Fair Lawn

Public Schools

Fair Lawn, NJ

Advanced Placement Chemistry

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AP Chemistry is a high school science class developed by the Fair Lawn Schools high school science faculty and aligned to The College Board Standards.

Science Department

Fair Lawn School District

Committee Credits

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Advanced Placement Chemistry

I. Course Synopsis

The Advanced Placement Chemistry Course is a seven-credit laboratory science course that meets seven class periods a week, and fulfills the curriculum requirements set forth by the College Board. The textbook for the course is Chemistry – The Central Science, 9th Edition Brown, LeMay, Burstein, Prentice Hall, 2003. Additional resources are listed at the end of this document.

The course is structured as an entry-level, college chemistry course, designed to provide students with both chemistry content knowledge, and advanced inquiry skills that will prepare them for future scientific coursework. This will be achieved by combining the essential knowledge students must have with the science practices they must master to create meaningful learning objectives.

The course is described in a Concept Outline that breaks the course down from the broadest concepts (Big Ideas) to the more specific content (Learning Objectives).

Big Ideas

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Enduring Understandings

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Essential Knowledge ⟷ **Science Practices**

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Learning Objectives
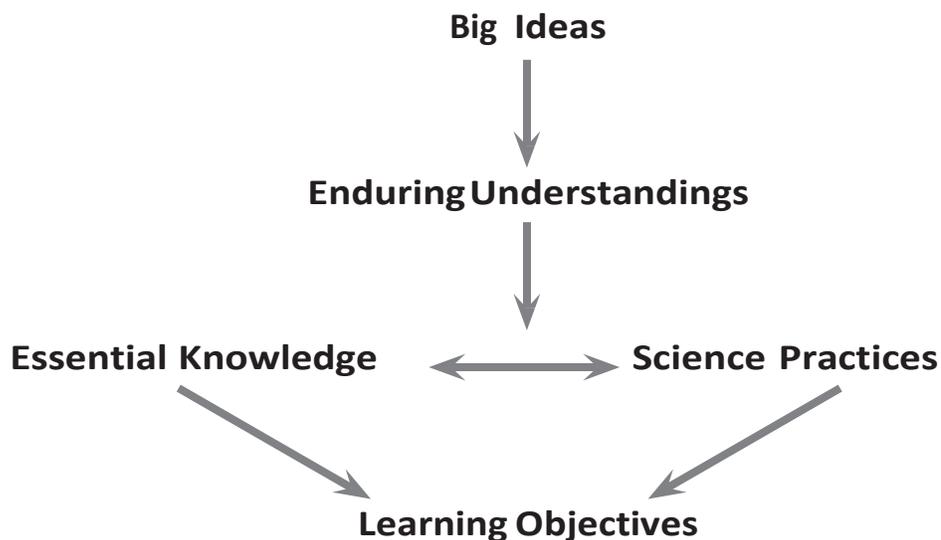
The Big Ideas (BI) are broken down into Enduring Understandings (EU), the scientific knowledge that students are expected to possess upon completion of the course. These Enduring Understandings are used to create specific Learning Objectives (LO) that combine the Essential Knowledge (EK) students must have and the Science Practices they must master. These Science Practices (SP) have been defined by the College Board as:

Science Practice 1 (SP1): The student can use representations and models to communicate scientific phenomena and solve scientific problems.
Science Practice 2 (SP2): The student can use mathematics appropriately.

Science Practice 3 (SP3): The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

Science Practice 4 (SP4): The student can plan and implement data collection strategies in relation to a particular scientific question.

Science Practice 5 (SP5): The student can perform data analysis and evaluation of evidence.

Science Practice 6 (SP6): The student can work with scientific explanations and theories.

Science Practice 7 (SP7): The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

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II. Philosophy & Rationale

The goal of the course is to foster deeper understanding of the most important chemistry concepts and the content that supports them. This will be done be discouraging factual recall, and encouraging inquiry based learning of essential concepts. In addition, students will develop advanced inquiry and reasoning skills (experimental design, data analysis, etc.) that will prepare them for the subsequent college level courses.

III. Scope & Sequence

Lab Equipment, Procedures, and Safety: 3 days

Unit 1: Atomic and Molecular Structure (BI 1)   6 Weeks   Chapters 1-3,6,7
- Pure Substances and Mixtures (properties, qualitative and quantitative analysis)
- Atomic Structure and Behavior
- Periodic Properties of Elements
- Atomic Models
- Conservation of Mass

Unit 2: Properties and Interactions of Matter   (BI 2) 8 Weeks   Ch: 2,4,8,10,11,25
- States of Matter (Properties, Particle Interactions)
    - Solid and Liquid Properties
    - Gas Laws
    - Solution Chemistry
- Intermolecular and Intramolecular Forces
- Chemical Bonding (Covalent, Ionic, Metallic)

