

College Preparatory Chemistry Pacing Guide

**Unit 1:** How can the substructures of atoms explain the observable properties of substances?  
How do ancient carbon atoms drive economic decisions in the modern world?

Estimated time to complete: 40 days

- İ **Part A (6 days):** How can I use the properties of something (in bulk quantities) to predict what is happening with the subatomic particles?
- İ **Part B (5 days):** Does thermal energy always transfer or transform in predictable ways?
- İ **Part C (4 days):** I want to do the right thing, what is the greener choice for grocery bags (paper or plastic/reusable vs. disposable); cold drink containers (plastic, glass, or aluminum); or hot drink containers (paper, Styrofoam, or ceramic)? [Clarification: Students should have the opportunity to select the product and use the Life Cycle Analysis (LCA) to make an evidence-based claim.]
- İ **Part D (5 days):** What makes water's properties essential to life on our planet? or Why do we look for water on other planets? or What makes water so special?
- İ **Part E (10 days):** How can a periodic table tell me about the subatomic structure of a substance?
- İ **Part F (10 days):** How can I use the periodic table to predict if I need to duck before mixing two elements?

**Unit 2:** How can one explain the structure, properties, and interactions of matter?

Estimated time to complete: 40 days

- İ **Part A (15 days):** How can I use the periodic table to predict if I need to duck before mixing two elements?
- İ **Part B (15 days):** Where do the atoms go during a chemical reaction?
- İ **Part C (5 days):** How do photosynthesis and cellular respiration result in the formation of new compounds?
- İ **Part D (5 days):** How do elements of a sugar molecule combine with other elements and what molecules are formed?

**Unit 3: How is energy transferred within a system?  
How do organisms obtain and use the energy they need to live and grow?**

Estimated time to complete: 40 days

- İ **Part A (3 days):** Does thermal energy always transfer or transform in predictable ways?
- İ **Part B (10 days):** How does energy flow in a chemical reaction?
- İ **Part C (5 days):** What is different inside a heat pack and a cold pack?
- İ **Part D (10 days):** Is it possible to change the rate of a reaction or cause two elements to react that do not normally want to?
- İ **Part E (10 days):** What can we do to make the products of a reaction stable?
- İ **Part F (2 days):** How do photosynthesis and cellular respiration result in a net transfer of energy?

**Unit 4: What happens in stars?**

Estimated time to complete: 40 days

- İ **Part A (8 days):** Why is fusion considered the Holy Grail for the production of electricity? Why aren't all forms of radiation harmful to living things?
- İ **Part B (8 days):** How do stars produce elements?
- İ **Part C (8 days):** Is the life span of a star predictable?
- İ **Part D (8 days):** If there was nobody there to Tweet about it, how do we know that there was a Big Bang?
- İ **Part E (8 days):** How can chemistry help us to figure out ancient events?

**Unit 5: How do Earth's geochemical processes and human activities affect each other?**

Estimated time to complete: 20 days

- İ **Part A (10 days):** What happens if we change the chemical composition of our atmosphere?
- İ **Part B (10 days):** How does carbon cycle among the hydrosphere, atmosphere, geosphere, and biosphere?

**Unit Summary**

***How can the substructures of atoms explain the observable properties of substances?***

***Why are we so lucky that water has the physical properties that it does?***

***How do ancient carbon atoms drive economic decisions in the modern world?***

In this unit of study, students use investigations, simulations, and models to make sense of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Students are expected to communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. The crosscutting concepts of *structure and function*, *patterns*, *energy and matter*, and *stability and change* are called out as the framework for understanding the disciplinary core ideas. Students will be *developing and using models*, *planning and conducting investigations*, *using mathematical thinking*, and *constructing explanations and designing solutions*. Students are also expected to use the science and engineering practices to demonstrate proficiency with the core ideas.

In this unit of study, students *develop and use models*, *plan and carry out investigations*, *analyze and interpret data*, and *engage in argument from evidence* to make sense of energy as a quantitative property of a system—a property that depends on the motion and interactions of matter and radiation within that system. They will also use the findings of investigations to provide a mechanistic explanation for the core idea that total change of energy in any system is always equal to the total energy transferred into or out of the system. Additionally, students develop an understanding that energy, at both the macroscopic and the atomic scales, can be accounted for as motions of particles or as energy associated with the configurations (relative positions) of particles.

Students apply their understanding of energy to explain the role that water plays in affecting weather. Students examine the ways that human activities cause feedback that create changes to other systems. Students are expected to demonstrate proficiency in *developing and using models*, *planning and carrying out investigations*, *analyzing and interpreting data*, *engaging in argument from evidence*, and using these practices to demonstrate understanding of core ideas. Students also develop possible solutions for major global problems. They begin by breaking these problems into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected not only to consider a wide range of criteria, but also to recognize that criteria need to be prioritized.

This unit is based on HS-PS3-4, HS-ESS2-5, HS-ESS3-2, and HS-ETS1-3.

**Student Learning Objectives**

**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-PS3-4)*

**Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.\*** *[Clarification*

*Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] (HS-PS2-6)*

**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.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.] (HS-PS1-3)*

**Suggested labs for this standard: Ask students to design an investigation of physical properties of simple substances. Goal: Students should conclude from their investigation that some substances (i.e. salt and sugar) melt at different temperatures, some freeze at different temperatures, some flow at different rates. Do not discuss ionic and covalent bonding here, but more simply the difference in physical properties.**

**Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** *[Clarification Statement: Emphasis is on physical investigations with water and a variety of solid materials. Examples of investigations include solubility, weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).] (HS-ESS2-5)*

