FREEHOLD REGIONAL HIGH SCHOOL DISTRICT

OFFICE OF CURRICULUM AND INSTRUCTION

SCIENCE DEPARTMENT

ADVANCED PLACEMENT CHEMISTRY

Grade Level: 11-12

Credits: 5

BOARD OF EDUCATION ADOPTION DATE:

AUGUST 31, 2015

SUPPORTING RESOURCES AVAILABLE IN DISTRICT RESOURCE SHARING
APPENDIX A: ACCOMMODATIONS AND MODIFICATIONS
APPENDIX B: ASSESSMENT EVIDENCE
APPENDIX C: INTERDISCIPLINARY CONNECTIONS

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AP CHEMISTRY
COURSE PHILOSOPHY
Advanced Placement Chemistry is a college level course that prepares the students for further study in the sciences. In this course, students develop a conceptual understanding of chemistry through the application of science practices and inquiry-based investigations. The extensive number of laboratory investigations in this class reinforces the collaborative nature of science in which teams work together to solve real-world problems. The course enduring understandings are based on the College Board's "big ideas" and the unit enduring understanding are based on the College Board enduring understandings.
COURSE DESCRIPTION
Advanced Placement Chemistry is the next step from *Academic/Honors Chemistry* for inquisitive students to cultivate a scientific mindset in the field of chemistry. Students will develop advanced inquiry, critical thinking, and reasoning skills by designing experiments, analyzing data, drawing conclusions and justifying those conclusions scientifically. *Advanced Placement Chemistry* provides extensive hands-on laboratory experience. This course further develops the interdisciplinary skills introduced in *Academic/Honors Chemistry* in which students must draw upon their reading, writing, and mathematical expertise to explore complex chemical concepts.

COURSE SUMMARY	
COURSE GOALS	
CG1: Students will solve scientific problems by utilizing reading, writing, mathematical, and science skills in collaboration with one another. CG2: Students will work collaboratively in order to collect and analyze data, and design possible solutions to complex theoretical and real-world problems. CG3: Students will craft and execute inquiry-based labs by problem-solving, gathering existing research, analyzing data, and utilizing laboratory skills.	
COURSE ENDURING UNDERSTANDINGS	COURSE ESSENTIAL QUESTIONS
CEU1: Chemical elements are the fundamental building materials of matter. All matter can be understood in terms of the arrangement of atoms and/or transfer of electrons. These atoms retain their identity in chemical reactions.	CEQ1a: What would have happened if the atom was never discovered? CEQ1b: How do we know that atoms are the building blocks of matter?
CEU2: Chemical and physical properties can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them. Changes in matter involve the rearrangement and/or reorganization of atoms and/or transfer of electrons.	CEQ2: How can understanding structure help us to make predictions about chemical and physical properties?
CEU3: Rates of chemical reactions are determined by details of molecular collisions. The laws of thermodynamics describe the essential role of energy, as well as explain and predict the direction of changes in matter. Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.	CEQ3: How can you control or alter the outcome of a chemical reaction?
CEU4: Lab skills and techniques are important in order to safely, effectively, and efficiently test hypotheses.	CEQ4: How do you design an effective experiment to collect and process essential data?

UNIT GOALS & PACING		
UNIT TITLE	**UNIT GOALS**	**RECOMMENDED DURATION**
Unit 1: Chemical Foundations	Students will analyze limiting reactants and stoichiometric relationships.	2 weeks
Unit 2: Reactions in Aqueous Solution	Students will investigate and analyze interactions between particles in aqueous solutions.	4 weeks
Unit 3: Gases	Students will justify the causes for natural phenomena using their understanding of the behavior of gases.	3 weeks
Unit 4: Thermochemistry	Students will analyze data to make conclusions about the transfer of heat in physical and chemical processes.	2 weeks
Unit 5: Electronic Structure & Chemical Periodicity	Students will evaluate the relationship between electronic structure and chemical behavior.	4 weeks
Unit 6: Chemical Bonding & Intermolecular Forces	Students will analyze physical changes to matter by connecting the concepts of structure and attractive forces to physical properties and the interaction between particles.	5 weeks
Unit 7: Kinetics	Students will interpret reaction rates in terms of the collision model and solve rate law scenarios using chemical kinetics.	3 weeks
Unit 8: Chemical Equilibrium	Students will analyze the dynamic nature of systems and their sensitivity to initial conditions and external perturbations.	6 weeks
Unit 9: Thermodynamics	Students will justify why some chemical reactions are spontaneous by using various driving forces related to energy.	2 weeks
Unit 10: Electrochemistry	Students will develop a scientific model for the transfer of electrons between substances to demonstrate how electrochemical cells produce voltage and electrolytic cells produce a redox reaction.	3 weeks

AP CHEMISTRY
UNIT 1: Chemical Foundations **SUGGESTED DURATION: 2 weeks**

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will analyze limiting reactants and stoichiometric relationships.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can: • use stoichiometric reasoning in situations that involve impure substances; • design experiments to determine concentration, composition, and identity of a substance; • generate appropriate representations, including macroscopic and particulate level views.
3	The student can: • state the utility of the mole to connect measurements made at the macroscopic level to the particulate level; • apply conservation of number of atoms to analyze systems both quantitatively and qualitatively; • interpret experiments designed to determine concentration and composition (e.g., gravimetric analysis, titrations, and Beer's law); • relate isotopic distributions to the average atomic mass, both qualitatively and quantitatively; • translate between different representations, including macroscopic and particulate level views.
2	The student can complete all score 3 performances with minor mistakes.
1	The student needs assistance in order to reach the performances listed in score 3.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: All matter is made of atoms. Atoms can interact to form compounds and rearrange to form new ones based upon stoichiometric relationships.	EQ1a: How do we know that all matter is made from atoms? EQ1b: Why is the mole the fundamental unit for counting numbers of atoms (particles) on the macroscopic level? EQ1c: How would you describe the mole to a new chemistry student? EQ1d: What is the role of stoichiometry in real-world applications?
EU2: Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.	EQ2: How do we know what we can't see?
EU3: Atoms are conserved in physical and chemical processes.	EQ3: How can we prove that matter is always conserved?

