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Atomic Structure and Properties
Unit Summary: 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 that they require moles as a unit of comparison. The periodic table provides information about each element's predictable periodicity as a function of the 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 and explain changes and interactions of chemical substances.
Primary Interdisciplinary Connections: Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy

Learning Targets

NJSLS Standards: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8	
Technology Standards: 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.C.1, 8.1.12.E.1, and 8.1.12.E.2	
ELA Companion Standards: RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5	
Content Statements:	
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.
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.
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.
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.
5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Ideas:

1. Scale, Proportion, and Quantity
2. Structure and Properties

Unit Essential Questions:	Unit Enduring Understandings:
• Why are eggs sold in a dozen? • How can the same element be used in nuclear fuel rods and fake diamonds?	• The mole allows different unit to be compared. • Chemical formulas identify substances by their unique combination of atoms. • Atoms and molecules can be identified by their electron distribution and energy. • The periodic table shows patterns in electronic structure and trends in atomic properties.

Unit Learning Targets

Students will…

- Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept.
- Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes.
- Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance.
- Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
- Represent the electron configuration of an element or ions of an element using the Aufbau principle.
- Explain the relationship between the photoelectron spectrum of an atom or ion and:
  a. The electron configuration of the species.
  b. The interactions between the electrons and the nucleus.
- Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.
- Explain the relationship between trends in the reactivity of elements and periodicity.

Evidence of Learning

Summative Assessment: Labs, Unit Tests, Benchmarks

Formative Assessments:

- Quizzes
- Chapter Tests
- Homework
- Projects

Lesson Plans

Activities/Interdisciplinary Connections	*Timeframe*
• Think-Pair-Share: Ask students to individually rank three samples in order of increasing number of particles, increasing mass, and increasing mole amounts (Sample A: 1.0 mole of carbon, Sample B: 18 grams of carbon monoxide, Sample C: 3.0 × 1023 molecules of water). Then have them compare and defend their choices with a partner. • Simulations: Conduct a simulation of a mass spectrometer, using a strong magnet and steel ball bearings of various masses, to show students how mass can be used to separate particles based on their ability to be manipulated in an electromagnetic field. Present samples of mass spectra for students to analyze and have them calculate the average atomic mass of an element. Discuss how mass spectrometry could be used to identify the presence of an element within a mixture and the isotopic abundance within an element. Forensic science applications and other modern uses of the technology can be discussed to give relevant context to the concepts. • Think-Pair-Share: Have students design an experiment to determine the percent composition of a mixture of sodium carbonate (inert) and sodium bicarbonate. After carrying out the experiment, provide them with a mock student report to analyze and critique. Then have them get into pairs and reflect on their particular approach and come up with additional approaches to this problem. Explore Representations Translate PES data into an electron configuration and/or predict a PES spectrum based on an element’s electron configuration or location in the periodic table. Have students compare their predictions to the actual electron configuration and discuss discrepancies.	1-3 Weeks

• Process Oriented Guided Inquiry Learning (POGIL): Given ionization energy data from various elements, guide students through a series of questions to help them rationalize the relationship of the charge of the ion to its position on the periodic table, its electronic structure, and reactivity	
Teacher Resources	*Teacher Note*
• Textbook • Notebook • Lab Notebook • PowerPoints • Chromebooks • Lab Materials	

Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:
• Use of visual and multisensory formats
• Use of assisted technology
• Use of prompts
• Modification of content and student products
• Testing accommodations
• Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:
• Adjusting the pace of lessons
• Curriculum compacting
• Inquiry-based instruction
• Independent study
• Higher-order thinking skills
• Interest-based content
• Student-driven instruction
• Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:
• Pre-teaching of vocabulary and concepts
• Visual learning, including graphic organizers
• Use of cognates to increase comprehension
• Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills • Scaffolding •Word walls •Sentence frames •Think-pair-share •Cooperative learning groups

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Molecular and Ionic Compound Structure and Properties	
Unit Summary: 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 the atomic properties to predict the type of bonding present between two atoms based on position.	
Primary Interdisciplinary Connections: Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3	
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy	
Learning Targets	
NJSLS Standards: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8	
Technology Standards: 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.C.1, 8.1.12.E.1, and 8.1.12.E.2	
ELA Companion Standards: RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5	
Content Statements:	
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.
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.
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.
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.
5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay

Big Idea:

1. Structure and Properties

Unit Essential Questions:	Unit Enduring Understandings:
• How has the discovery of DNA changed the world? • How are molecular compounds arranged?	• Atoms or ions bond due to interactions between them, forming molecules. • Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory.

