Chemistry in the Earth System A/B

Santa Maria Joint Union High School District

Submitted: Feb 11, 2021
Decision: Feb 24, 2021

ubmission Feedback

PPROVED

asic Course Information

hool(s) Offering This Course:

School Name	Course Learning Environment	Transcript Code(s)
Delta High School (053302)	Classroom Based	Abbreviation: Chem Earth SysA, Course Code: SC6653 Abbreviation: Chem Earth SysB, Course Code: SC6654
rnest Righetti High School (053303)	Classroom Based	Abbreviation: Chem Earth SysA, Course Code: SC6653 Abbreviation: Chem Earth SysB, Course Code: SC6654
anta Maria High School (053305)	Classroom Based	Abbreviation: Chem Earth SysA, Course Code: SC6653 Abbreviation: Chem Earth SysB, Course Code: SC6654
ioneer Valley High School (053847)	Classroom Based	Abbreviation: Chem Earth SysA, Course Code: SC6653 Abbreviation: Chem Earth SysB, Course Code: SC6654

Title: Chemistry in the Earth System A/B

Length of course: Full Year

Subject area: Science (D) / Chemistry

UC honors designation?	No
Prerequisites:	Physics of the Universe A/B (Required) Biology: The Living Earth A/B (Required) Algebra 1 A/B (Required)
Co-requisites:	None
Integrated (Academics / CTE)?	No
Grade levels:	10th, 11th, 12th

ourse Description

urse overview:

Chemistry in the Earth System AB is a laboratory-based college preparatory course. This course is defined in the 2019 California Science Framework, integrating Chemistry and Earth and Space Science standards from the California Next Generation Science Standards (NGSS). The course is divided into seven units, the first of which is a unit that focuses on executive science skills. The following six Instructional Segments (I.S.) centered on questions about observations of a specific phenomenon. The units address the concepts of combustion, heat and energy in the Earth System, atoms, elements, and molecules, chemical reactions, and the chemistry of climate change. Different phenomena require different amounts of classroom investigative time to explore and understand, so each Instructional Segment should take a different fraction of the school year. As students achieve the Performance Expectations (PEs) within the unit, they uncover Disciplinary Core Ideas (DCIs) from Physical Science, Earth and Space Science, and Engineering. Students engage in multiple Science and Engineering Practices (SEPs) in each unit not just those explicitly indicated in the PEs. Students also focus on one or two Crosscutting Concepts (CCCs) as tools to make sense of their observations and investigations; the CCCs are recurring themes in all disciplines of science and engineering and help tie these seemingly disparate fields together.

Chemistry in the Earth System AB is a "d" course and meets the District Graduation requirement for laboratory physical science.

urse content:

0. Setting the Stage

This unit focuses on the executive science skills necessary for planning and conducting an investigation, collecting and analyzing data, using mathematics and computational thinking, and engaging in argument from evidence. Students are introduced to and connections are made between the fundamentals of Chemistry which are anchored to Earth's solid geosphere, its liquid hydrosphere, and its gaseous atmosphere.

Essential Questions:

1. How do you make sense of the world around you?
2. What is chemistry?
3. What skills are needed to conduct chemistry investigations?
4. How are Scientific Questions generated and tested?
5. How can trends in data be identified, analyzed, and applied?

Performance Expectations:

- Generate scientific questions.
- Identify and measure independent and dependent variables and constants.
- Write a data collection procedure.
- Identify and analyze graphical trends and patterns.
- State a claim about the scientific question being investigated through a written Claim-Evidence-Reasoning concluding paragraph.
- Evaluate the consistency of the data and relate to sources of error.

NGSS Science and Engineering Practices (SEPs):

- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Engaging in Argument from Evidence

NGSS Cross-cutting Concepts (CCCs):

- Patterns
- Scale, Proportion, and Quantity
- Structure and Function

Unit Assignment(s):

Assignments in this unit aim to aid students in the development of scientific reasoning skills. Observing phenomena through the lenses of the SEP's and CCC's will be included. In addition, basic science skills will be reinforced through the use of NGSS Chemistry resources, in which development of the SEP's are supported.

Unit Lab Activities:

Review of mass, volume, density, and measurements are used to build and reinforce science executive skills such as how to make qualitative and quantitative observation, use scientific inquiry, logic, and reasoning to answer questions about the living world. Claim, evidence, reasoning (CER) format will be used to facilitate student's development of logic and reasoning after students investigate within rotating station labs.

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1. Combustion

In the brief introductory unit on combustion, students investigate the amount of stored chemical potential energy in food. They make observations of material properties at the bulk scale that they will later explain at the atomic scale The themes of combustion and CO_2 tie together several of the instructional segments.

