TOWNSHIP OF UNION PUBLIC SCHOOLS

AP Chemistry Lecture
AP Chemistry Lab
Curriculum Guide

January 2019

Mission Statement

The mission of the Township of Union Public Schools is to build on the foundations of honesty, excellence, integrity, strong family, and community partnerships. We promote a supportive learning environment where all students are challenged, inspired, empowered, and respected as diverse learners. Through cultivation of students' intellectual curiosity, skills and knowledge, our students can achieve academically and socially as well as contribute as responsible and productive citizens of our global community Philosophy Statement

Philosophy Statement

The Township of Union Public School District, as a societal agency, reflects democratic ideals and concepts through its educational practices. It is the belief of the Board of Education that a primary function of the Township of Union Public School System is to formulate a learning climate conducive to the needs of all students in general, providing therein for individual differences. The school operates as a partner with the home and community.

Statement of District Goals:

- Develop reading, writing, speaking, listening, and mathematical skills.
- Develop a pride in work and a feeling of self-worth, self-reliance, and self-discipline.
- Acquire and use the skills and habits involved in critical and constructive thinking.
- Develop a code of behavior based on moral and ethical principles.
- Work with others cooperatively.
- Acquire a knowledge and appreciation of the historical record of human achievement and failures and current societal issues.
- Acquire a knowledge and understanding of the physical and biological sciences.
- Participate effectively and efficiently in economic life and the development of skills to enter a specific field of work.
- Appreciate and understand literature, art, music, and other cultural activities.
- Develop an understanding of the historical and cultural heritage.
- Develop a concern for the proper use and/or preservation of natural resources.
- Develop basic skills in sports and other forms of recreation.

Course Description

The AP Chemistry course is a college level course which meets the requirements as outlined in the AP Chemistry course description. This course is designed to help students develop a conceptual framework for modern Chemistry and an appreciation of science as a process. Primary emphasis in this course is placed on understanding, analyzing, and applying rather than memorization. Essential to conceptual understanding is recognition of unifying themes that integrate the major topics as well as problem solving skills and scientific inquiry. Students are prepared to be critical and independent thinkers who are able to function effectively in a scientific and technological society. The textbook for the course is the 9th edition of General Chemistry by Ebbing and Gammon. In addition to the textbook, internet sources are used to illuminate concepts that are discussed in class. Classes meet each day for forty-two minutes. Twice a week an additional forty-two minute period is designed specifically for labs. Hands on lab components are designed to challenge the students' ability to understand the nature of the problems, formulate hypotheses, design and implement experiments, interpret data, and draw conclusions. Each lab is followed by a complete and formal report in a separate lab notebook ready for college review if required for lab credits. A post lab discussion of each lab exercise is done to emphasize science as a process and its relationship to the theoretical material and a test is administered as well. In addition to the book material, every chapter is summarized with problems and essays that we solve and discuss in class. Homework is required to be handed at the end of each chapter so corrections can be made. Students are assessed with quizzes, essays from old AP exams, take home assessments, and tests. The scoring is used to determine individual weaknesses so the student will know what to review and improve in those particular topics. Students are prepared so that they will be able to achieve an acceptable grade on the AP Exam in May. After the AP Exam, the remainder of the year is devoted to topics (including labs developed by students request) that were not covered before the exam and a research project into chemical, biochemical, and pharmaceutical companies. Students are to present to the class their own analysis of the company they chose to do research on.

Recommended Textbook

General Chemistry by Ebbing and Gammon, 9th Edition

Course Proficiencies

Students will be able to…

- Demonstrate the proper handling of chemicals and lab equipment
- Perform scientific measurements and apply mathematical operations
- Use the structure of the atom and electron arrangement to identify and explain the trends in the periodic table
- Distinguish between the following types of bonds: ionic, covalent and metallic, and their relationship to atomic structure and develop molecular orbitals.
- Write chemical formulas and name substances
- Identify the relationship between molecular shape and polarity for small molecules.
- Identify the types of reactions and be able to predict products from reactants
- Uphold the Law of Conservation of Matter by identifying and writing balanced chemical equations
- Understand the mathematics of chemistry by using and understanding the mole concept
- examine mathematical relationships in reactions using stoichiometric calculations
- Understand kinetics of reactions and integrate it to reaction quotient and its applications
- Distinguish between the four states of matter by applying the kinetic molecular theory
- Perform gas law calculations and their applications to everyday life
- Examine the factors that affect solubility and determine the concentration of solutions by different methods.
- Understand chemical equilibrium and its relationship to Kp, Ke, ΔG, and Ksp
- Distinguish between acids and bases and relate it to pH.
- Use calorimetry to understand enthalpy change and its affect on bond energy.
- Apply oxidation reduction reactions to the development of voltaic cell and calculations of their potential.

AP Chemistry Concepts at a Glance from word document https://www.hatboro-horsham.org/cms/lib/PA01000027/Centricity/Domain/383/AP%20Chemistry%20Concepts%20at%20a%20Glance.doc

Big Idea 1: The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.

- Enduring understanding 1.A: All matter is made of atoms. There are a limited number of types of atoms; these are the elements.

Essential knowledge:

1.A.1: Molecules are composed of specific combinations of atoms; different molecules are composed of combinations of different elements and of combinations of the same elements in differing amounts and proportions.

1.A.2: Chemical analysis provides a method for determining the relative number of atoms in a substance, which can be used to identify the substance or determine its purity.

1.A.3: The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.

- Enduring understanding 1.B: The atoms of each element have unique structures arising from interactions between electrons and nuclei.

Essential knowledge

1.B.1: The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom. Coulomb's law is qualitatively useful for understanding the structure of the atom.

1.B.2: The electronic structure of the atom can be described using an electron configuration that reflects the concept of electrons in quantized energy levels or shells; the energetics of the electrons in the atom can be understood by consideration of Coulomb's law.

- Enduring understanding 1.C: Elements display periodicity in their properties when the elements are organized according to increasing atomic number. This periodicity can be explained by the regular variations that occur in the electronic structures of atoms. Periodicity is a useful principle for understanding properties and predicting trends in properties. Its modern-day uses range from examining the composition of materials to generating ideas for designing new materials.

Essential knowledge:

1.C.1: Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure.

1.C.2: The currently accepted best model of the atom is based on the quantum mechanical model.

- Enduring understanding 1.D: Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms

Essential knowledge:

1.D.1: As is the case with all scientific models, any model of the atom is subject to refinement and change in response to new experimental results. In that sense, an atomic model is not regarded as an exact description of the atom, but rather a theoretical construct that fits a set of experimental data.

1.D.2: An early model of the atom stated that all atoms of an element are identical. Mass spectrometry data demonstrate evidence that contradicts this early model.

1.D.3: The interaction of electromagnetic waves or light with matter is a powerful means to probe the structure of atoms and molecules, and to measure their concentration.

- Enduring understanding 1.E: Atoms are conserved in physical and chemical processes.
  Essential knowledge:

1.E.1: Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types.

Essential knowledge:

1.E.2: Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants, as well as the efficiency of the transformation

Big Idea 2: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.

- Enduring understanding 2.A: Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.

Essential knowledge:

2.A.1: The different properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.

2.A.2: The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.

2.A.3: Solutions are homogenous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of the solutes and solvent.

- Enduring understanding 2.B: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.
  Essential knowledge:

2.B.1: London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.

2.B.2: Dipole forces result from the attraction among the positive ends and negative ends of polar molecules. Hydrogen bonding is a strong type of dipole-dipole force that exists when very electronegative atoms (N, O, and F) are involved.

2.B.3: Intermolecular forces play a key role in determining the properties of substances, including biological structures and interactions.

- Enduring understanding 2.C: The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.
  Essential knowledge:

2.C.1: In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond.

2.C.2: Ionic bonding results from the net attraction between oppositely charged ions, closely packed together in a crystal lattice.

2.C.3: Metallic bonding describes an array of positively charged metal cores surrounded by a sea of mobile valence electrons.

2.C.4: The localized electron bonding model describes and predicts molecular geometry using Lewis diagrams and the VSEPR model.

- Enduring understanding 2.D: The type of bonding in the solid state can be deduced from the properties of the solid state.

Essential knowledge:

2.D.1: Ionic solids have high melting points, are brittle, and conduct electricity only when molten or in solution.

2.D.2: Metallic solids are good conductors of heat and electricity, have a wide range of melting points, and are shiny, malleable, ductile, and readily alloyed

2.D.3: Covalent network solids generally have extremely high melting points, are hard, and are thermal insulators. Some conduct electricity.

2.D.4: Molecular solids with low molecular weight usually have low melting points and are not expected to conduct electricity as solids, in solution, or when molten.

Big Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.

- Enduring understanding 3.A: Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form.
  Essential knowledge:

3.A.1: A chemical change may be represented by a molecular, ionic, or net ionic equation.

3.A.2: Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to be simply an exercise done only by chemists.

- Enduring understanding 3.B: Chemical reactions can be classified by considering what the reactants are, what the products are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid-base, and oxidation-reduction reactions.
  Essential knowledge:

3.B.1: Synthesis reactions are those in which atoms and/or molecules combine to form a new compound. Decomposition is the reverse of synthesis, a process whereby molecules are decomposed, often by the use of heat.