**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-PS1-1)*

**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-ESS3-2)*

**Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.** (HS-ETS1-3)

**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.** (HS-ETS1-4)

<b>Part A (6 days):</b> <i>How can I use the properties of something (in bulk quantities) to predict what is happening with the subatomic particles?</i>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.</li> <li>Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.</li> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Plan and conduct an investigation individually and collaboratively to produce data that can serve as the basis for evidence for comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. In the investigation design, decide on types, how much, and accuracy of data needed to produce reliable measurements; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly.</li> <li>Use patterns in the structure of substances at the bulk scale to infer the strength of electrical forces between particles.</li> </ul>

<b>Part B (5 days):</b> <i>Does thermal energy always transfer or transform in predictable ways?</i>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.</li> <li>Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.</li> <li>Uncontrolled systems always move toward more stable states—that is,</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Plan and conduct an investigation individually or collaboratively to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined.</li> <li>Use models to describe a system and define its boundaries, initial conditions,</li> </ul>

<p>toward a more uniform energy distribution.</p> <p>ï Although energy cannot be destroyed, it can be converted into less useful forms—for example, to thermal energy in the surrounding environment.</p>	<p>inputs, and outputs.</p> <p>ï Design an investigation to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined, considering types, how much, and the accuracy of data needed to produce reliable measurements.</p> <p>ï Consider the limitations of the precision of the data collected and refine the design accordingly</p>
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**Part C (4 days)** : I want to do the right thing, what is the greener choice for *grocery bags (paper or plastic/reusable vs. disposable)*; *cold drink containers (plastic, glass, or aluminum)*; or *hot drink containers (paper, Styrofoam, or ceramic)*? *[Clarification: Students should have the opportunity to select the product and use the Life Cycle Analysis (LCA) to make an evidence-based claim.]*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.</li> <li>Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.</li> <li>When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, aesthetics, and to consider social, cultural, and environmental impacts.</li> <li>Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.</li> <li>Models (e.g., physical, mathematical, computer models) can be used to simulate why the molecular-level structure is important in the functioning of</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Communicate scientific and technical information about why the molecular - level structure is important in the functioning of designed materials.</li> <li>Evaluate a solution to a complex real-world problem based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoffs considerations to determine why the molecular level structure is important in the functioning of designed materials.</li> <li>Use mathematical models and/or computer simulations to show why the molecular level structure is important in the functioning of designed materials.</li> <li>Communicate scientific and technical information about the attractive and repulsive forces that determine the functioning of the material.</li> <li>Use mathematical models and/or computer simulations to show the attractive and repulsive forces that determine the functioning of the material.</li> </ul>

designed materials.	<ul style="list-style-type: none"> <li>Examine in detail the properties of designed materials, the structure of the components of designed materials, and the connections of the components to reveal the function.</li> <li>Use models (e.g., physical, mathematical, computer models) to simulate systems of designed materials and interactions--including energy, matter, and information flows--within and between designed materials at different scales.</li> </ul>
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<b>Part D (5 days) : What makes water's properties essential to life on our planet? or Why do we look for water on other planets? or What makes water so special?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.</li> <li>The functions and properties of water and water systems can be inferred from the overall structure, the way the components are shaped and used, and the molecular substructure.</li> <li>These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Plan and conduct an investigation individually and collaboratively of the properties of water and its effects on Earth materials and surface processes.</li> <li>Use models to describe a hydrological system and define its boundaries, initial conditions, inputs, and outputs.</li> <li>Design an investigation considering the types, how much, and accuracy of data needed to produce reliable measurements.</li> <li>Consider the limitations on the precision of the data collected and refine the design accordingly.</li> </ul>

<b>Part E (10 days): How can a periodic table tell me about the subatomic structure of a substance?</b>
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Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>• Different patterns may be observed at each of the scales at which a system is studied, and these patterns can provide evidence for causality in explanations of phenomena.</li> <li>• Each atom has a charged substructure.</li> <li>• An atom's nucleus is made of protons and neutrons and is surrounded by electrons.</li> <li>• The periodic table orders elements horizontally by number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns.</li> <li>• The repeating patterns of this table reflect patterns of outer electron states.</li> <li>• Patterns of electrons in the outermost energy level of atoms can provide evidence for the relative properties of elements at different scales.</li> <li>• Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>• Use the periodic table as a model to provide evidence for relative properties of elements at different scales based on the patterns of electrons in the outermost energy level of atoms in main group elements.</li> <li>• 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 in main group elements.</li> </ul>

**Part F (10 days):** *How can I use the periodic table to predict if I need to duck before mixing two elements?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>• The periodic table orders elements horizontally by number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns.</li> <li>• The repeating patterns of the periodic table reflect patterns of outer electron states.</li> <li>• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</li> <li>• Different patterns may be observed at each of the scales at which a system</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>• Use valid and reliable evidence (obtained from students' own investigations, models, theories, simulations, and peer review) showing the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties to construct and revise an explanation for the outcome of a simple chemical reaction.</li> <li>• Use the assumption that theories and laws that describe the outcome of simple chemical reactions operate today as they did in the past and will continue to do so in the future.</li> </ul>



<p>is studied, and these patterns can provide evidence for causality in explanations of phenomena.</p>	<ul style="list-style-type: none"> <li>Observe patterns in the outermost electron states of atoms, trends in the periodic table, and chemical properties.</li> <li>Use the conservation of atoms and the chemical properties of the elements involved to describe and predict the outcome of a chemical reaction.</li> </ul>
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Assessments		
*Formative Assessments provided for each subsection.		
Summative Assessments	Benchmark assessments	Alternative Assessments
<ul style="list-style-type: none"> <li>Chapter/Unit Tests</li> <li>Writing Assignments</li> <li>Lab Reports/Quizzes</li> </ul>	<ul style="list-style-type: none"> <li>New Jersey Student Learning Assessment Science (NJSLA)</li> <li>Quarterlies</li> <li>Performance Assessments</li> </ul>	<ul style="list-style-type: none"> <li>Oral Presentation</li> <li>Video Recording</li> <li>Virtual Labs</li> </ul>