Unit 3: Chemical and Physical Changes in Matter (BI 3) 8 Weeks   Ch: 3,4,5,10,16,20
- Chemical Equations
    - Regular, Ionic, Net Ionic
- Stoichiometric Calculations
- Types of Chemical Reactions
    - Synthesis, Decomposition, Acid-Base, Redox
- Energy Transformations in Physical and Chemical Changes
    - Combustion Reactions
    - Electrochemical Reactions

Unit 4: Rates of Chemical Reactions (BI 4)   6 Weeks   Ch: 14-16, 21
- Determining Rates of Reaction
  - Factors influencing rate
  - Determination of rate constant
  - Half-life and order of reaction
- Influence of Collision on Rate
- Reaction Mechanisms
- Catalysts

Unit 5: Energy in Chemical Systems (BI 5)   6 Weeks   Ch: 5,11,12,19,25
- Energy Transfer in Chemical Systems (Physical and Chemical Change)
  - Potential vs. Kinetic Energy
  - Calculation of Energy Transfer
- Relationship of Inter and Intramolecular forces to energy of a system
- Entropy in Chemical Systems

Unit 6: Chemical Equilibrium (BI 6)   6 Weeks   Ch: 13,15,16,17,19

- Equilibrium in Chemical Systems
  - Calculations of K and Q
- Stresses on Systems in Equilibrium (LeChateleir's Principle)
- Equilibrium and Acid-Base and Solution Chemistry
  - Titration, Buffers
  - Solubility
- Gibbs Free Energy and Equilibrium

IV. Unit Descriptions

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Unit 1: Atomic and Molecular Structure (BI 1)

Enduring Understandings
1.A: All matter is made up of atoms. There are a limited number of types of atoms; these are the elements.
1.B: The atoms of each element have unique structures arising from interactions between electrons and nuclei.
1.C: Elements display periodicity in their properties when they are organized according to increasing atomic number. Periodicity can be explained by regular variations in atomic structure and can be used to understand and predict properties of matter.
1.D: Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.
1.E: Atoms are conserved in physical and chemical processes.

Essential Question(s)
1. How does the arrangement of subatomic particles affect the properties of individual elements and the trends in properties?
2. How and why is experimental data used to generate atomic models?
3. How do atoms change during physical and chemical processes?

Essential Knowledge (EK) and Learning Objectives (LO)
EK1.A.1: Molecules are composed of specific combinations of atoms; different molecules are composed of combinations of different elements and of combinations of the same elements in differing amounts and proportions.

> LO 1.1: Use atomic molecular theory to explain why the ratio of the masses of the constituent elements in any pure sample of a compound are always identical. [SP 6]

EK1.A.2: Chemical analysis provides a method for determining the relative number of atoms in a substance, which can be used to identify the substance or determine its purity.

> LO 1.2: Apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures. [SP 2]

> LO 1.3: Select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance. [SP 2 and 6]

EK1.A.3: The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.

> LO 1.4: Demonstrate the relationship of the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively. [SP 7]

EK1.B.1: The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom.

> LO 1.5: Explain the distribution of electrons in an atom or ion based upon data and identify the atom or ion. [SP 1 and 6]

> LO 1.6: Analyze data relating to electron energies for patterns and relationships. [SP 5]

EK1.B.2: The electronic structure of the atom can be described using an electron configuration that reflects the concept of electrons in quantized energy levels or shells.

> LO 1.7: Describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb's Law to construct explanations of how the energies of electrons within shells in atoms vary. [SP 5 and 6]

> LO 1.8: Explain the distribution of electrons using Coulomb's Law to analyze measured energies. [SP 6]

EK1.C.1: Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure.

> LO 1.9: Predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model. [SP 6]

> LO 1.10: Justify with evidence the arrangement of the elements on the periodic table and apply periodic properties to chemical reactivity. [SP 6]

> LO 1.11: Analyze data, based on periodicity and the properties of binary compounds, to identify patterns and generate hypotheses related to the molecular design of compounds for which data are not supplied. [SP 3 and 5]

EK1.C.2: The currently accepted best model of the atom is based on the quantum mechanical model.

> LO 1.12: Analyze data to determine whether it suggests the need to refine the atomic

model from a classical shell model to a quantum mechanical model. [SP 6]

EK1.D.1: Any model of the atom is subject to refinement and change in response to new experimental results. In that sense, an atomic model is not regarded as an exact description of the atom, but rather a theoretical construct that fits a set of experimental data.

> LO 1.13: Given information about a particular model of the atom, determine if the model is consistent with specified evidence (i.e. ionization energy or spectroscopy data). [SP 5]

EK1.D.2: An early model of the atom stated that all atoms of an element are identical. Mass spectrometry data demonstrate evidence that contradicts this early model.