Unit Learning Targets

Students will…

- Explain the relationship between the type of bonding and the properties of the elements participating in the bond.
- Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.
- Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions.
- Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.
- Represent a molecule with a Lewis diagram.
- Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures.
- Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities:
    a. Explain structural properties of molecules.
    b. Explain electron properties of molecules.

Evidence of Learning

Summative Assessment: Labs, Unit Tests, Benchmarks

Formative Assessments:

- Quizzes
- Chapter Tests
- Homework
- Projects

Lesson Plans

Activities/Interdisciplinary Connections	*Timeframe*
• Think-Pair-Share: After a review of the graph of potential energy versus internuclear distance in a hydrogen molecule, have students pair up and describe what they believe the graph would look like for various other molecules. • Explore Representations: Demonstrate a model of ionic bonding. Put opaque adhesive tape on top of disk magnets to make “+” and “–” signs. Be sure to affix the tape on opposite sides for the differing charges (so that opposite ions have opposite magnetic polarity when arranged on a flat surface). Arrange the ions in an alternating array on the overhead projector to show the structure of an ionic crystal. Engage students in a discussion about malleability/brittleness, and ask why distorting an ionic crystal causes shattering. This also introduces Coulombic forces in a visual and memorable way. Then have students predict and identify the bonding in binary compounds using periodic trends. • Manipulatives: Have students use various sized/colored paper plates to illustrate a particular type of alloy (interstitial and/or substitutional). Then have them engage in a gallery walk around the room to listen to others explain the connection between the structure of the different alloys and the properties of each. • Simulations: Construct various VSEPR shapes using balloons to show the three-dimensional arrangement of atoms in various bonding arrangements. Then use a PhET simulation to help students see the effects of lone pairs and bonding pairs on molecular shape. Students can work on this individually after being shown how to use the interface, or it can be projected and examined as a class. Have students work with the simulation to add/remove bonds and add/remove lone pairs to determine the most likely threedimensional shape and bond angles in a molecule.	1-3 Weeks
Teacher Resources	*Teacher Note*
• Textbook • Notebook	

• Lab Notebook • PowerPoints • Chromebooks • Lab Materials	

Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:
• Use of visual and multisensory formats
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• Use of prompts
• Modification of content and student products
• Testing accommodations
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Examples of Strategies and Practices that Support Gifted & Talented Students:
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• Interest-based content
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• Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:
• Pre-teaching of vocabulary and concepts
• Visual learning, including graphic organizers
• Use of cognates to increase comprehension
• Teacher modeling
• Pairing students with beginning English language skills with students who have more advanced English language skills
• Scaffolding
•Word walls
•Sentence frames
•Think-pair-share
•Cooperative learning groups

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Intermolecular Forces and Properties	
Unit Summary: 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	
Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3	
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy	
Learning Targets	
NJSLS Standards: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8	
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ELA Companion Standards: RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5	
Content Statements:	
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.
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.
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.
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.
5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Ideas:

1. Scale Proportion and Quantity
2. Structure and Properties

Unit Essential Questions:

- How do interactions between particles influence mixtures?
- Why does the smell of perfume only last a short time?
- Why can you swim in water but you cannot walk through a wall?
- How are the properties of gases described?
- How can you determine the structure and concentration of a chemical species in a mixture?

Unit Enduring Understandings:

- Intermolecular forces can explain the physical properties of a material.
- Matter exists in three states: solid, liquid, and gas, and their differences are influenced by variances in spacing and motion of the molecules.
- Gas properties are explained macroscopically—using the relationships among pressure, volume, temperature, moles, gas constant—and molecularly by the motion of the gas.
- Interactions between intermolecular forces influence the solubility and separation of mixtures.
- Spectroscopy can determine the structure and concentration in a mixture of a chemical species.

Unit Learning Targets

Students will…

- Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when:
  a. The molecules are of the same chemical species.
  b. The molecules are of two different chemical species.
- Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles.
- Represent the differences between solid, liquid, and gas phases using a particulate-level model.
- Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.
- Explain the relationship between the motion of particles and the macroscopic properties of gases with:
  a. The kinetic molecular theory (KMT).
  b. A particulate model.
  c. A graphical representation
- Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.