What It Looks Like in the Classroom
<p>In this unit of study, students begin by understanding how the substructure of substances at the bulk scale infers the strength of electrical forces between particles. Students should plan and conduct investigations illustrating how the structure and interactions of matter determine the properties at the bulk amount. These investigations must take into account the accuracy of data required to produce reliable information and consider limitations on the precision of the data.</p> <p>Students should also plan and conduct investigations using attraction and repulsion (charges—cations/anions) at the atomic scale to explain the structure of matter at the bulk scale. For example, students could investigate how the strength of forces between particles is dependent on particle type (ions, atoms, molecules, networked materials [allotropes]). Students should examine crystal structures and amorphous structures.</p> <p>Students could further investigate the role of attraction and repulsion at the atomic scale by investigating melting point and boiling point. Students could plan and conduct an investigation using attraction and repulsion at the atomic scale to explain transformations of matter at the bulk scale—for example, collecting data to create cooling and heating curves.</p> <p>Students might also conduct research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles. Information should be gathered from multiple reliable sources and used to support claims. Any data reported should include appropriate units while considering limitations on measurements.</p> <p>In this unit of study, students begin building their understanding of the law of conservation of energy by planning and conducting investigations of thermal energy</p>

transfer. Students should investigate and describe a system focusing specifically on thermal energy transfer in a closed system. These investigations will provide opportunities for students to use models that can be made of a variety of materials, such as student-generated drawings and/or digital simulations, such as those available from [PhET](#). These models can be used to describe a system, and define its boundaries, initial conditions, inputs, and outputs.

Students should have the opportunity to ask and refine questions, using specific textual evidence, about the energy distribution in a system. Students should collect relevant data from several sources, including their own investigations, and synthesize their findings into a coherent understanding.

Using the knowledge that energy cannot be created or destroyed, students should create computational or mathematical models to calculate the change in the energy in one component of a system when the change in energy of the other component(s) and energy flows in and out of the systems are known. In order to do this, students should manipulate variables in specific heat calculations. For example, students can use data collected from simple Styrofoam calorimeters to investigate the mixing of water at different initial temperatures or the adding of objects at different temperatures to water to serve as a basis for evidence of uniform energy distribution among components of a system. Students might conduct an investigation using different materials such as various metals, glass, and rock samples. Using the specific heat values for these substances, students could create mathematical models to represent the energy distribution in a system, identify important quantities in energy distribution, map relationships, and analyze those relationships mathematically to draw conclusions.

These investigations will allow students to collect data to show that energy is transported from one place to another or transferred between systems, and that uncontrolled systems always move toward more stable states with more uniform energy distribution. Students should also observe during investigations that energy can be converted into less useful forms, such as thermal energy released to the surrounding environment. During the design and implementation of investigations, students must consider the precision and accuracy appropriate to limitations on measurement of the data collected and refine their design accordingly.

This unit will also focus on the planning and conducting of mechanical and chemical investigations of water. Properties to be investigated should include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks. This focus is particularly important since water's abundance on Earth's surface, and its unique combination of physical and chemical properties, are central to the planet's dynamics.

In order to understand how the periodic table can be used as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms, students must first understand the idea that atoms have a charged substructure consisting of a nucleus that is composed of protons and neutrons surrounded by electrons. Students should use a variety of models to understand the structure of an atom. Examples may include computer simulations, drawings, and kits. Students can create models of atoms by calculating protons, neutrons, and electrons in any given atom, isotope, or ion.

In order to understand the predictive power of the periodic table, students should write electron configurations for main group elements, paying attention to patterns of electrons in the outermost energy level. Students should annotate the periodic table to determine its arrangement horizontally by number of protons in the atom's nucleus and its vertical arrangement by the placement of elements with similar chemical properties in columns. Students should also be able to translate information about patterns in the periodic table into words that describe the importance of the outermost electrons in atoms.

- ✓ Students use the ideas of attraction and repulsion (i.e., charges—cations/anions) at the atomic scale to explain the structure of matter, such as in ion formation, and to explain the properties of matter such as density, luster, melting point, boiling point, etc.

In order to address how the substructure of substances at the bulk scale infers the strength of electrical forces between particles, emphasis should be placed on the importance of outermost electrons in bulk physical properties, bonding, and stability. Students must realize that valence electrons are important.

Students should plan and conduct investigations to show the structure and interactions of matter at the bulk amount. These investigations should illustrate the importance of accurate and reliable data while considering limitations on the precision of the data.

Students should also plan and conduct investigations using attraction and repulsion (charges—cations/anions) at the atomic scale to explain the properties of matter at the bulk scale—for example, investigating melting point, boiling point.

**Optional:** Students might also conduct research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles. Information should be gathered from multiple reliable sources and used to support claims. Any data reported should include appropriate units while considering limitations on measurements.

#### ***Suggested Integration of Engineering***

In this unit, students consider communicating scientific and technical information about why the molecular level structure is important in the functioning of designed materials. Students evaluate a solution to a complex real-world problem, such as electrically conductive materials made of metal, plastics made of organic polymers, or pharmaceuticals designed for specific biological targets, and then use a computer simulation to model the impact of that solution.