NGSS, CCSS, & AP LEARNING OBJECTIVES
NGSS: HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms. HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during chemical reactions. **CCSS:** 11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. 11-12.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 11-12 texts and topics*.
NGSS, CCSS, & AP LEARNING OBJECTIVES

11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.
11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
11-12.WHST.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

AP Learning Objectives:
1.1 The student can justify the observation that the ratio of masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory.
1.2 The student is able to apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixture.
1.3 The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance.
1.4 The student is able to connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively.
1.11 The student can 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.
1.12 The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model.
1.14 The student is able to use data from mass spectroscopy to identify the elements and masses of individual atoms of a specific element.
1.17 The student is able to express the Law of Conservation of Mass quantitatively and qualitatively using symbolic representations and particulate drawings.
1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes.
3.1 The students can translate among macroscopic observations of change, chemical equations, and particle views
3.2 The student can 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.
3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results.
3.4 The student is able to relate quantities (measured mass of substances, volumes of solutions, or volumes of pressure 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.
3.5 The student is able to design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and law of definite proportions.
3.6 The student is able to use data from synthesis or decomposition of a compound to confirm the conservation of matter and law of definite proportions.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1 , EQ 1a, b, c, d HS-PS1-7 11-12.RST.3 11-12.WHST.2 DOK 4	Lab: Limiting Reactants – In this laboratory investigation, students will demonstrate an understanding of limiting reactants and stoichiometric relationships. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students may perform a gravimetric analysis or continuous variation experiment. Students will assess the impact limiting reactants have on the percent yield of a reaction.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Gravimetric Analysis Lab: Determine the identity of a compound through gravimetric means. **Green Chemistry Analysis of a Mixture Lab:** Determine the relative amounts of $NaHCO_3$ and Na_2CO_3 in a mixture of the two substances by heating the mixture and eliminating the H_2O into the atmosphere. Students will utilize spreadsheet software to analyze their data.	polyatomic ions in compounds mole molecular equations ionic equations net ionic equations	Generate questions and choose variables for investigation Design and conduct experimental procedures Collect, analyze, interpret, and display data Determine how to present conclusions DOK 3
Continuous Variation Lab: Determine the correct mole ratio of reactants in an exothermic reaction by mixing different amounts of reactants and graphing temperature changes. Students will utilize lab equipment such as temperature probes and magnetic stirrers. Students will utilize spreadsheet software to analyze their data.	mole limiting reactant theoretical and percent yield	Generate questions and choose variables for investigation Design and conduct experimental procedures Collect, analyze, interpret, and display data Provide mathematical justifications Determine how to present conclusions DOK 3

AP CHEMISTRY
UNIT 2: Reactions in Aqueous Solutions — SUGGESTED DURATION: 4 weeks

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will investigate and analyze interactions between particles in aqueous solutions.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can: • explain how chemical processes result in the formation of new substances; • explain how the amount of new substances formed by chemical processes depends on the number, the types, and masses of elements in the reactants, as well as the efficiency of the transformation; • design an experiment on gravimetric analysis and do gravimetric calculations; • balance redox reactions and do stoichiometric calculations based on balanced redox reactions.
3	The student can: • explain that solutions are homogenous mixtures in which the physical properties are dependent on the concentration of the solute and the strength of the interaction between the particles of the solute and solvent; • write net ionic equations for reactions in aqueous solutions and use them to perform stoichiometric calculations; • carry out an acid base titration, analyze the data, and justify the goal of the titration; • demonstrate that conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes; • develop a logical argument to show that in oxidation-reduction (i.e., redox) reactions, there is a net transfer of electrons.
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of level 3 performances.
1	The student always needs assistance or makes large errors attempting to reach score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Chemical reactions are distinguished by the identity of their components. Atoms are conserved in physical and chemical processes.	EQ1: How do we know what we can't see?
EU2: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.	EQ2: How do you choose the most effective method to observe a chemical or physical transformation?

NGSS:
HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during chemical reactions.

CCSS:
11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
11-12.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 11-12 texts and topics*.

NGSS, CCSS, & AP LEARNING OBJECTIVES
11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. 11-12.WHST.1 Write arguments focused on discipline-specific content 11-12.WHST.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information. **AP Learning Objectives:** 1.2 The student is able to select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures. 1.3 The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance. 1.4 The student is able to connect the number of particles, moles, mass, and volume of substances to one another both qualitatively and quantitatively. 1.16 The student can 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. 1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. 1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes. 1.19 The student can design, and/or interpret data from, and experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. 1.20 The student can design, and/or interpret data, from an experiment that uses titration to determine the concentration of an analyte in a solution. 3.1 Students can translate among macroscopic observations of change, chemical equations, and particle views. 3.2 The student can translate an observed chemical change into a balanced equation and justify the choice of equation type molecular, ionic, or net ionic) in terms of utility for the given circumstances. 3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results. 3.4 The student is able to relate quantities (measured mass of substances) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion. 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer. 3.9 The student is able to design and/or interpret the results of an experiment involving a redox titration.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EU2 EQ1, EQ2 HS-PS1-7 11-12.RST.3 11-12.WHST.1 DOK 4	Lab: Titration – In this laboratory investigation, students will demonstrate understanding of proper titration techniques. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students may perform a gravimetric analysis or continuous variation experiment. Students will determine the concentration and/or molar mass of unknown samples.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Gravimetric Analysis Lab: Perform a gravimetric analysis lab to test samples for the amount of water hardness and calcium ions. Students will utilize spreadsheet software to analyze their data.	electrolytes properties of water precipitation reactions solubility rules gravimetric calculations	Complete a multi-step problem in gravimetric analysis Identify research questions and design investigations Design and conduct an experiment that includes data analysis and drawing conclusions DOK 3, 4
Acid Base Titration Lab: Perform a titration to standardize the given sodium hydroxide solution using KHP as the primary standard. Students will utilize spreadsheet software to analyze their data.	molarity preparation of solutions acid-base reactions titration	Complete a multi-step problem Identify research questions and design investigations Design and conduct an experiment that includes data analysis and drawing conclusions DOK 3, 4
Analysis of Hydrogen Peroxide Lab: Perform a redox titration to standardize potassium permanganate using ferrous ammonium sulfate. Determine the percent by mass of hydrogen peroxide in household hydrogen peroxide using the standardized potassium permanganate. Students will utilize spreadsheet software to analyze their data.	redox redox titrations	Complete a multi-step problem Identify research questions and design investigations Design and conduct an experiment that includes data analysis and drawing conclusions DOK 3, 4
Percent Copper in Brass Lab: Design a procedure to analyze the amount of copper in brass using visible spectroscopy.	gravimetric calculations	Complete a multi-step problem Design a procedure Justify a claim DOK 3, 4

AP CHEMISTRY
UNIT 3: Gases **SUGGESTED DURATION: 3 weeks**

UNIT OVERVIEW

UNIT LEARNING GOALS

Students will justify the causes for natural phenomena using their understanding of the behavior of gases.