> LO 1.14: Analyze data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element. [SP 1]

EK1.D.3: The interaction of electromagnetic waves or light with matter is a powerful means to probe the structure of atoms and molecules, and to measure their concentration.

> LO 1.15: Justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules. [SP 4]

> LO 1.16: Design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution. [SP 4 and 5]

EK1.E.1: Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types.

> LO 1.17: Express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. [SP 1]

EK1.E.2: Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants, as well as the efficiency of the transformation.

> LO 1.18: Apply conservation of atoms to the rearrangement of atoms in various processes. [SP 1]

> LO 1.19: Design, and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. [SP 4 and 5]

> LO 1.20: Design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution. [SP 4 and 5]

<u>Suggested Activities</u>
1. Labs:
   a. Determination of Empirical Formula Lab
   b. Reaction Types with Ionic Reactions
   c. Determination of the Molar Mass of and Acid by Titration with a Base
   d. Beer's Law: Determine the Concentration of Unknowns Using Spectroscopy.
2. Chapter outlines
3. Unit test/quiz

<u>NJSLS-S</u>
HS-PS-1-1, 1-3, 2-6, 4-1, 4-3, 4-4, 2-6

Unit 2: Properties and Interactions of Matter   (B.I. 2)

<u>Enduring Understandings</u>
2.A: Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.
2.B: Forces of attraction between particles are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.
2.C: The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.
2.D: The type of bonding in the solid state can be deduced from the properties of the solid state.

<u>Essential Question(s)</u>
1. How do the position and interaction of particles of a given substance determine its properties?
2. How do intramolecular and intermolecular forces affect substances behaviors?
3. How do the structures of a given substance relate to their bonding patterns?
4. How can you determine the bond type in a solid by measuring its physical properties?

<u>Essential Knowledge (EK) and Learning Objectives (LO)</u>
EK2.A.1: The different properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.

> LO 2.1: Predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views. [SP 6 and 7]
> LO 2.2: Explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium. [SP 7]

LO 2.3: Use aspects of particulate models (i.e., particle spacing, motion, and forces of attraction) to reason about observed differences between solid and liquid phases and among solid and liquid materials. [SP 6 and 7]

EK2.A.2: The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.

LO 2.4: Use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors. [SP 1 and 6]

LO 2.5: Use different representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample. [SP 1, 6, and 7]

LO 2.6: Apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. [SP 2]

EK2.A.3: Solutions are homogenous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of the solutes and solvent.

LO 2.7: Explain how solutes can be separated by chromatography based on intermolecular interactions. [SP 6]

LO 2.8: Draw and/or interpret representations of solutions that show the interactions between the solute and solvent. [SP 1 and 6]

LO 2.9: Create or interpret representations that link the concept of molarity with particle views of solutions. [SP 1]

LO 2.10: Design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components. [SP 4 and 5]

EK2.B.1: London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.

LO 2.11: Explain the trends in properties and/or predict properties of samples consisting of particles with no permanent dipole on the basis of London dispersion forces. [SP 6]

EK2.B.2: Dipole forces result from the attraction among the positive ends and negative ends of polar molecules. Hydrogen bonding is a strong type of dipole-dipole force.

> LO 2.12: Analyze data for real gases to identify deviations from ideal behavior and relate these to molecular interactions. [See SP 5 and 6]

> LO 2.13: Describe the relationships between the structural features of polar molecules and the forces of attraction between the particles. [SP 1]

> LO 2.14: Apply Coulomb's Law qualitatively (including using representations) to describe the interactions of ions, and the attractions between ions and solvents to explain the factors that contribute to the solubility of ionic compounds. [SP 1 and 6]

EK2.B.3: Intermolecular forces play a key role in determining the properties of substances, including biological structures and interactions.

> LO 2.15: Explain observations regarding the solubility of ionic solids and molecules in water and other solvents on the basis of particle views that include intermolecular interactions and entropic effects. [SP 1 and 6]

> LO 2.16: Explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces. [SP 6]

EK2.C.1: In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond.

> LO 2.17: Predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements. [SP 6]

> LO 2.18: Rank and justify the ranking of bond polarity on the basis of the location of the bonded atoms in the periodic table. [SP 6]

EK2.C.2: Ionic bonding results from the net attraction between oppositely charged ions, closely packed together in a crystal lattice.

> LO 2.19: Create visual representations of ionic substances that connect the microscopic structure to macroscopic properties, and/or use representations to connect the microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity). [SP 1 and 7]

EK2.C.3: Metallic bonding describes an array of positively charged metal cores surrounded by a sea of mobile valence electrons.

LO 2.20: Explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, and low volatility) and the shell model of the atom. [SP 6 and 7]

EK2.C.4: The localized electron bonding model describes and predicts molecular geometry using Lewis diagrams and the VSEPR model.

