PLANNED INSTRUCTION

A PLANNED COURSE FOR:

Advanced Placement Chemistry

Grade Level: 11 and 12

Date of Board Approval: _____2018________

Planned Instruction

Title of Planned Instruction: Advanced Placement Chemistry

Subject Area: Science **Grade(s):** 11 and 12

Course Description:
Advanced Placement Chemistry presents the topics covered in a first-year college chemistry course for science majors. The topics include structure of matter, states of matter, reaction types, stoichiometry, equilibrium, kinetics and thermodynamics. Laboratory applications and written lab reports, as well as, experiments designed by students are included in the curriculum. Students are expected to do a substantial amount of independent work and approximately 5 hours of work outside of class each week.

Time/Credit for the Course: 1 Full year, 144 hours, 1 science credit

Curriculum Writing Committee: Marisa Avery, College Board AP Chemistry Curriculum Framework from which this curriculum has been adapted, Amanda Pope, Brian Blaum

Curriculum Map

Marking Period One -Overview with time range in days: 45 days
This unit reviews topics from Honors Chemistry and Chemistry considering elements as the fundamental building blocks of matter. It expands the understanding that all matter can be understood in terms of rearrangement of atoms and that atoms retain their identity in chemical reactions from the first-year courses. Topics in this unit connect and explain the structure and arrangement of atoms, ions or molecules and the forces between them to chemical and physical properties of materials.

Marking Period One - Goals:
Understanding of:

- Molecules are composed of specific combinations of atoms.
- Different molecules are composed of combinations of different atoms or different ratios of the same atoms
- Chemical analysis can provide information about the composition and identity of a substance
- The mole is the fundamental unit for counting particles on the macroscopic level
- The mole draws quantitative connections between macroscopic chemical processes and the atomic level
- Coulomb 's Law is useful in explaining and understanding the structure of the atom
- The electronic structure of an atom can be described by an electron diagram or configuration that represents the energy levels and sub –levels
- Properties of atoms exhibit periodic trends that are reflective of electronic structure
- The currently accepted model of the atom is the quantum mechanical model
- The model of the atom is subject to change based on new experimental data
- Data now contradicts earlier models of that atom that indicated all atoms of an element were the same
- Light is a means to probe structure of atoms and molecules and to measure their concentration
- Physical and chemical process can be represented symbolically conserving all atoms
- The conservation of atoms allows the computation of masses involved in physical and chemical changes
- Chemical processes result in new substances

- The amount of new substances depends on the number and type of atoms and the efficiency of the process
- Properties of solids and liquids can be explained by differences in structure
- Gases can be modeled by a mathematical equation relating their properties
- Minimal attractive forces leave gases without a definite volume or shape
- Solutions are homogenous mixtures in which the properties depend on the concentration of the solute and the attractive forces
- All atoms and molecules have London dispersion forces
- London dispersion forces are often the strongest intermolecular force in large molecules
- Dipole forces are the attraction between positive and negative ends of polar molecules
- Hydrogen bonds are a strong type of dipole-dipole interactions
- Intermolecular forces determine the properties of biological structures
- Covalent bonding is the sharing of electrons between the nuclei of two atoms to form molecules or polyatomic ions
- Electronegativity difference account for the polarity of a covalent bond
- Ionic bonding is an attraction between oppositely charged ions in a closely packer crystal lattice
- Metallic bonding is a lattice of positive charge surrounded by a sea of mobile electrons
- Lewis structures and VSEPR model predict molecular geometry
- Ionic solids have high melting points are brittle and conduct electricity only when molten or in solution
- Metallic solids are good conductors of heat and electricity, have a wide range of melting points, are shiny, malleable, ductile and readily alloyed
- Covalent network solids have very high melting points, are hard, thermal insulators and some conduct electricity
- Molecular solids have low molecular weights and low melting points and do not conduct electricity in any state

Marking Period Two -Overview with time range in days: 45 days

This unit develops the details of how changes in matter involve the rearrangement of atoms or the transfer of electrons. It also details how the rate of changes in matter is determined by the specifics of molecular collisions.

Marking Period Two - Goals:

Understanding of:

- A chemical change may be represented by a molecular, ionic or net ionic equation
- Stoichiometric calculations using mole ratios from balanced chemical equations provide quantitative information in text book examples and real-world applications
- In synthesis reactions atoms and/or molecules combine to form new compounds
- Decomposition reactions are the reverse of synthesis usually by heating
- In a neutralization reaction, protons are transferred from an acid to a base
  In an oxidation-reduction reaction, electrons are transferred
- Production of heat or light, gas or precipitate formation, or a color change can indicate a chemical reaction
- Changes in energy for a chemical reaction can be endothermic or exothermic
- Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytical cells
- Reaction rate is dependent on concentration, partial pressure, phase, temperature and solvents
- Rate law relates reactant concentration to reaction rate
- Rate constant quantifies the magnitude and temperature dependency of the rate of reaction
- Elementary reactions can be unimolecular or contain more two collisions
- Insufficient activation energy results in an ineffective collision
- Improper orientation during a collision results in an ineffective collision
- A successful collision can associate a reaction path with an energy profile
- A series of elementary reactions leading to an overall reaction is the reaction mechanism
- The rate determining step is the elementary reaction that is the slowest and often sets the overall reaction rate
- Reaction intermediates are formed during the reaction are important in a reaction mechanism
- Catalyst lower the activation energy of an elementary step and provide a new and faster reaction pathway
- Classes of catalysts include acid-base catalyst, surface catalyst and enzyme

Marking Period Three -Overview with time range in days: 45 days
In this unit, students will study basic and advanced concepts in thermodynamics that explain the essential role of energy in chemical and physical change and use the principles of thermodynamics to predict the direction of changes in matter.

Marking Period Three - Goals
Understanding of:

- Temperature is the average kinetic energy of atoms and molecules
- kinetic energy transfer is heat transfer
- Heat is always transferred from a hot to a cold body
- Energy transfer between systems is heat transfer or work
- Two system exchange energy the energy is conserved
- There are three main processes that change the energy of chemical systems heating/cooling, phase transitions and chemical reactions
- Calorimetry is an experimental technique used to measure the change in heat energy of a chemical system
- Potential energy is associated with the geometric of the molecules and the electrostatic interactions between them
- The net energy change during a reaction is the sum of the bond breaking and the bond forming energies
- Bond breaking is always endothermic
- Bond forming is always exothermic
- The net energy change of a chemical reaction may be positive or negative
- Potential energy is associated with the attractive forces and the distance between molecules
- Chemical process can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular attractions
- Noncovalent and intermolecular interactions are important in biological and polymer systems
- Entropy is a measure of the dispersal of matter and energy
- Thermodynamically favored process involve both an increase in entropy and a decrease in energy
- The Gibb's free energy can be used to determine thermodynamic favorability in process that are not favored by both an increase in entropy and a decrease in energy
- Positive values for Gibb's free energy can be overcome by outside energy sources
- Kinetic restraints may limit thermodynamically favored process

Marking Period Four –Overview with time range in days: 45 days

Principles and concepts of chemical equilibrium are introduced. Students will learn to collect and analyze data from equilibrium system. Students will model equilibrium systems at the atomic level using particle representations and represent these systems mathematically and graphically.

Marking Period Four - Goals:

Understanding of:

- Many classes of reactions have both forward and reverse reactions
- The current state of a reversible reaction can be characterized by the amount of reactants that have become products
- The reaction quotient is the ratio of products to reactants
- When a system is at equilibrium macroscopic variables do not change over time
- Equilibrium results when the rate of the forward reaction equals the rate of the reverse reaction
- The equilibrium constant can be used to determine the if the equilibrium favors reactants or products
- Equilibrium systems respond to changes by partially countering the effect of the change
- A change to an equilibrium system cause the reaction quotient to differ from the equilibrium constant
- Equilibrium systems respond to change by bringing the reaction quotient to equal the equilibrium constant
- Principles of chemical equilibrium can be applied to acid-base chemistry
- The pH can be controlled by buffers
- Comparing pH to pKa can determine the extent of labile hydrogen ions in a conjugate acid-base pair
- Solubility can be understood as a chemical equilibrium
- When the difference in Gibb's free energy is larger than the thermal energy in a chemical reaction, the equilibrium constant is extreme
- When the difference in Gibb's free energy is comparable to the thermal energy, the equilibrium constant is near 1.

Curriculum Plan

<u>Unit:</u> Atoms, Elements, Structure, and Properties of Matter **<u>Time Range in Days:</u>** 45 days

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

Essential Questions:

- How many different types of atoms exist?
- How does the interaction between electrons and nuclei explain the unique structure of each element?
- How does the regular variation in the electronic structure of atoms explain periodicity, a useful principal for understanding properties and predicting trends in elements arranged by increasing atomic number?
- Why are atomic models constructed to explain experimental data?
- How are atoms conserved in chemical and physical processes? **Concepts:**
- Molecules are composed of specific combinations of atoms.
- Different molecules are composed of combinations of different atoms or different ratios of the same atoms
- Chemical analysis can provide information about the composition and identity of a substance
- The mole is the fundamental unit for counting particles on the macroscopic level
- The mole draws quantitative connections between macroscopic chemical processes and the atomic level
- Coulomb 's Law is useful in explaining and understanding the structure of the atom
- The electronic structure of an atom can be described by an electron diagram or configuration that represents the energy levels and sub –levels
- Properties of atoms exhibit periodic trends that are reflective of electronic structure
- The currently accepted model of the atom is the quantum mechanical model
- The model of the atom is subject to change based on new experimental data
- Data now contradicts earlier models of that atom that indicated all atoms of an element were the same
- Light is a means to probe structure of atoms and molecules and to measure their concentration

- Physical and chemical process can be represented symbolically conserving all atoms
- The conservation of atoms allows the computation of masses involved in physical and chemical changes
- Chemical processes result in new substances
- The amount of new substances depends on the number and type of atoms and the efficiency of the process

Competencies:

- Justify that the ratio of the masses of the elements in a pure substance is always identical on the basis of atomic molecular theory
- Select and apply mathematical routines to mass data to infer composition of element, compound or mixture
- Analyze mathematical data to justify a claim regarding the identity or purity of a substance
- Synthesize qualitatively and quantitatively number of particles, moles, mass and volume of substances to one another
- Explain the distribution of electrons in an atom or ion based on data
- Analyze data relating to electron energies for patterns and relationships
- Infer from PES data the electron structure of the atom
- Analyze the variation of electron energies within a shell using Coulomb's Law
- Predict trends in atomic properties based on location in the periodic table
- Justify with evidence the arrangement of the periodic table
- Apply periodic properties to chemical reactivity
- Analyze data to predict molecular design of compounds for which data are not supplied
- Analyze the need to refine the classic atomic model to the quantum mechanical model from a comparison of data
- Analyze data of a particular atomic model to determine if the model is consistent with specified evidence
- Analyze data from the mass spectrometer to identify element and masses
- Justify the selection of a specific type of spectrophotometer
- Design or interpret the results of an experiment to determine the concentration of an absorbing species
- Demonstrate the law of conservation of mass qualitatively and quantitatively using symbolic and particulate drawings
- Apply conservation to the rearrangement of atoms
- Design and/or interpret gravimetric analysis data to determine concentration of a species in solution

- Design and/or interpret titration data to determine concentration of a species in solution

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

Essential Questions:

- How can matter be described by physical properties?
- How do physical properties depend on spacing between particles and forces of attraction among them?
- How can change of state by temperature be explained by forces of attraction among particles?
- How can strong electrostatic attractions explain chemical bonds?
- How can the type of bonding in the solid state be deduced from the physical properties?