UNIT LEARNING SCALE

4	In addition to score 3 performances, the student can: • conduct an experiment to determine the molar volume of gas at STP; • use the molar volume of gas at STP in stoichiometric relationships between reactants and products in a gaseous system; • explain how van der Waal corrects the ideal gas law equation; • use the kinetic molecular theory to justify rates of effusion (i.e., Graham's law), average kinetic energy, and root mean square velocity.
3	The student can: • utilize Dalton's law of partial pressures to devise mathematical models for determining the effect of a mixture of gases on the pressure of a system; • justify the general gas laws (i.e., Boyle's, Charles', combined, and ideal).
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of level 3 performances.
1	The student always needs assistance or makes large errors attempting to reach score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Gases can be described by their 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.	EQ1a: What would you expect to happen if gases did not exert pressure or fill the volume of a container? EQ1b: How would the behavior of gaseous substances change if placed into conditions that are not "ideal"?

NGSS, CCSS, & AP LEARNING OBJECTIVES

NGSS:
HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale and infer the strength of electrical forces between particles.

CCSS:
11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.
11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
11-12.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.

NGSS, CCSS, & AP LEARNING OBJECTIVES
AP Learning Objectives: 1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. 1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes. 2.1 Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views. 2.4 The student is able to use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors. 2.5 The student is able to refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample. 2.6 The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. 2.12 The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions. 3.4 The student is able to 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. 3.5 The student is able to 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. 3.6 The student is able to use data from synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EQ1a, b HS-PS1-3 11-12.RST.2 11-12.WHST.7 DOK 4	Lab: Molar Volume of Gases – In this laboratory investigation, students will demonstrate understanding of the combined gas law and ideal gas law. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will determine the molar volume of a gas at non-ideal conditions.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Molecular Mass of a Volatile Liquid Lab: Determine the molar mass of an unknown volatile liquid and/or an unknown gas. **Boyle's Gas Law Lab:** Build manometers to measure the pressure of gases. **Graham's Law of Diffusion Demo:** HCl and NH3 are placed in either end of a glass tube. By looking at the formation of the NH_4Cl ring, the distance traveled by each gas is used to calculate MM.	Measurement of gases Boyle's gas law Charles' gas law Combined gas law Ideal gas law Graham's law of diffusion	Interpret information from complex experimental data pertaining to gases Apply mathematical models to solve problems involving one or more properties of gases (e.g., temperature, pressure, volume, number of particles present) Solve multi-step problems and justify answers mathematically DOK 3

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Molar Volume of a Gas Lab: Collect a sample of gas in a container that has been evacuated of air and replaced with water to ultimately determine the molar volume of a gas at STP. Students will utilize spreadsheet software to analyze their data.	Dalton's law of partial pressures molar volume of gases stoichiometry	Relate mathematical concepts to situations that involve gases Use gas law concepts to solve problems Perform an experimental procedure with multiple steps and multiple decision points to justify the laws of gases DOK 3
Kinetic Molecular Theory and Heat Activity: Add food coloring to water samples at different temperature water and monitor how long it takes for each solution to change color. Simulation of kinetic molecular theory (Phet Interactive Simulations)	kinetic molecular theory (KMT)	Provide mathematical justifications for natural phenomena involving gas molecules and their behavior on the particulate level according to the KMT Compare and contrast molecular motion of gas particles at different temperatures DOK 2, 3
Deviation Lab: Design a lab that justifies deviations at low temperatures and high pressures.	real gases deviation from ideal gas law	Design an experiment that utilizes mathematical concepts DOK 4

AP CHEMISTRY	
UNIT 4: Thermochemistry	SUGGESTED DURATION: 2 weeks

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will analyze data to make conclusions about the transfer of heat in physical and chemical processes.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can: • solve heat transfer problems that involve chemical reactions; • delineate the distribution of kinetic energies present at a given temperature, including connections to particulate representations; • describe how heat is connected to pressure-volume work; • describe how the second law limits the ability to convert heat to work; • interpret data from a calorimetry experiment to determine heat of reaction or dissolution; • design and interpret a calorimetry experiment; • generate and articulate with diagrams showing energy versus inter-particle separation; • delineate heat and energy in complex systems, such as those arising in biological systems.
3	The student can: • identify subsystems for more complex situations (e.g., work, reactions occurring in solution); • solve heat transfer problems that involve phase transitions; • relate average particle velocities to temperature and mass (e.g., less-massive particles move faster at a given temperature); • interpret data from a calorimetry experiment to determine heat capacity or heat of fusion; • use Hess's law to determine overall reaction enthalpy or establish a reaction as endo-/exothermic; • connect the bond energies of reactants and products to the heat of reaction; • delineate qualitatively the origins and consequences of substances that have different heat capacities; • explain relative magnitudes of thermodynamic properties in terms of molecular structure of the materials; • explain the strength and nature of chemical bonds and intermolecular forces; • interpret a graph of energy versus inter-particle separation; • analyze energy transformations for complex, multicomponent, or multistep processes.
2	The student can complete all score 3 performances with minor mistakes.
1	The student needs assistance in order to reach the performances listed in score 3.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.	EQ1: How do you choose the most effective method to observe a chemical or physical transformation involving energy?
EU2: 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.	EQ2: How is the definition of heat connected to the thermal energy exchange between two systems?
EU3: Energy is neither created nor destroyed, but only transformed from one form to another.	EQ3: How can we prove that energy is always conserved?

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU4: Breaking bonds requires energy and making bonds releases energy.	EQ4: How would the energy of the universe be affected if bonds did not have the ability to break or form?

<table><tr><th>NGSS, CCSS, & AP LEARNING OBJECTIVES</th></tr><tr><td>
NGSS:
HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

CCSS:
11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
11-12.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 11-12 texts and topics.
11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
11-12.RST.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
11-12.RST.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
11-12.WHST.1 Write arguments focused on discipline-specific content.
11-12.WHST.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
11-12.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.