3.B.2: In a neutralization reaction, protons are transferred from an acid to a base.

3.B.3: In oxidation-reduction redox) reactions, there is a net transfer of electrons. The species that loses electrons is oxidized, and the species that gains electrons is reduced.

- Enduring understanding 3.C: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.

Essential knowledge:

3.C.1: Production of heat or light, formation of a gas, and formation of a precipitate and/ or a color change are possible evidences that a chemical change has occurred.

3.C.2: Net changes in energy for a chemical reaction can be endothermic or exothermic.

3.C.3: Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytic cells.

Big Idea 4: Rates of chemical reactions are determined by details of the molecular collisions.

- Enduring understanding 4.A: Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time.

Essential knowledge:

4.A.1: The rate of a reaction is influenced by the concentration or pressure of reactants, the phase of the reactants and products, and environmental factors such as temperature and solvent.

4.A.2: The rate law shows how the rate depends on reactant concentrations.

4.A.3: The magnitude and temperature dependence of the rate of reaction is contained quantitatively in the rate constant.

- Enduring understanding 4.B: Elementary reactions are mediated by collisions between molecules. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.
  Essential knowledge

4.B.1: Elementary reactions can be unimolecular or involve collisions between two or more molecules.

4.B.2: Not all collisions are successful. To get over the activation energy barrier, the colliding species need sufficient energy. Also, the orientations of the reactant molecules during the collision must allow for the rearrangement of reactant bonds to form product bonds.

4.B.3: A successful collision can be viewed as following a reaction path with an associated energy profile.

- Enduring understanding 4.C: Many reactions proceed via a series of elementary reactions.
  Essential knowledge:

4.C.1: The mechanism of a multistep reaction consists of a series of elementary reactions that add up to the overall reaction.

4.C.2: In many reactions, the rate is set by the slowest elementary reaction, or rate-limiting step.

4.C.3: Reaction intermediates, which are formed during the reaction but not present in the overall reaction, play an important role in multistep reactions.

- Enduring understanding 4.D: Reaction rates may be increased by the presence of a catalyst.
  Essential knowledge:

4.D.1: Catalysts function by lowering the activation energy of an elementary step in a reaction mechanism, and by providing a new and faster reaction mechanism.

4.D.2: Important classes in catalysis include acid-base catalysis, surface catalysis, and enzyme catalysis.

Big Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.

- Enduring understanding 5.A: Two systems with different temperatures that are in thermal contact will exchange energy. The quantity of thermal energy transferred from one system to another is called heat.
  Essential knowledge:

5.A.1: Temperature is a measure of the average kinetic energy of atoms and molecules.

5.A.2: The process of kinetic energy transfer at the particulate scale is referred to in this course as heat transfer, and the spontaneous direction of the transfer is always from a hot to a cold body.

- Enduring understanding 5.B: Energy is neither created nor destroyed, but only transformed from one form to another.

Essential knowledge:

5.B.1: Energy is transferred between systems either through heat transfer or through one system doing work on the other system.

5.B.2: When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur through either heat exchange or work.

5.B.3: Chemical systems undergo three main processes that change their energy: heating/ cooling, phase transitions, and chemical reactions.

5.B.4: Calorimetry is an experimental technique that is used to determine the heat exchanged/transferred in a chemical system.

- Enduring understanding 5.C: Breaking bonds requires energy, and making bonds releases energy.

Essential knowledge:

5.C.1: Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them.

5.C.2: The net energy change during a reaction is the sum of the energy required to break the bonds in the reactant molecules and the energy released in forming the bonds of the product molecules. The net change in energy may be positive for endothermic reactions where energy is required, or negative for exothermic reactions where energy is released.

- Enduring understanding 5.D: Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.
  Essential knowledge

5.D.1: Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.

5.D.2: At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.

5.D.3: Noncovalent and intermolecular interactions play important roles in many biological and polymer systems.

- Enduring understanding 5.E: Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both.
  Essential knowledge:

5.E.1: Entropy is a measure of the dispersal of matter and energy.

5.E.2: Some physical or chemical processes involve both a decrease in the internal energy of the components ($\Delta H° < 0$) under consideration and an increase in the entropy of those components ($\Delta S° > 0$). These processes are necessarily "thermodynamically favored" ($\Delta G° < 0$).

5.E.3: If a chemical or physical process is not driven by both entropy and enthalpy changes, then the Gibbs free energy change can be used to determine whether the process is thermodynamically favored.

5.E.4: External sources of energy can be used to drive change in cases where the Gibbs free energy change is positive.

5.E.5: A thermodynamically favored process may not occur due to kinetic constraints (kinetic vs. thermodynamic control).

Big Idea 6: 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.

- Enduring understanding 6.A: Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.

Essential knowledge:

6.A.1: In many classes of reactions, it is important to consider both the forward and reverse reaction.

6.A.2: The current state of a system undergoing a reversible reaction can be characterized by the extent to which reactants have been converted to products. The relative quantities of reaction components are quantitatively described by the reaction quotient, Q.

6.A.3: When a system is at equilibrium, all macroscopic variables, such as concentrations, partial pressures, and temperature, do not change over time. Equilibrium results from an equality between the rates of the forward and reverse reactions, at which point $Q = K$.

6.A.4: The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side.

- Enduring understanding 6.B: Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.

Essential knowledge:

6.B.1: Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier’s principle).

6.B.2: A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of the original equilibrium state. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state.

- Enduring understanding 6.C: Chemical equilibrium plays an important role in acid-base chemistry and in solubility.

Essential knowledge:

6.C.1: Chemical equilibrium reasoning can be used to describe the proton-transfer reactions of acid-base chemistry.

6.C.2: The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to pKa allows one to determine the protonation state of a molecule with a labile proton.

6.C.3: The solubility of a substance can be understood in terms of chemical equilibrium.

- Enduring understanding 6.D: The equilibrium constant is related to temperature and the difference in Gibbs free energy between reactants and products.

Essential knowledge:

6.D.1: When the difference in Gibbs free energy between reactants and products ($\Delta G°$) is much larger than the thermal energy (RT), the equilibrium constant is either very small (for $\Delta G° > 0$) or very large (for $\Delta G° < 0$). When $\Delta G°$ is comparable to the thermal energy (RT), the equilibrium constant is near 1.

Laboratory Investigations: Content: (Notes: EU = Enduring Understandings; LO = Learning Objectives Bold type are mandatory labs)

Lab: Use density to determine the identity of unknowns, and percent sugar by comparison to a Standard Curve.* (SP2,4,5)

Given data (percent composition, density, etc) for various substances students will determine if it they are pure substances or mixtures

Big Ideas 1,2,3 EU: 1.A 1.B 1.E LO: 1.1-1.5,1.13,1.14,1.17,1.18

Lab: Precipitation Reactions (SP5)

Naming and Writing exercises/activity

Isomers activity [CR3a]

Reaction DEMOS – Students observe demonstrations of various reaction types and then write appropriately balanced chemical equations.

Big Ideas 1,2,3 EU: 2.A,2.B,2.C,2.D,5.D LO: 2.1, 2.10, 2.14, 2.15, 2.17, 2.19

Lab: Percent carbonate in an unknown carbonate by precipitation.* (SP2,4,5)

2) Stoichiometry. – Via Continuous Variations of Precipitate Formation. (SP2,3,5,6,7)

3) Solution and Dilution.* (SP2,4,5) Inquiry

4) Inquiry Activity - Gravimetric determination of a hydrate (optional, via on-line simulation –experimental design): * (SP4)

Given problems sets students are able to identify the limiting and excess reactants for a chemical reaction. (LO 1.4)

Big Ideas 1,2,3 EU: 1.A,1.E,3.A,3.B,3.C LO: 1.14,1.17- 1.19,3.1,3.2,3.5,3.6,5.10

Lab: Ionic Reactions and Aqueous Solutions (including acids and bases). (SP5)

2) Lab: How Much Acid is in Vinegar (by titration).* (SP2,3,4,6)

Paper exercise for predicting products and writingnet ionic reaction equations.

Big Ideas: 1,2,3 EU: 1.E,2.A,3.A,3.B,3.D LO: 1.18- 1.20,2.14,2.15,3.1- 3.4,3.8,6.3

Lab: Calorimetry (SP2,3,5,6)

2) Lab: Energy in Food (possible inquiry*) (SP2,3,4)

3) Lab (optional): Handwarmer

Big Idea 5 EU: 5.A,5.B,5.C,5.D,5.ELO: 3.11,5.2- 5.8,5.15

Lab: Atomic Spectrum of Hydrogen (optional)(SP6,7)

Given PES graphs and data students will determine electron configurations and the corresponding elements.

Big Ideas: 1 EU: 1.B,1.C,1.DLO: 1.5-1.10,1.12,1.13,1.15

Lab: Molecular Models – Molecular architecture (SP1,6,7)

• From chemical formulas, students are able to apply VSEPR Theory to draw Lewis diagrams and predict the geometry of molecules, build corresponding models, identify hybridization and make predictions about molecular polarity.

Students are able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization and make predictions about polarity.

