ACALANES UNION HIGH SCHOOL DISTRICT
COURSE OF STUDY: CURRICULAR AREA – SCIENCE

COURSE TITLE:	CHEMISTRY IN THE EARTH SYSTEM
GRADE LEVEL:	10-12
COURSE LENGTH:	One Year
PREFERRED PREVIOUS COURSE OF STUDY:	The Living Earth
CREDIT:	10 Credits
UC/CSU CREDIT:	Meets UC/CSU credit for Science requirement; subject area (“d”) - PENDING
GRADUATION REQUIREMENT:	Fulfills one year of two-year science requirement for graduation
STANDARDS AND BENCHMARKS:	Next Generation Science Standards
ADOPTED:	May 2, 2018
INSTRUCTIONAL MATERIALS:	TBD

COURSE DESCRIPTION:

Chemistry in the Earth System, a course based on the Next Generation Science Standards, explores the way in which matter interacts, combines and changes. This course explains how chemical processes help drive the earth system. By using science and engineering practices, evidence from experiments, research, and observations, students will learn how to formulate questions, evaluate claims, use mathematics and computational thinking, and develop models to make interpretations and investigate the natural world.

DEFINITIONS:

Instructional Segment: Grouping elements or concepts from multiple PEs in lessons, units, and/or assessments that students can develop and use together to build toward proficiency on a set of PEs in a coherent manner.

Performance Expectation: The NGSS is not a set of daily standards, but a set of expectations for what students should be able to do by the end of instruction (years or grade-bands). The performance expectations set the learning goals for students, but do not describe how students get there.

Crosscutting Concepts: These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.

Assessment Boundary: These specify the limits of assessment on the California Science Test. They are not meant to put limits on what can be taught or how it is taught, but to provide guidance.

Disciplinary Core Ideas: The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

Science and Engineering Practices: The practices are what students do to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

Phenomenon: Observable events that students can use the three dimensions to explain or make sense of.

Course Codes:
LS - Life Science
ESS - Earth and Space Science
ETS - Engineering and Technology and Applications of Science

COURSE INSTRUCTIONAL SEGMENTS:

1. Combustion
2. Heat and Energy in the Earth System
3. Atoms, Elements, and Molecules
4. Chemical Reactions
5. Chemistry of Climate Change
6. The Dynamics of Chemical Reactions and Ocean Acidification

CURRICULAR PRACTICES:

Within the Chemistry in the Earth System course, there are three distinct and equally important dimensions to learning science. These dimensions are combined to form each standard—or performance expectation—and each dimension works with the other two to help students build a cohesive understanding of science over time.

The Three Dimensions:

- The Science and Engineering Practices are what scientists/engineers DO.
- The Disciplinary Core Ideas are what scientists/engineers KNOW.
- The Crosscutting Concepts are HOW scientists/engineers THINK.

Crosscutting Concepts:

1. Patterns
2. Cause and effect
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter: flows cycles and conservation
6. Structure and function
7. Stability and change of systems

Science and Engineering Practices:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

ASSESSMENT: Chemistry in the Earth System incorporates a variety of assessment activities that mirror the variety in NGSS-aligned instructional practices. The distinction between instructional activities and assessment activities may be blurred, particularly when the assessment purpose is formative.

Assessments will focus on:

1. Tasks that have multiple components so they can yield evidence of three-dimensional learning (and multiple performance expectations).
2. Explicit attention to the connections among scientific concepts.
3. Gathering of information about how far students have progressed along a defined sequence of learning.

GRADING GUIDELINES: See AUHSD Grading Guidelines: Final Course Mark Determination

COURSE CONTENT:

Chemistry Instructional Segments	
Instructional Segment 1: Combustion	
Guiding Questions: What is energy, how is it measured, and how does it flow within a system? What mechanisms allow us to utilize the energy of our foods and fuels? What distinguishes a chemical change from a physical change? What are the characteristics of a combustion reaction?	
Unit Overview: In this brief introductory unit, students investigate the amount of stored chemical potential energy in food. They make observations of material properties at the bulk scale that they later explain in the atomic scale. The themes of combustion and CO_2 tie together several of the Instructional Segments. In this unit, students will study macroscopic changes in matter (such as melting), and relate to the forces and bonding between particles.	
Students who demonstrate understanding can:	**Clarification Statement:**
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.	Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension. *California Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure (Introduced, but not assessed until IS3)*

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.	Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved. (Introduced, but not assessed until IS3) *California Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products. (Introduced, but not assessed until IS4)*
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem- solving techniques. *California Assessment Boundary: Assessment does not include complex chemical reactions. (Introduced, but not assessed until IS7)*
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.	Emphasis is on explaining the meaning of mathematical expressions used in the model. *California Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields. (Introduced, but not assessed until IS2)*

Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
• [SEP-1] Asking Questions and Defining Problems • [SEP-2] Developing and Using Models • [SEP-4] Analyzing and Interpreting Data	• PS1.A: Structure and Properties of Matter • PS1.B: Chemical Reactions • PS3.D: Energy and Chemical Processes in Everyday Life	• [CCC-1] Patterns • [CCC-2] Cause and Effect • [CCC-4] System and System Models • [CCC-5] Energy and Matter: Flows, Cycles, and Conservation • [CCC-7] Stability and Change

Chemistry Instructional Segments	
Instructional Segment 2: Heat and Energy in the Earth System	
Guiding Questions: How is energy transferred and conserved? How can energy be modeled at macroscopic/bulk and particulate scales? What types of energy exist? What are sources of energy on Earth? How can energy be harnessed to perform useful tasks?	
Unit Overview: Students develop models of energy conservation within systems and the mechanisms of heat flow. They relate macroscopic heat transport to atomic scale interactions of particles, which they will apply in later units to construct models of interactions between atoms. They use evidence from Earth's surface to infer the heat transport processes at work in the planet's interior.	
Students who demonstrate understanding can:	**Clarification Statement:**
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.	Emphasis is on explaining the meaning of mathematical expressions used in the model. Students are able to describe and model, in terms of particles and intermolecular forces, what is happening within a substance during phase changes, or at different points on heating and cooling curves. *California Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*
HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).	Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth (potential energy), and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.

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).	Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water. *California Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*
	Kinetic theory of gases should be introduced at this time and revisited in IS5
HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments. Relation to water density/temperature and movement of fluids is discussed.
HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	Students will use established simulations to observe a current solution to a real-world problem and analyze the effectiveness of the solution.

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
• [SEP-2] Developing and Using Models • [SEP-3] Planning and Carrying Out Investigations • [SEP-5] Using mathematics and Computational Thinking • [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) • [SEP-7] Engaging in Argument from Evidence • [SEP-8] Obtaining, Evaluating, and Communicating Information	• PS3.A: Definitions of Energy • PS3.B: Conservation of Energy and Energy Transfer • ESS2.B: Plate Tectonics and Large-Scale System Interactions	• [CCC-1] Patterns • [CCC-2] Cause and Effect • [CCC-3] Scale, Proportion, and Quantity • [CCC-5] Energy and Matter: Flows, Cycles, and Conservation • [CCC-7] Stability and Change

Chemistry Instructional Segments
Instructional Segment 3: Atoms, Elements, and Molecules
Guiding Questions: What is the internal structure of atoms and how does this affect how atoms interact? What models can we use to predict the outcomes of chemical reactions?
Unit Overview: Students recognize patterns in the properties and behavior of elements, as illustrated on the periodic table. They use these patterns to develop a model of the interior structure of atoms and to predict how different atoms will interact based on their electron configurations. They use chemical equations to represent these interactions and begin to make simple stoichiometric calculations.

Students who demonstrate understanding can:	**Clarification Statement:**
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen. Students use the structure of the nucleus to predict the number of electrons and can relate an element's position on the periodic table to an atom's structure (especially electron structure). Students can differentiate between nuclear and chemical reactions and can apply the patterns and trends on periodic table to predict how atoms will interact. Students can relate the radiation emission by the electrons of atoms to the energy changes of the electron. *California Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*
	Students will utilize patterns in the periodic table and bonding to determine names and formulas for ionic, molecular, and simple organic compounds
HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.	Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen. Students use trends and patterns of the periodic table to predict bonding and the structure of compounds as well as describe or model a chemical reaction in terms of what is bonded. *California Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*

<table>
<tr><td>HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</td><td colspan="2">Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products (translation, mass to mass calculations), and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale (translation, molar mass calculations). Emphasis is on assessing students’ use of mathematical thinking and not on memorization and rote application of problem- solving techniques.

Students identify and describe the relevant components in the mathematical representations when relating the amounts of reactants and/or products and can derive the relationships and ratios used in dimensional analysis from their balanced equations and models of the reactions.

California Assessment Boundary: Assessment does not include complex chemical reactions.</td></tr>
<tr><td>Highlighted Science and Engineering Practices</td><td>Highlighted Disciplinary Core Ideas</td><td>Highlighted Crosscutting Concepts</td></tr>
<tr><td>● [SEP-1] Asking Questions and Defining Problems
● [SEP-2] Developing and Using Models
● [SEP-5] Using Mathematics and Computational Thinking
● [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)
● [SEP-7] Engaging in Argument from Evidence
● [SEP-8] Obtaining, Evaluating, and Communicating information</td><td>● PS1.A: Structure and Properties of matter
● PS1.B: Chemical Reactions
● PS2.B: Types of Interactions</td><td>● [CCC-1] Patterns
● [CCC-2] Cause and Effect
● [CCC-3] Scale, Proportion, and Quantity

● CCC-5] Energy and Matter: Flows, Cycles, and Conservation</td></tr>
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Chemistry Instructional Segments	
Instructional Segment 4: Chemical Reactions	
Guiding Questions: How do chemical reactions absorb and release energy? How are the matter and energy in chemical reactions related? What types of forces hold atoms together in molecules? How do forces impact and predict the properties of substances? What factors impact the rate of the chemical reaction? How can you predict the relative quantities of products in a chemical reaction?	
Unit Overview: Students refine their models of chemical bonds and chemical reactions. They compare the strength of different types of bonds and attractions and develop models of how energy is stored and released in chemical reactions.	
Students who demonstrate understanding can:	**Clarification Statement:**
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.	Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension. *California Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*