As students consider communicating scientific and technical information about why the molecular-level structure is important in the functioning of designed materials, the focus should be on attractive and repulsive forces. Students might research information about Life Cycle Analysis (LCA), which examines every part of the production, use, and final disposal of a product. LCA requires that students examine the inputs (raw materials and energy) required to manufacture products, as well as the outputs (atmospheric emissions, waterborne wastes, solid wastes, coproducts, and other resources). This allows them to make connections between molecular-level structure and product functionality. Students should evaluate the LCA process and communicate a solution to a real-world problem, such as the environmental impact of different types of grocery bags (paper or plastic/reusable vs. disposable), cold drink containers (plastic, glass, or aluminum), or hot drink containers (paper, Styrofoam, or ceramic). They should base their solution to their chosen real-world problem on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Students should then use technology to present a life-cycle-stage model that considers the LCA and typical inputs and outputs measured for their real-world problem. Students need to consider the properties of various materials (e.g. Molar mass, solubility, and bonding) to decide what materials to use for what purposes, inputs and outputs measured for their real-world problem. Students must consider the properties of various materials (e.g. solubility, bonding) to decide which materials to use for which purposes. When students have properties appropriate for the final use, they will be able to consider material uses in LCAs to determine if they are environmentally appropriate. For further reference, see ChemMatters, February 2014, "It's Not Easy Being Green, Or Is It?" at

[www.acs.org/content/acs/en/education/resources/highschool/chemmatters.html](http://www.acs.org/content/acs/en/education/resources/highschool/chemmatters.html).

To gain a more complete understanding, students might conduct short or more sustained research projects to determine how the properties of water affect Earth materials and surface processes. Once students have an understanding of the conservation of energy and the properties of water that allow it to absorb, store, and release large amounts of energy, the unit will transition to an engineering design problem.

Working from the premise that all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs, risks, and benefits, students will use cost–benefit ratios to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources.

For example, students might investigate the real-world technique of using hydraulic fracturing to extract natural gas from shale deposits versus other traditional means of acquiring energy from natural resources. Students will synthesize information from a range of sources into a coherent understanding of competing design solutions for extracting and utilizing energy and mineral resources. As students evaluate competing design solutions, they should consider that new technologies could have deep impacts on society and the environment, including some that were not anticipated. Some of these impacts could raise ethical issues for which science does not provide answers or solutions. In their evaluations, students should make sense of quantities and relationships associated with developing, managing, and utilizing energy and mineral resources. Mathematical models can be used to explain their evaluations. Students might represent their understanding by conducting a Socratic seminar as a way to present opposing views. Students should consider and discuss decisions about designs in scientific, social, and cultural contexts.

#### Connecting with English Language Arts/Literacy and Mathematics

##### *English Language Arts/Literacy*

- Translate information from the periodic table about the patterns of electrons in the outermost energy level of atoms into words that describe the relative properties of elements.
  - Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
  - Integrate and evaluate multiple design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios in order to reveal meaningful patterns and trends.
  - Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
  - Synthesize data from multiple sources of information in order to create data sets that inform design decisions and create a coherent understanding of

developing, managing, and utilizing energy and mineral resources.

- Cite specific textual evidence comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
  - Conduct short as well as more sustained research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles.
  - Gather applicable information from multiple reliable sources to support the claim that electrical forces between particles can be used to explain the structure of substances at the bulk scale.
  - Develop evidence comparing the structure of substances at the bulk scale and the strength of electrical forces between particles.

#### *Mathematics*

- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities representing periodic trends for main group elements based on patterns of electrons in the outermost energy level of atoms.
- Considering the outermost energy level of atoms, define appropriate quantities for descriptive modeling of periodic trends for main group elements based on patterns of electrons in outermost energy levels.
- Determine and interpret the scale and origin in graphs and data displays representing patterns of chemical properties, outer electron states of atoms, trends in the periodic table, and patterns of chemical properties.
- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities of simple chemical reactions.
  - Use symbols to represent energy distribution in a system when two components of different temperature are combined, and manipulate the representing symbols. Make sense of quantities and relationships in the energy distribution in a system when two components of different temperature are combined.
  - Use a mathematical model to describe energy distribution in a system when two components of different temperature are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
  - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the properties of water and their effects on Earth materials and surface processes.

**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4),(HS-ESS3-2) (HS-PS1-3)

**RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-3)

<b>RST.11-12.8</b>	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS3-2),(HS-PS3-4),(HS-ETS1-3)
<b>RST.11-12.9</b>	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-3)
<b>WHST.9-12.2</b>	Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-PS1-2)
<b>WHST.9-12.5</b>	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2, (HS-ETS1-3)
<b>WHST.9-12.7</b>	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-4), (HSESS2-5) (HS-PS1-3)
<b>WHST.11-12.8</b>	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3) (HS-ETS1-3)
<b>WHST.9-12.9</b>	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4) (HS-PS1-3)(HS-ETS1-3)
<b>SL.11-12.5</b>	Make strategic use of digital media (e.g., textual, graphical, audio, visual and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest (HS-PS1-4)
<i>Mathematics –</i>	
<b>MP.2</b>	Reason abstractly and quantitatively. (HS-PS3-4),(HS-ESS3-2),(HS-ETS1-3) (HS-ETS1-4)
<b>MP.4</b>	Model with mathematics. (HS-PS3-4), (HS-ETS1-3) (HS-ETS1-4)
<b>HSN-Q.A.1</b>	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2), (HS-PS1-3)
	<ul style="list-style-type: none"> <li>Use symbols to represent an explanation of the best of multiple design solutions for developing, managing, and utilizing energy and mineral resources and manipulate the representing symbols. Make sense of quantities and relationships in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources symbolically and manipulate the representing symbols.</li> <li>Use a mathematical model to explain the evaluation of multiple design solutions for developing, managing, and utilizing energy and mineral resources.</li> </ul>

Identify important quantities in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

### Modifications

*Teacher Note: Teachers identify the modifications that they will use in the unit.*

#### ï ELL

- o Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- o Audio books, movies, and other digital media in lieu of print versions
- o Native language texts and native language to English dictionary

#### ï Special Education

- o Modified assignments (ex: fewer problems per page)
- o Response to Intervention (RTI) ([www.help4teachers.com](http://www.help4teachers.com))
- o Follow all IEP modifications
- o Oral Instructions
- o Record lessons instead of taking notes
- o Outlines of lessons
- o Study Guides with answers
- o Word processor to type notes
- o Frequent breaks
- o Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).