Big Idea: 2 EU: 2.C,2.D LO: 1.7,1.8,2.1,2.13,2.17 -2.24,2.26,2.27,2.29,5.1,5.8

Lab: Molar Mass Of An Unknown Vapor*(SP3,4)

2) Molar Volume of A Gas – Collection by downward displacement of water. (SP2,5,6,7)

3) Lab simulation - Graham's Law of Diffusion (SP1,2)

Big Idea: 2,5 EU; 2.A,5.A,5.B,5.D LO: 2.1,2.4- 2.6,2.12,5.2,5.6

Lab: Chromatography* (SP4,6)

2) Lab: Separation of the Components of a Mixture* (SP3,4,6)

3) Distillation Demo: Given only chemical formulas of a variety of different types of compounds, students will describe the type of bonding, nature of the IMF's, and predict their properties.

Big Idea 2 EU: 2.A,2.B,2.C,2.D LO: 2.1,2.3,2.7-2.11,2.16,2.25,2.28- 2.32,5.1,5.10,5.11

Lab: Kinetics – Sulfur Deposition (SP2,5)

For a variety of different reactions, students will analyze sets of rate versus concentration data to determine the order of each reactant, and the overall Rate Law.

Students create energy diagrams to explain why catalysts and raising the temperature can increase the rate of a chemical reaction.

Big Idea 1,4 EU: 1.E,4.A,4.B,4.C,4.D LO: 1.15,1.16,4.1- 4.9

Lab: Keq Determination of FeSCNspecies –Two Methods (including Spectrometry) (SP2,5,6)

Given the stress put on a system at equilibrium, students predict the shift and resultant observations

Big Idea: 1,3,6 EU: 1.E,3.A,6.A,6.B LO: 1.16,5.16-5.18,6.1- 6.10

Lab: Standardization of a Basic Solution, and Determination of the Molar Mass and pKa of an Unknown Acid. (SP2,4,5,6)

2) Lab (optional): Acid-base titration curve

Big Idea 1,3,6 EU: 1.E,3.A,3.B,6.A,6.B,6.C LO: 1.20,2.1,2.2,3.3,3.7,6.1,6.2

Lab (optional): Favorability/Spontaneity –S odium Nitrate Solution

Given chemical reactions students are able to calculate ΔH, ΔS, and ΔG for the reactions. Using these values they will be able to determine whether the reaction is thermodynamically favorable

Big Idea 3,5,6 EU: 3.A,3.B,3.C,5.A,5.B,5.C,5.D,5.E,6.C,6.D LO: 2.15,3.11,3.12,5.2,5.12- 5.18,6.2,6.24,6.25

Lab: Electroplating (SP3,6,7)

2) Redox Titration (Computer Simulation) (SP2,5)

Big Idea 1,3,5,6 EU: 1E, 3.A,3.B,3.C,5.B,5.C,5.D 6.D LO: 1.20, 2.15, 2.6, 6.11-6.23

Curriculum Units

Unit 1: Basics of Chemistry

1. Chemistry and Measurement
2. Atoms, Molecules and ions
3. Calculations with Chemical Formulas and Equations
4. Chemical Reactions
5. The Gaseous State
6. Thermochemistry

Unit 2: Atomic and Molecular Structure

7. Quantum Theory of the Atom
8. Electronic Configurations and Periodicity
9. Ions and covalent Bonding
10. Molecular geometry and Bonding theory

Unit 3: States Of Matter and Solutions

11. Liquids and Solids
12. Solutions

Unit 4: Chemical Reactions and Equilibrium

13. Rates of Reactions
14. Chemical Equilibrium
15. Acids and Bases
16. Acid-Base Equilibria
17. Solubility and Complex-ion Equilibria
18. Thermodynamics
19. Electrochemistry

Unit 5: Chemistry of the Elements

20. Nuclear Chemistry
23. Organic Chemistry

Pacing Guide- Course

Content	Number of Days
Unit 1: Basics of Chemistry	37
1. Chemistry and Measurement	
2. Atoms, Molecules and ions	
3. Calculations with Chemical Formulas and Equations	
4. Chemical Reactions	
5. The Gaseous State	
6. Thermochemistry	
Unit 2: Atomic and Molecular Structure	18
7. Quantum Theory of the Atom	
8. Electronic Configurations and Periodicity	
9. Ions and covalent Bonding	
10. Molecular geometry and Bonding Theory	
Unit 3: States Of Matter and Solutions	10
11. Liquids and Solids	
12. Solutions	
Unit 4: Chemical Reactions and Equilibrium	85
13. Rates of Reactions	
14. Chemical Equilibrium	
15. Acids and Bases	
16. Acid-Base Equilibria	
17. Solubility and Complex-ion Equilibria	
18. Thermodynamics	
19. Electrochemistry	
Unit 5: Chemistry of the Elements	8

Alignment of AP Chemistry Enduring Understandings and Essential Knowledge With NGSS Disciplinary Core Ideas

The curriculum guide on the following pages represents an alignment between the NGSS and the AP Chemistry course. These resources show the conceptual similarities between the two sets of courses. The content of the NGSS was compared to the content in the AP Chemistry course guides to identify areas of conceptual similarity. The specific language of each AP Essential Knowledge (AP EK) statement was compared to the Disciplinary Core Idea (DCI) elements associated with each Next Generation Science Standards (NGSS) Performance Expectation (PE) to demonstrate similar content or conceptual foundation.

Acknowledgement: http://www.nextgenscience.org/sites/default/files/NGSS%20Accelerated%20Model%20Course%20Pathways.pdf

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.A All matter is made of atoms. There are a limited number of types of atoms; these are the elements.	**1.A.1** Molecules are composed of specific combinations of atoms; different molecules are composed of combinations of different elements and of combinations of the same elements in differing amounts and proportions.	**MS.PS1.A: Structure and Properties of Matter** Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).	**MS-PS1-1** Develop models to describe the atomic composition of simple molecules and extended structures.	Both **NGSS MS.PS1.A** and **AP EK 1.A.1** describe the basic composition of molecules. However, **EK 1.A.1 parts a through d** include details (e.g., about atomic mass) that are not included in the NGSS.
1.A All matter is made of atoms. There are a limited number of types of atoms; these are the elements.	**1.A.3** The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.	**HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**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-PS1-7** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	Both **NGSS HS.PS1.B** and **AP EK1.A.3** describe balanced chemical equations and the idea of quantifying numbers of atoms. **NGSS PE HS-PS1-7** makes this connection even more clear through its integration of the practice with the DCI and crosscutting concept. EK 1.A.3, however**,** includes details of the mole and Avogadro's number that are not included in the NGSS.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.B The atoms of each element have unique structures arising from interactions between electrons and nuclei.	**1.B.1** The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom. Coulomb's law is qualitatively useful for understanding the structure of the atom.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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-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.	The NGSS and AP both describe the attraction between charged particles as a key component to the structure and properties of the atom. **AP EK 1.B.1 parts a through c** include details of Coulomb's law and ionization energy that are not specified in the NGSS. **EK 1.B.1 parts d and e** also relate to **NGSS HS.PS4.B**, but the AP parts include more detail about Photoelectron spectroscopy than does the NGSS.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.B The atoms of each element have unique structures arising from interactions between electrons and nuclei.	**1.B.2** The electronic structure of the atom can be described using an electron configuration that reflects the concept of electrons in quantized energy levels or shells; the energetics of the electrons in the atom can be understood by consideration of Coulomb's law.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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-PS1-2** 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-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.	The NGSS and AP both describe the energetics of electrons in atoms as being described by Coulomb's law. The NGSS, however, only focus on the outer electrons of atoms, whereas **AP EK 1.B.2** describes the different energy levels or "shells" of electrons.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.C Elements display periodicity in their properties when the elements are organized according to increasing atomic number. This periodicity can be explained by the regular variations that occur in the electronic structures of atoms. Periodicity is a useful principle of understanding properties and predicting trends in properties. Its modern-day uses range from examining the composition of materials to generating ideas for designing new materials.	**1.C.1** Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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.	Both **NGSS HS.PS1.A** and **AP EK 1.C.1** describe periodicity of the elements. EK 1.C.1 includes additional details about electron shells, ionization energy, and atomic radii that are not included in the NGSS.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.C Elements display periodicity in their properties when the elements are organized according to increasing atomic number. This periodicity can be explained by the regular variations that occur in the electronic structures of atoms. Periodicity is a useful principle of understanding properties and predicting trends in properties. Its modern-day uses range from examining the composition of materials to generating ideas for designing new materials.	**1.C.2** The currently accepted best model of the atom is based on the quantum mechanical model.	**HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	**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.	**NGSS HS.PS2.B** forms a foundation for **AP EK 1.C.2** by describing Coulomb's law in reference to subatomic particles. EK 1.C.2 goes beyond the NGSS, however, by describing the quantum mechanical model of the atom, including electron spin.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.D Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.	**1.D.1** As is the case with all scientific models, any model of the atom is subject to refinement and change in response to new experimental results. In that sense, an atomic model is not regarded as an exact description of the atom, but rather a theoretical construct that fits a set of experimental data.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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	The NGSS form the foundation for **AP EK 1.D.1** by describing a basic model of the atom in **NGSS HS.PS1.A** and by describing electrical forces within atoms in both **HS.PS1.A** and **HS.PS2.B**, leading students to an understanding of ionization energies for **EK 1.D.1 part b**.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.D Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atom.	**1.D.3** The interaction of electromagnetic waves or light with matter is a powerful means to probe the structure of atoms and molecules, and to measure their concentration.	**HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed. **HS.PS4.B: Electromagnetic Radiation** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. Photoelectric materials emit electrons when they absorb light of a high-enough frequency. **HS.PS4.C: Information Technologies and Instrumentation** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. **HS.ESS1.A: The Universe and Its Stars** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	**HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. **HS-PS4-5** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. **HS-ESS1-2** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	Both the NGSS and **AP EK 1.D.3** describe interactions of electromagnetic waves (or light) with matter, and that information can be gained through this interaction. **EK 1.D.3 part a** goes beyond the NGSS by describing Planck's equation. **EK 1.D.3 part b** describes some specific uses of infrared vs. ultraviolet and visible radiation, which also relates to other parts of **NGSS HS.PS4.B** that are not included here (associated with **HS-PS4-4**). **EK 1.D.3 part c** goes beyond the NGSS by describing use of the Beer-Lambert law.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.E Atoms are conserved in physical and chemical processes.	**1.E.1** Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types.	**HS.PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **HS.PS3.D: Energy in Chemical Processes** The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. **HS.ESS2.D: Weather and Climate** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. **HS.LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.	**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-PS1-7** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **HS-ESS2-6** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. **HS-LS2-4** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. **HS-LS2-5** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	Both the NGSS and **AP EK 1.E.1** describe that atoms are conserved during chemical reactions and that these reactions can be depicted symbolically. **EK 1.E.1 part a** goes beyond the NGSS by describing two specific different types of representations of physical and chemical processes.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.E Atoms are conserved in physical and chemical processes.	**1.E.2** Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants, as well as the efficiency of the transformation.	**HS.PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**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-PS1-7** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved	Both the NGSS and **AP EK 1.E.2** connect conservation of atoms to quantification of chemical reactants and products. EK 1.E.2 goes beyond the NGSS by describing gravimetric analysis and titrations in **parts e and f**.