Concepts:

- Properties of solids and liquids can be explained by differences in structure
- Gases can be modeled by a mathematical equation relating their properties
- Minimal attractive forces leave gases without a definite volume or shape
- Solutions are homogenous mixtures in which the properties depend on the concentration of the solute and the attractive forces
- All atoms and molecules have London dispersion forces
- London dispersion forces are often the strongest intermolecular force in large molecules
- Dipole forces are the attraction between positive and negative ends of polar molecules
- Hydrogen bonds are a strong type of dipole-dipole interactions
- Intermolecular forces determine the properties of biological structures
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- Electronegativity difference account for the polarity of a covalent bond
- Ionic bonding is an attraction between oppositely charged ions in a closely packer crystal lattice
- Metallic bonding is a lattice of positive charge surrounded by a sea of mobile electrons
- Lewis structures and VSEPR model predict molecular geometry
- Ionic solids have high melting points are brittle and conduct electricity only when molten or in solution

- Metallic solids are good conductors of heat and electricity, have a wide range of melting points, are shiny, malleable, ductile and readily alloyed
- Covalent network solids have very high melting points, are hard, thermal insulators and some conduct electricity
- Molecular solids have low molecular weights and low melting points and do not conduct electricity in any state

Competencies:

- Predict properties of substances based on chemical formulas
- Explain properties of substances based on particle view
- Infer the relative strength of acids and bases based on molecular structure and intermolecular forces
- Interpret observed differences among phases and materials using the particulate model
- Predict properties of ideal and non-gases using Kinetic Molecular Theory and intermolecular attractive forces
- Using multiple representations of gases predict the effect of changes in properties on the gas
- Apply mathematical relationships to determine variables for ideal gases
- Interpret the results chromatography using intermolecular interactions
- Create or interpret representations of solutions showing the interactions between solute and solvent
- Create or interpret representations that link the concept of molarity with particle view
- Design or interrupt the results of a separation experiment using the strength of interactions of the components
- Predict or explain the properties of sample with the London dispersion force as the primary interaction
- Interpret real gas data to determine deviation from ideal based on intermolecular forces
- Synthesize the theory of molecular structure and forces of attraction
- Interpret the interactions of ions and the attraction of ions to solvents as factors that contribute to solubility using Coulomb's Law
- Interpret particle view observations of solubility as intermolecular interactions and entropic effects
- Interpret properties of molecular compounds in terms of types and strengths of intermolecular forces
- Predict bonding type in binary compounds by the position in the periodic table and the electronegativity of the elements

- Justify and rank bond polarity on the basis of location in the periodic table
- Create visual representations of ionic substances
- Connect the microscopic structures of a visual representation to macroscopic properties such as boiling point, hardness, low volatility or conductivity.
- Connect metal bonding model to properties of metals
- Predict geometry of molecules, hybridization and molecular polarity from Lewis diagrams and VSEPR theory
- Design or evaluate a plan to collect data needed to deduce the bonding type of a sample solid
- Create a representation of an ionic solid that includes structure and interactions of the substance
- Connect representation of an ionic structure to structure and interactions present at the atomic level
- Evaluate the properties of metals and metal alloys to determine if an alloy has formed and identify the type of alloy
- Create particulate level views that illustrate the differences in the properties of metals and metal alloys
- Predict the properties of metals using the electron sea model of metallic bonding
- Create a representation of a metallic solid that illustrates the structure and interactions of the metal
- Connect the properties of a metallic solid to atomic level structure and interactions
- Create a representation of a covalent solid that illustrates the structure and interactions present in the substance
- Connect a representation of a covalent solid to atomic level structure and interactions
- Create a representation of a molecular solid that illustrates the structure and interactions present in the substance
- Connect a representation of a molecular solid to atomic level structure and interactions

Standard(s): PA Core State Standards for Mathematics, PA Academic Standards, PA Core State Standards for English Language Arts & Literacy in Science and Technical Subjects, Academic Standards for Science and Technology and Engineering Education

Standards Addressed: (See Appendix for Description)

N-Q1, N-Q2, N-Q3, N-VM1, A-SSE1, A-SSE2, A-APR1, A-APR2, A-APR6, A-CED1, A-CED2, A-CED4, A-REI1, A-REI3, A-REI10, A-REI11, F-IF1, F-IF4, F-IF5, F-BF1a, F-LE1, F-LE2, F-LE3, F-LE5 G-GMD3, G-GMD4, G-MG1, G-MG2, G-MG3, S-ID1, S-ID2, S-ID3, S-ID4, S-ID5a,b,c, S-ID7, S-ID8, S-ID9, S-IC2, S-IC3, S-IC6, S8.A.1.1.4, S8.A.1.3.1, S8.A.1.3.2, S8.A.1.3.3, S8.A.2.1.4, S8.A.2.1.5, S8.A.2.2.1, S8.A.3.1.2, S8.A.3.1.2, S8.C.2.1.2, S8.C.2.1.3, S8.C.3.1.1, S8.C.3.1.2, S11.A.1.3.1, S11.A.2.1.3, S11.A.2.1.5, S11.A.2.2.1, S11.A.3.1.2, S11.A.3.2.1, S11.A.3.2.3, S11.A.3.3.3, S11.C.1.1.1, S11.C.1.1.3, S11.C.2.1.1, RST.1, RST.2, RST.3, RST.4, RST.5, RST.6, RST.7 , WHST.1, WHST.2, WHST.4, WHST.5, 3.2.C.A1, 3.2.C.A2, 3.2.C.A4, 3.2.C.A5, 3.2.12.A5

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Focus Question(s):

- How many different types of atoms exist?
- How does the interaction between electrons and nuclei explain the unique structure of each element?
- How does the regular variation in the electronic structure of atoms explain periodicity, a useful principal for understanding properties and predicting trends in elements arranged by increasing atomic number?
- Why are atomic models constructed to explain experimental data?
- How are atoms conserved in chemical and physical processes?
- How can matter be described by physical properties?
- How do physical properties depend on spacing between particles and forces of attraction among them?
- How can change of state by temperature be explained by forces of attraction among particles?
- How can strong electrostatic attractions explain chemical bonds?
- How can the type of bonding in the solid state be deduced from the physical properties?

Goals: Students will be able to

- Identify and classify different types of sub-atomic particles
- Predict properties and trends among elements using variation in atomic structure

- Prove that atoms are conserved in physical and chemical processes
- Connect physical states to spacing between particles and intermolecular forces and temperature
- Infer type of bonding in solids from physical properties
- Design experiments to measure physical properties
- Create models that accurately reflect the underlying molecular geometry for molecular and polyatomic species and the arrangement of atoms in ionic, covalent network and metal substances
- Predict the effect of changes on the properties of gases

Objectives:

- Justify that the ratio of the masses of the elements in a pure substance is always identical on the basis of atomic molecular theory (DOK-level 3)
- Select and apply mathematical routines to mass data to infer composition of element, compound or mixture (DOK-level 2)
- Analyze mathematical data to justify a claim regarding the identity or purity of a substance (DOK-level 3)
- Synthesize qualitatively and quantitatively number of particles, moles, mass and volume of substances to one another (DOK-level 4)
- Explain the distribution of electrons in an atom or ion based on data (DOK-level 2)
- Analyze data relating to electron energies for patterns and relationships (DOK-level 3)
- Infer from PES data the electron structure of the atom (DOK-level 3)
- Analyze the variation of electron energies within a shell using Coulomb's Law (DOK-level 4)
- Predict trends in atomic properties based on location in the periodic table (DOK-level 3)
- Justify with evidence the arrangement of the periodic table (DOK-level 3)
- Apply periodic properties to chemical reactivity (DOK-level 2)
- Analyze data to predict molecular design of compounds for which data are not supplied (DOK-level 4)
- Analyze the need to refine the classic atomic model to the quantum mechanical model from a comparison of data (DOK-level 4)
- Analyze data of a particular atomic model to determine if the model is consistent with specified evidence (DOK-level 4)
- Analyze data from the mass spectrometer to identify element and masses (DOK-level 4)

- Justify the selection of a specific type of spectrophotometer (DOK-level 3)
- Design or interpret the results of an experiment to determine the concentration of an absorbing species (DOK-level 4)
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- Interpret real gas data to determine deviation from ideal based on intermolecular forces (DOK-level 3)
- Synthesize the theory of molecular structure and forces of attraction (DOK-level 4)
- Interpret the interactions of ions and the attraction of ions to solvents as factors that contribute to solubility using Coulomb’s Law (DOK-level 3)

- Interpret particle view observations of solubility as intermolecular interactions and entropic effects (DOK-level 3)
- Interpret properties of molecular compounds in terms of types and strengths of intermolecular forces (DOK-level 3)
- Predict bonding type in binary compounds by the position in the periodic table and the electronegativity of the elements (DOK-level 3)
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- Connect representation of an ionic structure to structure and interactions present at the atomic level (DOK-level 4)
- Evaluate the properties of metals and metal alloys to determine if an alloy has formed and identify the type of alloy (DOK-level 3)
- Create particulate level views that illustrate the differences in the properties of metals and metal alloys (DOK-level 4)
- Predict the properties of metals using the electron sea model of metallic bonding (DOK-level 3)
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- Create a representation of a molecular solid that illustrates the structure and interactions present in the substance (DOK-level 4)
- Connect a representation of a molecular solid to atomic level structure and interactions (DOK-level 4)

Core Activities and Corresponding Instructional Methods:

- Integrate academic and content specific vocabulary
- Direct instruction and practice on sub-atomic particles, electron diagrams and periodic trends, identify components of bonding and molecular geometry, analysis of intermolecular forces as related to physical properties.
- Lead a classroom discussion that prompts students to compare and contrast various methods utilized in obtaining solutions
- Guided practice: Include step-by-step written explanation of solutions to open-ended questions
- Build background knowledge by having students engage in various types of laboratory experiments including open-ended and inquiry
- Graphing utility (LoggerPro and Microsoft Excel)
- Analyze examples of applications of concepts
- Classroom discussion and guided practice on building models from analyzing data in a real-world situation (i.e. physical properties, molecular geometries and electrostatic forces)
- Develop both a verbal and/or written logical argument to support conclusions about behaviors of graphs and expected results of bonding relationships

Assessments:

Diagnostic: Quizzes and homework

Formative:

- Teacher observation and questioning
- Homework preparation
  Graded homework
  Practice using previous AP exam questions
- Quizzes
- Chapter Tests
- Lab reports
- Practice inquiry labs and experimental design

Summative:

- Final Assessment for Unit 1
- Cumulative Final Assessments
- Advanced Placement Practice Exam from the College Board

Extensions:

- Rigorous worksheets in chemistry
- Rigorous practice programs
- Textbook applications and extensions

- Students can design their own physical property experiments on a substance of their choice.
- Students can design their own gravimetric analysis experiment from acceptable substances researched by students
- Additional exercises in Chemistry, pp 76-80 questions 2.11-2.86; pp 249-252 questions 6.13-6.80; pp289-292 questions 7.17-7.82; pp 330-333 questions 8.15-8.76; pp 385-388 questions 9.13-9.68; pp 426-430 questions 10.13-10.96; pp 464-468 questions 11.9-11.72;

Correctives:

- Remediation practice worksheets
- More extensive direct instruction
- Re-teaching with Practice Problems recommended by AP.
- Review exercises in Chemistry, p80-81 questions 2.87-2.114; p 253-254 questions 6.81-6.104; pp 294-295 questions 7.79-7.101; pp 334 questions 8.77-8.91; pp 389-390 questions 9.85-9.102; pp430-431 questions 10.97-10.113; pp 468-469 questions 11.73-11.80;

Materials and Resources

- Chemistry textbook
- Chemistry Laboratory Manuel
- Inquiry method labs from AP Central
- Vernier LoggerPro
- Microsoft Office Suite
- DERIVE
- Minitab 12
- SMART notebook
- Smartboard
- Edmodo web site
- Practice worksheets
- Graphing calculator
- Laptop computers
- Digital balances
- Rulers
- Syringes
- Graduated cylinders
- Assorted metals
- Water
- Ethyl alcohol
- Thermometers or temperature probes
- Beakers
- Hot plates
- Stearic or benzoic acid

- Molecular model kits and/or software
- Bunsen burners
- Test tubes
- Ring stand
- Test tube clamps
- Gas collecting bottles
- Watch glasses
- Troughs
- Rubber tubing
- Large glass cylinders
- Copper wire
- Copper(II) sulfate
- Potassium chlorate
- Magnesium metal
- Hydrochloric acid

<u>Unit:</u> Chemical Reactions and Electrochemistry **<u>Time Range in Days:</u>** 45 days

Big Idea #1: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.

Essential Questions:

- How are chemical represented by balanced chemical equations?
- How are chemical reactions classified?
- What are ways that chemical and physical transformation can be observed?
- What are the typical ways that a change in energy is observed in a chemical or chemical transformation?