- Calculate the number of solute particles, volume, or molarity of solutions.
- Using particulate models for mixtures:
    a. Represent interactions between components.
    b. Represent concentrations of components.
- Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.
- Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region.
- Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.
- Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity.

Evidence of Learning

Summative Assessment: Labs, Unit Tests, Benchmarks

Formative Assessments:

- Quizzes
- Chapter Tests
- Homework
- Projects

Lesson Plans

Activities/Interdisciplinary Connections	*Timeframe*
• Demo with Q&A: Fill a long glass tube halfway with water and then layer ethanol over the top and fill the tube, leaving one inch at the top. Have a student mark the liquid level with a permanent marker and invert the tube (with thumb pressed firmly over the top) several times. A noticeable volume decrease occurs, and students should hypothesize why. Introduce a model showing the interparticle spacing between ethanol molecules and water molecules. The model takes into account the spacing between molecules and why volume is not a conserved quantity (unlike mass). Review hydrogen bonding as a relevant interparticle force for this demonstration • Explore Representations: Have students create particle representations for samples of solid, liquid, and gaseous H2O. Each diagram should contain 10 molecules, and students should show	1-4 weeks

how the placement and motion of the particles varies in each phase. • Explore Representations: Begin by telling students that hexane does not mix with water, but ethanol does. Then have them create a particulate representation of each of the mixtures (which illustrate the interactions between the molecules that allow/disallow the solubility). • Post-Lab Discussion: After investigating three different dyes using chromatography, have students determine which of the three dyes is the most polar based on macroscopic observations and an understanding of the interactions between the dyes and the solvent, or between the dyes and the paper. Then have them discuss their answers (based on evidence) and evaluate the strengths of each other's claims using both the evidence and understanding of intermolecular forces. • Predict and Confirm: Have students use a Sep-Pak C18 Cartridge (Flinn Scientific AP8917) to separate Grape Kool-Aid into its component red and blue dyes. Then have them compare the separated dyes to reference solutions of common food dyes using a spectrophotometer and measure the percent transmittance at 25 nm intervals across the range of 400 nm–750 nm.	
Teacher Resources	*Teacher Note*
• Textbook • Notebook • Lab Notebook • PowerPoints • Chromebooks • Lab Materials	

Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:
• Use of visual and multisensory formats
• Use of assisted technology
• Use of prompts

• Modification of content and student products
• Testing accommodations
• Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:
• Adjusting the pace of lessons
• Curriculum compacting
• Inquiry-based instruction
• Independent study
• Higher-order thinking skills
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• Student-driven instruction
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•Word walls
•Sentence frames
•Think-pair-share
•Cooperative learning groups

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Chemical Reactions

Unit Summary:
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.

Primary Interdisciplinary Connections:
Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3

21st Century Career and Life Themes:
Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy

Learning Targets

NJSLS Standards:
HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8

Technology Standards:
8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.C.1, 8.1.12.E.1, and 8.1.12.E.2

ELA Companion Standards:
RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5

Content Statements:

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.
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.
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.
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.
5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Ideas:

1. Scale Proportion and Quantity
2. Transformations

Unit Essential Questions:	Unit Enduring Understandings:
• What makes fireworks explode? • Why is the mass of a raw egg different than a boiled egg? • What are the processes related to changes in a substance?	• A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations. • When a substance changes into a new substance, or when its properties change, no mass is lost or gained. • A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

Unit Learning Targets

Students will…

- Identify evidence of chemical and physical changes in matter.
- Represent changes in matter with a balanced chemical or net ionic equation:
    a. For physical changes.
    b. For given information about the identity of the reactants and/or products.
    c. For ions in a given chemical reaction.
- Represent a given chemical reaction or physical process with a consistent particulate model.
- Explain the relationship between macroscopic characteristics and bond interactions for: a. Chemical processes. b. Physical processes.
- Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.
- Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.
- Identify a reaction as acid-base, oxidation-reduction, or precipitation.
- Identify species as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.
- Represent a balanced redox reaction equation using half-reactions

Evidence of Learning
Summative Assessment: Labs, Unit Tests, Benchmarks
Formative Assessments: • Quizzes • Chapter Tests • Homework • Projects