Activities for Unit 1

Apply the Law of Conservation of Mass to a chemical problem.
Perform mathematical operations rounding to the proper number of significant digits.
Make measurements and report them using SI units.
Determine the density of different materials and substances.
Perform calculations using dimensional analysis.
Write nuclides describing elements and isotopes.
Determine atomic masses from appropriate data.
Write chemical formulas from names and name chemical compounds from formulas – both ionic and molecular and acids (including oxoacids).
Write and balance chemical equations.
Perform all types of Stoichiometric calculations between mass, particles and volumes of gases.
Calculate percent composition of elements in a compound.
Calculate the mass of an element in a given mass of a compound.
Calculate the percentage of C, H and O from combustion data.
Determine empirical formulas from mass data or percent data.
Determine molecular formula percent composition and molecular mass.
Use stoichiometric calculations to relate amounts of reactants and products in chemical reactions.
Calculate limiting reactant and excess reactant in a chemical reaction.
Calculate percent yield by first calculating theoretical yield.
Write complete and net ionic equations.
Write molecular, complete and net ionic equations for precipitation reactions.
Assign oxidation numbers according to the Rules.
Balance Redox reactions using Half reactions.
Calculate Molarity.
Determine dilution concentrations.
Perform gravimetric and volumetric calculations.
Express and use Boyle's Law, Charles' Law, Avogadro's Law and combined Gas Law.
Use the Ideal Gas Law to determine gas density, and molecular mass of a vapor.
Solve stoichiometric problems involving gases.
Calculate partial pressures and mole fractions of gas in a mixture.
Calculate the amount of gas collected over water.
Calculate the ratio of effusion rates.
Use van der Waals equation.
Write thermochemical equations and manipulate them applying the appropriate Rules.
Calculate the heat absorbed or evolved in a reaction given enthalpy and mass data.
Perform calorimetric calculations.
Apply Hess' Law to obtain enthalpy changes.
Use standard enthalpies of formation in calculations.
Concept Exploration.
Text Online Resource Questions CRSIRM's.

Lab Investigations:

 Lab – Equipment identification and Measurement.
 Lab – Density
 Lab - Chemical Reactions
 Lab – Determining Percent Carbonate in An Unknown Carbonate By Precipitation..
 Lab – Ionic Reactions and Aqueous Solutions. (Precipitation).
 Lab – How Much Acid Is in Vinegar (by titration, volumetric analysis).
. Lab – Determine Molar Volume of A Gas.
 Lab – Calorimetry

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.A Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.	**2.A.1** The difference properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.	**MS.PS1.A: Structure and Properties of Matter** Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **MS.PS3.A: Definitions of Energy** The term "heat as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. The temperature of a system is proportional to the average kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. **HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *(continued on next page)*	**MS-PS1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **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-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 motions of particles (objects) and energy associated with the relative position of particles (objects).	Both the NGSS and **AP EK 2.A.1** describe the differences between solids and liquids at a molecular level, and describe strength of attraction between particles as an explanation for the properties of matter. The NGSS build the foundation for discussion of different states of matter in middle school. **EK 2.A.1 part a** also relates to other parts of **MS.PS1.A** that are not listed here (regarding crystal structures). **EK 2.A.1 part e** goes beyond the NGSS by describing energetics of liquid/solid phase changes.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	2.A.1 The difference properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.		
2.A Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.	**2.A.2** The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.	**MS.PS1.A: Structure and Properties of Matter** Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **MS.PS3.A: Definitions of Energy** The term "heat as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(continued on next page)*	**MS-PS1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **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. *(continued on next page)*	Both the NGSS and **AP EK 2.A.2** describe gases and the intermolecular interactions that govern the behavior of gases. The NGSS build the foundation for discussion of different states of matter in middle school, and then build the foundation for mathematical representations of gas laws through a thorough coverage of intermolecular forces and energy in the high school standards. EK 2.A.2 goes beyond the NGSS by describing ideal gases; by describing the mathematical relationships between P, V, and T; and by discussing qualitative use of the Maxwell-Boltzmann distribution.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	2.A.2 The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.	The temperature of a system is proportional to the average kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. **HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. *(continued on next page)*	**HS-PS2-6** Communicate scientific and technical information about why the 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 the motions of particles (objects) and energy associated with the relative position of particles (objects). **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-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	2.A.2 The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.	These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed. **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.		
2.A Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.	**2.A.3** Solutions are homogenous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of the solutes and solvent.	**HS.PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material 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-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*	The NGSS build the foundation for **AP EK 2.A.3** by describing release or absorption of energy during reactions, and by describing intermolecular interactions. EK 2.A.3 goes beyond the NGSS by including details of solutions, their properties, how to describe solutions with molarity, and by descriptions of distillation.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.B Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.	**2.B.3** Intermolecular forces place a key role in determining the properties of substances, including biological structures and interactions.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	**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-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 motions of particles (objects) and energy associated with the relative position of particles (objects).	The NGSS and **AP EK 2.B.3** both describe intermolecular forces as crucial to determining the properties of substances. EK 2.B.3 goes beyond the NGSS by describing some effects of intermolecular forces on gases, including noble gases (**part c**), discussing graphs of pressure-volume relationships (**part d**), and by including examples of enzyme catalysis and hydrophilic and hydrophobic regions of proteins (**part e**).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.C The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.	**2.C.1** In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *(continued on next page)*	**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-PS1-2** 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-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-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-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-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 motions of particles (objects) and energy associated with the relative position of particles (objects). *(continued on next page)*	Bonding is a result of forces, proximity, and energy. This provides a basis for understanding all types of bonding. Both the NGSS and **AP EK 2.C.1** describe bonding as a result of intermolecular forces, and both describe bond energies. EK 2.C.1 goes beyond the NGSS by describing specific types of bonds (e.g., polar covalent, nonpolar covalent, ionic) and bond lengths.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	2.C.1 In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	**HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.C The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.	**2.C.2** Iconic bonding results from the net attraction between oppositely charged ions, closely packed together in a crystal lattice.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	**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-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-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.* **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	Bonding is a result of forces, proximity, and energy. This provides a basis for understanding all types of bonding. Both the NGSS and **AP EK 2.C.2** describe intermolecular forces and Coulomb's law as describing electrostatic forces between particles. EK 2.C.2 goes beyond the NGSS by describing cations and anions in an ionic crystal lattice.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.C The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.	**2.C.3** Metallic bonding describes an array of positively charged metal cores surrounded by sea of mobile valence electrons.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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-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.	Bonding is a result of forces, proximity, and energy. This provides a basis for understanding all types of bonding. Both the NGSS and **AP EK 2.C.3** describe valence electrons relating to the patterns of properties of materials, and describe attraction between particles. EK 2.C.3 goes beyond the NGSS by relating these concepts to a description of metallic bonding.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.D The type of bonding in the solid state can be deduced from the properties of the solid state.	**2.D.1** Iconic solids have high melting points, are brittle, and conduct electricity only when molten or in solution.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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.*	Both the NGSS and **AP EK 2.D.1** describe Coulombic interactions between particles and their effects on the properties of materials. EK 2.D.1 goes beyond the NGSS, however, by including details of ionic solids and their specific properties.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.D The type of bonding in the solid state can be deduced from the properties of the solid state.	**2.D.2** Metallic solids are good conductors of heat and electricity, have a wide range of melting points, and are shiny malleable, ductile, and readily alloyed.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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.*	Both the NGSS and **AP EK 2.D.2** describe valence electrons relating to the patterns of properties of materials. EK 2.D.2 goes beyond the NGSS by including details of properties of metals and alloys.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.D The type of bonding in the solid state can be deduced from the properties of the solid state.	**2.D.3** Covalent network solids have properties that reflect their underlying 2-D or 3-D networks of covalent bonds. Covalent network solids generally have extremely high melting points and are hard.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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.*	Both the NGSS and **AP EK 2.D.3** describe intermolecular forces and periodicity relating to the patterns of properties of materials. EK 2.D.3 goes beyond the NGSS by including details and properties of covalent network solids and of Graphite and Silicon.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.D The type of bonding in the solid state can be deduced from the properties of the solid state.	**2.D.4** Molecular solids with low molecular weight usually have low melting points and are not expected to conduct electricity as solids, in solution, or when molten.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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.*	Both the NGSS and **AP EK 2.D.4** describe intermolecular forces relating to the patterns of properties of materials. EK 2.D.4 goes beyond the NGSS by including molecular solids and their properties.