Concepts:

- A chemical change may be represented by a molecular, ionic or net ionic equation
- Stoichiometric calculations using mole ratios from balanced chemical equations provide quantitative information in text book examples and real-world applications
- In synthesis reactions atoms and/or molecules combine to form new compounds
- Decomposition reactions are the reverse of synthesis usually by heating
- In a neutralization reaction, protons are transferred from an acid to a base
- In an oxidation-reduction reaction, electrons are transferred
- Production of heat or light, gas or precipitate formation, or a color change can indicate a chemical reaction
- Changes in energy for a chemical reaction can be endothermic or exothermic
- Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytical cells

Competencies:

- Translate among observations of change chemical equations and particle view
- Convert an observed chemical change into a balanced chemical equation
- Justify a choice of equation type in terms of the given circumstances
- Predict the results of performing a reaction in the laboratory
- Analyze the deviations of actual experiments from the expected results
- Design a plan to collect data from a synthesis or decomposition reaction
- Design a plan to confirm the law of conservation of matter in the laboratory
- Design a plan to confirm the law of definite proportions in the laboratory
- Confirm from synthesis or decomposition data collected in the laboratory the law of conservation of matter
- Confirm from synthesis or decomposition data collected in the laboratory the law of definite proportions
- Justify compounds as Bronstead-Lowry acids, bases, and/pr conjugate acid-base pairs using proton transfer reactions

- Justify the identification of redox reactions in terms of electron transfer
- Design an experiment in the laboratory involving a redox reaction
- Interpret the results of an experiment involving a redox reaction
- Evaluate the classification of a process as physical, chemical or ambiguous change based on observation
- Distinguish between rearrangement of covalent interactions and noncovalent interactions
- Interpret observations of energy changes in a reaction or process into a balanced chemical equation
- Interpret observations of energy changes in a reaction or process as a graphical representation
- Predict qualitative or quantitative change in a galvanic or electrolytic cell based on half-cell reactions or Faraday's Law
- Analyze data from galvanic or electrolytic reactions in the laboratory
- Interpret from data underlying redox reaction in galvanic and electrolytic cells

Big Idea # 2: Rates of chemical reactions are determined by details of molecular collisions

Essential Questions:

- How are reactions rate dependent on temperature and environmental changes measured?
- What mediates elementary reactions?
- Which molecular collisions lead to products in a chemical reaction?
- How do elementary reactions produce a chemical reaction?
- How does a series of elementary reactions produce a reaction rate?
- How does a catalyst increase the reaction rate? **Concepts:**
- Reaction rate is dependent on concentration, partial pressure, phase, temperature and solvents
- Rate law relates reactant concentration to reaction rate
- Rate constant quantifies the magnitude and temperature dependency of the rate of reaction
- Elementary reactions can be unimolecular or contain more two collisions
- Insufficient activation energy results in an ineffective collision
- Improper orientation during a collision results in an ineffective collision
- A successful collision can associate a reaction path with an energy profile
- A series of elementary reactions leading to an overall reaction is the reaction mechanism
- The rate determining step is the elementary reaction that is the slowest and often sets the overall reaction rate
- Reaction intermediates are formed during the reaction are important in a reaction mechanism
- Catalyst lower the activation energy of an elementary step and provide a new and faster reaction pathway

- Classes of catalysts include acid-base catalyst, surface catalyst and enzyme

Competencies:

- Design an experiment measuring the effect of temperature, concentration and surface area on reaction rate
- Interpret the results of a laboratory experiment that measures the effect of changes in concentration, temperature and surface area on reaction rate
- Analyze concentration versus time data to determine the rate law for a zeroth-, first-, or second-order reaction
- Connect radioactive half-life data to first-order rate qualitatively and quantitatively
- Justify a first-order kinetics from half-life data
- Connect the elementary reaction mechanism to the order and rate constant of an individual reacting species
- Justify the success of collisions that produce product in terms of the energy distribution and molecular orientation
- Predict qualitatively the temperature dependence of a reaction rate from energy profile of elementary reactions
- Interpret reaction mechanisms for consistency with rate data
- Infer from a reaction mechanism the presence of a reaction intermediate
- Translate among energy profile, particulate, symbolic representations of a chemical reaction occurring with and without a catalyst
- Interpret changes in reaction rate as the results of an acid-base, surface or enzyme catalyst
- Justify the selection of an appropriate mechanism based on type of catalyst or lack of a catalyst

Standard(s): PA Core State Standards for Mathematics, PA Academic Standards, PA Core State Standards for English Language Arts & Literacy in Science and Technical Subjects

Standards Addressed: (See Appendix for Description)

N-RN1 , N-Q1 , N-VM6 , A-SSE1 , A-SSE3a,b,c , A-CED1 , A-CED2 , A-CED4 , A-REI1 , A-REI2 , A-REI5 , A-REI10 , A-REI11 , F-IF1 , F-IF4 , F-IF5 , F-IF6 , F-IF7a,e , F-IF8b, F-BF1a,b,c , F-BF3 , F-BF5 , F-LE1a,b,c , F-LE2 , F-LE3 , F-LE4 , F-LE5, S-ID61, S-IC6 , S-ID2 , S-ID3 , S-ID6a,b,c , S-ID7, S8.A.1.1.4 , S8.A.1.3.1 , S8.A.1.3.2 , S8.A.1.3.3 , S8.A.2.1.4 , S8.A.2.1.5 , S8.A.2.2.1 , S8.A.3.1.2 , S8.A.3.1.2 , S8.C.2.1.2 , S8.C.2.1.3 , S8.C.3.1.1 , S8.C.3.1.2 , S11.A.2.1.2 , S11.A.2.1.3 , S11.A.2.1.5 , S11.A.2.2.1 , S11.A.3.1.1, S11.A.3.1.2 , S11.A.3.1.3 , S11.A.3.2.1 , S11.A.3.2.3 , RST.1 , RST.2 , RST.3 , RST.4 , RST.5 , RST.6, RST.7, WHST.1, WHST.2, WHST.4, WHST.5, 3.2.C.A1, 3.2.C.A2, 3.2.C.A3, 3.2.C.A 6

Overview: This unit develops the details of how changes in matter involve the rearrangement of atoms or the transfer of electrons. It also details how the rate of changes in matter is determined by the specifics of molecular collisions.

Focus Question(s):

- How are chemical represented by balanced chemical equations?
- How are chemical reactions classified?
- What are ways that chemical and physical transformation can be observed?
- What are the typical ways that a change in energy is observed in a chemical or chemical transformation? How are reactions rates that depend on temperature and environmental changes measured?
- What mediates elementary reactions?
- Which molecular collisions lead to products in a chemical reaction?
- How do elementary reactions produce a chemical reaction?
- How does a series of elementary reactions produce a reaction rate?
- How does a catalyst increase the reaction rate?

Goals: Students will be able to

- Represent a chemical change by a molecular, ionic or net ionic equation
- Provide quantitative information from stoichiometric calculations
- Write chemical equations for synthesis reactions
- Write chemical equations for decomposition reactions
- Write chemical equations for proton transfer in neutralization reactions
- Write equations for electron transfer in oxidation reduction reactions
- Recognize that the production of heat or light, gas, or precipitate formation or a color change can indicate a chemical change
- Recognize from a variety of inputs when a reaction is endothermic or exothermic
- Interpret the interconversion between chemical and electrical energy in galvanic and electrolytic cells
- Reason about situations as reaction rate is dependent on concentration, partial pressure, phase, temperature and solvents
- Formulate rate laws relating reactant concentration to reaction rate
- Quantify the rate constant as the magnitude and temperature dependency of the rate of reaction
- Write elementary reactions unimolecular or contain two or more collisions
- Recognize successful and unsuccessful collisions and their causes
- Build a series of elementary reactions into an overall reaction mechanism
- Identify rate determining step is the elementary reaction that is the slowest and often sets the overall reaction rate
- Reaction intermediates are formed during the reaction are important in a reaction mechanism

- Solve problems and create graphs when catalyst lower the activation energy of an elementary step and provide a new and faster reaction pathway
- Recognize the various classes of catalysts

Objectives:

- Translate among observations of change chemical equations and particle view (DOK-level 3)
- Convert an observed chemical change into a balanced chemical equation (DOK-level 3)
- Justify a choice of equation type in terms of the given circumstances (DOK-level 4)
- Predict the results of performing a reaction in the laboratory (DOK-level 3)
- Analyze the deviations of actual experiments from the expected results (DOK-level 4)
- Design a plan to collect data from a synthesis or decomposition reaction (DOK-level 4)
- Design a plan to confirm the law of conservation of matter in the laboratory (DOK-level 4)
- Design a plan to confirm the law of definite proportions in the laboratory (DOK-level 4)
- Confirm from synthesis or decomposition data collected in the laboratory the law of conservation of matter (DOK-level 4)
- Confirm from synthesis or decomposition data collected in the laboratory the law of definite proportions (DOK-level 4)
- Justify compounds as Bronsted-Lowry acids, bases, and/or conjugate acid-base pairs using proton transfer reactions (DOK-level 3)
- Justify the identification of redox reactions in terms of electron transfer (DOK-level 3)
- Design an experiment in the laboratory involving a redox reaction (DOK-level 4)
- Interpret the results of an experiment involving a redox reaction (DOK-level 3)
- Evaluate the classification of a process as physical, chemical or ambiguous change based on observation (DOK-level 3)
- Distinguish between rearrangement of covalent interactions and noncovalent interactions (DOK-level 2)
- Interpret observations of energy changes in a reaction or process into a balanced chemical equation (DOK-level 3)

  Interpret observations of energy changes in a reaction or process as a graphical representation (DOK-level 3)
- Predict qualitative or quantitative change in a galvanic or electrolytic cell based on half-cell reactions or Faraday's Law
- Analyze data from galvanic or electrolytic reactions in the laboratory (DOK-level 4)

- Interpret from data underlying redox reaction in galvanic and electrolytic cells (DOK-level 3)
- Design an experiment measuring the effect of temperature, concentration and surface area on reaction rate (DOK-level 4)
- Interpret the results of a laboratory experiment that measures the effect of changes in concentration, temperature and surface area on reaction rate (DOK-level 3)
- Analyze concentration versus time data to determine the rate law for a zeroth-, first-, or second-order reaction (DOK-level 4)
- Connect radioactive half-life data to first-order rate qualitatively and quantitatively (DOK-level 4)
- Justify a first-order kinetics from half-life data (DOK-level 3)
- Connect the elementary reaction mechanism to the order and rate constant of an individual reacting species (DOK-level 4)
- Justify the success of collisions that produce product in terms of the energy distribution and molecular orientation (DOK-level 3)
- Predict qualitatively the temperature dependence of a reaction rate from energy profile of elementary reactions (DOK-level 3)
- Interpret reaction mechanisms for consistency with rate data (DOK-level 3)
- Infer from a reaction mechanism the presence of a reaction intermediate
- Translate among energy profile, particulate, symbolic representations of a chemical reaction occurring with and without a catalyst (DOK-level 3)
- Interpret changes in reaction rate as the results of an acid-base, surface or enzyme catalyst (DOK-level 3)
- Justify the selection of an appropriate mechanism based on type of catalyst or lack of a catalyst (DOK-level 3)

Core Activities and Corresponding Instructional Methods:

- Integrate academic and content specific vocabulary
- Direct instruction and practice on writing chemical equations for synthesis, decomposition, acid/base and redox systems, and reaction mechanisms, determining a rate law, the factors that affect rate and the graphs associated with reaction kinetics.
- Lead a classroom discussion that prompts students to compare and contrast various methods utilized in obtaining solutions
- Guided practice: Include step-by-step written explanation of solutions to open-ended questions
- Build background knowledge by laboratory experiments on mass conversions and reaction rate
- Graphing utility (Microsoft Excel, LoggerPro)
- Analyze examples of applications of functions

- Classroom discussion and guided practice on building models from analyzing data in a real-world situation (i.e. percent yield experiments, acid-base and redox titrations, iodine-clock rate experiment)
- Develop both a verbal and/or written logical argument to support conclusions about behaviors of graphs and laboratory results

Assessments:

Diagnostic: Quizzes and homework

Formative:

- Teacher observation and questioning
- Homework preparation
- Graded homework
- Practice using previous AP exam questions
- Quizzes
- Chapter Tests
- Lab reports
- Practice inquiry labs and experimental design

Summative:

- Final Assessment for Unit 2
- Cumulative Final Assessments

Advanced Placement Practice Exam from the College Board

Extensions:

- Rigorous worksheets in chemistry
- Rigorous practice programs
- Textbook applications and extensions
- Students can design a mass analysis experiments on a reaction of their choice with approval of the instructor
- Students can design an electrochemistry with the approval of the instructor
- Students can design their own rate of reaction experiment from acceptable substances researched by students and approved by the instructor
- Additional exercises in Chemistry, pp pp112-116, questions 3.9-3.86; pp 155-159, questions 4.13-4.90; pp 612-617, questions 14.17-14.88; pp 892-897, questions 20.13-20.96

Correctives:

- Remediation practice worksheets
- More extensive direct instruction
- Re-teaching with Practice Problems recommended by AP.
- Review exercises in Chemistry, pp 117, questions 3.87-3.105; pp 159-160, questions 4.91-4.104; pp 617-619, questions 14.89-14.116; pp 897-898, questions 20.97-20.110

Materials and Resources

- Chemistry textbook
- Chemistry Laboratory Manuel

- Inquiry method labs from AP Central
- Vernier LoggerPro
- Microsoft Office Suite
- DERIVE
- Minitab 12
- SMART notebook
- Smartboard
- Edmodo web site
- Practice worksheets
- Graphing calculator
- Laptop computers
- Digital balances
- Conductivity probes
- Volumetric flasks
- Erlenmeyer flasks
- Beakers
- Hot plates
- pH probes
- Computer interface boxes
- Burettes
- Sodium hydroxide
- Hydrochloric acid
- Nitric acid
- Weak acids such as acetic and citric
- Acid/base indicators
- Ionic and molecular solids (white)
- Well plates Test reagents
- pH paper
- Test tubes
- Potassium permanganate
- Iron (II) sulfate
- Sodium hypochlorite (commercial bleach)
- Stopwatches
- Graph paper
- Semi-log paper
- Video
- Potassium iodate
- Starch
- Sodium metabisulfite
- Potassium iodide
- Sodium thiosulfate
- Sodium sulfite
- Sulfuric acid

- Volt meters
- Voltage sources
- Alligator clips
- Metals
- Solutions of metal nitrates or sulfates

Unit: **Chemical Thermodynamics** **Time Range in Days:** 45 days

Big Idea #1: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter

Essential Questions:

- How do systems exchange thermal energy?
- What is heat?
- What is the first law of thermodynamics?
- How is energy related to the breaking and forming of chemical bonds?
- What are the energy requirements for overcoming intermolecular forces?
- How are chemical and physical forces driven by the first and second laws of thermodynamics?

Concepts:

- Temperature is the average kinetic energy of atoms and molecules
- kinetic energy transfer is heat transfer
- Heat is always transferred from a hot to a cold body
- Energy transfer between systems is heat transfer or work
- Two system exchange energy the energy is conserved
- There are three main processes that change the energy of chemical systems heating/cooling, phase transitions and chemical reactions
- Calorimetry is an experimental technique used to measure the change in heat energy of a chemical system
- Potential energy is associated with the geometric of the molecules and the electrostatic interactions between them
- The net energy change during a reaction is the sum of the bond breaking and the bond forming energies
- Bond breaking is always endothermic
- Bond forming is always exothermic
- The net energy change of a chemical reaction may be positive or negative
- Potential energy is associated with the attractive forces and the distance between molecules
- Chemical process can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular attractions
- Noncovalent and intermolecular interactions are important in biological and polymer systems
- Entropy is a measure of the dispersal of matter and energy
- Thermodynamically favored process involve both an increase in entropy and a decrease in energy
- The Gibb's free energy can be used to determine thermodynamic favorability in process that are not favored by both an increase in entropy and a decrease in energy

- Positive values for Gibb's free energy can be overcome by outside energy sources
- Kinetic restraints may limit thermodynamically favored process

Competencies:

- Create or interpret graphical representations of the relationship between potential energy and the distance between atoms
- Create or interpret graphical representations of the relationship between potential energy and factors that contribute to interaction strength such as bond order and polarity
- Create or interpret graphical representations of particle motion such as drawings with vectors and Maxwell-Boltzmann distributions
- Predict the transfer of thermal energy between two systems from molecular collisions
- Predict the energy transfer between two systems from the law of conservation of energy
- Justify the type heat or work of energy transferred and the direction of the energy flow from the law of conservation of energy
- Predict the magnitude of energy changes when two un-reacting substances are mixed or brought into contact with one another
- Justify quantities of energy changes in heating/cooling a substance using heat capacity
- Justify energy of a phase change using heat of fusion and/or vaporization
- Justify energy changes of a chemical reaction using enthalpy of the reaction
- Justify energy changes as work using pressure and volume data
- Design a calorimetry experiment to determine the change in enthalpy of a chemical process at constant pressure
- Interpret experimental data of calorimetry experiment
- Connect qualitatively and quantitatively reaction enthalpy and bond energies
- Predict relative magnitude of forces acting within a collection of molecules
- Justify process as physical or chemical change from intramolecular and intermolecular interactions
- Evaluate the noncovalent interactions in molecules
- Connect molecular shape to the presence and magnitude of intramolecular and intermolecular interactions
- Predict the sign and magnitude of entropy change from representations and models
- Predict a thermodynamically favored process by determining either qualitatively or quantitatively the sign of both enthalpy and entropy and the Gibb's free energy
- Determine the thermodynamic favorability of a process from the change in Gibb's free energy

- Connect the application of external energy sources and the coupling of favorable and unfavorable reactions to changes in the thermodynamic favorability of a process
- Predict qualitative changes in systems of coupled reactions that share a common intermediate on the basis of LeChatelier's principle.
- Predict quantitative changes in systems of coupled reactions that share a common based on the equilibrium constant for the combined reaction
- Critique thermodynamic processes ability to produce or not produce large amounts of product from initial conditions and kinetic effects

Standard(s): PA Core State Standards for Mathematics, PA Academic Standards, PA Core State Standards for English Language Arts & Literacy in Science and Technical Subjects

Standards Addressed: (See Appendix for Description)

N-Q1 , N-VM3 , N-Q2 , N-Q3 , A-SSE1a,b , A-CED1 , A-CED2 , A-CED4 , A-REI1 , A-REI2 , A-REI3 , A-REI6 , A-REI10 , A-REI11 , F-IF1 , F-IF4 , F-IF5, F-BF1a,b,c , F-BF5 , S-ID61 , S-IC6 , S-ID2 , S-ID3 , S-ID6a,b,c , S-ID7, S8.A.1.1.4 , S8.A.1.3.1 , S8.A.1.3.2 , S8.A.1.3.3 , S8.A.2.1.4 , S8.A.2.1.5 , S8.A.2.2.1 , S8.A.3.1.2 , S8.A.3.1.2 , S8.C.2.1.2 , S8.C.2.1.3 , S8.C.3.1.1 , S8.C.3.1.2 , S11.A.1.1.4 , S11.A.1.1.5 , S11.A.1.3.1 , S11.A.2.1.3 , S11.A.2.1.5 , S11.A.2.2.1 , S11.A.3.1.1 , S11.A.3.1.3 , S11.A.3.2.1 , S11.A.3.2.2 , S11.C.2.1.2, RST.1 , RST.2 , RST.3 , RST.4 , RST.5 , RST.6 , RST.7, WHST.1 , WHST.2 , WHST.4 , WHST.5, 3.2.C.A1 , 3.2.C.A2 , 3.2.C.A4 , 3.2.C.A6 , ,

Overview: In this unit, students will study basic and advanced concepts in thermodynamics that explain the essential role of energy in chemical and physical change, and use the principles of thermodynamics to predict the direction of changes in matter.

Focus Question(s):

- How do systems exchange thermal energy?
- What is heat?
- What is the first law of thermodynamics?
- How is energy related to the breaking and forming of chemical bonds?
- What are the energy requirements for overcoming intermolecular forces?
- How are chemical and physical forces driven by the first and second laws of thermodynamics?

Goals: Students will be able to

- Model Temperature as the average kinetic energy of atoms and molecules
- Model kinetic energy transfer as heat transfer
- Design experiments where heat is from a hot to a cold body
- Connect energy transfer between systems to heat transfer or work
- Model two system exchange energy the energy is conserved

- There are use appropriate math and science models to describe the three main processes that change the energy of chemical systems heating/cooling, phase transitions and chemical reactions
- Use calorimetry as an experimental technique used to measure the change in heat energy of a chemical system
- Connect potential energy to the geometric of the molecules and the electrostatic interactions between them
- Calculate and draw bonding models showing the net energy change during a reaction is the sum of the bond breaking and the bond forming energies
- Chemical process can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular attractions
- Model, interpret and calculate the entropy of a chemical reaction
- Using qualitative and quantitative analysis determine the thermodynamically favorability of a process involving both changes in entropy and in energy

Objectives:

- Create or interpret graphical representations of the relationship between potential energy and the distance between atoms (DOK – Level 4)
- Create or interpret graphical representations of the relationship between potential energy and factors that contribute to interaction strength such as bond order and polarity (DOK – Level 4)
- Create or interpret graphical representations of particle motion such as drawings with vectors and Maxwell-Boltzmann distributions (DOK – Level 4)
- Predict the transfer of thermal energy between two systems from molecular collisions (DOK – Level 3)
- Predict the energy transfer between two systems from the law of conservation of energy (DOK – Level 3)
- Justify the type heat or work of energy transferred and the direction of the energy flow from the law of conservation of energy (DOK – Level 3)
- Predict the magnitude of energy changes when two un-reacting substances are mixed or brought into contact with one another (DOK – Level 3)
- Justify quantities of energy changes in heating/cooling a substance using heat capacity (DOK – Level 3)
- Justify energy of a phase change using heat of fusion and/or vaporization (DOK – Level 3)
- Justify energy changes of a chemical reaction using enthalpy of the reaction (DOK – Level 3)
- Justify energy changes as work using pressure and volume data
- Design a calorimetry experiment to determine the change in enthalpy of a chemical process at constant pressure
- Interpret experimental data of calorimetry experiment (DOK – Level 3)
- Connect qualitatively and quantitatively reaction enthalpy and bond energies (DOK – Level 4)

- Predict relative magnitude of forces acting within a collection of molecules (DOK – Level 3)
- Justify process as physical or chemical change from intramolecular and intermolecular interactions (DOK – Level 3)
- Evaluate the noncovalent interactions in molecules (DOK – Level 4)
- Connect molecular shape to the presence and magnitude of intramolecular and intermolecular interactions (DOK – Level 4)
- Predict the sign and magnitude of entropy change from representations and models (DOK – Level 3)
- Predict a thermodynamically favored process by determining either qualitatively or quantitatively the sign of both enthalpy and entropy and the Gibb's free energy (DOK – Level 3)
- Determine the thermodynamic favorability of a process from the change in Gibb's free energy (DOK – Level 2)
- Connect the application of external energy sources and the coupling of favorable and unfavorable reactions to changes in the thermodynamic favorability of a process (DOK – Level 4)
- Predict qualitative changes in systems of coupled reactions that share a common intermediate on the basis of LeChatelier's principle (DOK – Level 3)
- Predict quantitative changes in systems of coupled reactions that share a common based on the equilibrium constant for the combined reaction (DOK – Level 3)
- Critique thermodynamic processes ability to produce or not produce large amounts of product from initial conditions and kinetic effects (DOK – Level 4)

Core Activities and Corresponding Instructional Methods:

- Integrate academic and content specific vocabulary
- Direct instruction and practice on modeling thermodynamic process in chemical reaction such as bond breaking and bond forming and entropy, calculations involving heat transfer, Gibb's free energy, entropy and enthalpy.
- Lead a classroom discussion that prompts students to compare and contrast various methods utilized in obtaining solutions
- Guided practice: Include step-by-step written explanation of solutions to open-ended questions
- Build background knowledge by laboratory experiments on mass conversions and reaction rate
- Graphing utility (Microsoft Excel, LoggerPro)
- Analyze examples of applications of functions
- Classroom discussion and guided practice on building models analyzing data in a real-world situation (i.e. heat transfer experiments, laboratory measurements of heat of reaction)

- Develop both a verbal and/or written logical argument to support conclusions about behaviors of graphs and laboratory results

Assessments:
Diagnostic: Quizzes and homework

Formative:
- Teacher observation and questioning
- Homework preparation
- Graded homework
- Practice using previous AP exam questions
- Quizzes
- Chapter Tests
- Lab reports
- Practice inquiry labs and experimental design

Summative:
- Final Assessment for Unit 3
- Cumulative Final Assessments
- Advanced Placement Practice Exam from the College Board