AP Learning Objectives:
3.11 The student is able to 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.
5.3 The student can 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.
5.4 The student is able to use the 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.
5.5 The student is able to use conservation of energy to relate the magnitudes of the energy changes when two non-reacting substances are mixed or brought into contact with one another.
5.6 The student is able to 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 $P\Delta V$ work.
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NGSS, CCSS, & AP LEARNING OBJECTIVES
5.7 The student is able to design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical reaction at constant pressure. 5.8 The student is able to draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds.

COMMON ASSESSMENT

ALIGNMENT	DESCRIPTION
LG 1 EU1, EU2, EU3, EU4 EQ1, EQ2, EQ3, EQ4 HS-PS1-4, HS-PS3-1, HS-PS3-4 11-12.RST.3, 7, 8 11-12.WHST.7 DOK4	Lab: Calorimetry – In this laboratory investigation, students will demonstrate understanding of calorimetry techniques. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will perform a series of reactions and calculate the enthalpy of reaction, proving Hess's law.

SUGGESTED STRATEGIES

ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Thermodynamics – Enthalpy of Reaction and Hess's Law Lab: Three acid-base reactions are chosen so that the third reaction equals the first reaction minus the second one. They are measured for temperature change by calorimetry. The values of heat change and enthalpy of reaction are calculated for each reaction. Students will utilize spreadsheet software to analyze their data.	enthalpy of reaction Hess's law calorimetry	Use basic laboratory instruments including a thermometer, digital balance, and graduated cylinders Compute values using equations with one unknown Apply the law of conservation of energy to analyze possible sources of error DOK 3
College Board Investigation #12 -"The Hand Warmer Design Challenge: Where Does the Heat Come From?" Design an effective, safe, environmentally benign, and inexpensive hand warmer. Students will utilize lab equipment such as temperature probes and magnetic stirrers. Students will utilize spreadsheet software to analyze their data.	basic laboratory instruments law of conservation of energy sources of error enthalpy of reaction Hess's law calorimetry specific heat capacity	Use models to analyze situations Make claims and predictions based on scientific theories and models Design a solution to a problem Evaluate the evidence provided by data DOK 4

UNIT 5: Electronic Structure & Chemical Periodicity	SUGGESTED DURATION: 4 weeks

UNIT OVERVIEW

UNIT LEARNING GOALS

Students will evaluate the relationship between electronic structure and chemical behavior.

UNIT LEARNING SCALE

4	In addition to score 3 performances, the student can: • write the electron configuration of elements from their photoelectron spectrum; • find ionization energy values from photoelectron spectrum data; • design an experiment involving spectroscopy to quantify the concentration/amount of a substance; • interpret data in which spectroscopy is used for qualitative analysis.
3	The student can: • explain how the study of the properties of light and waves and the atomic spectrum of hydrogen provide an insight to the electronic structure of atoms; • solve problems based on the Bohr equation to calculate the energy of an electron in an atom; • write ground state electron configuration for elements; • identify valence electrons; • draw Lewis dot structures; • recognize a periodic repetition in properties of the elements; • predict properties of elements based on their location in the periodic table; • list the shortcomings of the Bohr model of the atom; • explain the modification that led to the quantum mechanical model of the atom; • describe the shapes and energies of orbitals.
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of score 3 performances.
1	The student needs assistance or makes large errors in attempting to reach score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: The atoms of each element have unique structures arising from interactions between electrons and nuclei.	EQ1a: What is the basis for the structure of the atom? EQ1b: How can the concepts of Coulomb's law be used to understand the energetics of electrons in an atom or ion? EQ1c: How can the electronic structure of an atom be described?
EU2: Periodicity is a useful principle for understanding properties and predicting trends in properties. Its modern-day uses range from examining the composition of materials to generating ideas for designing new materials.	EQ2a: What do periodic properties of atoms reflect? EQ2b: Which model of the atom is the currently accepted model?
EU3: Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.	EQ3: How do we know what we can't see?

NGSS, CCSS, & AP LEARNING OBJECTIVES
NGSS: HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. HS-PS4-4 Evaluate the validity and reliability of claims in punished materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. **CCSS:** 11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. 11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. 11-12.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 11-12 texts and topics*. 11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas. 11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. 11-12.RST.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. 11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently. 11-12.WHST.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **AP Learning Objectives:** 1.5 The student is able to explain the distribution of electrons in an atom or ion based upon data. 1.6 The student is able to analyze data relating to electron energies for patterns and relationships. 1.7 The student is able to 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. 1.8 The student is able to explain the distribution of electrons using Coulomb's law to analyze measured energies. 1.9 The student is able to predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model. 1.10 Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity. 1.11 The student can 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. 1.12 The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model. 1.15 The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EU2, EU3 EQ1a, b, c, EQ2a, b, EQ3 HS-PS4-1, HS-PS4-4, HS-PS4-5 11-12.RST.3, 4, 7 11-12.WHST.2 DOK 4	Lab: Beer's Law – In this laboratory investigation, students will demonstrate understanding of the method of color spectroscopy. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will utilize graphing software to determine the concentration of unknown colored solutions.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Understanding Electron Configuration Activity: Write complete and short hand configurations for a given number of elements and deduce patterns in electron configurations for elements within a group and a period. **Building a Periodic Table Activity:** Construct an alien periodic table based on information and clues provided. **Photoelectron Spectroscopy Video:** Watch an MIT open courseware video on photoelectron spectroscopy (PES) to analyze the photo electron spectra of various elements. Then write the electron configuration of an element from its photo electron spectrum.	electron configuration Aufbau principle valence electrons Lewis dot structures	Critique the distribution of electrons within atoms Draw conclusions from PES data about how energies of electrons within shells vary Explain the PES of an element in terms of its electron configuration Based on PES data find the binding energy of a given electron in an atom Complete a multistep problem based on electron arrangement and PES DOK 3, 4

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Periodic Table Activity: Pair elements by family or period. Rationalize the change in electronegativity of each group based on the electronic structure of the atom. **Periodic Table Dry Lab:** Graph values for atomic radius, electronegativity, and ionization energy to predict trends and explain the organization of the periodic table. **Reactivity of Alkali and Alkaline Earth Metals Video:** Watch a video on the reactivity of the alkali and alkaline earth metals. Relate reactivity to ionization energy and electron arrangement.	periodic trends table arrangement based on electronic properties	Critique data with accuracy and precision using graphs Determine periodic trends Justify abnormalities in certain periodic trends Draw conclusions from experimental data on periodic trends DOK 3
Flame Test of Salt Solutions Lab: Identify positive ions by performing flame tests. **Spectroscopy of Gases Using Discharge Tubes Lab:** Observe and sketch the emission spectra of various known gases from gas discharge tubes using a spectroscope. Determine what elements are in a fluorescent light bulb. Determine energy of emission for various spectral lines. **Analysis of Food Dyes in Beverages Lab:** Utilize a spectroscopy to determine the concentration of dye in a sports drink. Students will utilize spreadsheet software to analyze their data.	properties of light and waves atomic spectra of hydrogen quantum mechanical model quantum theory electron orbitals orbital shape and energies spectroscopy	Conduct an investigation Explain why flame tests can be used to identify positive ions only Critique the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules Complete a multistep problem Provide an explanation for the need to refine the atomic model from a classical shell model to the quantum mechanical model DOK 3