Essential Questions:

1. What is energy, how is it measured, and how does it flow within a system?
2. What mechanisms allow us to utilize the energy of our foods and fuels?

NGSS Performance Expectations (PEs):

- **HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles
- **HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction

NGSS Science and Engineering Practices (SEPs):

- Asking questions
- Analyzing and interpreting data
- Developing and using models

NGSS Cross-cutting Concepts (CCCs):

- Energy and Matter: Flows, Cycles, and Conservation
- Patterns
- Stability and change
- Cause and effect: Mechanism and explanation
- Systems and system models.

Unit Assignment(s):

Keep a Fire Burning - In this unit assignment, students deepen their understanding of energy and matter through the study of combustion. Students apply the laws of conservation of energy and matter as they investigate and develop system models of combustion. To fully understand the phenomenon of California Wildfires students identify factors that sustain a combustion reaction by exploring the amount of energy stored in fuel samples, students then model the changes that occur when wood is burned and relate the change in energy that occurs during combustion to the change in chemical bonds from reactants to products. They identify patterns in how matter and energy are conserved and then apply this knowledge to explain their observation in related phenomena such as the dropping rubber balls of different masses movement of a pendulum.

Unit Lab Activities:

Conservation of Mass in Chemical Reactions - In this hands on experiment, students carry out an investigation to design a system that will support their understanding that mass is conserved throughout a chemical reaction of sodium bicarbonate with acetic acid. Students are provided with the materials they will need to design and conduct this experiment. Students begin by designing their experimental procedure on a whiteboard using the criteria that their system should include all reactants and products in this chemical reaction. Students implement their experimental designs, collect data, discuss their

results, and redesign their experimental designs to improve the collection of data. This experiment concludes with students presenting their experimental design process and their analysis of collected data to the class, as well as a CER statement in answer to the question, Is your experimental design for this investigation a closed system?

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2. Heat and Energy In the Earth System

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.

Essential Questions:

1. How is energy transferred and conserved?.
2. How can energy be harnessed to perform useful tasks?

NGSS Performance Expectations (PEs):

- **HS-PS3-1.** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- **HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
- **HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics) .
- **HS-ESS2-3.** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.
- **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.

NGSS Science and Engineering Practices (SEPs):

- Developing and Using Models
- Planning and Carrying Out Investigations
- Using Mathematical and Computational Thinking
- Constructing Explanations (science) and Designing Solutions (for engineering)

NGSS Cross-cutting Concepts (CCCs):

- Systems and System Models
- Energy and Matter: Flows, Cycles, and Conservation

Unit Assignment(s):

Earthquakes in My Backyard - In this unit assignment, students will have the opportunity to relate how thermal convection of materials in the mantle leads to the movement and collision of tectonic plates which result in earthquakes. This assignment begins with students researching and recording on a map the locations of the most recent earthquakes in

California. Next, students observe a convection current demo and complete a KWL chart. In the first column, students write what they know (K) about Earth's interior structure and how heat flows between different layers. In the second column, students write what they want to learn (W) about Earth's interior. In the third column, students write what they have learned so far (L) about the movement of materials through the convection current demo. Students then use GPS data to track the movement of the tectonic plates in California. They are then asked to connect the plate movements with geological events in this case California earthquake locations. Additionally, students are asked to describe, using evidence, how convection in Earth's mantle drives the movements of the tectonic plates in California resulting in earthquakes.

Unit Lab Activities:

Thermal Energy and Heat Transfer - This hands on experiment begins with the phenomena of ice melting on different materials to demonstrate how different materials can conduct thermal energy at different rates and a discussion with students to determine why they think the ice melted at such different rates. Students then carry out an investigation to evaluate the heat flow of metals using microscale calorimeters. They use the data from their investigation to calculate heat for strips of aluminum, copper, iron, and zinc. This investigation concludes with students working in their lab groups to write an argument describing to an outside party why ice melts at different rates on different materials. Students will present arguments in the form of a peer review constructed as a "boardwalk" activity to suggest edits (one similarity and one clarifying question).

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3. Atoms, Elements, and Molecules

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

Essential Questions:

1. What is inside atoms and how does this affect how they interact?
2. What models can we use to predict the outcomes of chemical reactions?

NGSS Performance Expectations (PEs):

- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- **HS-PS1-2**. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
- **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

NGSS Science and Engineering Practices (SEPs):

- Developing and Using Models
- Using Mathematics and Computational Thinking
- Constructing Explanation (for science) and Designing Solutions (for engineering)
- Engaging in Argument from Evidence

NGSS Crosscutting Concepts (CCCs):

- Patterns
- Energy and Matter: Flows, Cycles, and Conservation

Unit Assignment(s):

Explore Atomic Particles - This unit assignment begins with students investigating the mass and relative abundance of isotopes for the “bean bag” element (symbol Bg) and calculating the atomic mass of this element to reinforce that all of these “atoms” are from the same element (beans), but that each different size of bean represents a different isotope of that element. Students then explore atomic particles by analyzing a data set to discover how the number of protons, not the number of neutrons or electrons, determines the identity of each element. They also investigate how ionic charge is determined from the relative number of protons and electrons. This assignment concludes with students using computer simulations such as PhET or GIZMOS to reinforce the different parts of an atom, the concept of isotopes and relative abundance.