Extensions:
- Rigorous worksheets in chemistry
- Rigorous practice programs
- Textbook applications and extensions
- Students can design a experiments on a calorimetry experiment with approval of the instructor
- Students can design a heat of reaction experiment with the approval of the instructor
- Additional exercises in Chemistry, pp 203-208, questions 5.13-5.98; pp 840-844, questions 19.11-19.84

Correctives:
- Remediation practice worksheets
- More extensive direct instruction
- Re-teaching with Practice Problems recommended by AP.
  Review exercises in Chemistry, pp 208-209, questions 5.99-5.113; pp 844-845, questions 19.85-19.102

Materials and Resources
- Chemistry textbook
- Chemistry Laboratory Manuel
- Inquiry method labs from AP Central
- Vernier LoggerPro
- Microsoft Office Suite
- DERIVE
- Minitab 12
- SMART notebook

- Smartboard
- Edmodo web site
- Practice worksheets
- Graphing calculator
- Laptop computers
- Digital balances
- Bunsen burners
- Beakers
- Hot plates
- Temperature probes
- Thermometers
- Styrofoam cups
- Test tubes
- Video
- Tin cans
- Candles
- Hydrochloric acid
- Sodium hydroxide
- Citric acid
- Aluminum metal
- Iron bolts
- Magnesium metal
- Magnesium oxide
- Calcium chloride anhydrous
- Calcium Chloride dihydrate

Unit: Chemical Equilibrium and Kinetics **Time Range in Days:** 45 days

Big Idea #1: Any bond or intermolecular attraction that can be formed can be broken. The two processes are in dynamic competition, sensitive to initial conditions and external perturbations

Essential Questions:

- What is chemical equilibrium?
- How do external perturbations affect equilibrium systems?
- What is the role of chemical equilibrium in acid-base chemistry?
- What is the role of chemical equilibrium in solubility?
- How is the equilibrium constant related to temperature?
- How is the equilibrium constant related to the change in Gibb's free energy in a chemical reaction?

Concepts:

- Many classes of reactions have both forward and reverse reactions
- The current state of a reversible reaction can be characterized by the amount of reactants that have become products
- The reaction quotient is the ratio of products to reactants
- When a system is at equilibrium macroscopic variables do not change over time
- Equilibrium results when the rate of the forward reaction equals the rate of the reverse reaction
- The equilibrium constant can be used to determine the if the equilibrium favors reactants or products
- Equilibrium systems respond to changes by partially countering the effect of the change
- A change to an equilibrium system cause the reaction quotient to differ from the equilibrium constant
- Equilibrium systems respond to change by bringing the reaction quotient to equal the equilibrium constant
- Principles of chemical equilibrium can be applied to acid-base chemistry
- The pH can be controlled by buffers
- Comparing pH to pKa can determine the extent of labile hydrogen ions in a conjugate acid-base pair
- Solubility can be understood as a chemical equilibrium
- When the difference in Gibb's free energy is larger than the thermal energy in a chemical reaction, the equilibrium constant is extreme
- When the difference in Gibb's free energy is comparable to the thermal energy, the equilibrium constant is near 1.

Competencies:

- Connect experimental observations of physical, chemical, biological or environmental process to reversibility of underlying chemical reactions or processes
- Evaluate a manipulation of chemical reactions for the effects of the manipulation on the reaction quotient or the equilibrium constant
- Connect kinetics to equilibrium using principles of equilibrium
- Infer the relative rates of the forward and reverse reactions using principles of equilibrium
- Predict the weather a reaction will proceed toward products or reactants from a set of initial conditions and the tendency of the reaction quotient to approach the equilibrium constant
- Evaluate data from a system at equilibrium to calculate the equilibrium constant
- Synthesize initial conditions, value of the equilibrium constant, stoichiometric relationships and the law of mass action to qualitatively and quantitatively produce an accurate model of a particular system at equilibrium
- Determine from the extreme value of the equilibrium constant which chemical species will have very large or very small concentrations at equilibrium
- Predict the effects of stresses on a system using LeChatelier's principle
- Design a set of initial conditions that will optimize a particular outcome using LeChatelier's principle
- Connect LeChatelier's principle to the reaction quotient and the equilibrium constant through the effects of stresses
- Create representations of strong, weak or polyprotic acids and strong bases that model the amount of each species present at equilibrium
- Appraise and reason about strong and weak acid solutions with similar pH values, percent ionization of the acid, the concentrations needed to achieve the same pH, the amount of base needed to reach the equivalence point in a titration
- Interpret titration data for monoprotic and polyprotic acids involving the titration of a weak or strong acid by a strong base or a weak or strong base by a strong acid for concentration of titrant, equilibrium constant of the acid or base
- Appraise a given solution as neutral, and reason the meaning of a neutral solution is the equivalence of the concentration of hydrogen and hydroxide ions as opposed to a pH value of 7 in chemical and biological systems
- Appraise a solution as containing a mixture of acid/base species in order to evaluate the pH and concentration of all chemical species

- Appraise a given solution as being the solution of a monoprotic weak acid or base including salts in which one ion is a weak acid or base and evaluate the concentrations of all species in the solution
- Infer the relative strengths of weak acids or bases from given equilibrium concentrations
- Appraise an arbitrary mixture of weak and strong acids and bases for which species will react strongly with one another and what species will be present in large concentrations at equilibrium
- Design a buffer solution with a specific pH and buffer capacity by selecting appropriate acid base conjugates and the concentrations needed to achieve the capacity
- connect the predominate form of a chemical species involving a labile proton to the pH of a solution and the equilibrium constant associated with the labile proton
- Appraise a solution as a buffer solution and the buffer mechanism upon the reaction that would occur on the addition of acid or base
- Predict the solubility of a salt or the relative solubility of salts from solubility product constants
- Interpret solubility data for relative solubility and solubility product constant values
- Interpret data on relative solubility and connect data to factors that affect solubility
- Analyze enthalpic and entropic changes associated with dissociation of salts
- Create particulate level representations of the enthalpic and entropic changes associated with the dissociation of a salt
- Connect the equilibrium constant to the Gibb's free energy, temperature, and thermodynamic favorability

Standard(s): Common Core State Standards for Mathematics, PA Academic Standards, Common Core State Standards for English Language Arts & Literacy in Science and Technical Subjects

Standards Addressed: (See Appendix for Description)

N-RN1, N-RN2, N-Q1, N-Q2, N-Q3, A-SSE1a,b, A-SSE2 , A-SSE3, A-SSE6, A-CED1, A-CED2, A-CED3, A-CED4, A-REI1, A-REI2, A-REI3, A-REI4a,b,c, A-REI10, A-REI11, F-IF1, F-BF1 a,b,c, F-IF4, F-IF5, F-IF7a,b, F-IF8b, F-IF9, F-LE1a,b,c, F-LE2, F-LE3, F-LE4, F-LE5, S-ID61, S-IC6, S-ID2, S-ID3, S-ID6a,b,c, S-ID7, S8.A.1.1.4, S8.A.1.3.1, S8.A.1.3.2, S8.A.1.3., S8.A.2.1.4, S8.A.3.1.2, S8.A.2.1.5, S8.A.2.2.1, S11.A.1.1.5, S11.A.1.3.1, S11.A.2.1.3, S11.A.2.1.5, S11.A.2.2.1, S11.A.3.1.2, S11.A.3.2.1 , S11.A.3.2.3, RST.1 , RST.2 , RST.3 , RST.4 , RST.5 , RST.6, RST.7 , WHST.1, WHST.2, WHST.4 , WHST.5, 3.2.C.A1, 3.2.12.A5 , 3.2.C.A2 , 3.2.C.A4 , 3.2.C.A6

Overview: Principles and concepts of chemical equilibrium are introduced. Students will learn to collect and analyze data from equilibrium system. Students will model equilibrium systems at the atomic level using particle representations and represent these systems mathematically and graphically.

Focus Question(s):

- What is chemical equilibrium?
- How do external perturbations affect equilibrium systems?
- What is the role of chemical equilibrium in acid-base chemistry?
- What is the role of chemical equilibrium in solubility?
- How is the equilibrium constant related to temperature?
- How is the equilibrium constant related to the change in Gibb's free energy in a chemical reaction?

Goals: Students will be able to

- Select chemical and physical processes that have both forward and reverse directions of change
- Quantify the current state of a reversible reaction by the amount of reactants that have become products as a ratio called the reaction quotient
- Provide qualitative and quantitative properties of a system at equilibrium, especially macroscopic variables that do not change over time
- Provide qualitative and quantitative evidence that equilibrium results when the rate of the forward reaction equals the rate of the reverse reaction
- Use the equilibrium constant to determine the if the equilibrium favors reactants or products
- Provide qualitative and quantitative evidence that equilibrium systems respond to changes by partially countering the effect of the change

- Provide qualitative and quantitative evidence   that a change to an equilibrium system cause the reaction quotient to differ from the equilibrium constant
- Provide qualitative and quantitative evidence that equilibrium systems respond to change by bringing the reaction quotient to equal the equilibrium constant
- Apply principles of chemical equilibrium to acid-base chemistry
- Provide qualitative and quantitative evidence that the pH can be controlled by buffers
- Compare pH to pKa to determine the extent of labile hydrogen ions in a conjugate acid-base pair
- That Provide qualitative and quantitative evidence solubility can be understood as a chemical equilibrium
- Provide qualitative and quantitative evidence that when the difference in Gibb's free energy is larger than the thermal energy in a chemical reaction, the equilibrium constant is extreme
- Provide qualitative and quantitative evidence that when the difference in Gibb's free energy is comparable to the thermal energy; the equilibrium constant is near 1.

Objectives:

- Connect experimental observations of physical, chemical, biological or environmental process to reversibility of underlying chemical reactions or processes (DOK – Level 4)
- Evaluate a manipulation of chemical reactions for the effects of the manipulation on the reaction quotient or the equilibrium constant (DOK – Level 3)
- Connect kinetics to equilibrium using principles of equilibrium (DOK – Level 4)
- Infer the relative rates of the forward and reverse reactions using principles of equilibrium (DOK – Level 3)
- Predict the weather a reaction will proceed toward products or reactants from a set of initial conditions and the tendency of the reaction quotient to approach the equilibrium constant (DOK – Level 3)
- Evaluate data from a system at equilibrium to calculate the equilibrium constant (DOK – Level 3)
- Synthesize initial conditions, value of the equilibrium constant, stoichiometric relationships and the law of mass action to qualitatively and quantitatively produce an accurate model of a particular system at equilibrium (DOK – Level 4)
- Determine from the extreme value of the equilibrium constant which chemical species will have very large or very small concentrations at equilibrium (DOK – Level 2)
- Predict the effects of stresses on a system using LeChatelier's principle (DOK – Level 3)

- Design a set of initial conditions that will optimize a particular outcome using LeChatelier's principle (DOK – Level 3)
- Connect LeChatelier's principle to the reaction quotient and the equilibrium constant through the effects of stresses (DOK – Level 4)
- Create representations of strong, weak or polyprotic acids and strong bases that model the amount of each species present at equilibrium (DOK – Level 4)
- Appraise and reason about strong and weak acid solutions with similar pH values, percent ionization of the acid, the concentrations needed to achieve the same pH, the amount of base needed to reach the equivalence point in a titration (DOK – Level 4)
- Interpret titration data for monoprotic and polyprotic acids involving the titration of a weak or strong acid by a strong base or a weak or strong base by a strong acid for concentration of titrant, equilibrium constant of the acid or base
- Appraise a given solution as neutral, and reason the meaning of a neutral (DOK – Level 3) solution is the equivalence of the concentration of hydrogen and hydroxide ions as opposed to a pH value of 7 in chemical and biological systems
- Appraise a solution as containing a mixture of acid/base species in order to evaluate the pH and concentration of all chemical species (DOK – Level 4)
- Appraise a given solution as being the solution of a monoprotic weak acid or base including salts in which one ion is a weak acid or base and evaluate the concentrations of all species in the solution (DOK – Level 4)
- Infer the relative strengths of weak acids or bases from given equilibrium concentrations (DOK – Level 3)
- Appraise an arbitrary mixture of weak and strong acids and bases for which species will react strongly with one another and what species will be present in large concentrations at equilibrium (DOK – Level 4)
- Design a buffer solution with a specific ph and buffer capacity by selecting appropriate acid base conjugates and the concentrations needed to achieve the capacity (DOK – Level 4)
- Connect the predominate form of a chemical species involving a labile proton to the pH of a solution and the equilibrium constant associated with the labile proton (DOK – Level 4)
- Appraise a solution as a buffer solution and the buffer mechanism upon the reaction that would occur on the addition of acid or base (DOK – Level 4)
- Predict the solubility of a salt or the relative solubility of salts from solubility product constants (DOK – Level 3)
- Interpret solubility data for relative solubility and solubility product content values (DOK – Level 3)
- Interpret data on relative solubility and connect data to factors that affect solubility (DOK – Level 3)
- Analyze enthalpic and entropic changes associated with dissociation of salts (DOK – Level 4)