504:

- Utilize graphic organizers to help provide a purpose for reading and increase comprehension

- Assign peer tutor
- Provide clear and specific directions
- Provide class notes ahead of time to allow students to preview material and increase comprehension
- Provide extended time
- Simplify written and verbal instructions

**ï Gifted and Talented**

- Peer Tutoring
- Cooperative Learning Groups
- Differentiated Instruction
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.

**Students at Risk of School Failure:**

- Extended Time
- Flexible Grouping
- Small Group Instruction
- Peer Buddies
- Tiered Activities
- Manipulatives
- Graphic Organizers

ï

**Career Readiness Standards**

- 9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth.
- 9.2.12.CAP.5: Assess and modify a personal plan to support current interests and postsecondary plans.

**Research on Student Learning**

Students of all ages show a wide range of beliefs about the nature and behavior of particles. They lack an appreciation of the very small size of particles; believe there must be something in the space between particles; have difficulty in appreciating the intrinsic motion of particles in solids, liquids and gases; and have problems in



conceptualizing forces between particles ([NSDL, 2015](#)).

### Prior Learning

Prior to entering the chemistry course, students should understand:

#### *Physical science*

- Substances are made from different types of atoms, which combine with one another in various ways.
- Atoms form molecules that range in size from two atoms to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others.
- In a gas, the molecules are widely spaced except when they happen to collide.
- In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Substances react chemically in characteristic ways.
- In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, whereas others store energy.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.
- These physical and chemical properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting point of rocks.

### Connections to Other Courses

*Physical science*

- Each atom has a charged substructure consisting of a nucleus made of protons and neutrons and surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- A stable molecule has less energy than does the same set of atoms separated; at least this much energy is required in order to take the molecule apart.
- Chemical processes, their rates, and whether or not they store or release energy can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved in chemical reactions, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the energy stored in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

*Life Science*

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

*Earth and space science*

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

**Sample of Open Education Resources**

[Energy Forms and Changes](#): This simulation allows students to investigate thermal energy transfer.

[Build an Atom](#): This simulation allows students to create different illustrations of atoms and provides evidence that protons determine the identity of the element.

[Periodic Table Trends](#): This is a virtual investigation of the periodic trends.

[Path to Periodic Table](#): This investigation provides students with the opportunity to make sense of how and why the periodic table is organized the way that it is. Students will re-create the thought process that Dmitri Mendeleev and Julius Lothar Meyer went through to devise their early periodic tables.

[Castle of Mendeleev](#): Students engage in a fantasy world that requires them to make claims, based on evidence, regarding the identity of unknown materials.

[Heating and Cooling Curves](#): Students evaluate the spacing and energy of particles in different phases.

[States of Matter](#): Illustration of properties of a substance as a solid, liquid and gas.

[Periodicity of Elements](#): Students evaluate the pattern of valence electrons in the periodic table

[Intermolecular Forces](#): Students evaluate how Coulombic Attraction is affected by the number of valence electrons and principal energy levels.

[Game: Which element does not belong?](#) : Students look at the period and family to determine which element does not fit in with the others.

[Periodic Table Interactive](#) : Useful study tool for all things periodic table.

[Building Atoms](#): Interactive activity where students build atoms by stacking electron orbitals, adding electrons to the orbitals, and viewing how the electron configuration can be used to determine the structure of an atom.

[Atomic and Ionic Structure of the first 12 elements](#): View the Bohr model and quantum model of each of the first 12 elements. You can also ionize the atoms to see how the structure would respond.

**Links to Free and Low Cost Instructional Resources**

*Note- The majority of the student sense-making experiences found at these links predate the NGSS. Most will need to be modified to include science and engineering*

*practices, disciplinary core ideas, and cross cutting concepts. [The EQuIP Rubrics for Science](#) can be used as a blueprint for evaluating and modifying instructional materials.*

- ï American Association for the Advancement of Science: <http://www.aaas.org/programs>
- ï American Association of Physics Teachers: <http://www.aapt.org/resources/>
- ï American Chemical Society: <http://www.acs.org/content/acs/en/education.html>
- ï Concord Consortium: Virtual Simulations: <http://concord.org/>
- ï International Technology and Engineering Educators Association: <http://www.iteaconnect.org/>
- ï National Earth Science Teachers Association: <http://www.nestanet.org/php/index.php>
- ï National Science Digital Library: <https://nsdl.oercommons.org/>
- ï National Science Teachers Association: <http://ngss.nsta.org/Classroom-Resources.aspx>
- ï North American Association for Environmental Education: <http://www.naaee.net/>
- ï Phet: Interactive Simulations <https://phet.colorado.edu/>
- ï Physics Union Mathematics (PUM): <http://pum.rutgers.edu/>
- ï Science NetLinks: <http://www.aaas.org/program/science-netlinks>

## Appendix A: NGSS and Foundations for the Unit

**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-PS3-4)

**Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** *[Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]* (HS-ESS2-5)

**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-PS1-1)

**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..] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]* (HS-PS1-3)

**Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.\*** *[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]* (HS-PS2-6)

**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-ESS3-2)

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. *[Clarification Statement: See Three-Dimensional Teaching and Learning Section for examples].* (HS-ETS1-3)

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. (HS-ETS1-4)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Planning and Carrying Out Investigations</b></p> <p>ÿ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4)</p> <p><b>Engaging in Argument from Evidence</b></p> <p>ÿ Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2)</p> <p><b>Planning and Carrying Out Investigations</b></p> <p>ÿ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and</p>	<p><b>PS3.B: Conservation of Energy and Energy Transfer</b></p> <p>ÿ Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-4)</p> <p>ÿ Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4)</p> <p><b>PS3.D: Energy in Chemical Processes</b></p> <p>ÿ Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-4)</p> <p><b>ESS3.A: Natural Resources</b></p> <p>ÿ All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)</p>	<p><b>Systems and System Models</b></p> <p>ÿ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)</p> <p><b>Structure and Function</b></p> <p>ÿ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5)</p> <p>-----</p> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <p>ÿ Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2)</p>