LO 2.21: Use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity. [SP 1]

EK2.D.1: Ionic solids have high melting points, are brittle, and conduct electricity only when molten or in solution.

LO 2.22: Design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid. [SP 4]
LO 2.23: The student can create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance. [SP 1]

LO 2.24: Explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level. [SP 1, 6, and 7]

EK2.D.2: Metallic solids are good conductors of heat and electricity, have a wide range of melting points, and are shiny, malleable, ductile, and readily alloyed.

LO 2.25: Compare the properties of metal alloys with their constituent elements to determine if an alloy has formed, identify the type of alloy formed, and explain the differences in properties using particulate level reasoning. [SP 1 and 7]

LO 2.26: Use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys. [SP 6 and 7]

LO 2.27: Create a representation of a metallic solid that shows essential characteristics of the structure and interactions present in the substance. [SP 1]

LO 2.28: Explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level. [SP 1, 6, and 7]

EK2.D.3: Covalent network solids generally have extremely high melting points, are hard, and are thermal insulators. Some conduct electricity.

LO 2.29: Create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance. [SP 1]

LO 2.30: Explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level. [SP 1, 6, and 7]

EK2.D.4: Molecular solids with low molecular weight usually have low melting points and are not expected to conduct electricity as solids, in solution, or when molten.

LO 2.31: Create a representation of a molecular solid that shows essential characteristics of the structure and interactions present in the substance. [SP 1]

LO 2.32: Explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level. [SP 1, 6, and 7]

<u>Suggested Activities</u>
1. Labs:
    a. Thin Layer Chromatography
    b. Separation by Distillation
    c. Computer Lab on Liquids and Solids
    d. Crystal Models, Metals, and Minerals (Model Building)
    e. Preparation and Standardization of a Basic Solution
    f. Covalent Model Building and Analysis
    g. Molecular Modeling (Computer)
    h. Determining the Molar Mass of a Vapor

<u>NJSLS-S</u>
HS-PS-1-1, 1-3, 2-6, 4-1, 4-3, 4-4, 2-6

Unit 3: Chemical and Physical Changes in Matter (BI 3)
<u>Enduring Understandings</u>
3.A: Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form.
3.B: Chemical reactions can be classified by considering what the reactants are, what the products are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid-base, and oxidation-reduction reactions.
3.C: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.

<u>Essential Question(s)</u>
1. How do chemical equations apply to the purpose of a laboratory?
2. How does a balanced chemical equation (stoichiometry) represent what is occurring at the atomic or molecular level? Apply stoichiometry in both gas and solution chemistry.

3. How do the types of chemical reactions (including acid-base and redox) differ? How are they used in society?

4. How can experimental data for any of the types of reactions be used to determine the quantities of reactants or products or the efficiency of the reaction?

5. How is energy involved in physical changes, chemical changes and electrochemical changes, both qualitatively and quantitatively?

Essential Knowledge (EK) and Learning Objectives (LO)

EK3.A.1: A chemical change may be represented by a molecular, ionic, or net ionic equation.

> LO 3.1: Translate among macroscopic observations of change, chemical equations, and particle views. [SP 1 and 7]

> LO 3.2: Translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic) in terms of utility for the given circumstances. [SP 1 and 7]

EK3.A.2: Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to be simply an exercise done only by chemists.

> LO 3.3: Use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results. [SP 2 and 5]

> LO 3.4: Relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion. [SP 2, 5, and 6]

EK3.B.1: Synthesis reactions are those in which atoms and/or molecules combine to form a new compound. Decomposition is the reverse of synthesis, a process whereby molecules are decomposed, often by the use of heat.

> LO 3.5: Design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. [SP 2 and 4]

> LO 3.6: Use data from synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. [SP 2 and 6]

EK3.B.2: In a neutralization reaction, protons are transferred from an acid to a base.

LO 3.7: Identify compounds as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, using proton-transfer reactions to justify the identification. [SP 6]

EK3.B.3: In oxidation-reduction (redox) reactions, there is a net transfer of electrons. The species that loses electrons is oxidized, and the species that gains electrons is reduced.

LO 3.8: Identify redox reactions and justify the identification in terms of electron transfer. [SP 6]

LO 3.9: Design and/or interpret the results of an experiment involving a redox titration. [SP 4 and 5]

EK3.C.1: Production of heat or light, formation of a gas, and formation of a precipitate and/or a color change are possible evidences that a chemical change has occurred.

LO 3.10: Classify a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations, and the distinction between rearrangement of covalent interactions and noncovalent interactions. [SP 1 and 6]

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

LO 3.11: Interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes. [SP 1 and 4]

EK3.C.3: Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytic cells.