Activities for Unit 2:

Determine the wavelength or frequency of a hydrogen atom transition.
Calculate the wavelength of a moving particle according to DeBroglie.
Identify the Trends of atomic radius, ionization energy and electron affinity across Periods and down Groups in the Periodic Table.
Determine relative successive 1st, 2nd, 3rd, etc ionization energies of atoms of elements.
Define basic, acidic and amphoteric oxides.
Use the Born-Haber cycle to calculate lattice energies.
Identify bonding pairs and lone pairs of electrons.
Identify single, double and triple covalent bonds.
Write Lewis formulas.
Write resonance formulas.
Write Lewis formulas that are exceptions to the Octet Rule.
Use formal charges to identify the best formulas.
Determine bond orders.
Use bond energies to calculate delta H's
Predict and illustrate molecular geometries of small molecules applying the principles of VSEPR Model, showing any lone pairs of electrons.
Determine molecular polarity.
Apply Valence Bond Theory.
Using MO Theory, determine the molecular orbital electron configurations for homo-and heteronucleardiatomic molecules.
Text Problems.
Exercises.
Concept Exploration.
Text Online Resource Questions CRSIRM's.

Lab Investigations:
Lab – Atomic spectrum of hydrogen.
Lab – Molecular model-building.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.A Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form.	**3.A.1** A chemical change may be represented by a molecular, iconic, or net iconic equation.	**HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**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-PS1-7** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	The NGSS provide a foundation for **AP EK 3.A.1** by describing symbolic representations of balanced chemical equations, and by emphasizing conservation of atoms in chemical reactions. However, EK 3.A.1 is more specific than the NGSS. In particular, **EK 3.A.1 part b** goes beyond the NGSS by differentiating between molecular, ionic, and net ionic reaction equations and the situations in which they might be used.
3.A Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form.	**3.A.2** Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to be simply an exercise done only by chemists.	**HS.PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**HS-PS1-7** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	**NGSS HS.PS1.B** provides a foundation for **AP EK 3.A.2** by describing conservation of atoms and symbolic representations of chemical reactions. EK 3.A.2 goes beyond the NGSS by discussing mole ratios, requiring calculations of chemical products (**part a**), and by discussing the use of solution chemistry and titrations as avenues for calculations of stoichiometry (**part c**). This EK also relates to other parts of HS.PS1.B not listed here (e.g., associated with **HS-PS1-6**).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.B Chemical reactions can be classified by considering what the reactants are, what the products are, or how they changed from one into the other. Classes of chemical reaction include synthesis, decomposition, acid-base, and oxidation-reduction reactions.	**3.B.1** Synthesis reactions are those in which atoms and/or molecules combine to form a new compound. Decomposition is the reverse of synthesis, a process whereby molecules are decomposed, often by the use of heat.	**HS.PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**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.	The NGSS provide a foundation for **AP EK 3.B.1** by describing the outcomes of simple chemical reactions. EK 3.B.1 goes beyond the NGSS by explicitly naming synthesis and decomposition reactions. This EK also relates to other parts of **NGSS HS.PS1.A** not listed here (e.g., associated with **HS-PS1-4**).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.C Chemical and physical transformations may be observed in several ways and typically involve a change in energy.	**3.C.1** Production of heat or light, formation of a gas, and formation of a precipitate and/or a color change are possible evidences that a chemical change has occurred.	**HS.PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**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-PS1-2** 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-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.	The NGSS and **AP EK 3.C.1** both describe the connection between molecular structure and macroscopic properties, that changes in properties can occur during chemical reactions, and that these changes involve the storage or release of energy. The NGSS provide the foundation for understanding why these changes occur. EK 3.C.1 goes beyond the NGSS to list specific changes that might occur, differentiating between physical and chemical changes (**parts b and c**), and requiring identification of precipitation, acid-base, and redox reactions (**part d**).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.C Chemical and physical transformations may be observed in several ways and typically involve a change in energy.	**3.C.2** Net changes in energy for a chemical reaction can be endothermic or exothermic.	**HS.PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system.	**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-PS3-1** 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 motions of particles (objects) and energy associated with the relative position of particles (objects).	The NGSS and **AP EK 3.C.2** both describe that chemical reactions can either store energy or release energy. EK 3.C.2 goes beyond the NGSS by using the terms "endothermic" and "exothermic," and by discussing energy diagrams. The NGSS provide the foundation for understanding why these energy changes occur.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.C Chemical and physical transformations may be observed in several ways and typically involve a change in energy.	**3.C.3** Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytic cells.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **HS.PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed. **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**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-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	The NGSS provide a foundation for understanding **AP EK 3.C.3**, by describing transfer and conversion of energy, models of energy at the molecular level, and the effects of electric fields. The specific content of EK 3.C.3 goes beyond the NGSS, including redox reactions, galvanic cells, Gibbs free energy, and Faraday's laws.

Activities for Unit 3:

Calculate the heat required for a phase change of a given mass of substance.
Apply the Clausius-Clapeyron equation.
Calculate vapor pressure and heat of vaporization.
Draw phase diagrams from given information.
Predict relative properties based on intermolecular forces.
Determine the number of atoms in a unit cell.
Calculate atomic mass from unit-cell dimension and density.
Calculate unit cell dimension from unit-cell type and density
Apply Henry's Law.
Perform conversions between the different methods of expressing concentration.
Calculate tvapor pressure lowering.
Calculate boiling point elevation and freezing point depression.
Calculate molecular mass of solute from molality.
Calculate molecular mass from freezing point depression.
Calculate osmotic pressure.
Text Problems
Exercises.
Concept Exploration
Text Online Resource Questions CRSIRM's.

Lab Investigation:
Lab – Determine density of the vapor of a volatile liquid?

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time.	**4.A.1** The rate of a reaction is influenced by the concentration or pressure of reactants, the phase of the reactants and products, and environmental factors such as temperature and solvent.	**HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	**HS-PS1-5** 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. **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 motions of particles (objects) and energy associated with the relative position of particles (objects).	The NGSS and **AP EK 4.A.1** both describe reaction rates and the conditions that influence them. EK 4.A.1 goes beyond the NGSS by describing spectroscopic determination of chemical concentration through Beer's law. The NGSS also provide a foundation for understanding EK 4.A.1 by describing the kinetic energy of particles.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time.	**4.A.3** The magnitude and temperature dependence of the rate of reaction is contained quantitatively in the rate constant.	**HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	**HS-PS1-5** 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. **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 motions of particles (objects) and energy associated with the relative position of particles (objects).	The NGSS provide a foundation for **AP EK 4.A.3** by describing reaction rates and temperature dependence of reaction rates, along with describing the kinetic energy of particles. EK 4.A.3 goes beyond the NGSS with its focus on the rate constant. **EK 4.A.3 part e** is also related to **NGSS HS.PS1.C**.
4.B Elementary reactions are mediated by collisions between molecules. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.	**4.B.2** Not all collisions are successful. To get over the activation energy barrier, the colliding species need sufficient energy. Also, the orientations of the reactant molecules during the collision must allow for the rearrangement of reactant bonds to form product bonds.	**HS.PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**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.	The NGSS provide a foundation for **AP EK 4.B.2** by describing activation energy and collisions of molecules. EK 4.B.2 goes beyond the NGSS by including details of reactant molecule orientation, collision models, and the Maxwell-Boltzmann distribution.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.B Elementary reactions are mediated by collisions between molecules. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.	**4.B.3** A successful collision can be viewed as following a reaction path with an associated energy profile.	**HS.PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	**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-PS1-5** 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. **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	Both the NGSS and **AP EK 4.B.3** describe chemical reactions as collisions that involve breaking and forming bonds, rearranging atoms, and involving energy. Both also describe the reaction rate being affected by temperature. EK 4.B.3 goes beyond the NGSS by describing reaction coordinates and energy profiles, as well as the Arrhenius equation.