<p>consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-ESS2-5)</p> <p><b>Constructing Explanations and Designing Solutions</b></p> <p>Ï Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)</p> <p><b>Developing and Using Models</b></p> <ul style="list-style-type: none"> <li>Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)</li> </ul> <p><b>Planning and Carrying Out Investigations</b></p> <ul style="list-style-type: none"> <li>Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)</li> </ul> <p><b>Constructing Explanations and Designing Solutions</b></p> <ul style="list-style-type: none"> <li>Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to</li> </ul>	<p><b>ETS1.B: Developing Possible Solutions</b></p> <p>Ï When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (<i>secondary to HS-ESS3-2</i>),(<i>secondary HS-ESS3-4</i>)</p> <p><b>ESS2.C: The Roles of Water in Earth's Surface Processes</b></p> <p>Ï The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)</p> <p><b>ETS1.A: Defining and Delimiting Engineering Problems</b></p> <p>Ï Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)</p> <p>Ï Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-</p>	<p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <p>Ï New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)</p> <p>-----</p> <p><b>Connections to Nature of Science</b></p> <p><b>Science Addresses Questions About the Natural and Material World</b></p> <p>Ï Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2)</p> <p>Ï Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2)</p> <p>Ï Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)</p> <p>-----</p> <p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2),(HS-PS1-3)</li> </ul> <p><b>Structure and Function</b></p>
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<p>do so in the future. (HS-PS1-2)</p> <ul style="list-style-type: none"> <li>Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)</li> </ul> <p><b>Obtaining, Evaluating, and Communicating Information</b></p> <ul style="list-style-type: none"> <li>Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)</li> </ul> <p><b>Using Mathematics and Computational Thinking</b></p> <ul style="list-style-type: none"> <li>Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)</li> </ul>	<p>ETS1-1)</p> <p><b>ETS1.B: Developing Possible Solutions</b></p> <p>ï When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</p> <p>ï Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</p> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <p>ï Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)</p> <p><b>PS1.A: Structure and Properties of Matter</b></p> <ul style="list-style-type: none"> <li>Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)</li> <li>The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron</li> </ul>	<ul style="list-style-type: none"> <li>Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)</li> </ul> <p><b>Systems and System Models</b></p> <ul style="list-style-type: none"> <li>Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (HS-ETS1-4)</li> </ul> <p>-----</p> <p><b><i>Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World</i></b></p> <p>New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)</p>
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	<p>states. (HS-PS1-1),(HS-PS1-2)</p> <ul style="list-style-type: none"> <li>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (<i>secondary to HS-PS2-6</i>)</li> </ul> <p><b>PS2.B: Types of Interactions</b></p> <ul style="list-style-type: none"> <li>Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (<i>secondary to HS-PS1-1</i>),(<i>secondary to HS-PS1-3</i>)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</li> <li>Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</li> </ul>	
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<b>Embedded English Language Arts/Literacy and Mathematics</b>	
English Language Arts/Literacy –	

<b>RST.11-12.1</b>	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4),(HS-ESS3-2) (HS-PS1-3)
<b>RST.11-12.7</b>	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-3)
<b>RST.11-12.8</b>	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS3-2),(HS-PS3-4),(HS-ETS1-3)
<b>RST.11-12.9</b>	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-3)
<b>WHST.9-12.2</b>	Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-PS1-2)
<b>WHST.9-12.5</b>	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2, (HS-ETS1-3)
<b>WHST.9-12.7</b>	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-4), (HSESS2-5) (HS-PS1-3)
<b>WHST.11-12.8</b>	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3) (HS-ETS1-3)
<b>WHST.9-12.9</b>	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4) (HS-PS1-3)(HS-ETS1-3)
<b>SL.11-12.5</b>	Make strategic use of digital media (e.g., textual, graphical, audio, visual and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest (HS-PS1-4)
<i>Mathematics –</i>	
<b>MP.2</b>	Reason abstractly and quantitatively. (HS-PS3-4),(HS-ESS3-2),(HS-ETS1-3) (HS-ETS1-4)
<b>MP.4</b>	Model with mathematics. (HS-PS3-4), (HS-ETS1-3) (HS-ETS1-4)
<b>HSN-Q.A.1</b>	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2), (HS-PS1-3)



## Unit Summary

***How can one explain the structure, properties, and interactions of matter?***

***How do organisms obtain and use the energy they need to live and grow?***

In this unit of study, students will *develop and use models, plan and conduct investigations, use mathematical thinking, and construct explanations and design solutions* as they develop an understanding of the substructure of atoms while providing more mechanistic explanations of the properties of substances. Chemical reactions can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students also apply an understanding of the process of *optimization and engineering design* to chemical reaction systems. Students will also construct explanations for the role of energy in the cycling of matter in organisms. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate these explanations. The crosscutting concept of *matter and energy* provides students with insights into the structures and processes of organisms. Students are expected to *develop and use models, plan and conduct investigations, use mathematical thinking, and construct explanations and design solutions* as they demonstrate proficiency with the disciplinary core ideas. The crosscutting concepts of *patterns, energy and matter, and stability and change* are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *developing and using models, planning and conducting investigations, using mathematical thinking, and constructing explanations and designing solutions*.