AP CHEMISTRY	
UNIT 6: Chemical Bonding and Intermolecular Forces	SUGGESTED DURATION: 5weeks

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will analyze physical changes to matter by connecting the concepts of structure and attractive forces to physical properties and the interaction between particles.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can relate properties and physical changes of solutions to the intermolecular attractions between solute and solvent particles.
3	The student can: • create energy diagrams as a model for particle interactions and phase changes; • identify and justify the intermolecular forces of attraction and polarity of molecules for various types of liquids and solids; • design, interpret, and justify molecular structures based upon Lewis dot structures, resonance, formal charge, polarity, dipole moments, VSEPR models and molecular shapes.
2	The student can complete all score 3 performances with minor mistakes.
1	The student needs assistance in order to reach the performances listed in score 3.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: 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.	EQ1a: How can particulate models be used to demonstrate and ultimately differentiate between the different phases of matter? EQ1b: How do the forces of attraction between particles influence the phase and properties of the substance? EQ1c: How is it possible that a molecule is nonpolar, yet it has polar bonds?
EU2: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.	EQ2: What would happen if all of the forces of attraction between particles were the same?
EU3: The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds. The nature and strength of these forces determine the properties and nature of the bond.	EQ3: How do you think substances would exist if there were no forces of attraction between atoms?
EU4: The type of bonding in the solid state can be deduced from the properties of the solid state.	EQ4: How can you explain the role the type of bond has on the properties of the substance?
EU5: Breaking bonds requires energy, and making bonds releases energy.	EQ5: How can molecular motion be used to induce phase changes? What if the molecules stopped moving?

NGSS, CCSS, & AP LEARNING OBJECTIVES
NGSS: HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

NGSS, CCSS, & AP LEARNING OBJECTIVES
CCSS: 11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. 11-12.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 11-12 texts and topics*. 11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas. 11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently. 11-12.WHST.1 Write arguments focused on discipline-specific content. 11-12.WHST.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. **AP Learning Objectives (Bonding):** 2.17 The student can 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. 2.18 The student is able to rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table. 2.21 The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity. 2.22 The student is able to design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid. 2.28 The student is able to explain a representation that connects properties of an ionic or molecular solid to its structural attributes and to the interactions present at the atomic level. 2.30 The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level. 5.1 (edited)The student is able to 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), which influence the interaction strength. **AP Learning Objectives (Intermolecular Forces & Phase Changes):** 2.3 The student is able to 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. 5.9 The student is able to make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within molecules and the types of intermolecular forces through which the molecules interact. 5.10 The student can support a 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 intermolecular forces versus intramolecular forces. 2.7 The student is able to explain how solutes can be separated by chromatography based on intermolecular interactions 2.10 The student can 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. 2.11 The student is able to explain the trends in properties and/or predict the properties of sample consisting of particles with no permanent dipole on the basis of London Dispersion Forces. 5.11 The student is able to identify the intermolecular interactions within and between large molecules, and/or connect the shape and function of the large molecules to the presence and magnitude of these interactions. 2.13 The student is able to describe the relationships between the structural features of polar molecules and the forces of attraction between the particles. 2.16 The student is able to explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces.

NGSS, CCSS, & AP LEARNING OBJECTIVES
2.19 The student can 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). 2.20 The student is able to explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, ductility, and low volatility) and the shell model of the atom. 2.25 The student is able to 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. 2.26 Students can use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys. 2.23 The student can create a representation of an ionic solid that show essential characteristics of the structure and interactions present in the substance. 2.24 The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level. 2.31 The student can create a representation of a molecular solid that show essential characteristics of the structure and interactions present in the substance. 2.32 The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level. 2.27 The student can create a representation of a metals that show essential characteristics of the structure and interactions present in the substance. 2.28 The student is able to explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level. 3.32 The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present in the substance. 5.1 The student is able to create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as polarity (for intermolecular interactions), which influence the interaction strength. 5.7 The student is able to 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 or phase transition) at constant pressure. **AP Learning Objectives (Intermolecular Attractions in Solutions):** 2.8 The student can draw and/or interpret representations of solutions that show the interactions between the solute and solvent. 2.9 The student is able to create or interpret representations that line the concept of molarity with particle views of solutions. 2.14 The student is able to 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. 2.15 The student is able to explain observations regarding the solubility of ionic solids and molecules in water and the solvents on the basis of particle views that include intermolecular interactions and entropic effects.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EU2, EU3, EU4, EU5 EQ1a, b, c, EQ2, EQ3, EQ4, EQ5 HS-PS1-3, HS-PS2-6 11-12.RST.2, 4 11-12.WHST.1, 4 DOK 4	Lab: Investigation of Solids (Chemical Bonds) – In this laboratory investigation, students will analyze the properties that result from the different types of bonding. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will deduce the type of bonding in a substance based upon its properties.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Bonding Lab: Investigate ionic and molecular substances deducing properties of their bonds in the process. Students will create flowcharts using software.	structure & bonding ionic bonding covalent bonding (polar and nonpolar) metallic bonding	Describe and explain examples and non-examples of bonding Classify and organize compounds according to the type of bond DOK 2
Atomic Theory Dry Activity: Draw a series of molecules and polyatomic ions. From those drawings predict geometry, hybridization, and polarity. **Atomic Theory Demonstration:** View 3-D graphics of the different compounds on the Internet.	Lewis structures resonance structures formal charge bond polarity dipole moments VSEPR models molecular shape molecule polarity hybridization lattice energy	Cite evidence and develop a logical argument for validation of a Lewis structure Explain the shapes molecules form during bonding based upon the VSEPR model Use the VSEPR shape of a molecule to justify the overall polarity of the molecule Relate thermodynamic phenomena to the energy released during lattice formation DOK 2, 3
Preparation of Solutions Lab: Create solutions of specified concentrations gravimetrically and by dilution. Solution concentrations will be checked for accuracy using a spectrophotometer. **Design Your Own Lab:** Given a list of chemicals and equipment, design a lab to justify the effect of number of solute particles in the solution has on a specific colligative property. Students will use Vernier interface, temperature, and pressure probes. Students will utilize spreadsheet software to analyze their data.	solution solute solvent composition of solutions vapor pressure of solutions colligative properties colloids suspensions Van’t Hoff factor	Design and conduct an experiment Justify the change of property based upon amount of solute in a solution DOK 4