LO 3.12: Make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/ or Faraday's laws. [SP 2 and 6]

LO 3.13: Analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions. [SP 5]

Suggested Activities
1. Labs:
    a. Titration Curve and Acid Base Indicators
    b. Determining the Enthalpy of Formation of a Compound

    c.   Analysis of a Hydrogen Peroxide Solution (Redox Titration)
    d.   Corrosion Reactions
    e.   Building Electrochemical Cells and Determining Their E^o
    f.   Determining the Value of the Faraday and the Atomic Mass of Copper

NJSLS-S
HS-PS-1-2, 3-3, 1-7

Unit 4: Rates of Chemical Reactions (BI 4)

Enduring Understandings
4.A: Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time.
4.B: Elementary reactions are mediated by collisions between molecules. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.
4.C: Many reactions proceed via a series of elementary reactions.
4.D: Reaction rates may be increased by the presence of a catalyst.

Essential Question(s)
1. How do factors (temperature, pressure and concentration of reactants) affect rate of reaction?
2. How is the rate law used to determine rate of reaction? How are the factors mentioned above taken into account?
3. How do collisions relate to the rate of reaction?
4. How does a reaction mechanism explain a multi-step reaction?
5. How (by what mechanism) do catalysts affect rates of reaction?

Essential Knowledge (EK) and Learning Objectives (LO)
EK4.A.1: The rate of a reaction is influenced by the concentration or pressure of reactants, the phase of the reactants and products, and environmental factors such as temperature and solvent.

    LO 4.1: Design and/or interpret the results of an experiment regarding the factors (i.e., temperature, concentration, surface area) that may influence the rate of a reaction. [SP 4 and 5]

EK4.A.2: The rate law shows how the rate depends on reactant concentrations.

    LO 4.2: Analyze concentration vs. time data to determine the rate law for a zeroth-, first-, or second-order reaction. [SP 5]

EK4.A.3: The magnitude and temperature dependence of the rate of reaction is contained

quantitatively in the rate constant.

> LO 4.3: Connect the half-life of a reaction to the rate constant of a first-order reaction and justify the use of this relation in terms of the reaction being a first-order reaction. [SP 2]

EK4.B.1: Elementary reactions can be uni-molecular or involve collisions between two or more molecules.

> LO 4.4: Connect the rate law for an elementary reaction to the frequency and success of molecular collisions, including connecting the frequency and success to the order and rate constant, respectively. [SP 7]

EK4.B.2: Not all collisions are successful. To get over the activation energy barrier, the colliding species need sufficient energy. Also, the orientations of the reactant molecules during the collision must allow for the rearrangement of reactant bonds to form product bonds.

> LO 4.5: Explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation. [SP 6]

EK4.B.3: A successful collision can be viewed as following a reaction path with an associated energy profile.

> LO 4.6: Use representations of the energy profile for an elementary reaction (from the reactants, through the transition state, to the products) to make qualitative predictions regarding the relative temperature dependence of the reaction rate. [SP 1 and 6]

EK4.C.1: The mechanism of a multi-step reaction consists of a series of elementary reactions that add up to the overall reaction.

EK4.C.2: In many reactions, the rate is set by the slowest elementary reaction, or rate-limiting step.

EK4.C.3: Reaction intermediates, which are formed during the reaction, but not present in the overall reaction, play an important role in multi-step reactions.

> LO 4.7: Evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate of a reaction, and data that can be used to infer the presence of a reaction intermediate. [SP 6]

EK4.D.1: Catalysts function by lowering the activation energy of an elementary step in a reaction mechanism, and by providing a new and faster reaction mechanism.

LO 4.8: Translate among reaction energy profile representations, particulate representations, and symbolic representations (chemical equations) of a chemical reaction occurring in the presence and absence of a catalyst. [SP 1]

EK4.D.2: Important classes in catalysis include acid-base catalysis, surface catalysis, and enzyme catalysis.

LO 4.9: Explain changes in reaction rates arising from the use of acid-base catalysts, surface catalysts, or enzyme catalysts, including selecting appropriate mechanisms with or without the catalyst present. [SP 6 and 7]

Suggested Activities
1. Labs:
   a. Nuclear Chemistry (order of reaction), paper and pencil
   b. Rate of Reaction (Determining the Order of a Reactant)
   c. Determining the Equilibrium Constant for a Reaction using a Spectrophotometer.

NJSLS-S
HS-PS-1-2, 3-3, 1-7

Unit 5: Energy in Chemical Reactions (BI 5)

Enduring Understandings
5.A: Two systems with different temperatures that are in thermal contact will exchange energy. The quantity of thermal energy transferred from one system to another is called heat.
5.B: Energy is neither created nor destroyed, but only transformed from one form to another.
5.C: Breaking bonds requires energy, and making bonds releases energy.
5.D: Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.
5.E: Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both.