Lesson Plans	
Activities/Interdisciplinary Connections	*Timeframe*
• Explore Representations: Have students work through an online simulation of particulate-level representations of various single-displacement reactions. Then have them translate these particle level views into net ionic equations. • Simulations: Have students view a simulated reaction pertaining to a limiting reagent problem. Each iteration of the simulation provides students with different unknown concentrations of the reactants from which students calculate the amount of product that is dissolved. Then have them check their answers upon completion of the simulation. • Think-Pair-Share: Ask students to connect four different particulate representations with a strong acid-strong base titration curve between HCl + NaOH. The representations depict the acid before base has been added, the half equivalence point of the titration, the equivalence point of the titration, and some point beyond the equivalence point (excess base). Have students defend their choices with a partner. • Critique Reasoning: After a review of different types of chemical reactions (acid-base, redox, precipitation), give students a series of 10 reactions (both the equation and a short demo of the reaction taking place). Have them identify what type of reaction is taking place and justify that claim with evidence. Then have them pair up and evaluate the strength of each other's claims. • Simulations: After viewing a simulation on metal/metal ion reactions, provide students with several 1 molar solutions and a piece of aluminum and ask them to select a solution that would react	1-4 weeks

to coat the Al. Students who select incorrect solutions should go back and revisit the simulation.	
Teacher Resources	*Teacher Note*
• Textbook • Notebook • Lab Notebook • PowerPoints • Chromebooks • Lab Materials	

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•Word walls
•Sentence frames

- Think-pair-share
- Cooperative learning groups

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Kinetics	
Unit Summary: 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.	
Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3	
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy	
Learning Targets	
NJSLS Standards: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8	
Technology Standards: 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.C.1, 8.1.12.E.1, and 8.1.12.E.2	
ELA Companion Standards: RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5	
Content Statements:	
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6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Ideas:

1. Transformations
2. Energy

Unit Essential Questions:	Unit Enduring Understandings:
• Why are some reactions faster than other reactions? • How long will a marble statue last? • How can a sports drink cure a headache? • How does bread rise?	• Some reactions happen quickly, while others happen more slowly and depend on reactant concentrations and temperature. • There is a relationship between the speed of a reaction and the collision frequency of particle collisions. • Many chemical reactions occur through a series of elementary reactions. These elementary reactions when combined form a chemical equation. • The speed at which a reaction occurs can be influenced by a catalyst.

Unit Learning Targets

Students will…

- Explain the relationship between the rate of a chemical reaction and experimental parameters.
- Represent experimental data with a consistent rate law expression.
- Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time.
- Represent an elementary reaction as a rate law expression using stoichiometry
- Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions.
- Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile.
- Identify the components of a reaction mechanism.
- Identify the rate law for a reaction from a mechanism in which the first step is rate limiting.
- Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting.
- Represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile.
- Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism.

Evidence of Learning
Summative Assessment: Labs, Unit Tests, Benchmarks
Formative Assessments: • Quizzes • Chapter Tests • Homework • Projects

Lesson Plans	
Activities/Interdisciplinary Connections	*Timeframe*
• Post-Lab Discussion: As an introduction to kinetics, have students form small groups to design an experiment to establish a relationship between the rate and a specific reaction parameter of Alka-Seltzer tablets in water. Have them select varying temperature, concentration, mass, or surface area and decide which data to collect. Groups use whiteboards to present their data and major findings to the rest of the class. • Post-Lab Discussion: Using a spectrophotometer, have students measure the absorbance of a solution of green food coloring after bleach has been added. Have them use Excel to prepare different graphs of the data, such as absorbance vs. time, and 1/(absorbance) vs. time. Students should use a linear regression analysis to determine the most linear fit, the order of the reaction, and the effect on the value of k when the concentration of bleach is increased. Have student groups share and compare their results. • Critique Reasoning: Using a balance and a stopwatch, have students determine the rate order of a burning birthday candle by preparing graphs in Excel, and use a linear regression analysis to determine the most linear fit and the value of the rate constant, k. Have students justify why the rate of mass disappearance of the candle does not change as the candle burns down. Then have them compare their results with other groups to see if their results are consistent. • Critique Reasoning: Working in small groups, have students evaluate the appropriateness of	1-4 weeks

reaction mechanisms for a given reaction for which the rate law is established. Have groups share their conclusions with the rest of the class and then discuss why certain choices must be eliminated and why there might be more than one possible mechanism that is valid. Have classmates provide feedback to the groups on the validity of their conclusions • Manipulatives: Give students a blank multistep reaction energy profile with a series of labels on the side. Have them work with a partner to correctly place the labels next to the blanks indicated on the profile and then share/evaluate their diagrams with another pair of students.	
Teacher Resources	*Teacher Note*
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- Word walls
- Sentence frames
- Think-pair-share
- Cooperative learning groups