Unit Lab Activities:

Elemental Metals, Nonmetals, and Metalloids - This hands on investigation begins with a brief discussion about “valuable” elements. Students are asked to name valuable elements and think about the properties of these elements and the location of these elements on the periodic table. This discussion should evolve so students are considering elements based on the property of conductivity. Students are then asked to carry out an investigation using a conductivity meter and a bar magnet to rate the conductivity of different elemental samples: aluminum strip, carbon rod, iron nail, silicon lump, sulfur lump, mossy tin. Students then use their findings to identify patterns in the periodic table which are associated with conductivity. This investigation concludes with students writing an argument in which they make a claim about the relationship between the element’s conductivity, location in the periodic table, and electron configuration.

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4. Chemical Reactions

Students define 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.

Essential Questions:

1. What holds atoms together in molecules?
2. How do chemical reactions absorb and release energy?

NGSS Performance Expectations (PEs):

- **HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- **HS-PS1-5.** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

- **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- **HS-PS2-4.** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
- **HS-PS3-5.** 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.

NGSS Science and Engineering Practices (SEPs):

- Developing and Using Models
- Planning and Carrying Out Investigations
- Using Mathematical and Computational Thinking
- Constructing Explanations (for science) and Designing Solution (for engineering)

NGSS Crosscutting Concepts (CCCs):

- Patterns
- Cause and Effect
- Energy and Matter: Flows, Cycles, and Conservation

Unit Assignment(s):

Collision Theory - This unit assignment begins with a teacher-led discussion about why energy is required to light a match. To facilitate this discussion the teacher lights stick matches using a hot plate. During this demonstration, students are encouraged to call out their observations when they see changes in the match heads. This demonstration concludes with the teacher generating a visual list of the student ideas about what was happening on the molecular level to make the match heads ignite. Students then explore collision theory using a computer simulation (PhET or Gizmos). During this exploration, students will determine what leads to a successful collision between particles in a chemical reaction. Students will also determine the effect of temperature and/or the addition of a catalyst on reaction rates. This assignment concludes with students making a claim about why the match required a certain amount of energy input before the match head ignited, supported by their observations.

Unit Lab Activities:

Reaction Rates and Equilibrium - This is a summative hands on investigation in which students are asked to carry out an investigation to determine how reaction rates change based on reactant concentration and temperature. This investigation begins with the instructor demonstrating the decomposition of hydrogen peroxide. Students then design a procedure to study the effect of hydrogen peroxide concentration on reaction rate. They record their data from their trials, analyze their results, and record patterns they observed in their experiment. In the second part of this investigation, students will explore how temperature influences the solubility of sodium acetate. Students then are asked to construct an explanation of their results using the terms of Le Chatelier's principle. Student data should support these two relationships - concentration of hydrogen peroxide and reaction rates, as well as temperature of a sodium acetate solution, increases to rate of dissolution.

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5. Chemistry of Climate Change

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 how different molecules trap heat in the atmosphere. Students evaluate different chemical engineering solutions that can reduce the impacts of climate change

Essential Questions:

1. What regulates weather and climate?
2. What effects are humans having on the climate?

NGSS Performance Expectations (PEs):

- **HS-ESS2-2**. Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.
- **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.
- **HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- **HS-ESS3-2.** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
- **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.
- **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

NGSS Science and Engineering Practices (SEPs):

- Developing and Using Models
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Engaging in Argument from Evidence

NGSS Crosscutting Concepts (CCCs):

- Cause and Effect: Mechanism and Explanation
- Systems and Systems Models
- Energy and Matter: Flows, Cycles, and Conservation
- Stability and Change

Unit Assignment(s):

Carbon Dioxide and Its Role in Climate - To prompt student discussion about the greenhouse effect, this unit assignment will begin with a discussion about why the interior of a car gets so hot if the car is parked in the sun. Students carry out an activity to lay the foundation that anthropogenic greenhouse gasses play a role in climate change. Using a direct heat source, students compare the temperature increases of a closed system with ambient air to a closed system with additional carbon dioxide as a product of antacid effervescent-tablet catabolism. Students then choose a variable to manipulate to test the closed system again and look for patterns. Students then use a Flow of Energy and Greenhouse Gases simulation to help reinforce the concepts of absorption and reflection of energy. In this simulation, students observe how energy from the sun is absorbed, radiated, and reflected in the Earth system. They investigate changes to energy inputs and outputs by exploring solar flux, human effects, and supervolcanoes. And, explore how melting polar ice caps change Earth's

temperature and how rising sea levels affect ice cover on Earth. This assignment concludes with students connecting what they learned in the virtual simulation to the data they collected in their inquiry lab to propose the relationship between greenhouse gases and Earth's temperature.