Essential Question(s)
1. How do heat and temperature relate in terms of potential and kinetic energy?
2. How does energy transfer occur in a chemical system? How is this difference measured based on the process?
3. How are inter and intramolecular forces related to energy required to make a physical or chemical change occur?

4. How are entropy and Gibbs Free Energy used to determine whether a reaction is thermodynamically favored?

<u>Essential Knowledge (EK) and Learning Objectives (LO)</u>

EK5.A.1: Temperature is a measure of the average kinetic energy of atoms and molecules.

> LO 5.1: Create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular interactions), which influence the interaction strength. [SP 1 and 7]

> LO 5.2: Relate temperature to the motions of particles, either via particulate representations, such as drawings of particles with arrows indicating velocities, and/or via representations of average kinetic energy and distribution of kinetic energies of the particles, such as plots of the Maxwell- Boltzmann distribution. [SP 1 and 7]

EK5.A.2: The process of kinetic energy transfer at the particulate scale is referred to in this course as heat transfer, and the spontaneous direction of the transfer is always from a hot to a cold body.

> LO 5.3: Generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions.   [SP 7]

EK5.B.1: Energy is transferred between systems either through heat transfer or through one system doing work on the other system.

EK5.B.2: When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur through either heat exchange or work.

> LO 5.4: Use conservation of energy to relate the magnitudes of the energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat versus work), or the direction of energy flow. [SP 1 and 2]

> LO 5.5: Use conservation of energy to relate the magnitudes of the energy changes when two nonreacting substances are mixed or brought into contact with one another. [SP 2]

EK5.B.3: Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.

> LO 5.6: Use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/ vaporization, relate energy changes

associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to PΔV work.   [SP 2]

EK5.B.4: Calorimetry is an experimental technique that is used to measure the change in energy of a chemical system.

> LO 5.7: Design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure. [SP 4 and 5]

EK5.C.1: Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them.

EK5.C.2: The net energy change during a reaction is the sum of the energy required to break the bonds in the reactant molecules and the energy released in forming the bonds of the product molecules. The net change in energy may be positive for endothermic reactions where energy is required, or negative for exothermic reactions where energy is released.

> LO 5.8: Draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds. [SP 2 and 7]

EK5.D.1: Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.

> LO 5.9: Make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact. [SP 6]

EK5.D.2: At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.

> LO 5.10: Support the claim about whether a process is a chemical or physical change (or may be classified as both) based on whether the process involves changes in intramolecular versus intermolecular interactions.   [SP 5]

EK5.D.3: Noncovalent and intermolecular interactions play important roles in many biological and polymer systems.

> LO 5.11: Identify the noncovalent interactions within and between large molecules, and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions. [SP 7]

EK5.E.1: Entropy is a measure of the dispersal of matter and energy.

LO 5.12: Use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes. [SP 1]

EK5E.2: Some physical or chemical processes involve both a decrease in the internal energy of the components ($\Delta H° < 0$) under consideration and an increase in the entropy of those components ($\Delta S° > 0$). These processes are necessarily "thermodynamically favored" ($\Delta G° < 0$).

LO 5.13: Predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or qualitatively) the signs of both $\Delta H°$ and $\Delta S°$, and calculation or estimation of $\Delta G°$ when needed. [SP 2 and 6]

EK5.E.3: If a chemical or physical process is not driven by both entropy and enthalpy changes, then the Gibbs free energy change can be used to determine whether the process is thermodynamically favored.

LO 5.14: Determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. [SP 2]

EK5.E.4: External sources of energy can be used to drive change in cases where the Gibbs free energy change is positive.

LO 5.15: Explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause processes that are not thermodynamically favorable to become favorable. [SP 6]

LO 5.16: Use LeChatelier's principle to make qualitative predictions for systems in which coupled reactions that share a common intermediate drive formation of a product. [SP 6]

LO 5.17: Make quantitative predictions for systems involving coupled reactions that share a common intermediate, based on the equilibrium constant for the combined reaction. [SP 6]

EK5.E.5: A thermodynamically favored process may not occur due to kinetic constraints (kinetic vs. thermodynamic control).

LO 5.18: The student can explain why a thermodynamically favored chemical reaction may not produce large amounts of product (based on consideration of both initial conditions and kinetic effects), or why a thermodynamically unfavored chemical reaction can produce large amounts of product for certain sets of initial conditions. [SP 1 and 7]

Suggested Activities

1. Labs:
    a. Determining the Enthalpy of Formation of a Compound

b.   Isomer Model Building and Analysis

NJSLS-S
HS-PS-1-2, 3-3, 1-7

Unit 6: Chemical Equilibrium (BI 6)

Enduring Understandings
6.A: Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.
6.B: Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.
6.C: Chemical equilibrium plays an important role in acid-base chemistry and in solubility.
6.D: The equilibrium constant is related to temperature and the difference in Gibbs free energy between reactants and products.