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Thermodynamics	
Unit Summary: 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. Thermodynamics 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.	
Primary Interdisciplinary Connections: Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3	
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy	
Learning Targets	
NJSLS Standards: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8	
Technology Standards: 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.C.1, 8.1.12.E.1, and 8.1.12.E.2	
ELA Companion Standards: RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5	
Content Statements:	
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.
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.
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6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Idea:

1. Energy

Unit Essential Questions:	**Unit Enduring Understandings:**
• Why is energy released when water becomes an ice cube? • How are chemical transformations that require bonds to break and form influenced by energy?	• Changes in a substance's properties or change into a different substance requires an exchange of energy. • The energy exchanged in a chemical transformation is required to break and form bonds.

Unit Learning Targets

Students will…

- Explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation.
- Represent a chemical or physical transformation with an energy diagram.
- Explain the relationship between the transfer of thermal energy and molecular collisions.
- Calculate the heat q absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature.
- Explain changes in the heat q absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition.
- Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction.
- Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction.
- Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation.
- Represent a chemical or physical process as a sequence of steps.

Evidence of Learning

Summative Assessment: Labs, Unit Tests, Benchmarks

Formative Assessments:

- Quizzes
- Chapter Tests
- Homework
- Projects

Lesson Plans	
Activities/Interdisciplinary Connections	*Timeframe*
• Think-Pair-Share: Have student pairs generate a list of exothermic and endothermic processes that occur in their everyday life. Have them share their lists with other pairs to determine if they have correctly identified these common processes in terms of endo- or exothermicity. • Demo with Q&A: After working a few practice problems in groups with the $q = mC\Delta T$ equation, demonstrate that heating 40 g of copper pellets to 80°C and placing them into 40 g of 20°C water does not result in 50°C as a final temperature. Have students reason why and then record the final temperature of the copper/water mixture. Then have them calculate the specific heat capacity of copper and compare it to published values. As a class discussion, account for deviations from the expected results • Process Oriented Guided Inquiry Learning (POGIL): Have students wet one finger with water and keep one finger dry then wave them in the air to see which feels cooler. Have them respond to a series of guided questions about the energy transfers involved in the evaporation process. Next, two beakers are heated side by side on a hot plate. Heating a beaker with 100 g of water on the same hot plate alongside a beaker with 100 g of 1-propanol results in very different changes in temperature. Through guided inquiry, students derive the concept of specific heat. As a class, compare whether the two liquids have been treated "fairly," and the concept of molar heat capacity is established and compared to specific heat capacity • Think-Pair-Share: Have pairs of students examine tables of average bond enthalpy and establish patterns with regard to bond order, atomic radius, and bond length. Similar patterns are examined for the standard enthalpies of formation. Have student pairs work through several practice problems using bond energies and enthalpies of formation to determine the enthalpy of a chemical reaction and compare their calculations. • Post-Lab Discussion: Have students apply Hess's	1-3 weeks

law by reacting magnesium metal and magnesium oxide with hydrochloric acid to determine the enthalpy change of the following reaction: $Mg + O_2 \rightarrow MgO$. Then have them evaluate their results and discuss sources of error.	
Teacher Resources	*Teacher Note*
• Textbook • Notebook • Lab Notebook • PowerPoints • Chromebooks • Lab Materials	

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and Gifted & Talented Students

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•Word walls •Sentence frames •Think-pair-share •Cooperative learning groups

AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Equilibrium
Unit Summary: 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. Subsequent units will explore equilibrium constants that arise from acid-base chemistry.
Primary Interdisciplinary Connections: Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy

Learning Targets

NJSLS Standards:
HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8

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ELA Companion Standards:
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Content Statements:

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8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Ideas:

1. Scale, Proportion, and Quantity
2. Transformations

Unit Essential Questions:	**Unit Enduring Understandings:**
• Why is a waterfall considered a spontaneous reaction? • How can reactions occur in more than one direction? • How is caffeine removed from coffee? • Why is food stored in a refrigerator?	• Some reactions can occur in both forward and reverse directions, sometimes proceeding in each direction simultaneously • A system at equilibrium depends on the relationships between concentrations, partial pressures of chemical species, and equilibrium constant K. • Systems at equilibrium respond to external stresses to offset the effect of the stress. • The dissolution of a salt is a reversible process that can be influenced by environmental factors such as pH or other dissolved ions.