## Student Learning Objectives

**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-PS1-2)*

**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.] (HS-PS1-7)*

**Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.] (HS-LS1-5)*

**Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular*

*respiration.*] (HS-LS1-7)

Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]* (HS-LS1-6)

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. *[Clarification Statement: See Three-Dimensional Teaching and Learning Section for examples].* (HS-ETS1-3)

**Part A (15 days):** *How can I use the periodic table to predict if I need to duck before mixing two elements?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>The fact that atoms are conserved together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</li> <li>Different patterns may be observed at each of the scales at which a system is studied, and these patterns can provide evidence for causality in explanations of phenomena.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Use valid and reliable evidence (obtained from students' own investigations, models, theories, simulations, and peer review) showing the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties to construct and revise an explanation for the outcome of a simple chemical reaction.</li> <li>Use the assumption that theories and laws that describe the outcome of simple chemical reactions operate today as they did in the past and will continue to do so in the future.</li> <li>Observe patterns in the outermost electron states of atoms and trends in the periodic table</li> <li>Use the conservation of atoms and the chemical properties of the elements involved to describe and predict the outcome of a chemical reaction.</li> </ul>

<b>Part B (15 days): Where do the atoms go during a chemical reaction?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>The fact that atoms are conserved, together with the knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</li> <li>The total amount of matter in closed systems is conserved.</li> <li>The total amount of matter in a chemical reaction system is conserved.</li> <li>Changes of matter in a system can be described in terms of how matter flows into, out of, and within that system.</li> <li>Changes of matter in a chemical reaction system can be described in terms of matter flows into, out of, and within that system.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Use mathematical representations of chemical reaction systems to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</li> <li>Use mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale, using the mole as the conversion from the atomic to the macroscopic scale.</li> <li>Use the fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, to describe and predict chemical reactions.</li> <li>Describe changes of matter in a chemical reaction system in terms of matter flows into, out of, and within that system.</li> </ul>
<b>Part C (5 days): How do photosynthesis and cellular respiration result in the formation of new compounds?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>The process of photosynthesis converts light energy to glucose by converting carbon dioxide plus water into sugars plus released oxygen.</li> <li>As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.</li> <li>Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Provide a mechanistic explanation for how photosynthesis transforms light energy into glucose.</li> <li>Use their understanding of conservation of matter to illustrate the inputs and outputs of matter, and the transformation of energy from light to glucose in photosynthesis.</li> <li>Construct an evidence-based model, to illustrate that cellular respiration is a</li> </ul>

<p>formed that can transport energy to muscles.</p> <ul style="list-style-type: none"><li>• Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.</li></ul>	<p>chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed.</p>
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<b>Part D (5 days): How do elements of a sugar molecule combine with other elements and what molecules are formed?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>Sugar molecules contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.</li> <li>As matter flows through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.</li> <li>Changes of matter in a system can be described in terms of matter flowing into, out of, and within that system.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.</li> <li>Construct and revise an explanation, based on valid and reliable evidence from a variety of sources (including models, theories, simulations, peer review) and on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon based molecules.</li> <li>Use evidence from models and simulations to support explanations for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.</li> </ul>

<b>Assessments</b>		
<b>*Formative Assessments provided for each subsection.</b>		
<b>Summative Assessments</b>	<b>Benchmark assessments</b>	<b>Alternative Assessments</b>
<ul style="list-style-type: none"> <li>Chapter/Unit Tests</li> <li>Writing Assignments</li> <li>Lab Reports/Quizzes</li> </ul>	<ul style="list-style-type: none"> <li>New Jersey Student Learning Assessment Science (NJSLA)</li> <li>Quarterlies</li> <li>Performance Assessments</li> </ul>	<ul style="list-style-type: none"> <li>Oral Presentation</li> <li>Video Recording</li> <li>Virtual Labs</li> </ul>

<b>What It Looks Like in the Classroom</b>
In unit 2, students will use their understanding of atomic structure and periodic trends to describe and predict chemical reactions, and the conservations of mass within a system. Students will understand that the total amount of matter in a closed system (including chemical reaction systems) is conserved. Changes of energy



and matter in the system can be described in terms of how energy and matter flow into, out of, and within that system. Using this knowledge, and knowledge of the chemical properties of elements, students should be able to describe and predict simple chemical reactions in terms of mass and conversion of kinetic to stored energy.

The mole concept and stoichiometry are used to show proportional relationships between masses of reactants and products. Students should be able to use balanced equations to show mass relationships between reactants and products. Students should also gain an understanding of the use of dimensional analysis to perform mass to mole conversions that demonstrate how mass is conserved during chemical reactions. Focus should be on students' use of mathematics to demonstrate their thinking about proportional relationships among masses of reactants and products and to make connections between the atomic and macroscopic world. Students should use units appropriately and consistently, considering limitations on measurement, for the purpose of descriptive modeling of the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.

To explain the outcomes of chemical reactions using the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties, students should use investigations, simulations, and models of chemical reactions to prove that atoms are conserved. For example, students might observe simple reactions in a closed system and measure the mass before and after the reaction as well as count atoms in reactants and products in chemical formulas. Students should also construct chemical formulas involving main group elements in order to model that atoms are conserved in chemical reactions (the Law of Conservation of Mass). Students need to describe and predict simple chemical reactions, including combustion, involving main group elements. Students should use units when modeling the outcome of chemical reactions. When reporting quantities, students should choose a level of accuracy appropriate to limitations on measurement.

Students should also be able to write a rigorous explanation of the outcome of simple chemical reactions, using data from their own investigations, models, theories, and simulations. They should strengthen their explanations by drawing and citing evidence from informational text.

- ✓ Students also use the ideas of attraction and repulsion (charges—cations/anions) at the atomic scale to explain transformations of matter—for example, reaction with oxygen, reactivity of metals, types of bonds formed, and number of bonds formed. Students will explain bonding through the patterns in outermost electrons, periodic trends, and chemical properties.

This unit of study continues to build will also approach the content from a life science standpoint. Students will use their understanding of chemical reactions and the conservation of matter to support their learning as they model photosynthesis and cellular respiration. Work with chemical reactions will help students develop explanations for the formation of amino acids and other large, carbon-based molecules. Also, students continue developing and using models, constructing explanations and designing solutions, and obtaining, evaluating, and communicating information.