Activities for Unit 4:

Determine order from the rate law.
Determine rate law from initial rates.
Use an integrated rate law.
Plot kinetic data to determine a rate law.
Use the Arrhenius Equation.
Write the overall chemical equation from a mechanism.
Determine molecularity of an elementary reaction.
Write the rate equation for an elementary reaction.
Determine rates laws from mechanisms with an initial slow step, fast step, or equilibrium step.
Apply stoichiometry to an equilibrium mixture.
Write equilibrium constant expressions.
Obtain an equilibrium constant from a reaction composition.
Write Kc for a reaction with pure solids and liquids.
Use the reaction quotient.
Obtain one equilibrium concentration given others.
Solve equilibrium problems involving a linear equation or quadratic equation.
Apply Le Chatelier’s Principle.
Identify acid and base species.
Identify acid-base conjugate pairs.
Decide whether reactants or products are favored in an acid-base s in solutions of a strong acid or base.
Calculate concentrations of hydronium ion and hydroxide ion.
Calculate pH from hydronium ion concentration and visa versa.
Determine Ka from solution pH.
Calculate conc’n of species in a weak acid or base sol’n usingKa’s or Kb’s.
Calculate conc’n of species in a sol’n of a polyprotic acid.
Predict whether a salt solution is acid, basic or neutral.
Obtain Ka from Kb or Kb from Ka.
Calculate conc’n of species in a salt sol’n.
Calculate the common-ion effect on acid ionization (the effect of a strong acid, or a conjugate base).
Calculate the pH of a buffer from given volumes of solution.
Calculate the pH of a buffer when a strong acid or base is added.
Calculate the pH at the equivalence point
Text Problems.
Exercises.
Concept Exploration
Text Online Resource Questions CRSIRM’s.
Write solubility product expressions.
Calculate Ksp from solubility and visa versa.

Calculate solubilities in solutions containing common ions.
Predict whether precipitation will occur, given ion concentrations.
Determine the qualitative effect of pH on solubility.
Calculate the concentrations of metal ion-complex ion equilibria.
Predict whether a precipitate will form in the presence of a complex ion.
Calculate the entropy change for a phase transition.
Predict the sign of an entropy change for a reaction.
Calculate ΔS for a reaction.
Calculate ΔG from ΔH and ΔS.
Calculate ΔG from standard free energies of formation.
Interpret the sign of ΔG.
Write the expression for a thermodynamic equilibrium constant.
Calculate K from standard free energy change.
Calculate ΔG and K at various temperatures.
Balance reaction by the half-reaction method (acidic and basic solution)
Sketch and label a voltaic cell.
Write a cell reaction from cell notation and visa versa.
Determine the direction of spontaneity from electrode potentials.
Calculate cell potential from electrode potentials.
Calculate free energy change from electrode potentials.
Calculate cell potential from free energy change.
Calculate the equilibrium constant from cell potential.
Calculate cell potential for nonstandard conditions using Nernst Equation.

Lab Investigations:
Lab – Kinetics
Lab – Keq of FeSCN.
Lab – Standardization of a strong basic solution.
Lab – Determine the molar mass (and therefore the identity) of an unknown weak acid.
Lab – Determine A Solubility Product Constant.
Lab – Spontaneity – Sodium nitrate Solution.
Lab – Electrochemical Cell

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.A Two systems with different temperatures that are in thermal contact will exchange energy. The quantity of thermal energy transferred from one system to another is called heat.	**5.A.1** Temperature is a measure of the average kinetic energy of atoms and molecules.	**MS.PS3.A: Definitions of Energy** Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **MS.PS3.B: Conservation of Energy and Energy Transfer** Energy is spontaneously transferred out of hotter regions or objects and into colder ones. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.	**MS-PS3-3** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* **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 motions of particles (objects) and energy associated with the relative position of particles (objects). **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).	The NGSS and **AP EK 5.A.1** both include that temperature provides a description of the average kinetic energy of particles (atoms and molecules). EK 5.A.1 goes beyond the NGSS by including a description of the Kelvin temperature scale (**part b**) and of the Maxwell-Boltzmann distribution (**part c**).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.A Two systems with different temperatures that are in thermal contact will exchange energy. The quantity of thermal energy transferred from one system to another is called heat.	**5.A.2** The process of kinetic energy transfer at the particulate scale is referred to in this course as heat transfer, and the spontaneous direction of the transfer is always from a hot to a cold body.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.	**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 motions of particles (objects) and energy associated with the relative position of particles (objects). **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).	Both the NGSS and **AP EK 5.A.2** describe energy transfer from one object to another, kinetic energy of particles association with temperature, and the tendency of systems to move toward a uniform energy distribution. **EK 5.A.2 part f** goes beyond the NGSS by describing specific heat capacities.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.B Energy is neither created nor destroyed, but only transformed from one form to another.	**5.B.1** Energy is transferred between systems either through heat transfer or through one system doing work on the other system.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.	**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 motions of particles (objects) and energy associated with the relative position of particles (objects). **HS-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of 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).	Both the NGSS and **AP EK 5.B.1** describe transfer of energy between objects and from one form to another. **EK 5.B.1 part c** goes beyond the NGSS by explicitly describing work done by a gas.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.B Energy is neither created nor destroyed, but only transformed from one form to another.	**5.B.2** When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur though either heat exchange or work.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **HS.PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.	**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-PS3-4** 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).	Both the NGSS and **AP EK 5.B.2** describe the transfer, transformation, and conservation of energy between systems, including the transfer of thermal energy. EK 5.B.2 goes beyond the NGSS by explicitly naming "work."

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.B Energy is neither created nor destroyed, but only transformed from one form to another.	**5.B.3** Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.	**HS.PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. *(continued on next page)*	**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-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-PS3-1** 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 motions of particles (objects) and energy associated with the relative position of particles (objects).	The NGSS and **AP EK 5.B.3** both describe thermal energy transfer between systems and to the surroundings, and chemical reactions that either store or release energy. The NGSS also provide a foundation for understanding phase transitions by describing kinetic energy of particles (**HS.PS3.A**) and by describing properties of different states of matter, in another section not listed here (**MS.PS1.A**). EK 5.B.3 goes beyond the NGSS by describing specific heat capacity, molar enthalpy of vaporization, and enthalpy change of reactions.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	5.B.3 Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system.		
5.B Energy is neither created nor destroyed, but only transformed from one form to another.	**5.B.4** Calorimetry is an experimental technique that is used to determine the heat exchanged/transferred in a chemical system.	**MS.PS3.A: Definitions of Energy** Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **MS.PS3.B: Conservation of Energy and Energy Transfer** The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**MS-PS3-4** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. **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).	The NGSS provide a foundation for **AP EK 5.B.4** by describing transfer of thermal energy, conservation of energy, and the connection between temperature and kinetic energy of particles. EK 5.B.4 goes beyond the NGSS by describing the details of calorimetry.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.C Breaking bonds requires energy, and making bonds releases energy.	**5.C.1** Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them.	**HS.PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	**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-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-PS3-2** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	The NGSS and **AP EK 5.C.1** both describe energy associated with the configuration of particles and electrostatic interactions between them. Both also describe bond energies. **EK 5.C.1 parts a and e** go beyond the NGSS by describing bond length and atomic vibration, and **EK 5.C.1 part d** describes double and triple bonds.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.C Breaking bonds requires energy, and making bonds releases energy.	**5.C.2** The net energy change during a reaction is the sum of the energy required to break the bonds in the reactant molecules and the energy released in forming the bonds of the product molecules. The net change in energy may be positive for endothermic reactions where energy is required, or negative for exothermic reactions where energy is released.	**HS.PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS3.A: Definitions of Energy** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**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-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of 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).	Both the NGSS and **AP EK 5.C.2** describe bonds broken and formed during chemical reactions, potential and kinetic energy of chemical systems, conservation of energy, and thermal equilibrium. EK 5.C.2 goes beyond the NGSS by describing the details of kinetic and potential energy assumptions that can be made about reactants and products in endothermic vs. exothermic reactions (**part d**), by describing parts of Hess's law (**part f**), and by discussing uses of tables of standard enthalpies of formation (**part g**).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.D Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.	**5.D.1** Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.	**HS.PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. *(continued on next page)*	**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-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-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-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 motions of particles (objects) and energy associated with the relative position of particles (objects). **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	The NGSS and **AP EK 5.D.1** both include discussions of potential energy in chemical systems and of electrostatic interactions between atoms or molecules. EK 5.D.1 goes beyond the NGSS by distinguishing dipole-dipole, dipole-induced dipole, and induced dipole-induced dipole interactions (part a); naming dispersion forces (part b); and describing hydrogen bonding (part c).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	5.D.1 Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.	These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.		
5.D Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.	**5.D.2** At the particular scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.	**PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**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-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.	The NGSS and **AP EK 5.D.2** both describe bonds breaking and forming in chemical reactions, and also describe intermolecular interactions in different phases of matter. EK 5.D.2 goes beyond the NGSS by comparing chemical versus physical changes and discussing interactions that could be classified either way (e.g., dissolution of a salt in water).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.D Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.	**5.D.3** Noncovalent and intermolecular interactions play important roles in many biological and polymer systems.	**HS.PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **HS.LS1.C: Organization for Matter and Energy Flow in Organisms** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.	**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-LS1-6** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.	Both the NGSS and **AP EK 5.D.3** describe the effect of the structure of substances on the properties of those substances. The NGSS also provide a foundation for EK 5.D.3 by describing that large carbon-based molecules (including proteins) are formed from smaller molecules, including carbon, hydrogen, and oxygen. EK 5.D.3 goes beyond the NGSS by describing noncovalent interactions and their effect on the shape of molecules (such as enzymes).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
5.E Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both.	**5.E.1** Entropy is a measure of the dispersal of matter and energy.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **HS.PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. Uncontrolled systems always evolve toward more stable states --that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.	**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 motions of particles (objects) and energy associated with the relative position of particles (objects). **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).	The NGSS build a foundation for **AP EK 5.E.1** by describing that uncontrolled systems always evolve toward a more stable and uniform state, and by describing kinetic energy of particles. EK 5.E.1 goes beyond the NGSS by describing Entropy in detail, including predictions of entropy change.