Unit Learning Targets

Students will…

- Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations.
- Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions.
- Represent the reaction quotient Q_c or Q_p , for a reversible reaction, and the corresponding equilibrium expressions $K_c = Q_c$ or $K_p = Q_p$.
- Calculate K_c or K_p based on experimental observations of concentrations or pressures at equilibrium.
- Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium.
- Represent a multistep process with an overall equilibrium expression, using the constituent K expressions for each individual reaction.
- Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant.
- Represent a system undergoing a reversible reaction with a particulate model.
- Identify the response of a system at equilibrium to an external stress, using Le Châtelier's

principle.

- Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium.
- Calculate the solubility of a salt based on the value of K_{sp} for the salt.
- Identify the solubility of a salt, and/or the value of K_{sp} for the salt, based on the concentration of a common ion already present in solution.
- Identify the qualitative effect of changes in pH on the solubility of a salt.
- Explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process.

Evidence of Learning

Summative Assessment: Labs, Unit Tests, Benchmarks

Formative Assessments:

- Quizzes
- Chapter Tests
- Homework
- Projects

Lesson Plans

Activities/Interdisciplinary Connections	*Timeframe*
• Manipulatives: Give groups of students containers that hold objects representing particles in an equilibrium mix (beads work well here). Each bead represents a molecule in a reversible synthesis reaction. The law of mass action is introduced, and students are asked to calculate K. Each group should get the same value for K, even though the number of particles in each container is different. Each group of students then gets a new container that represents a mixture not at equilibrium, and they calculate the ratio using the law of mass action. The concept of Q is introduced and then students determine if and how they could get the ratio of reactants and products to be equal to K by attaching or detaching beads. • Identify Subtasks: Given a gaseous equilibrium process, have students construct the expression that can ultimately be used to calculate the K_p . • Demo with Q&A: Prepare a solution of cobalt (II) chloride in dry ethanol. Demonstrate various methods to shift the equilibrium position: adding	1-4 weeks

water, heating, cooling, layering with dry acetone, adding silver nitrate to precipitate chloride ions from solution, and measuring the temperature change of the solution as concentrated hydrochloric acid is added. As a class, have students analyze what each change does to the predominant species in the equilibrium mixture and then generalize patterns for Le Châtelier's principle. • Post-Lab Discussion: After examining the K_{sp} polyatomic vs. monoatomic ions, etc.), have students investigate the tables for patterns (including ion charge, ionic radius, K_{sp} of lead (II) iodide. One drop of 0.1 M potassium iodide is added to 250 mL of 0.01 M lead (II) nitrate. A precipitate forms but then dissolves as it dissipates through the solution based on K_{sp}, have students calculate whether the precipitate should have formed and connect this calculation with what was initially observed. Have them determine how many milliliters of the 0.1 M KI solution would need to be added for a lasting precipitate to be formed. Then have them share their calculated values and agree as a class which is the best answer	
Teacher Resources	*Teacher Note*
• Textbook • Notebook • Lab Notebook • PowerPoints • Chromebooks • Lab Materials	

Differentiating Instruction:
Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:
- Use of visual and multisensory formats
- Use of assisted technology
- Use of prompts
- Modification of content and student products
- Testing accommodations

• Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:
• Adjusting the pace of lessons
• Curriculum compacting
• Inquiry-based instruction
• Independent study
• Higher-order thinking skills
• Interest-based content
• Student-driven instruction
• Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:
• Pre-teaching of vocabulary and concepts
• Visual learning, including graphic organizers
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AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Acids and Bases	
Unit Summary: 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. 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 that often reaches equilibrium quickly. In the final unit, the equilibrium constant is related to temperature and the difference in Gibbs free energy between the reactants and products.	
Primary Interdisciplinary Connections: Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3	
21st Century Career and Life Themes: Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, and Information Literacy	
Learning Targets	
NJSLS Standards: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-7, and HS-PS1-8	
Technology Standards: 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.C.1, 8.1.12.E.1, and 8.1.12.E.2	
ELA Companion Standards: RST.9-10.7, RST.11-12.1, WHST.9-12.2, WHST.9-12.5, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9 , and SL.11-12.5	
Content Statements:	
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.
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.
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.
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.
5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a

	reaction occurs.
6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Big Idea:

1. Structure and Properties

Unit Essential Questions:	**Unit Enduring Understandings:**
• How are reactions involving acids and bases related to pH? • How does your body maintain pH balance?	• The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved. • A buffered solution resists changes to its pH when small amounts of acid or base are added.