- Create particulate level representations of the enthalpic and entropic changes associated with the dissociation of a salt (DOK – Level 4)
- Connect the equilibrium constant to the Gibb's free energy, temperature, and thermodynamic favorability (DOK – Level 4)

Core Activities and Corresponding Instructional Methods:

- Integrate academic and content specific vocabulary
- Direct instruction and practice on modeling equilibrium processes including molecular, gaseous, acid-base and solubility, and relating the Gibb's free energy, entropy and enthalpy to equilibrium systems
- Lead a classroom discussion that prompts students to compare and contrast various methods utilized in obtaining solutions
- Guided practice: Include step-by-step written explanation of solutions to open-ended questions
- Build background knowledge by laboratory experiments on mass conversions and reaction rate
- Graphing utility (Graph paper, Microsoft Excel, LoggerPro)
- Analyze examples of applications of functions
- Classroom discussion and guided practice on building models analyzing data in a real-world situation (i.e. LeChatelier's principle experiments, solubility product determinations and laboratory measurements properties of acid-base reactions)
- Develop both a verbal and/or written logical argument to support conclusions about behaviors of graphs and laboratory results

Assessments:

Diagnostic: Quizzes and homework

Formative:

- Teacher observation and questioning
- Homework preparation
- Graded homework
- Practice using previous AP exam questions
- Quizzes
- Chapter Tests
- Lab reports
- Practice inquiry labs and experimental design

Summative:

- Final Assessment for Unit 4
- Cumulative Final Assessments
- Advanced Placement Practice Exam from the College Board

Extensions:

- Rigorous worksheets in chemistry
- Rigorous practice programs
- Textbook applications and extensions
- Students can design a experiments on a equilibrium experiment with approval of the instructor
- Students can design an acid-base analysis experiment with the approval of the instructor
- Additional exercises in Chemistry, p 158-159, questions 4.79-4.90; pp 560-562, questions 13.13-13.60; pp 657-661, questions 15.13-15.70; pp 710-713, questions 16.13-16.98; pp 759-763 questions 17.13-17.82; pp 843-844, questions 19.75-19.84; p 894-895, questions 20.51-20.60

Correctives:

- Remediation practice worksheets
- More extensive direct instruction
- Re-teaching with Practice Problems recommended by AP.
- Review exercises in Chemistry, p 159-160, questions 4.91-4.104; p 564-565, questions 13.91-13.105; pp 661-662 questions 15.71-15.94; pp 713-715, questions 16.99-16.115; pp 763-764, questions 17.83-17.109; pp 844-845, questions 19.95-19.102; p 897, questions 20.97 and 20.102

Materials and Resources

- Chemistry textbook
- Chemistry Laboratory Manuel
- Inquiry method labs from AP Central
- Vernier LoggerPro
- Microsoft Office Suite
- DERIVE
- Minitab 12
- SMART notebook
- Smartboard
- Edmodo web site
- Practice worksheets
- Graphing calculator
- Laptop computers
- Digital balances
- Spectrophotometer
- Beakers
- Cuvettes
- Stopwatches
- Computer interface boxes
- pH electrodes

- Buffer solutions
- Weak acids and their salts such as citric acid and sodium citrate
- Burettes
- Flasks
- NaOH
- HCl
- H_2SO_4
- HNO_3
- Soluble salts such as nitrates, acetates and certain chlorides
- Insoluble salts such as carbonates, hydroxides and some chloride

Primary Textbook(s) Used for this Course of Instruction

Name of Textbook: Chemistry: The Central Science AP Edition-Fourteenth Edition

Textbook ISBN #: 978-0-13-465095-1

Textbook Publisher &Year of Publication: Pearson Prentice Hall 2018

Curriculum Textbook is utilized in: Advanced Placement Chemistry

Appendix

<u>Common Core State Standards for Mathematics</u>

NUMBER AND QUANTITY

<u>Real Number System</u> N -RN

Extend the properties of exponents to rational exponents.

1. Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents. *For example, we define $5^{1/3}$ to be the cube root of 5 because we want $(5^{1/3})^3 = 5^{(1/3)3}$ to hold, so $(5^{1/3})^3$ must equal 5.*

2. Rewrite expressions involving radicals and rational exponents using the properties of exponents.

Use properties of rational and irrational numbers.

3. Explain why the sum or product of two rational numbers is rational; that the sum of a rational number and an irrational number is irrational; and that the product of a nonzero rational number and an irrational number is irrational.

<u>Quantities</u> N-Q

Reason quantitatively and use units to solve problems.

1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

2. Define appropriate quantities for the purpose of descriptive modeling.

3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

<u>The Complex Number System</u> N -CN

Perform arithmetic operations with complex numbers.

1. Know there is a complex number i such that $i^2 = -1$, and every complex number has the form $a + bi$ with a and b real.

2. Use the relation $i^2 = -1$ and the commutative, associative and distributive properties to add, subtract and multiply complex numbers.

3. Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers. Represent complex numbers and their operations on the complex plane.

4. Represent complex numbers on the complex plane in rectangular and polar form (including real and imaginary numbers), and explain why the rectangular and polar forms of a given complex number represent the same number.

5. Represent addition, subtraction, multiplication, and conjugation of complex numbers geometrically on the complex plane; use properties of this representation for computation. *For example,* $(-1 + \sqrt{3}\, i)^3 = 8$ *because* $(-1 + \sqrt{3}\, i)$ *has modulus* 2 *and argument* 120°.

6. Calculate the distance between numbers in the complex plane as the modulus of the difference, and the midpoint of a segment as the average of the numbers at its endpoints.

Use complex numbers in polynomial identities and equations.

7. Solve quadratic equations with real coefficients that have complex solutions.

8. Extend polynomial identities to the complex numbers. *For example, rewrite* $x^2 + 4$ *as* $(x + 2i)(x - 2i)$.

9. Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials.

<u>Vector and Matrix Quantities</u> N -VM

Represent and model with vector quantities.

1. Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., $\boldsymbol{v}$, $|\boldsymbol{v}|$, $||\boldsymbol{v}||$, v).

2. Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point.

3. Solve problems involving velocity and other quantities that can be represented by vectors.
   Perform operations on vectors.

4. Add and subtract vectors.

   a. Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes.

   b. Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum.

   c. Understand vector subtraction $\boldsymbol{v} - \boldsymbol{w}$ as $\boldsymbol{v} + (-\boldsymbol{w})$, where $-\boldsymbol{w}$ is the additive inverse of $\boldsymbol{w}$, with the same magnitude as $\boldsymbol{w}$ and pointing in the opposite direction. Represent vector subtraction graphically by connecting the tips in the appropriate order, and perform vector subtraction component-wise.

5. Multiply a vector by a scalar.

   a. Represent scalar multiplication graphically by scaling vectors and possibly reversing their direction; perform scalar multiplication component-wise, e.g., as $c(v_x, v_y) = (cv_x, cv_y)$.

   b. Compute the magnitude of a scalar multiple $c\boldsymbol{v}$ using $||c\boldsymbol{v}|| = |c|v$. Compute the direction of $c\boldsymbol{v}$ knowing that when $|c|v \neq 0$, the direction of $c\boldsymbol{v}$ is either along $\boldsymbol{v}$ (for $c > 0$) or against $\boldsymbol{v}$ (for $c < 0$).

<u>Perform operations on matrices and use matrices in applications</u>.

6. Use matrices to represent and manipulate data, e.g., to represent payoffs or incidence relationships in a network.

7. Multiply matrices by scalars to produce new matrices, e.g., as when all of the payoffs in a game are doubled.

8. Add, subtract and multiply matrices of appropriate dimensions.

9. Understand that, unlike multiplication of numbers, matrix multiplication for square matrices is not a commutative operation, but still satisfies the associative and distributive properties.

10. Understand that the zero and identity matrices play a role in matrix addition and multiplication similar to the role of 0 and 1 in the real numbers. The determinant of a square matrix is nonzero if and only if the matrix has a multiplicative inverse.

11. Multiply a vector (regarded as a matrix with one column) by a matrix of suitable dimensions to produce another vector. Work with matrices as transformations of vectors.

12. Work with 2 × 2 matrices as transformations of the plane, and interpret the absolute value of the determinant in terms of area.

ALGEBRA

<u>Seeing Structure in Expressions</u> A-SSE

Interpret the structure of expressions

1. Interpret expressions that represent a quantity in terms of its context.

    a. Interpret parts of an expression, such as terms, factors, and coefficients.

    b. Interpret complicated expressions by viewing one or more of their parts as a single entity. *For example, interpret* $P(1+r)^n$ *as the product of P and a factor not depending on P.*

2. Use the structure of an expression to identify ways to rewrite it. *For example, see* $x^4 – y^4$ *as* $(x^2)^2 – (y^2)^2$, *thus recognizing it as a difference of squares that can be factored as* $(x^2 – y^2)(x^2 + y^2)$.

Write expressions in equivalent forms to solve problems

3. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

    a. Factor a quadratic expression to reveal the zeros of the function it defines.

    b. Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.

c. Use the properties of exponents to transform expressions for exponential functions. *For example the expression* 1.15^t *can be rewritten as* $(1.15^{1/12})^{12t} \approx 1.012^{12t}$ *to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.*

4. Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems. *For example, calculate mortgage payments.*

<u>Arithmetic with Polynomials and Rational Expressions</u> A -APR

Perform arithmetic operations on polynomials

1. Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction and multiplication; add, subtract and multiply polynomials.

Understand the relationship between zeros and factors of polynomials

2. Know and apply the Remainder Theorem: For a polynomial $p(x)$ and a number a, the remainder on division by $x – a$ is $p(a)$, so $p(a) = 0$ if and only if $(x – a)$ is a factor of $p(x)$.

3. Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.

Use polynomial identities to solve problems

4. Prove polynomial identities and use them to describe numerical relationships. *For example, the polynomial identity* $(x^2 + y^2)^2 = (x^2 – y^2)^2 + (2xy)^2$ *can be used to generate Pythagorean triples.*

5. (+) Know and apply the Binomial Theorem for the expansion of $(x + y)^n$ in powers of x and y for a positive integer n, where x and y are any numbers, with coefficients determined for example by Pascal's Triangle.**

**The Binomial Theorem can be proved by mathematical induction or by a combinatorial argument.

Rewrite rational expressions

6. Rewrite simple rational expressions in different forms; write $a(x)/b(x)$ in the form $q(x) + r(x)/b(x)$, where $a(x)$, $b(x)$, $q(x)$, and $r(x)$ are polynomials with the degree of $r(x)$ less than the

degree of $b(x)$, using inspection, long division or, for the more complicated examples, a computer algebra system.

7. Understand that rational expressions form a system analogous to the rational numbers, closed under addition, subtraction, multiplication and division by a nonzero rational expression; add, subtract, multiply and divide rational expressions.

<u>Creating Equations</u> A -CED

Create equations that describe numbers or relationships

1. Create equations and inequalities in one variable and use them to solve problems. *Include equations arising from linear and quadratic functions, and simple rational and exponential functions.*

2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

3. Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. *For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.*

4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *For example, rearrange Ohm's law V =IR to highlight resistance R.*

<u>Reasoning with Equations and Inequalities</u> -RE I

Understand solving equations as a process of reasoning and explain the reasoning

1. Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

2. Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.

Solve equations and inequalities in one variable

3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

4. Solve quadratic equations in one variable.

   a. Use the method of completing the square to transform any quadratic equation in x into an equation of the form $(x - p)^2 = q$ that has the same solutions. Derive the quadratic formula from this form.

   b. Solve quadratic equations by inspection (e.g., for $x^2 = 49$), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as $a \pm bi$ for real numbers a and b.

Solve systems of equations

5. Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.

6. Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.

7. Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. *For example, find the points of intersection between the line* $y = -3x$ and the circle $x^2 + y^2 = 3$.

8. Represent a system of linear equations as a single matrix equation in a vector variable.

9. Find the inverse of a matrix if it exists and use it to solve systems of linear equations (using technology for matrices of dimension 3 × 3 or greater).

Represent and solve equations and inequalities graphically

10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

11. Explain why the x-coordinates of the points where the graphs of the equations $y = f(x)$ and $y = g(x)$ intersect are the solutions of the equation $f(x) = g(x)$; find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential and logarithmic functions.

12. Graph the solutions to a linear inequality in two variables as a half-plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes. **FUNCTIONS**

Interpreting Functions F-IF

Understand the concept of a function and use function notation

1. Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then $f(x)$ denotes the output of f corresponding to the input x. The graph of f is the graph of the equation $y = f(x)$.

2. Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

3. Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers. *For example, the Fibonacci sequence is defined recursively by* $f(0) = f(1) = 1$, $f(n+1) = f(n) + f(n-1)$ *for* $n \geq 1$.

Interpret functions that arise in applications in terms of the context

4. For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.*

5. Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. *For example, if the function h(n) gives the number of person-hours it takes to assemble n engines in a factory, then the positive integers would be an appropriate domain for the function.*

6. Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

Analyze functions using different representations

7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

a. Graph linear and quadratic functions and show intercepts, maxima and minima.

b. Graph square root, cube root and piecewise-defined functions, including step functions and absolute value functions.

c. Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.

d. Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline and amplitude.

8. Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

a. Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values and symmetry of the graph, and interpret these in terms of a context.

b. Use the properties of exponents to interpret expressions for exponential functions. *For example, identify percent rate of change in functions such as* $y = (1.02)^t$, $y = (0.97)^t$, $y = (1.01)^{12t}$, $y = (1.2)^{t/10}$, *and classify them as representing exponential growth or decay.*

9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables or by verbal descriptions). *For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum.*

Building Functions F-BF

Build a function that models a relationship between two quantities

1. Write a function that describes a relationship between two quantities.

a. Determine an explicit expression, a recursive process or steps for calculation from a context.

b. Combine standard function types using arithmetic operations. *For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.*

c. Compose functions. *For example, if T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t)) is the temperature at the location of the weather balloon as a function of time.*

2. Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms.

Build new functions from existing functions

3. Identify the effect on the graph of replacing $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x + k)$ for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. *Include recognizing even and odd functions from their graphs and algebraic expressions for them.*

4. Find inverse functions.

   a. Solve an equation of the form f(x) = c for a simple function f that has an inverse and write an expression for the inverse. *For example,* $f(x) = 2x^3$ *or* $f(x) = (x+1)/(x–1)$ *for* $x \neq 1$.

   b. Verify by composition that one function is the inverse of another.

   c. Read values of an inverse function from a graph or a table, given that the function has an inverse.

   d. Produce an invertible function from a non-invertible function by restricting the domain.

5. Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.

<u>Linear, Quadratic and Exponential Models</u> F -LE

Construct and compare linear, quadratic and exponential models and solve problems

1. Distinguish between situations that can be modeled with linear functions and with exponential functions.

a. Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.

b. Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

c. Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.

2. Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship or two input-output pairs (include reading these from a table).

3. Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically or (more generally) as a polynomial function.

4. For exponential models, express as a logarithm the solution to $ab^{ct} = d$ where *a*, *c*, and *d* are numbers and the base *b* is 2, 10 or *e*; evaluate the logarithm using technology.

Interpret expressions for functions in terms of the situation they model

5. Interpret the parameters in a linear or exponential function in terms of a context.

Trigonometric Functions F-TF

Extend the domain of trigonometric functions using the unit circle

1. Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle.

2. Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise around the unit circle.

3. Use special triangles to determine geometrically the values of sine, cosine and tangent for $\pi/3$, $\pi/4$ and $\pi/6$, and use the unit circle to express the values of sine, cosine and tangent for $\pi-x$, $\pi+x$, and $2\pi-x$ in terms of their values for x, where x is any real number.

4. Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions.

Model periodic phenomena with trigonometric functions

5. Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency and midline.

6. Understand that restricting a trigonometric function to a domain on which it is always increasing or always decreasing allows its inverse to be constructed.

7. Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.

Prove and apply trigonometric identities

8. Prove the Pythagorean identity $\sin^2(\theta) + \cos^2(\theta) = 1$ and use it to find $\sin(\theta)$, $\cos(\theta)$ or $\tan(\theta)$ given $\sin(\theta)$, $\cos(\theta)$ or $\tan(\theta)$ and the quadrant of the angle.

9. Prove the addition and subtraction formulas for sine, cosine and tangent and use them to solve problems.

GEOMETRY

<u>Congruence</u> G-CO

Experiment with transformations in the plane

1. Know precise definitions of angle, circle, perpendicular line, parallel line and line segment, based on the undefined notions of point, line, distance along a line and distance around a circular arc.

2. Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).

3. Given a rectangle, parallelogram, trapezoid or regular polygon, describe the rotations and reflections that carry it onto itself.

4. Develop definitions of rotations, reflections and translations in terms of angles, circles, perpendicular lines, parallel lines and line segments.

5. Given a geometric figure and a rotation, reflection or translation, draw the transformed figure using, e.g., graph paper, tracing paper or geometry software. Specify a sequence of transformations that will carry a given figure onto another.

Understand congruence in terms of rigid motions

6. Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent.

7. Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent.

8. Explain how the criteria for triangle congruence (ASA, SAS and SSS) follow from the definition of congruence in terms of rigid motions.

Prove geometric theorems

9. Prove theorems about lines and angles. *Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints.*
10. Prove theorems about triangles. *Theorems include: measures of interior angles of a triangle sum to 180°; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point.*

11. Prove theorems about parallelograms. *Theorems include: opposite sides are congruent, opposite angles are congruent, the diagonals of a parallelogram bisect each other, and conversely, rectangles are parallelograms with congruent diagonals.*

Make geometric constructions

12. Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). *Copying a segment; copying an angle; bisecting a segment; bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.*

13. Construct an equilateral triangle, a square and a regular hexagon inscribed in a circle.

<u>Similarity, Right Triangles, and Trigonometry</u> G-SRT

Understand similarity in terms of similarity transformations

1. Verify experimentally the properties of dilations given by a center and a scale factor:

   a. A dilation takes a line not passing through the center of the dilation to a parallel line, and leaves a line passing through the center unchanged.

   b. The dilation of a line segment is longer or shorter in the ratio given by the scale factor.

2. Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides.

3. Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar.

Prove theorems involving similarity

4. Prove theorems about triangles. *Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity.*
5. Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.

Define trigonometric ratios and solve problems involving right

6. Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

7. Explain and use the relationship between the sine and cosine of complementary angles.

8. Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

Apply trigonometry to general triangles

9. Derive the formula $A = 1/2\ ab \sin(C)$ for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side.

10. Prove the Laws of Sines and Cosines and use them to solve problems.

11. Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).

Circles G-C

Understand and apply theorems about circles

1. Prove that all circles are similar.

2. Identify and describe relationships among inscribed angles, radii and chords. *Include the relationship between central, inscribed and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.*

3. Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle.

4. Construct a tangent line from a point outside a given circle to the circle.

Find arc lengths and areas of sectors of circles

5. Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector.

Expressing Geometric Properties with Equations G-GPE

Translate between the geometric description and the equation for a conic section

1. Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

2. Derive the equation of a parabola given a focus and directrix.

3. Derive the equations of ellipses and hyperbolas given the foci, using the fact that the sum or difference of distances from the foci is constant.

Use coordinates to prove simple geometric theorems algebraically

4. Use coordinates to prove simple geometric theorems algebraically. *For example, prove or disprove that a figure defined by four given points in the coordinate plane is a rectangle; prove or disprove that the point (1, √3) lies on the circle centered at the origin and containing the point (0, 2).*

5. Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point).

6. Find the point on a directed line segment between two given points that partitions the segment in a given ratio.

7. Use coordinates to compute perimeters of polygons and areas of triangles and rectangles, e.g., using the distance formula.

<u>Geometric Measurement and Dimension</u> G-GMD

Explain volume formulas and use them to solve problems

1. Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid and cone. *Use dissection arguments, Cavalieri's principle, and informal limit arguments.*

2. Give an informal argument using Cavalieri's principle for the formulas for the volume of a sphere and other solid figures.

3. Use volume formulas for cylinders, pyramids, cones and spheres to solve problems.

Visualize relationships between two-dimensional and three-dimensional objects

4. Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

<u>Modeling with Geometry</u> G-MG

Apply geometric concepts in modeling situations

1. Use geometric shapes, their measures and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

STATISTICS AND PROBABILITY

<u>Interpreting Categorical and Quantitative Data</u> S-ID

Summarize, represent and interpret data on a single count or measurement variable

1. Represent data with plots on the real number line (dot plots, histograms and box plots).

2. Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

3. Interpret differences in shape, center and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

4. Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets and tables to estimate areas under the normal curve.

Summarize, represent and interpret data on two categorical and quantitative variables

5. Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal and conditional relative frequencies). Recognize possible associations and trends in the data.

6. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

    a. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. *Use given functions or choose a function suggested by the context. Emphasize linear, quadratic and exponential models.*

b. Informally assess the fit of a function by plotting and analyzing residuals.

c. Fit a linear function for a scatter plot that suggests a linear association.

Interpret linear models

7. Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.

8. Compute (using technology) and interpret the correlation coefficient of a linear fit.

9. Distinguish between correlation and causation.

<u>Making Inferences and Justifying Conclusions</u> S-IC

Understand and evaluate random processes underlying statistical experiments

1. Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

2. Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. *For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?*

Make inferences and justify conclusions from sample surveys, experiments and observational studies

3. Recognize the purposes of and differences among sample surveys, experiments and observational studies; explain how randomization relates to each.

4. Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

5. Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.
6. Evaluate reports based on data.

<u>Conditional Probability and the Rules of Probability</u> S-CP

Understand independence and conditional probability and use them to interpret data

1. Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections or complements of other events ("or," "and," "not").

2. Understand that two events *A* and *B* are independent if the probability of *A* and *B* occurring together is the product of their probabilities, and use this characterization to determine if they are independent.

3. Understand the conditional probability of *A* given *B* as *P*(*A* and *B*)/*P*(*B*), and interpret independence of *A* and *B* as saying that the conditional probability of *A* given *B* is the same as the probability of *A*, and the conditional probability of *B* given *A* is the same as the probability of *B*.

4. Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. *For example, collect data from a random sample of students in your school on their favorite subject among math, science and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.*

5. Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. *For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.*

Use the rules of probability to compute probabilities of compound events in a uniform probability model

6. Find the conditional probability of *A* given *B* as the fraction of *B*'s outcomes that also belong to *A,* and interpret the answer in terms of the model.

7. Apply the Addition Rule, P(A or B) = P(A) + P(B) – P(A and B), and interpret the answer in terms of the model.

8. Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)P(B|A) = P(B)P(A|B), and interpret the answer in terms of the model.

9. Use permutations and combinations to compute probabilities of compound events and solve problems.

Using Probability to Make Decisions S-MD

Calculate expected values and use them to solve problems

1. Define a random variable for a quantity of interest by assigning a numerical value to each event in a sample space; graph the corresponding probability distribution using the same graphical displays as for data distributions.

2. Calculate the expected value of a random variable; interpret it as the mean of the probability distribution.

3. Develop a probability distribution for a random variable defined for a sample space in which theoretical probabilities can be calculated; find the expected value. *For example, find the theoretical probability distribution for the number of correct answers obtained by guessing on all five questions of a multiple-choice test where each question has four choices, and find the expected grade under various grading schemes.*

4. Develop a probability distribution for a random variable defined for a sample space in which probabilities are assigned empirically; find the expected value. *For example, find a current data distribution on the number of TV sets per household in the United States, and calculate the expected number of sets per household. How many TV sets would you expect to find in 100 randomly selected households?*

Use probability to evaluate outcomes of decisions

5. Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

    a. Find the expected payoff for a game of chance. *For example, find the expected winnings from a state lottery ticket or a game at a fastfood restaurant.*

    b. Evaluate and compare strategies on the basis of expected values. *For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.*

6. Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).

7. Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Pennsylvania Academic Standards

S8.A.1.1.4: Develop descriptions, explanations, predictions and models using evidence.
S8.A.1.2.3: Describe fundamental scientific or technological concepts that could solve practical problems (e.g., Newton's laws of motion, Mendelian genetics).
S8.A.1.3.1: Use ratio to describe change (e.g., percents, parts per million, grams per cubic centimeter, mechanical advantage).
S8.A.1.3.2: Use evidence, observations or explanations to make inferences about change in systems over time (e.g., carrying capacity, succession, population dynamics, loss of mass in chemical reactions, indicator fossils in geologic time scale) and the variables affecting these changes.
S8.A.1.3.3: Examine systems changing over time, identifying the possible variables causing this change, and drawing inferences about how these variables affect this change.
S8.A.1.1.2: Explain how certain questions can be answered through scientific inquiry and/or technological design.
S8.A.2.1.4: Interpret data/observations; develop relationships among variables based on data/observations to design models as solutions.
S8.A.2.1.5: Use evidence from investigations to clearly communicate and support conclusions.
S8.A.2.1.6: Identify a design flaw in a simple technological system and devise possible working solutions
S8.A.2.2.1: Describe the appropriate use of instruments and scales to accurately and safely measure time, mass, distance, volume or temperature under a variety of conditions.
S8.A.3.1.1: Describe a system (e.g., watershed, circulatory system, heating system, agricultural system) as a group of related parts with specific roles that work together to achieve an observed result.
S8.A.3.1.2: Explain the concept of order in a system [e.g., (first to last: manufacturing steps, trophic levels); (simple to complex: cell, tissue, organ, organ system)].
S8.A.3.1.3: Distinguish among system inputs, system processes, system outputs and feedback (e.g., physical, ecological, biological, informational).
S8.A.3.1.4: Distinguish between open loop (e.g., energy flow, food web) and closed loop (e.g., materials in the nitrogen and carbon cycles, closed-switch) systems.
S8.A.3.3.1: Identify and describe patterns as repeated processes or recurring elements in human-made systems (e.g., trusses, hub-and-spoke system in communications and transportation systems, feedback controls in regulated systems).

S8.C.1.1.1: Explain the differences among elements, compounds and mixtures.
S8.C.1.1.2: Use characteristic physical or chemical properties to distinguish one substance from another (e.g., density, thermal expansion/contraction, freezing/melting points, streak test).
S8.C.1.1.3: Identify and describe reactants and products of simple chemical reactions.

S8.C.2.1.2: Explain how energy is transferred from one place to another through convection, conduction or radiation.
S8.C.2.1.3: Describe how one form of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) can be converted into a different form of energy.
S8.C.2.2.1: Describe the Sun as the major source of energy that impacts the environment.
S8.C.2.2.2: Compare the time span of renewability for fossil fuels and the time span of renewability for alternative fuels.
S8.C.3.1.1: Describe forces acting on objects (e.g., friction, gravity, balanced versus unbalanced).
S8.C.3.1.2: Distinguish between kinetic and potential energy.

S11.A.1.1.3: Evaluate the appropriateness of research questions (e.g., testable vs. not-testable).
S11.A.1.1.4: Explain how specific scientific knowledge or technological design concepts solve practical problems (e.g., momentum, Newton's universal law of gravitation, tectonics, conservation of mass and energy, cell theory, theory of evolution, atomic theory, theory of relativity, Pasteur's germ theory, relativity, heliocentric theory, ideal gas laws).
S11.A.1.1.5: Analyze or compare the use of both direct and indirect observation as means to study the world and the universe (e.g., behavior of atoms, functions of cells, birth of stars).
S11.A.1.2.2: Use case studies (e.g., Wright brothers' flying machine, Tacoma Narrows Bridge, Henry Petroski's Design Paradigms) to propose possible solutions and analyze economic and environmental implications of solutions for real world problems.
S11.A.1.3.1: Use appropriate quantitative data to describe or interpret change in systems (e.g., biological indices, electrical circuit data, automobile diagnostic systems data).
S11.A.1.3.4: Compare the rate of use of natural resources and their impact on sustainability.
S11.A.2.1.2: Critique the elements of the design process (e.g. identify the problem, understand criteria, create solutions, select solution, test/evaluate, communicate results) applicable to a specific technological design.
S11.A.2.1.3: Use data to make inferences and predictions, or to draw conclusions, demonstrating understanding of experimental limits.
S11.A.2.1.5: Communicate results of investigations using multiple representations.
S11.A.2.2.1: Evaluate appropriate methods, instruments and scale for precise quantitative and qualitative observations (e.g., to compare properties of materials, water quality).
S11.A.3.1.1: Apply systems analysis, showing relationships (e.g., flowcharts, concept maps), input and output and measurements to explain a system and its parts.
S11.A.3.1.2: Analyze and predict the effect of making a change in one part of a system on the system as a whole.
S11.A.3.1.3: Use appropriate quantitative data to describe or interpret a system (e.g., biological indices, electrical circuit data, automobile diagnostic systems data).
S11.A.3.1.4: Apply the universal systems model of inputs, processes, outputs and feedback to a working system (e.g., heating, motor, food production) and identify the resources necessary for operation of the system.

S11.A.3.2.1: Compare the accuracy of predictions represented in a model to actual observations and behavior.
S11.A.3.2.2: Describe advantages and disadvantages of using models to simulate processes and outcomes.
S11.A.3.2.3: Describe how relationships represented in models are used to explain scientific or technological concepts (e.g., dimensions of objects within the solar system, life spans, size of atomic particles, topographic maps).
S11.A.3.3.2: Compare stationary physical patterns (e.g., crystals, layers of rocks, skeletal systems, tree rings, atomic structure) to the object's properties.
S11.A.3.3.3: Analyze physical patterns of motion to make predictions or draw conclusions (e.g., solar system, tectonic plates, weather systems, atomic motion, waves).

S11.B.3.2.3: Explain how natural processes (e.g., seasonal change, catastrophic events, habitat alterations) impact the environment over time.
S11.B.3.3.2: Compare the impact of management practices (e.g., production, processing, research, development, marketing, distribution, consumption, byproducts) in meeting the need for commodities locally and globally.

S11.C.1.1.1: Explain that matter is made of particles called atoms and that atoms are composed of even smaller particles (e.g., protons, neutrons, electrons).
S11.C.1.1.3: Explain the formation of compounds (ionic and covalent) and their resulting properties using bonding theories.
S11.C.1.1.5: Predict the behavior of gases through the application of laws (e.g., Boyle's law, Charles' law, or ideal gas law).
S11.C.2.1.1: Compare or analyze waves in the electromagnetic spectrum (e.g., ultraviolet, infrared, visible light, X-rays, microwaves) as well as their properties, energy levels and motion.
S11.C.2.1.2: Describe energy changes in chemical reactions.
S11.C.2.1.3: Apply the knowledge of conservation of energy to explain common systems (e.g., refrigeration, rocket propulsion, heat pump).
S11.C.2.1.4: Use Ohm's Law to explain relative resistances, currents and voltage.
S11.C.2.2.2: Explain the practical use of alternative sources of energy (i.e., wind, solar, and biomass) to address environmental problems (e.g., air quality, erosion, resource depletion).
S11.C.3.1.1: Explain common phenomena (e.g., a rock in a landslide, an astronaut during a space walk, a car hitting a patch of ice on the road) using an understanding of conservation of momentum.
S11.C.3.1.2: Design or evaluate simple technological or natural systems that incorporate the principles of force and motion (e.g., simple machines, compound machines).
S11.C.3.1.3: Describe the motion of an object using variables (i.e., acceleration, velocity, displacement).
S11.C.3.1.4: Explain how electricity induces magnetism and how magnetism induces electricity as two aspects of a single electromagnetic force.

S11.C.3.1.5: Calculate the mechanical advantage for moving an object by using a simple machine.
S11.C.3.1.6: Identify elements of simple machines in compound machines.

S11.D.1.2.1: Evaluate factors affecting availability, location, extraction and use of natural resources.

Common Core State Standards for English Language Arts & Literacy in Science and Technical Subjects

Reading Standards for Literacy in Science and Technical Subjects 6-12
Grades 9-10 students:

RST.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

RST.2: Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon or concept; provide an accurate summary of the text.

RST.3: Follow precisely a complex multistep procedure when carrying out experiments, taking measurements or performing technical tasks attending to special cases or exceptions defined in the text.

RST.4: Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

RST.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).

RST.6: Analyze the author's purpose in providing an explanation, describing a procedure or discussing an experiment in a text, defining the question the author seeks to address.

RST.7: Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.8: Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

RST.9: Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

RST.10: By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science and Technical Subjects 6-12 Grades 9-10 students:

WHST.1: Write arguments focused on discipline-specific content.

a. Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons and evidence.

b. Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.

c. Use words, phrases and clauses to link the major sections of the text, create cohesion and clarify the relationships between claim(s) and reasons, between reasons and evidence and between claim(s) and counterclaims.

d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

e. Provide a concluding statement or section that follows from or supports the argument presented.

WHST.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments or technical processes.

a. Introduce a topic and organize ideas, concepts and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables) and multimedia when useful to aiding comprehension.

b. Develop the topic with well-chosen, relevant and sufficient facts, extended definitions, concrete details, quotations or other information and examples appropriate to the audience's knowledge of the topic.

c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion and clarify the relationships among ideas and concepts.

d. Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

e. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

f. Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

WHST.4: Produce clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience.

WHST.5: Develop and strengthen writing as needed by planning, revising, editing, rewriting or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

WHST.6: Use technology, including the Internet, to produce, publish and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.

WHST.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

WHST.8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

WHST.9: Draw evidence from informational texts to support analysis, reflection and research.

WHST.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes and audiences.

Academic Standards for Science and Technology and Engineering Education

3.2.C.A1: Differentiate between physical properties and chemical properties. Differentiate between pure substances and mixtures; differentiate between heterogeneous and homogeneous mixtures. Explain the relationship of an element's position on the periodic table to its atomic number, ionization energy, electro-negativity, atomic size, and classification of elements. Use electro-negativity to explain the difference between polar and nonpolar covalent bonds.

3.2.C.A2: Compare the electron configurations for the first twenty elements of the periodic table. Relate the position of an element on the periodic table to its electron configuration and compare its reactivity to the reactivity of other elements in the table. Explain how atoms combine to form compounds through both ionic and covalent bonding. Predict chemical formulas based on the number of valence electrons. Draw Lewis dot structures for simple molecules and ionic compounds. Predict the chemical formulas for simple ionic and molecular compounds. Use the mole concept to determine number of particles and molar mass for elements and compounds. Determine percent compositions, empirical formulas, and molecular formulas.

3.2.C.A4: Predict how combinations of substances can result in physical and/or chemical changes. Interpret and apply the laws of conservation of mass, constant composition (definite proportions), and multiple proportions. Balance chemical equations by applying the laws of conservation of mass. Classify chemical reactions as synthesis (combination), decomposition, single displacement (replacement), double displacement, and combustion. Use stoichiometry to predict quantitative relationships in a chemical reaction.

3.2.C.A5: MODELS Recognize discoveries from Dalton (atomic theory), Thomson (the electron), Rutherford (the nucleus), and Bohr (planetary model of atom), and understand how each discovery leads to modern theory. Describe Rutherford's "gold foil" experiment that led to the discovery of the nuclear atom. Identify the major components (protons, neutrons, and electrons) of the nuclear atom and explain how they interact.

3.2.12.A4: Apply oxidation/reduction principles to electrochemical reactions. Describe the interactions between acids and bases.

3.2.12.A5: MODELS/PATTERNS Use VSEPR theory to predict the molecular geometry of simple molecules. CONSTANCY AND CHANGE Predict the shift in equilibrium when a system is subjected to a stress.

Checklist to Complete and Submit with Curriculum:

_____ A hard copy of the curriculum using The template entitled "Planned Instruction," available on the district website

_____ Hard copies of all supplemental resources not available electronically

_____ The primary textbook form(s)

_____ The appropriate payment form, in compliance with the maximum curriculum writing hours noted on the first page of this document

_____ A USB/Flash Drive containing a single file that will print the curriculum in its intended sequence from beginning to end and all supplemental resources that are available in electronic format.

Each principal and/or department chair has a schedule of First and Second Readers/Reviewers. Each Reader/Reviewer must sign & date below.

First Reader/Reviewer Printed Name____________________________

First Reader/Reviewer Signature_______________________________ Date_________

Second Reader/Reviewer Printed Name__________________________

Second Reader/Reviewer Signature _____________________________ Date__________