Activities for Unit 5:

Predict relative stability of nuclides.
Predict the type of radioactive decay.
Use the notation for a bombardment reaction.
Calculate half-lives.
Write structural formulas for all compounds being studied.
Name compounds.
Text Problems.
Exercises.
Concept Exploration
Text Online Resource Questions CRSIRM's.

Lab Investigations:
Lab – Molecular modeling of isomers of hexane

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
6.A Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.	**6.A.1** In many classes of reactions, it is important to consider both the forward and reverse reaction.	**HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.	**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.	Both the NGSS and **AP EK 6.A.1** describe reversible reactions. EK 6.A.1 goes beyond the NGSS by describing specific examples of reversible reactions, such as transfer of protons in acid-base reactions and transfer of electrons in redox reactions.
6.A Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.	**6.A.3** When a system is at equilibrium, all macroscopic variables, such as concentrations, partial pressures, and temperature, do not change over time. Equilibrium results from an equality between the rates of the forward and reverse reactions, at which point *Q=K.*	**HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**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-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).	The NGSS and **AP EK 6.A.3** both describe equilibrium in chemical systems, and reversible reactions. EK 6.A.3 goes beyond the NGSS by including more specificity about equilibrium, including describing Q and K.
6.A Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.	**6.A.4** The magnitude of the equilibrium constant, *K*, can be used to determine whether the equilibrium lies toward the reactant side or produce side.	**HS.PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**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-PS1-6** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	The NGSS and **AP EK 6.A.4** both describe equilibrium in chemical systems, reversible reactions, and properties of elements. EK 6.A.4 goes beyond the NGSS by describing the equilibrium constant, *K*, and its use in making predictions about the outcome of chemical reactions.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
6.B Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.	**6.B.1** Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier's principle).	**HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.	**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.	Both the NGSS and **AP EK 6.B.1** describe Le Chatelier's principle. This is explicit in the **HS-PS1-6** clarification statement (not shown). EK 6.B.1 goes beyond the NGSS by specifying stresses that should be used to predict the effect on the system.
6.C Chemical equilibrium plays an important role in acid-base chemistry and in solubility.	**6.C.3** The solubility of a substance can be understood in terms of chemical equilibrium.	**HS.PS1.B: Chemical Reactions** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.	**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.	Both the NGSS and **AP EK 6.C.3** describe Le Chatelier's principle, reversible reactions, and equilibrium. EK 6.C.3 goes beyond the NGSS by discussing details of solubility and free energy change, and listing particular salts that are soluble in water. This concept is also related to **NGSS HS-PS1-3**.

The following standards are threaded throughout all units of the NJSLS-Science:

21st Century Life and Career Standards: Career Awareness, ELD Standards, and Technology Standards.

WIDA ELD Standards: Teaching with Standards | WIDA

WIDA has established language development standards for English and Spanish. These standards represent the language students need to be successful in early childhood programs and Grades K-12.

The first standard, **Social and Instructional Language,** reflects the ways in which students interact socially to build community and establish working relationships with peers and teachers in ways that support learning.

The remaining four standards present ways multilingual learners can communicate information, ideas and concepts necessary for academic success in **Language Arts, Math, Science** and **Social Studies**.

Specifically in Science Standard 4- Language of Science- English Language learners communicate information, ideas and concepts necessary for academic success in the content area of science.

New Jersey Student Learning Standards

Standard 9

21st Century Life and Careers

In today's global economy, students need to be lifelong learners who have the knowledge and skills to adapt to an evolving workplace and world. To address these demands, Standard 9, 21st Century Life and Careers, which includes the 12 Career Ready Practices, establishes clear guidelines for what students need to know and be able to do in order to be successful in their future careers and to achieve financial independence.

Mission: *21st century life and career skills enable students to make informed decisions that prepare them to engage as active citizens in a dynamic global society and to successfully meet the challenges and opportunities of the 21st century global workplace.*

Vision: To integrate 21st Century life and career skills across the K-12 curriculum and to foster a population that:

- Continually self-reflects and seeks to improve the essential life and career practices that lead to success.
- Uses effective communication and collaboration skills and resources to interact with a global society.
- Is financially literate and financially responsible at home and in the broader community.
- Is knowledgeable about careers and can plan, execute, and alter career goals in response to changing societal and economic conditions.
- Seeks to attain skill and content mastery to achieve success in a chosen career path.

Career Ready Practices

Career Ready Practices describe the career-ready skills that all educators in all content areas should seek to develop in their students. They are practices that have been linked to increase college, career, and life success. Career Ready Practices should be taught and reinforced in all career exploration and preparation programs with increasingly higher levels of complexity and expectation as a student advances through a program of study.

CRP1. Act as a responsible and contributing citizen and employee.

Career-ready individuals understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.

CRP2. Apply appropriate academic and technical skills.

Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.

CRP3. Attend to personal health and financial well-being.

Career-ready individuals understand the relationship between personal health, workplace performance and personal well-being; they act on that understanding to regularly practice healthy diet, exercise and mental health activities. Career-ready individuals also take regular action to contribute to their personal financial wellbeing, understanding that personal financial security provides the peace of mind required to contribute more fully to their own career success.

CRP4. Communicate clearly and effectively and with reason.

Career-ready individuals communicate thoughts, ideas, and action plans with clarity, whether using written, verbal, and/or visual methods. They communicate in the workplace with clarity and purpose to make maximum use of their own and others' time. They are excellent writers; they master conventions, word choice, and organization, and use effective tone and presentation skills to articulate ideas. They are skilled at interacting with others; they are active listeners and speak clearly and with purpose. Career-ready individuals think about the audience for their communication and prepare accordingly to ensure the desired outcome.

CRP5. Consider the environmental, social and economic impacts of decisions.

Career-ready individuals understand the interrelated nature of their actions and regularly make decisions that positively impact and/or mitigate negative impact on other people, organization, and the environment. They are aware of and utilize new technologies, understandings, procedures, materials, and regulations affecting the nature of their work as it relates to the impact on the social condition, the environment and the profitability of the organization.

CRP6. Demonstrate creativity and innovation.

Career-ready individuals regularly think of ideas that solve problems in new and different ways, and they contribute those ideas in a useful and productive manner to improve their organization. They can consider unconventional ideas and suggestions as solutions to issues, tasks or problems, and they discern which ideas and suggestions will add greatest value. They seek new methods, practices, and ideas from a variety of sources and seek to apply those ideas to their own workplace. They take action on their ideas and understand how to bring innovation to an organization.

CRP7. Employ valid and reliable research strategies.

Career-ready individuals are discerning in accepting and using new information to make decisions, changes. They use reliable research process to search for new information. They evaluate the validity of sources when considering the use and adoption of external information or practices in their workplace situation.

CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.

Career-ready individuals readily recognize problems in the workplace, understand the nature of the problem, and devise effective plans to solve the problem. They are aware of problems when they occur and take action quickly to address the problem; they thoughtfully investigate the root cause of the problem prior to introducing solutions. They carefully consider the options to solve the problem. Once a solution is agreed upon, they follow through to ensure the problem is solved, whether through their own actions or the actions of others.

CRP9. Model integrity, ethical leadership and effective management.

Career-ready individuals consistently act in ways that align personal and community-held ideals and principles while employing strategies to positively influence others in the workplace. They have a clear understanding of integrity and act on this understanding in every decision. They use a variety of means to positively impact the directions and actions of a team or organization, and they apply insights into human behavior to change others' action, attitudes and/or beliefs. They recognize the near-term and long-term effects that management's actions and attitudes can have on productivity, morals and organizational culture.

CRP10. Plan education and career paths aligned to personal goals.

Career-ready individuals take personal ownership of their own education and career goals, and they regularly act on a plan to attain these goals. They understand their own career interests, preferences, goals, and requirements. They have perspective regarding the pathways available to them and the time, effort, experience and other requirements to pursue each, including a path of entrepreneurship. They recognize the value of each step in the education and experiential process, and they recognize that nearly all career paths require ongoing education and experience. They seek counselors, mentors, and other experts to assist in the planning and execution of career and personal goals.

CRP11. Use technology to enhance productivity.

Career-ready individuals find and maximize the productive value of existing and new technology to accomplish workplace tasks and solve workplace problems. They are flexible and adaptive in acquiring new technology. They are proficient with ubiquitous technology applications. They understand the inherent risks-personal and organizational-of technology applications, and they take actions to prevent or mitigate these risks.

CRP12. Work productively in teams while using cultural global competence.

Career-ready individuals positively contribute to every team, whether formal or informal. They apply an awareness of cultural difference to avoid barriers to productive and positive interaction. They find ways to increase the engagement and contribution of all team members. They plan and facilitate effective team meetings.