Essential Question(s)
1.   How does equilibrium relate to rates of reactions and concentrations of reactants and products?
2.   How are the quantitative values of K and Q used to analyze systems at equilibrium?
3.   How is LeChatelier's principal used to predict the shifts in equilibrium?
4.   How does equilibrium relate to acid-base, buffer and solubility systems?
5.   How does the equilibrium constant relate to Gibbs Free Energy?

Essential Knowledge (EK) and Learning Objectives (LO)
EK6.A.1: In many classes of reactions, it is important to consider both the forward and reverse reaction.

> LO 6.1: Given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes. [SP 6]

EK6.A.2: The current state of a system undergoing a reversible reaction can be characterized by the extent to which reactants have been converted to products. The relative quantities of reaction components are quantitatively described by the reaction quotient, Q.

> LO 6.2: Given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on Q or K. [SP 2]

EK6.A.3: When a system is at equilibrium, all macroscopic variables, such as concentrations, partial pressures, and temperature, do not change over time. Equilibrium results from an equality

between the rates of the forward and reverse reactions, at which point Q = K.

LO 6.3: Connect kinetics to equilibrium by using reasoning about equilibrium, such as LeChatelier's principle, to infer the relative rates of the forward and reverse reactions. [SP 7]

LO 6.4: Given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached. [SP 2 and 6]

LO 6.5: Given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. [SP 2]

LO 6.6: Given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use stoichiometric relationships and the law of mass action (Q equals K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction. [SP 2 and 6]

EK6.A.4: The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side.

LO 6.7: For a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentrations at equilibrium. [SP 2]

EK6.B.1: Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (LeChatelier's principle).

LO 6.8: Use LeChatelier's principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. [SP 1 and 6]

LO 6.9: Use LeChatelier's principle to design a set of conditions that will optimize a desired outcome, such as product yield. [SP 4]

EK6.B.2: A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of the original equilibrium state. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state.

LO 6.10: Connect LeChatelier's principle to the comparison of Q to K by explaining the effects of the stress on Q and K. [SP 1 and 7]

EK6.C.1: Chemical equilibrium reasoning can be used to describe the proton-transfer reactions of acid-base chemistry.

LO 6.11: Generate or use a particulate representation of an acid (strong or weak or polyprotic) and a strong base to explain the species that will have large versus small concentrations at equilibrium. [SP 1 and 2]

LO 6.12: Reason about the distinction between strong and weak acid solutions with similar values of pH, including the percent ionization of the acids, the concentrations needed to achieve the same pH, and the amount of base needed to reach the equivalence point in a titration. [SP 1]

LO 6.13: Interpret titration data for monoprotic or polyprotic acids involving titration of a weak or strong acid by a strong base (or a weak or strong base by a strong acid) to determine the concentration of the titrant and the pKa for a weak acid, or the pKb for a weak base. [SP 5]

LO 6.14: Based on the dependence of K_w on temperature, reason that neutrality requires $[H^+] = [OH^-]$ as opposed to requiring pH = 7, including especially the applications to biological systems. [SP 2 and 6]

LO 6.15: Identify a given solution as containing a mixture of strong acids and/or bases and calculate or estimate the pH (and concentrations of all chemical species) in the resulting solution. [SP 2 and 6]

LO 6.16: Identify 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), calculate the pH and concentration of all species in the solution, and/ or infer the relative strengths of the weak acids or bases from given equilibrium concentrations. [SP 2 and 6]

LO 6.17: Given an arbitrary mixture of weak and strong acids and bases (including polyprotic systems), determine which species will react strongly with one another (i.e., with K >1) and what species will be present in large concentrations at equilibrium. [SP 6]

EK6.C.2: The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to pKa allows one to determine the protonation state of a molecule with a labile proton.

LO 6.18: Design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity. [SP 2, 4, and 6]

LO 6.19: Relate the predominant form of a chemical species involving a labile proton (i.e., protonated/deprotonated form of a weak acid) to the pH of a solution and the pKa associated with the labile proton. [SP 2, 5, and 6]

LO 6.20 The student can identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base. [See SP 6.4]

EK6.C.3: The solubility of a substance can be understood in terms of chemical equilibrium.

LO 6.21: Predict the solubility of a salt, or rank the solubility of salts, given the relevant Ksp values. [SP 2 and 6]

LO 6.22: Interpret data regarding solubility of salts to determine, or rank, the relevant Ksp values. [SP 2 and 6]

LO 6.23: Interpret data regarding the relative solubility of salts in terms of factors (common ions, pH) that influence the solubility. [SP 5]

LO 6.24: Analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations. [See SP 1 and 7]

EK6.D.1: When the difference in Gibbs free energy between reactants and products ($\Delta G°$) is much larger than the thermal energy (RT), the equilibrium constant is either very small (for $\Delta G° > 0$) or very large (for $\Delta G° < 0$). When $\Delta G°$ is comparable to the thermal energy (RT), the equilibrium constant is near 1.