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Investigation of Solids Lab: Investigate types of solids using various experimental techniques. **Evaporation of Liquids Lab:** Using a data collection device, show the temperature curves of various liquids (teacher) and deduce the differences based on IMFs (students). **Vapor Pressure of Liquids Lab:** Measure the vapor pressure of ethanol at different temperatures to determine ΔH. **Sticky Situation AP Lab:** Utilize paper chromatography to separate a mixture of food dye based upon IMFs. **Wet Dry Carbon Dioxide Lab:** View the three phases as dry ice sublimes in a closed system. **Effect on Biological Systems Activity:** Examine a demonstration size model of DNA or an alpha helix. Identify which atoms/base pairs are particularly involved in hydrogen bonding within the molecule, causing the helical structure. Discuss how increased UV light, due to ozone depletion, can cause chemical reactions, mutations, and disruption of hydrogen bonding. Students will use Vernier interface, temperature, and pressure probes. Students will utilize spreadsheet software to analyze their data.	intermolecular forces hydrogen bonding London dispersion forces dipole-dipole forces metals network molecules phase changes vapor pressure heating & cooling curves phase diagrams separations techniques	Develop generalizations of the results obtained and the strategies applied when investigating know solids and apply them to unknowns Interpret information from a heating/cooling curve about the nature of the intermolecular forces responsible for the phase change(s) of the substance Complete a multi-step problem DOK 3, 4

AP CHEMISTRY
UNIT 7: Kinetics **SUGGESTED DURATION: 3 weeks**

UNIT OVERVIEW

UNIT LEARNING GOALS

Students will interpret reaction rates in terms of the collision model and solve rate law scenarios using chemical kinetics.

UNIT LEARNING SCALE

4	In addition to score 3 performances, the student can: • draw energy profile diagrams for catalyzed and uncatalyzed reaction pathways for a multi- step reaction; • use the Arrhenius equation to do computations involving the relationship between the rate constant and temperature; • identify the connection between the influence of temperature on the reaction rate and a reaction energy profile (e.g., Boltzmann distributions and activation energy); • design an experiment to determine the rate law of a reaction using integrated rate laws.
3	The student can: • provide a basic definition of reaction rate; • explain that reaction rate is influenced by factors such as temperature, surface area, and concentration; • identify the type of rate law; • use the rate law to compute the rate and write a rate equation; • use collision theory to explain the dependence of reaction rate on concentration and temperature; • draw energy profile diagrams for catalyzed and uncatalyzed reaction pathways; • identify reaction intermediates and catalysts in a reaction mechanism; • predict whether a proposed mechanism is consistent with experimental data and reaction stoichiometry.
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of the score 3 performances.
1	The student always needs assistance or makes large errors attempting to reach the score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.	EQ1a: What impact would it have on daily life, if all reactions happen at the same rate? EQ1b: How does the collision model explain the dependence of reaction rates on concentration and time at a molecular level?
EU2: Many reactions proceed via a series of elementary reactions.	EQ2: Is the overall rate of a reaction dependent on the number of elementary steps?
EU3: Reaction rates may be increased by the presence of a catalyst.	EQ3: How would the kinetic control of a reaction be affected in the absence of catalysts?

NGSS, CCSS, & AP LEARNING OBJECTIVES

NGSS:
HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

NGSS, CCSS, & AP LEARNING OBJECTIVES
CCSS: 11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. 11-12.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 11-12 texts and topics. 11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas. 11-12.RST.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. 11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently. 11-12.WHST.1 Write arguments focused on discipline-specific content 11-12.WHST.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **AP Learning Objectives:** 4.1 The student is able to 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. 4.2 The student is able to analyze concentration vs time data to determine the rate law for a zeroth, first, or second order reaction. 4.3 The student is able to 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. 4.4 The student is able to 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. 4.5 The student is able to explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation. 4.6 The student is able to 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. 4.7 The student is able to evaluate the 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. 4.8 The student can 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. 5.2 The student is able to relate temperature to the motions of particles either via particulate representations, and/or via representations of activation energy, such as plots of the Maxwell-Boltzmann distribution.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG 1 EU1, EU2, EU3 EQ1a, b, EQ2, EQ3 HS-PS1-5 11-12.RST.3, 4 11-12.WHST.1, 2 DOK 4	Lab: Iodine Clock Reaction– In this laboratory investigation, students will demonstrate understanding of a clock reaction. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will determine the order of a reaction in a given reactant using integrated rate law equations.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Rate of Decomposition of Calcium Carbonate Lab: Design kinetics experiments for the heterogeneous reaction of calcium carbonate with hydrochloric acid. **Kinetics of Crystal Violet Fading Lab:** Use spectroscopy and graphical analysis to determine the rate law for the color-fading reaction of crystal violet with sodium hydroxide. **"How Does Temperature Affect the Rate of a Reaction?" - Demo:** Two light sticks, one at room temperature and the other from a refrigerator are activated at the same time. The light stick at room temperature produces a bright glow immediately. The one from the refrigerator takes much longer to produce a much dimmer glow.	rates of reactions factors that affect the rate of reactions rate equation determination initial rates integrated rate laws	Specify a problem Design and conduct an experiment Analyze data and form conclusions Explain how temperature affects the rate of a chemical reaction using collision theory Develop a logical argument to show how integrated rate laws can be used to find the order of a reaction DOK 3, 4
Energy Profile Diagrams Activity: Create energy diagrams to explain why catalysts increase the rate of a chemical reaction.	reaction pathways reaction mechanisms activation energy collision theory	Identify reaction intermediates and catalysts from a given reaction mechanism and justify the choice Critique one step and multistep energy profile diagrams Explain why catalysts increase the rate of a reaction based on the collision model Design an alternate approach to find the rate determining step for a reaction that involves a multistep mechanism DOK 3, 4
Maxwell - Boltzmann Plots Activity: Create Maxwell-Boltzmann diagrams to explain why raising the temperature can increase the rate of a chemical reaction.	collision theory activation energy Boltzmann distribution	Relate the effect of temperature on the motions of particles using Maxwell-Boltzmann plots Explain the difference between collisions that convert reactants to products and those that do not DOK 2, 3