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.	Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved. *California Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*
HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other. *California Assessment Boundary: Assessment is limited to systems containing two objects.*
HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields. Student's will qualitatively apply Coulomb's Law to bonding and the interactions between charged particles. *California Assessment Boundary: Assessment is limited to systems with two objects.*
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.	Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules. *California Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*
HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem- solving techniques. *California Assessment Boundary: Assessment does not include complex chemical reactions.*

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	PS1.B: Chemical reactions ETS1.C: Optimizing the Design Solution	[CCC-1] Patterns [CCC-2] Cause and Effect [CCC-5] Energy and Matter: Flows, Cycles, and Conservation [CCC-7] Stability and Change

Chemistry of the Earth Instructional Segments
Instructional Segment 5: Chemistry of Climate Change
Guiding Questions: How does hydrocarbon combustion affect the carbon cycle in Earth's different spheres (lithosphere, hydrosphere, biosphere, and atmosphere)? What happens to the visible and IR light from the sun as it enters and exits Earth's atmosphere? What regulates weather and climate? What effects are humans having on the climate?
Unit Overview: Students develop models of energy flow in Earth's climate. They revisit combustion reactions from IS1 to focus on emissions from fossil fuel energy sources. They apply models of the structures of molecules to explain that certain molecules trap heat in the atmosphere. Students evaluate different chemical engineering solutions that can reduce the impact of climate change.

Students who demonstrate understanding can:	**Clarification Statements & Assessment Boundaries:**
	Quantitative evaluation of Kinetic Molecular Theory of gases is introduced. (Ideal Gas Law, Combined Gas Law, and Dalton's Law of Partial Pressures)
HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	The carbon cycle is a property of the Earth system that arises from interactions among the hydrosphere, atmosphere, geosphere, and biosphere. Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.
HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition. Students use intuitive definitions of reflection/scattering of light, not to the level of optics. *California Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.*
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can climate feedback that cause changes to other Earth systems.	Examples should include positive and negative feedback loops, such as how an increase in greenhouse gases causes a rise in lower atmosphere and ocean temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent. Students use provided information about molecular structure and its impact on vibrational energy absorbed by those molecules.
HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.*	Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea

	organism health and marine populations. *California Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*
HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition). *California Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.*
HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*	[Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-4] Analyzing and Interpreting Data [SEP-5] Using Mathematics and Computational Thinking [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	[PS3.B] Conservation of Energy and Energy Transfer [PS3.D] Energy and Chemical Processes in Everyday Life [PS4.B] Electromagnetic Radiation [ESS2.A] Earth Materials and Systems [ESS2.D] Weather and Climate [ESS3.A] Natural Resources [ESS3.B] Natural Hazards [ESS3.C] Human Impacts on Earth Systems [ESS3.D] Global Climate Change [LS2.B] Cycles of Matter and Energy Transfer in Ecosystems	[CCC-1] Patterns [CCC-2] Cause and Effect [CCC-4] System and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation [CCC-6] Structure and Function [CCC-7] Stability and Change Influence of Science, Engineering, and Technology on Society and the Natural World

Chemistry of the Earth Instructional Segments	
Instructional Segment 6: The Dynamics of Chemical Reactions and Ocean Acidification	
Guiding Questions: How can you alter chemical equilibrium and reaction rates? How has the chemistry of the ocean changed since the industrial revolution? What is the relationship between increased atmospheric carbon dioxide and the ocean's changing acidity? How can you predict the relative quantities of products in a chemical reaction at equilibrium?	
Unit Overview: Students investigate the effects of fossil fuel combustion on ocean chemistry. They develop models of equilibrium in chemical reactions and design systems that can shift the equilibrium. Students conduct original research on the interaction between ocean water and shell-building organisms.	
Students who demonstrate understanding can:	**Clarification Statements & Assessment Boundaries:**
	Emphasis on the molarity of solutions and relating pH scale to concentrations of solutions
HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem- solving techniques. *California Assessment Boundary: Assessment does not include complex chemical reactions. (Revisited from IS3 and IS4)*
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	Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] *California Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*
HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would	Emphasis is on the conceptual/qualitative application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection

produce increased amounts of products at equilibrium.*	between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products. *California Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	[PS1.B] Chemical reactions [ESS2.A] Earth Materials and Systems [ESS3.C] Human Impacts on Earth Systems [ESS3.D] Global Climate Change [LS2.A] Interdependent Relationships in Ecosystems [LS2.B] Cycles of Matter and Energy Transfer in Ecosystems [ETS1.C] Optimizing the Design Solution	[CCC-2] Cause and Effect [CCC-4] System and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation [CCC-6] Structure and Function [CCC-7] Stability and Change