LO 6.25: Express the equilibrium constant in terms of $\Delta G°$ and RT and use this relationship to estimate the magnitude of K and, consequently, the thermodynamic favorability of the process. [SP 2]

Suggested Activities
1. Labs:
   a. Titration Curve and Acid Base Indicators
   b. Interactive Computer Lab on Acids and Bases
   c. Determining the Equilibrium Constant (K_i) for a reaction using a Spectrophotometer
   d. The Preparation and Testing of a Buffer Solution

NJSLS-S
HS-PS-1-4, 1-5, 1-6, 3-1, 3-2, 3-4

V. Course Materials

Textbook:
Chemistry – The Central Science, 9th Edition
       Theodore Brown, H. Eugene LeMay, Bruce E. Burstein, Julia R. Burdge
        Prentice Hall, Pearson Education, Inc. 2003

Laboratory Resources:
AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2013. The College Board.

Additional Resources:
AP Chemistry Guided Inquiry Activities for the Classroom. 2013. The College Board.
POGIL Activities for High School Chemistry. Lauta Trout Editor. 2012. Flinn Scientific.

Technology:
Vernier Lab Quest Data collection devices and associated measurement probes will be used for laboratory experiments.

Computers will be used for research, data analysis and inquiry learningng assignments.

Chapter Correlations & Time Frames

Unit	AP Chem CP Time Frame	"Chemistry -The Central Science", 9th Ed
1 Atomic Structure	September-October	1-3, 6, 7
2 Properties & Interactions of Matter	October-December	2,4,8,10,11,25
3 Chemical & Physical Changes	December – February	3,4,5,10,16,20
4 Rates of Chemical Reactions	February-March	14-16,21
5 Energy in Chemical Systems	April-May	5,11,12,19,25
6 Chemical Equilibrium	May-June	13,15,16,17,19

Suggested Activities & Suggested Modifications for Special Education Students, ELL Students, Students at Risk, and Gifted Students:

1. Students with special needs and ELL learners may be provided with key vocabulary terms prior to the unit beginning. In particular, the amount of key vocabulary terms should be reduced for ELL students.
2. ELL students may be provided with additional visual aids. For additional modifications, refer to Classroom Instruction that Works for ELL Learners *or the* SIOP protocol.
3. Gifted students may be challenged by asking them to form additional connections between biology, chemistry, and physics.

VI. Assessments

Regular tests, quizzes, lab reports, homework assignments, class participation, etc. will be required throughout marking periods 1 – 4.

VII. Cross Curricular Aspects

NJSLS Literacy: Click on the link to the High School Evidence Statements to see expectations related to literacy for this unit. In addition, a focus of the course will be on the development of the LAL standards for science & technical subjects.

NJSLS Math: Students will be expected to perform measurement, modeling, apply algebra, and geometry and statistics.

Interdisciplinary Connections and Alignment to Technology standards

Science classes in the Fair Lawn Public schools promote career-readiness skills related to Personal Financial Literacy (9.1) and Career Awareness, Exploration, and Presentation (9.2). Some course concepts from the Career and Technical Education Standards (9.3), but these are not directly correlated since our district is not a CTE program.

The Fair Lawn Public Schools District fosters an environment that promotes career-readiness skills in all content areas. Whereas Career Ready Practices are explored consistently, specific alignment to Personal Finance Literacy (9.1) and Career Awareness, Exploration, and Presentation Standards (9.2) are included in the district level document (below). When appropriate, the Career and Technical Education Standards (9.3) have been reviewed and aligned as well.

Examples: 9.2B: Career exploration in each unit of study.

In addition, every effort is made to integrate technology and engineering into our science classes. Educational Technology (8.1) and Technology Education, Engineering, Design, and Computational Thinking – Programming (8.2) standards are cross connected throughout our science programs.

Examples: 8.1A: Use spreadsheets to analyze & interpret data from laboratories, 6-12.
                       Use the internet to increase productivity and efficiency, 9-12.
             8.1B,C: Use data to solve real-world problems, 6-12.
                     Use online platforms to collaborate & address global issues, 9-12.
             8.1F: Collect and analyze data using internet and data simulations, 6-12.
             8.2A: Become aware of the invention process, 3-5.
             8.2B: Become aware of the global impacts on technology, 6-12.
             8.2C: Apply the design process to pushes & pulls, K-2.
             8.2D: Use tools to reduce work, K-2.

For additional detail on how these standards are integrated throughout the Fair Lawn Schools curriculum, review the Fair Lawn Public Schools District Alignment to Technology & Career Readiness & 21st Century Skills Standards Curriculum Appendix.