2014 New Jersey Core Curriculum Content Standards - Technology

Content Area	**Technology**		
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**		
Strand	**A. Technology Operations and Concepts:** *Students demonstrate a sound understanding of technology concepts, systems and operations.*		
Grade Level bands	**Content Statement Students will:**	**Indicator**	**Indicator**
P	Understand and use technology systems.	8.1.P.A.1	Use an input device to select an item and navigate the screen
		8.1.P.A.2	Navigate the basic functions of a browser.
	Select and use applications effectively and productively.	8.1.P.A.3	Use digital devices to create stories with pictures, numbers, letters and words.
		8.1.P.A.4	Use basic technology terms in the proper context in conversation with peers and teachers (e.g., camera, tablet, Internet, mouse, keyboard, and printer).
		8.1.P.A.5	Demonstrate the ability to access and use resources on a computing device.
K-2	Understand and use technology systems.	8.1.2.A.1	Identify the basic features of a digital device and explain its purpose.
	Select and use applications effectively and productively.	8.1.2.A.2	Create a document using a word processing application.
		8.1.2.A.3	Compare the common uses of at least two different digital applications and identify the advantages and disadvantages of using each.
		8.1.2.A.4	Demonstrate developmentally appropriate navigation skills in virtual environments (i.e. games, museums).
		8.1.2.A.5	Enter information into a spreadsheet and sort the information.
		8.1.2.A.6	Identify the structure and components of a database.
		8.1.2.A.7	Enter information into a database or spreadsheet and filter the information.
3-5	Understand and use technology systems.	8.1.5.A.1	Select and use the appropriate digital tools and resources to accomplish a variety of tasks including solving problems.
	Select and use applications effectively	8.1.5.A.2	Format a document using a word processing application to enhance text

	and productively.		and include graphics, symbols and/ or pictures.
		8.1.5.A.3	Use a graphic organizer to organize information about problem or issue.
		8.1.5.A.4	Graph data using a spreadsheet, analyze and produce a report that explains the analysis of the data.
		8.1.5.A.5	Create and use a database to answer basic questions.
		8.1.5.A.6	Export data from a database into a spreadsheet; analyze and produce a report that explains the analysis of the data.
6-8	Understand and use technology systems.	8.1.8.A.1	Demonstrate knowledge of a real world problem using digital tools.
	Select and use applications effectively and productively.	8.1.8.A.2	Create a document (e.g. newsletter, reports, personalized learning plan, business letters or flyers) using one or more digital applications to be critiqued by professionals for usability.
		8.1.8.A.3	Use and/or develop a simulation that provides an environment to solve a real world problem or theory.
		8.1.8.A.4	Graph and calculate data within a spreadsheet and present a summary of the results
		8.1.8.A.5	Create a database query, sort and create a report and describe the process, and explain the report results.
9-12	Understand and use technology systems.	8.1.12.A.1	Create a personal digital portfolio which reflects personal and academic interests, achievements, and career aspirations by using a variety of digital tools and resources.
	Select and use applications effectively and productively.	8.1.12.A.2	Produce and edit a multi-page digital document for a commercial or professional audience and present it to peers and/or professionals in that related area for review.
		8.1.12.A.3	Collaborate in online courses, learning communities, social networks or virtual worlds to discuss a resolution to a problem or issue.
		8.1.12.A.4	Construct a spreadsheet workbook with multiple worksheets, rename tabs to reflect the data on the worksheet, and use mathematical or logical functions, charts and data from all worksheets to convey the results.
		8.1.12.A.5	Create a report from a relational database consisting of at least two tables and describe the process, and explain the report results.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**B. Creativity and Innovation:** *Students demonstrate creative thinking, construct knowledge and develop innovative products and process using technology.*

Grade Level bands	Content Statement Students will:	Indicator	Indicator
P	Apply existing knowledge to generate new ideas, products, or processes. Create original works as a means of personal or group expression.	8.1.P.B.1	Create a story about a picture taken by the student on a digital camera or mobile device.
K-2		8.1.2.B.1	Illustrate and communicate original ideas and stories using multiple digital tools and resources.
3-5		8.1.5.B.1	Collaborative to produce a digital story about a significant local event or issue based on first-person interviews.
6-8		8.1.8.B.1	Synthesize and publish information about a local or global issue or event (ex. telecollaborative project, blog, school web).
9-12		8.1.12.B.2	Apply previous content knowledge by creating and piloting a digital learning game or tutorial.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**C. Communication and Collaboration:** *Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.*

Grade Level bands	**Content Statement**	**Indicator**	**Indicator**
P	Interact, collaborate, and publish with peers, experts, or others by employing a variety of digital environments and media. Communicate information and ideas to multiple audiences using a variety of media and formats. Develop cultural understanding and global awareness by engaging with learners of other cultures. Contribute to project teams to produce original works or solve problems.	8.1.P.C.1	Collaborate with peers by participating in interactive digital games or activities.
K-2		8.1.2.C.1	Engage in a variety of developmentally appropriate learning activities with students in other classes, schools, or countries using various media formats such as online collaborative tools, and social media.
3-5		8.1.5.C.1	Engage in online discussions with learners of other cultures to investigate a worldwide issue from multiple perspectives and sources, evaluate findings and present possible solutions, using digital tools and online resources for all steps.
6-8		8.1.8.C.1	Collaborate to develop and publish work that provides perspectives on a global problem for discussions with learners from other countries.
9-12		8.1.12.C.1	Develop an innovative solution to a real world problem or issue in collaboration with peers and experts, and present ideas for feedback through social media or in an online community.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**D. Digital Citizenship:** *Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.*

Grade Level bands	**Content Statement**	**Indicator**	**Indicator**
K-2	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.2.D.1	Develop an understanding of ownership of print and nonprint information.
3-5	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.5.D.1	Understand the need for and use of copyrights.
		8.1.5.D.2	Analyze the resource citations in online materials for proper use.
	Demonstrate personal responsibility for lifelong learning.	8.1.5.D.3	Demonstrate an understanding of the need to practice cyber safety, cyber security, and cyber ethics when using technologies and social media.
	Exhibit leadership for digital citizenship.	8.1.5.D.4	Understand digital citizenship and demonstrate an understanding of the personal consequences of inappropriate use of technology and social media.
6-8	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.8.D.1	Understand and model appropriate online behaviors related to cyber safety, cyber bullying, cyber security, and cyber ethics including appropriate use of social media.
	Demonstrate personal responsibility for lifelong learning.	8.1.8.D.2	Demonstrate the application of appropriate citations to digital content.
		8.1.8.D.3	Demonstrate an understanding of fair use and Creative Commons to intellectual property.
	Exhibit leadership for digital citizenship.	8.1.8.D.4	Assess the credibility and accuracy of digital content.
		8.1.8.D.5	Understand appropriate uses for social media and the negative consequences of misuse.
9-12	Advocate and practice safe, legal, and responsible use of information and technology.	8.1.12.D.1	Demonstrate appropriate application of copyright, fair use and/or Creative Commons to an original work.
	Demonstrate personal responsibility for	8.1.12.D.2	Evaluate consequences of unauthorized electronic access (e.g., hacking)

	lifelong learning.		and disclosure, and on dissemination of personal information.
		8.1.12.D.3	Compare and contrast policies on filtering and censorship both locally and globally.
	Exhibit leadership for digital citizenship.	8.1.12.D.4	Research and understand the positive and negative impact of one's digital footprint.
		8.1.12.D.5	Analyze the capabilities and limitations of current and emerging technology resources and assess their potential to address personal, social, lifelong learning, and career needs.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**E: Research and Information Fluency:** *Students apply digital tools to gather, evaluate, and use information.*

Grade Level bands	**Content Statement** **Students will:**	**Indicator**	**Indicator**
P	Plan strategies to guide inquiry.	8.1.P.E.1	Use the Internet to explore and investigate questions with a teacher's support.
K-2	Plan strategies to guide inquiry Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks.	8.1.2.E.1	Use digital tools and online resources to explore a problem or issue.
3-5	Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the	8.1.5.E.1	Use digital tools to research and evaluate the accuracy of, relevance to, and appropriateness of using print and non-print electronic information sources to complete a variety of tasks.

	appropriateness for specific tasks.		
6-8	Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks. Process data and report results.	8.1.8.E.1	Effectively use a variety of search tools and filters in professional public databases to find information to solve a real world problem.
9-12	Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks. Process data and report results.	8.1.12.E.1	Produce a position statement about a real world problem by developing a systematic plan of investigation with peers and experts synthesizing information from multiple sources.
		8.1.12.E.2	Research and evaluate the impact on society of the unethical use of digital tools and present your research to peers.

Content Area	**Technology**
Standard	**8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.**
Strand	**F: Critical thinking, problem solving, and decision making:** *Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.*

Grade Level bands	**Content Statement Students will:**	**Indicator**	**Indicator**
K-2	Identify and define authentic problems and significant questions for	8.1.2.F.1	Use geographic mapping tools to plan and solve problems.

	investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.		
3-5	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions	8.1.5.F.1	Apply digital tools to collect, organize, and analyze data that support a scientific finding.
6-8	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.	8.1.8.F.1	Explore a local issue, by using digital tools to collect and analyze data to identify a solution and make an informed decision.

9-12	Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.	8.1.12.F.1	Evaluate the strengths and limitations of emerging technologies and their impact on educational, career, personal and or social needs.