Unit Learning Targets

Students will…

- Calculate the values of pH and pOH, based on K_w and the concentration of all species present in a neutral solution of water.
- Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base.
- Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.
- Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases.
- Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.
- Explain the relationship between the strength of an acid or base and the structure of the molecule or ion.
- Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pK_a of the conjugate acid or the pK_b of the conjugate base.
- Explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered solution.
- Identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer.
- Explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution.

Evidence of Learning
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Lesson Plans	
Activities/Interdisciplinary Connections	*Timeframe*
• Post-Lab Discussion: Rainbow Acid Indicator (Flinn Scientific Item U0012) is added to 0.001 M solutions of HCl, H_2SO4, and $HC_2H_3O_2$. Have students reason out why the pH values are not the same, and introduce the concept of K_a. Then have them calculate the pH of each solution to explain their earlier observations. Percent ionization is discussed and how ICE charts reflect the percent ionization is explained. • Post-Lab Discussion: After collecting data on a weak acid/strong base titration, have students create a titration curve (pH as a function of the volume of base added). Then have them identify relative points on the graph based on group discussion (e.g., equivalence point). • Demo with Q&A: Add an Alka-Seltzer tablet to 200 mL of water and pour the resulting solution into three small beakers. Add deionized water to three more beakers. Add universal indicator to all six beakers and then add strong acids and strong bases to each beaker to demonstrate buffering ability and buffer capacity. Have students develop particulate-level drawings to illustrate what is happening in the beakers in the context of "buffering ability." • Simulations: Using a ChemCollective virtual lab, ask students to develop a buffer that will have a particular pH after an amount of strong acid is added.	1-4 weeks
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AP Chemistry- 11th – 12th grade Unit of Study

Unit Title: Applications of Thermodynamics	
Unit Summary: This unit allows students to connect principles and calculations across Units 5–8. 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.	
Primary Interdisciplinary Connections: Math: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, and HSN-Q.A.3	
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Big Idea:

1. Structure and Properties

Unit Essential Questions:	**Unit Enduring Understandings:**
• How does water flow uphill? • How is the favorability of a chemical or physical transformation determined? • How is electrical energy generated using chemical reactions?	Some chemical or physical processes cannot occur without intervention. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation. Electrical energy can be generated by chemical reactions.

Unit Learning Targets

Students will…

- Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
- Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
- Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^o .
- Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
- Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o , and T.
- Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
- Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
- Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
- Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
- Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

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Lesson Plans	
Activities/Interdisciplinary Connections	*Timeframe*
• Think-Pair-Share: Given a problem pertaining to thermodynamic favorability, have students think through how enthalpy and/or entropy is driving the thermodynamic favorability of the reaction. Have them pair up and explain their reasoning for whether or not the reaction is thermodynamically favorable and what is driving that favorability. After the pairs have discussed their responses, have them share with other pairs to get feedback on their rationale. • Demo with Q&A: Construct a simple battery by submerging two electrodes (Mg and Cu) into orange juice and attaching it to the battery compartment of a quartz clock. Instruct students to ask as many questions as they can while the clock is running. Allow the clock to run for as long as possible and then examine the magnesium anode after a day to see if it corrodes away. As a class, examine the table of standard reduction potentials and discuss where the electrons are coming from and going to in order to power the clock. • Critique Reasoning: Have students mass a new penny with an analytical balance. They attach the penny to the negative electrode, which is attached to a 9-volt battery. A zinc strip is attached to the positive electrode. The penny is submerged for 10 minutes in a 1.0 M NaOH solution with zinc dust and the zinc electrode. Students dry the penny and mass it again. Using Faraday's laws, have them calculate the current that must have been delivered to plate the zinc onto the penny. Then have student pairs share and peer review each other's reasoning.	1-3 weeks

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