Unit Lab Activities:

Albedo and Composition of Earth's Surface - In this lab students carry out an investigation to determine how albedo and specific heat influence how fast temperature change occurs in a substance. They will measure the temperature change in several samples placed under a heat lamp and formulate a prediction for the relationship between surface substance and temperature change. Students will then design and conduct a field experiment using infrared thermometers to test their prediction. This investigation concludes with students using the data from their laboratory and field experiments to create an infographic describing their findings describing the relationship between albedo and the composition of Earth's surfaces.

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6. Dynamics of Chemical Reactions and Ocean Acidification

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.

Essential Questions:

1. How can you alter chemical equilibrium and reaction rates?
2. How can you predict the relative quantities of products in a chemical reaction?

NGSS Performance Expectations (PEs):

- **HS-PS1-5.** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- **HS-PS1-6.** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
- **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- **HS-ESS2-2.** Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.
- **HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

NGSS Science and Engineering Practices (SEPs):

- Developing and Using Models
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

NGSS Crosscutting Concepts (CCCs):

- Patterns
- Energy and Matter: Flows, Cycles, and Conservation
- Stability and Change

Unit Assignment(s):

Reducing Carbon Footprints - In this assignment, students calculate their personal carbon footprint using a Carbon Footprint Calculator website. Students then analyze the components of their footprint and brainstorm ways that they can reduce their personal carbon footprint. Students are then challenged to apply what they have learned about reducing their personal carbon footprint to their school or city. In order to facilitate the idea that this is a local and personal issue, students pick one component of a carbon footprint to research then write a persuasive letter to the school board or city council proposing carbon footprint reduction ideas. The letter will include a clear explanation of the problem and their solution supported by evidence from their research.

Unit Lab Activities:

Calcium Carbonate and Shell Production - In this investigation, students evaluate how different concentrations of hydrochloric acid affect the time it takes to dissolve calcium carbonate. They record data on the volume of gas produced and the different concentrations of hydrochloric acid at various times. They identify patterns in how the change in concentration of hydrochloric acid affects the gas production by the calcium carbonate. Students identify the gas being produced in the reaction. They draw conclusions on how this relates to calcifying organisms and ocean acidification. Students construct an explanation about how the amount of available calcium carbonate could affect the ocean food web system and humans. Students then use the virtual lab, *The Effect of Ocean Acidification on Shells*, to explore how ocean pH and temperatures are expected to change if global CO_2 emissions do not change. Students analyze and interpret their findings from this virtual lab and add this understanding to their model of the impacts of ocean acidification. Students then work to design solutions to mitigate ocean acidification which are presented to the class.

ourse Materials

Websites

itle	Author(s)/Editor(s)/Compiler(s)	Affiliated Institution or Organization	URL

Title	Author(s)/Editor(s)/Compiler(s)	Affiliated Institution or Organization	URL
AMTA - Chemistry	[empty]	American Modeling Teacher Association, University of Arizona	https://www.modelinginstruction.org/
AMTA - Chemistry	[empty]	American Modeling Teacher Association, University of Arizona	https://www.modelinginstruction.org/
AMTA - Chemistry	[empty]	American Modeling Teacher Association, University of Arizona	https://www.modelinginstruction.org/
NGSS Pathfinder	[empty]	Concord Consortium	https://concord.org/ngss/
PhET Interactive Simulation	[empty]	University of Colorado, Boulder	https://phet.colorado.edu/
PhET Interactive Simulation	[empty]	University of Colorado, Boulder	https://phet.colorado.edu/
Gizmos Simulations	[empty]	Explore Learning	https://www.explorelearning.com
CK12.org	[empty]	CK12 Foundation	https://www.ck12.org
NewsELA.com	[empty]	NewsELA	https://newsela.com/
PIVOT Interactives	[empty]	PIVOT Interactives	https://www.pivotinteractives.com/
PIVOT Interactives	[empty]	PIVOT Interactives	https://www.pivotinteractives.com/
PBS/NOVA	[empty]	Public Broadcasting Service/NOVA	https://www.pbs.org/show/nova/episodes/ https://www.pbs.org/wgbh/nova/brand/education
Ocean Acidification	[empty]	BioInteractrives	https://www.biointeractive.org/
Urban Heat Island	Norman Herr	California State University Northridge	https://sites.google.com/site/drnormanherr/
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