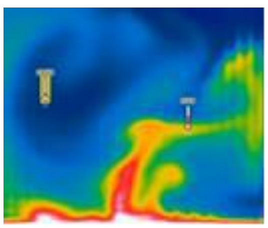
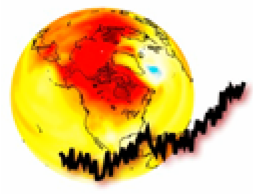
2018-19 Chemistry Course Map

Overview

	***1*** ***Combustion***	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 will later explain in the atomic scale. The themes of combustion and CO_2 tie together several of the Instructional Segments.
	**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.
	**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.
	**4** Chemical Reactions	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.

	**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.
	**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.

Segment 1

Chemistry in the Earth System – 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?
Performance Expectations
Students who demonstrate understanding can: 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.**[Clarification Statement: 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.] [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. **[Clarification Statement: 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.] [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. **[Clarification Statement: 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.] [Assessment Boundary: Assessment does not include complex chemical reactions.] (Introduced, but not assessed until IS6. Revisited in 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. **[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [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)**

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

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**

Segment 2

Chemistry in the Earth System – Instructional Segment 2: Heat and Energy in the Earth System
Guiding Questions: • How is energy transferred and conserved? • How can energy be harnessed to perform useful tasks?
Performance Expectations

Students who demonstrate understanding can:

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. **[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [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). **[Clarification Statement: 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, 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). **[Clarification Statement: 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.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.] HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. **[Clarification Statement: 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.]** 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.
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-2] Developing and Using Models **[SEP-3] Planning and Carrying Out**	**PS3.A: Definitions of Energy** **PS3.B: Conservation of Energy and Energy Transfer**	**[CCC-1] Patterns** **[CCC-2] Cause and Effect**

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**	**ESS2.B: Plate Tectonics and Large-Scale System Interactions**	**[CCC-3] Scale, Proportion, and Quantity** **[CCC-5] Energy and Matter: Flows, Cycles, and Conservation** **[CCC-7] Stability and Change**

Segment 3

Chemistry in the Earth System – Instructional Segment 3: Atoms, Elements, and Molecules
Guiding Questions: • What is inside atoms and how does this affect how they interact? • What models can we use to predict the outcomes of chemical reactions?
Performance Expectations
Students who demonstrate understanding can: 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. **[Clarification Statement: 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.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]**

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. **[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]** HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **[Clarification Statement: 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.] [Assessment Boundary: Assessment does not include complex chemical reactions.] (Introduced here and revisited again in IS4 and IS6)**
The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	**Highlighted Disciplinary Core Ideas**	**Highlighted Crosscutting Concepts**
[SEP-1] Asking Questions and Defining Problems	**PS1.A: Structure and Properties of matter**	**[CCC-1] Patterns** **[CCC-2] Cause and**

[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-6] Constructing Explanations (for science) and Designing Solutions (for engineering)** **[SEP-7] Engaging in Argument from Evidence** **[SEP-8] Obtaining,**	**PS1.B: Chemical Reactions** **PS2.B: Types of Interactions**	**Effect** **[CCC-3] Scale, Proportion, and Quantity** **[CCC-5] Energy and Matter: Flows, Cycles, and Conservation**

Evaluating, and Communicating Information]		

Chemistry in the Earth System – Instructional Segment 4: Chemical Reactions
Guiding Questions: • What holds atoms together in molecules? • How do chemical reactions absorb and release energy?
Performance Expectations
Students who demonstrate understanding can: 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. **[Clarification Statement: 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.] [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. **[Clarification Statement: 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.] [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. **[Clarification Statement: 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.] [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. **[Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*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. **[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [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. **[Clarification Statement: 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.] [Assessment Boundary: Assessment does not include complex chemical reactions.] (Introduced in IS3 and revisited again in IS6)**

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

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 in the Earth System – Instructional Segment 5: Chemistry of Climate Change
Guiding Questions: • What regulates weather and climate? • What effects are humans having on the climate?
Performance Expectations
Students who demonstrate understanding can: **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.** [Clarification Statement: 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-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** [Clarification Statement: 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.] [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-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: 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-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.]

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. [Clarification Statement: 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).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

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.* [Clarification Statement: 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.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems	PS3.B: Conservation of Energy and Energy Transfer	ESS3.A: Natural Resources
[SEP-2] Developing and Using Models	PS3.D: Energy and Chemical Processes in Everyday Life	
[SEP-3] Planning and Carrying Out Investigations	PS4.B: Electromagnetic Radiation	
[SEP-4] Analyzing and Interpreting Data	ESS2.A: Earth Materials and Systems	
[SEP-5] Using Mathematics and Computational Thinking	ESS2.D: Weather and Climate	

and

Function

[CCC-1] Patterns

[CCC-7]

Stability

and

Change

[CCC-

2]

Cause

and

Effect

Influence of Science,

[CCC-4]

System

and

System

Models

[CCC-5]

Energy

and

Matter:

Flows,

Cycles,

and

Conservat

ion

[CCC-6]

Structure

[SEP-7] Engaging in Argument from Evidence **[SEP-8] Obtaining, Evaluating, and Communicating Information**	**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**	**Engineering, and Technology on Society and the Natural World**

Chemistry in the Earth System – Instructional Segment 6: The Dynamics of Chemical Reactions and Ocean Acidification
Guiding Questions: • How can you alter chemical equilibrium and reaction rates? • How can you predict the relative quantities of products in a chemical reaction?
Performance Expectations
Students who demonstrate understanding can: 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. **[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [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 produce increased amounts of products at equilibrium.* **[Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection 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.] [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-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **[Clarification Statement: 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.] [Assessment Boundary: Assessment does not include complex chemical reactions.] (Revisited from IS3 and IS4)**

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. **[Clarification Statement: 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. **[Clarification Statement: 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.]

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems	**PS1.B: Chemical reactions**	**[CCC-2] Cause and Effect**
[SEP-2] Developing and Using Models	**ESS2.A: Earth Materials and Systems**	**[CCC-4] System and System Models**
[SEP-3] Planning and Carrying Out Investigations	**ESS3.C: Human Impacts on Earth Systems**	**[CCC-5] Energy and Matter: Flows, Cycles, and Conservation**
[SEP-5] Using Mathematics and Computational	**ESS3.D: Global Climate Change**	**[CCC-6] Structure and Function**
	LS2.A: Interdependent	**[CCC-7] Stability and**

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	Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems ETS1.C: Optimizing the Design Solution	Change