AP CHEMISTRY	
UNIT 8: Chemical Equilibrium	**SUGGESTED DURATION: 6 weeks**

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will analyze the dynamic nature of systems and their sensitivity to initial conditions and external perturbations.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can: • use Le Chatelier's principle and stoichiometry to explain about complex situations (e.g., liquid-vapor equilibria in systems with different volumes, addition of an inert gas at constant volume); • demonstrate the connection between equilibrium constants and forward/reverse rate constants for single-step reactions; • use equilibrium reasoning to design conditions that optimize a desired result, such as product yield; • connect reasoning based on Le Chatelier's principle to reasoning based on comparison of Q and K; • articulate and justify which species will be present in large versus small concentrations in equilibrium systems containing mixtures of acids, bases, and salts; • interpret titration curves for unfamiliar situations, including identifying the majority species at any point; • design buffers with a target pH and buffer capacity; • explain the consequences of the temperature dependence of K_w; • articulate when ranking of solubility does and does not follow the ranking of K_{sp}.
3	The student can: • map real systems (e.g., solubility of salts and molecules, vapor pressures) onto equilibrium processes; • given data, identify the point at which a system reaches equilibrium and relate this to a balance of forward and reverse rates; • clearly recognize the distinction between initial and equilibrium conditions; • formulate different sets of concentrations that satisfy the equilibrium expression • explain that Le Chatelier's principle predicts a shift from one equilibrium state to another equilibrium state in response to a stress; • determine pH of a strong acid/base; • interrelate pH, K_a, and K_b for solutions of a strong or weak acid or base; • articulate, justify, and generate representations of which species will be present in large versus small concentrations in simple solutions, such as a single component acid solution; • identify the ionization state of a weak acid, given the pH and pK_a; • identify a particular mixture as being a buffer solution, estimate the pH, and identify the reactions occurring; • describe and/or interpret changes in a titration curve for different strength acids or different concentrations of the same acid; • generate particulate representations of buffer solutions; • relate solubility to K_{sp} for arbitrary salts; • explain the meaning of a saturated solution and its relation to solubility and K_{sp}; • use Le Chatelier's principle to reason qualitatively about the common ion effect and pH-sensitive solubility.
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of the score 3 performances.
1	The student always needs assistance or makes large errors attempting to reach the score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.	EQ1a: Why should both the forward and reverse reaction be considered while studying many classes of reactions? EQ1b: How can the extent of a reaction be characterized? EQ1c: When is a system said to be in a state of equilibrium?
EU2: Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.	EQ2: What effect does an external disturbance have on the original equilibrium state of a system and why?
EU3: Chemical equilibrium plays an important role in acid-base chemistry and in solubility.	EQ3a: How can chemical equilibrium be used to explain proton transfer reactions? EQ3b: How can solubility of a substance be understood using chemical equilibrium?
EU4: The equilibrium constant is related to temperature and the difference in Gibbs free energy between reactants and products.	EQ4: How is the value of the equilibrium constant related to the change in Gibbs free energy and the thermal energy?

NGSS, CCSS, & AP LEARNING OBJECTIVES

NGSS:
HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

CCSS:
11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
11-12.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 11-12 texts and topics.
11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.
11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
11-12.WHST.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
11-12.WHST.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
11-12.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.
11-12.WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

AP Learning Objectives:
5.16 The student can use Le Chatelier's principle to make qualitative predictions for systems in which coupled reactions that share a common intermediate drive formation of a product.
5.17 The student can make quantitative predictions for systems involving coupled reactions that share a common intermediate, based on the equilibrium constant for the combined reaction.
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.

NGSS, CCSS, & AP LEARNING OBJECTIVES
6.1 The student is able to, 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. 6.2 The student can, 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. 6.3 The student can connect kinetics to equilibrium by using reasoning about equilibrium, such as Le Chatelier's principle, to infer the relative rates of the forward and reverse reactions. 6.4 The student can, 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. 6.5 The student can, given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. 6.6 The student can, 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. 6.7 The student is able, 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. 6.8 The student is able to use Le Chatelier's principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. 6.9 The student is able to use Le Chatelier's principle to design a set of conditions that will optimize a desired outcome, such as product yield. 6.10 The student is able to connect Le Chatelier's principle to the comparison of Q to K by explaining the effects of the stress on Q and K. 6.25 The student is able to 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.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EU2, EU3, EU4 EQ1a, b, c, EQ2, EQ3a, b, EQ4 HS-PS1-6 11-12.RST.4, 7 11-12.WHST.2, 7 DOK 4	Lab: Le Chatelier's Principle – In this laboratory investigation, students will demonstrate understanding of the effect of applying various stresses on reactions that are at equilibrium. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will justify a reaction's shift to re-establish equilibrium once a stress has been applied.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
College Board Investigation #13 – "Can we Make the Colors of the Rainbow? An Application of Le Chatelier's Principle." Investigate six chemical equilibrium systems to analyze patterns and trends in the principles, concepts, and definitions of equilibrium.	equilibrium chemical reactions pH precipitation of an ion	Collect and analyze data to identify patterns or relationships Make claims and predictions based on evidence DOK 3

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
College Board Investigation #14 – "Acid-Base Titration: How Do the Structure and the Initial Concentration of an Acid and a Base Influence the pH of the Resultant Solution During a Titration?" Complete a titration of an acid with a base and analyze the resultant titration curve.	pH meters limits of precision and accuracy stoichiometry calculations mole limiting reagents excess reagents Lewis structure of acids and bases acids bases titration curves strong and weak acids and bases Percent error of a calculated K_a or K_b	Use representations and models to analyze situations or solve problems qualitatively and quantitatively Apply mathematical routines to quantities Analyze data to identify patterns or relationships Connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas DOK 3, 4
College Board Investigation #15 – "To What Extent do Common Household Products have Buffering Activity?" The objective of this experiment is for students to investigate a variety of household substances to determine which of them exhibit buffering activity. The choice of specific test materials and procedure should be determined by the student.	buret or burette pH measurement titration Acid-Base equilibria Buffers Solubility equilibria	Refine observations and measurements based on data analysis Construct explanations based on evidence produced through scientific practices Make claims and predictions based on scientific theories and models DOK 3, 4

AP CHEMISTRY
UNIT 9: Thermodynamics **SUGGESTED DURATION: 2 weeks**

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will justify why some chemical reactions are spontaneous by using various driving forces related to energy.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can solve real-world applications involving the influence of free energy.
3	The student can apply a mathematical model to determine reaction direction and spontaneity based upon the thermodynamic relationship between enthalpy, entropy and free energy.
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of the score 3 performances.
1	The student always needs assistance or makes large errors attempting to reach the score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both.	EQ1: Why does everything in the universe move towards a state of disorder?

NGSS, CCSS, & AP LEARNING OBJECTIVES

NGSS:
HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

CCSS:
11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
11-12.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 11-12 texts and topics*.
11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.
11-12.RST.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
11-12.RST.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
11-12.WHST.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
11-12.WHST.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
11-12.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.

NGSS, CCSS, & AP LEARNING OBJECTIVES
AP Learning Objectives: 5.12 The student is able to use representations and models to predict the sign and relative magnitude of the entropy associated with chemical or physical processes. 5.13 The student is able to predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or qualitatively) the signs of both ΔH^o and ΔS^o, and calculation or estimation of ΔG^o when needed. 5.14 The student is able to determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. 5.15 The student is able to explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause the processes that are not thermodynamically favorable to become thermodynamically favorable. 5.18 The student is 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. 6.24 The student can analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations. 6.25 The student is able to express the equilibrium constant in terms of ΔG^o and RT and use this relationship to estimate the magnitude of K and consequently, the thermodynamic favorability of the process.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EQ1 HS-PS1-4, HS-PS3-1 11-12.RST.4 11-12.WHST.2, 4, 7 DOK 4	Lab: Solubility and Determination of ΔH^o, ΔS^o, ΔG^o of Calcium Hydroxide – In this laboratory investigation, students will collect and analyze data. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will determine the ΔH^o, ΔS^o, ΔG^o of Calcium Hydroxide.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Thermodynamic Stretch Activity: Feel the enthalpy and find the entropy when you stretch a rubber band. **Spontaneous Assembly of Straws Activity:** Observe and model spontaneity using straws. **Counting Bonds in a Cold Reaction Activity:** Two solids are mixed into a freezing liquid. **The Collapsing 1-L Bottle Activity:** Demonstrate a reaction with negative enthalpy and entropy. **Videos:** The above activities are also in video form on the Flinn Scientific website.	laws of thermodynamics spontaneous process entropy spontaneity free energy enthalpy equilibrium rate	Use representations and models to analyze situations or solve problems qualitatively and quantitatively DOK 2, 3

AP CHEMISTRY	
UNIT 10: Electrochemistry	**SUGGESTED DURATION: 3 weeks**

UNIT OVERVIEW

UNIT LEARNING GOALS

Students will develop a scientific model for the transfer of electrons between substances to demonstrate how electrochemical cells produce voltage and electrolytic cells produce a redox reaction.

UNIT LEARNING SCALE

4	In addition to score 3 performances, the student can: • explain the difference between spontaneous and non-spontaneous reactions within electrochemical cells; • explain what factors influence the life of the electrochemical cell (i.e., battery).
3	The student can: • interpret information from electrochemical cells; • utilize the Nernst equation to make predictions about how changes to the system will influence the voltage output.
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and can do the majority of the score 3 performances.
1	The student always needs assistance or makes large errors attempting to reach the score 3 performances.
0	Even with help, the student does not exhibit understanding of performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: Chemical reactions can be classified by considering what the reactants are, what the products are, or how they change from one into the other.	EQ 1: Do all electrochemical cells (i.e., batteries) "die"? Can any electrochemical cell (i.e., battery) last forever?
EU2: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.	EQ2: How do you choose the most effective method to observe a chemical or physical transformation involving energy?

NGSS, CCSS, & AP LEARNING OBJECTIVES

NGSS:

HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms.
HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS3-3 Design, build, and refine a device that works within given constraints to convert on form of energy into another form of energy.
HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

CCSS:

11-12.RST.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
11-12.RST.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
11-12.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 11-12 texts and topics*.
11-12.RST.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

NGSS, CCSS, & AP LEARNING OBJECTIVES
11-12.RST.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. 11-12.RST.10 By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently. 11-12.WHST.1 Write arguments focused on discipline-specific content 11-12.WHST.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **AP Learning Objectives:** 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer. 3.9 The student is able to design and/or interpret the results of an experiment involving a redox titration 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's laws 3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.

COMMON ASSESSMENT	
ALIGNMENT	DESCRIPTION
LG1 EU1, EU2 EQ1, EQ2 HS-PS1-1, HS-PS1-4, HS-PS2-6, HS-PS3-3, HS-PS4-5 11-12.RST.3, 4 11-12.WHST.1 , 2 DOK 4	Lab: Voltaic Cell – In this laboratory investigation, students will find the reduction potentials of a series of reactions using voltaic cells/multi-meters. Students will design and conduct an experiment related to a real-world problem that requires multiple variables, interpretation of data, and use of mathematical concepts. Students will construct their own reduction potential table, perform dilutions, and test the Nernst equation.

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Redox Titration Lab: Perform a redox titration to standardize potassium permanganate using oxalic acid. Determine the percent by mass of iron in ferrous sulfate using the standardized potassium permanganate. **Creating an Activity Series Lab:** Carry out a series of single replacement reactions in well plates and construct an activity series of metals based on the observations. Students will utilize spreadsheet software to analyze their data.	redox reactions	Identify and balance redox reactions Solve multistep problems involving balanced redox reactions Conduct an experiment to determine the percent by mass of iron in ferrous sulfate DOK 3, 4

SUGGESTED STRATEGIES		
ACTIVITIES AND LABS	DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE
Electrochemical Cells Lab: Construct various electrochemical cells and measure the voltage generated. From these measurements, determine the concentration of copper ions in solution and the k_{sp} of silver chloride. **Electrolysis and Electroplating Activity:** Write a paper on the application of electrolysis in the process of electroplating. Demonstrate an understanding of electrolytic cells and Faraday's laws.	electrochemical cells electrochemical voltage electrolytic cells Faraday's laws	Design an experiment to construct various electrochemical cells and measure voltage Draw conclusions from data Research and explain the concept of electroplating Explain the application of electrolysis and Faraday's laws in the process of electroplating DOK 3, 4