In particular, both photosynthesis and cellular respiration will be the reactions used to emphasize that the reactants (inputs) and products (outputs) show the transfer of matter from one system of interacting molecules to another. In developing models to represent how photosynthesis transforms light energy into stored chemical energy (glucose) and the inputs and outputs of cellular respiration, students might use digital media in presentations to enhance understanding.

*[Clarification, The focus of this unit is on the basic inputs and outputs of these processes. The specific biological steps of the Calvin cycle, Glycolysis, and Krebs cycle are not the focus this unit].* In photosynthesis, light energy is converted to stored energy when carbon dioxide and water are converted into sugars. Oxygen is released in this process. The organism then converts the chemical energy (glucose) into a usable form (A.T.P) on the cellular level through the process of cellular respiration.

At the same time, students take an in-depth look at the polymerization of sugar; they should research and investigate how simple sugars (made from carbon, hydrogen, and oxygen) are combined and recombined in different structures with specific functions. Students will construct and revise explanations for how simple sugars help form hydrocarbon backbones (amino acids) or carbon-based backbones (protein, DNA, new organism). Explanations should be supported and revised using evidence from multiple sources of text, models, theories, simulations, students' own investigations, and peer review. Students' explanations should describe the formation of amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA) that can be used, for example, to form new cells. It is important to remember that students are only required to conceptually understand the process, not the specific chemical reactions or the identification of macromolecules such as amino acids and DNA.

#### Connecting with English Language Arts/Literacy

##### *English Language Arts/Literacy*

- Write 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 of elements using well-chosen, relevant, and sufficient facts; extended definitions; and concrete details from students' own investigations, models, theories, simulations, and peer review.
- Develop and strengthen explanations for the outcome of a simple chemical reaction by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties of elements.
- Draw evidence from informational texts about the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties of elements to construct a rigorous explanation of the outcome of a simple chemical reaction.
- Make strategic use of digital media in presentations to enhance understanding of how photosynthesis transforms light energy into stored chemical energy.
- Use digital media in presentations to enhance understanding of the inputs and outputs of the process of cellular respiration.
- Cite specific textual evidence to support how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.
- Use evidence from multiple sources to clearly communicate an explanation for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.

- Revise an explanation for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant.
- Draw evidence from informational texts to describe how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large, carbon-based molecules.

#### *Mathematics*

- Use units as a way to understand the outcome of a simple chemical reaction involving main group elements based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Choose and interpret units consistently in chemical reactions.
- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities of simple chemical reactions.
- Represent an explanation that atoms, and therefore mass, are conserved during a chemical reaction symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the conservation of atoms and mass during chemical reactions symbolically and manipulate the representing symbols.
- Use units as a way to understand the conservation of atoms and mass during chemical reactions; choose and interpret units consistently in formulas representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale; choose and interpret the scale and origin in graphs and data displays representing the conservation of atoms and mass in chemical reactions.
- Define appropriate quantities for the purpose of descriptive modeling of the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.

#### **Modifications**

*Teacher Note: Teachers identify the modifications that they will use in the unit.*

#### ï ELL

- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Audio books, movies, and other digital media in lieu of print versions

- o Native language texts and native language to English dictionary

#### ï Special Education

- o Modified assignments (ex: fewer problems per page)
- o Response to Intervention (RTI) ([www.help4teachers.com](http://www.help4teachers.com))
- o Follow all IEP modifications
- o Oral Instructions
- o Record lessons instead of taking notes
- o Outlines of lessons
- o Study Guides with answers
- o Word processor to type notes
- o Frequent breaks
- o Provide students with multiple choices for how they can represent their understanding (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).

#### 504:

- Utilize graphic organizers to help provide a purpose for reading and increase comprehension
- Assign peer tutor
- Provide clear and specific directions
- Provide class notes ahead of time to allow students to preview material and increase comprehension
- Provide extended time
- Simplify written and verbal instructions

#### ï Gifted and Talented

- o Peer Tutoring
- o Cooperative Learning Groups
- o Differentiated Instruction
- o Use project-based science learning to connect science with observable phenomena.

- o Structure the learning around explaining or solving a social or community-based issue.

**Students at Risk of School Failure:**

- Extended Time
- Flexible Grouping
- Small Group Instruction
- Peer Buddies
- Tiered Activities
- Manipulatives
- Graphic Organizers

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**Career Readiness Standards**

- 9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth.
- 9.2.12.CAP.5: Assess and modify a personal plan to support current interests and postsecondary plans.

**Research on Student Learning**

Middle- and high-school student thinking about chemical change tends to be dominated by the obvious features of the change. For example, some students think that when something is burned in a closed container, it will weigh more because they see the smoke that was produced. Further, many students do not view chemical changes as interactions. They do not understand that substances can be formed by the recombination of atoms in the original substances. Rather, they see chemical change as the result of a separate change in the original substance, or changes, each one separate, in several original substances. For example, some students see the smoke formed when wood burns as having been driven out of the wood by the flame ([NSDL, 2015](#)).

**Prior Learning***Physical science*

- i Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- i Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- i Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- i In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely

spaced and may vibrate in position but do not change relative locations.

- ï Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- ï The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- ï Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change.
- ï Some chemical reactions release energy, others store energy.

#### *Life science*

- ï Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.
- ï Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.
- ï Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- ï Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

#### Connections to Other Courses

##### *Physical science*

- Substances are made from different types of atoms, which combine with one another in various ways.
- Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules,

and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change.

- Some chemical reactions release energy, others store energy.

#### *Life science*

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.
- Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

#### Sample of Open Education Resources

- ï [Ionic Bonding Interactive Game](#): Students fit together cations and anions to create ionic compounds.
- ï [Molecular Geometry](#): Students evaluate how the number of bonds and lone pairs of electrons determine the shape of a molecule.
- ï [Types of Chemical Reactions](#): Students apply the analogy of dancing to identify different types of reactions.
- ï [Balancing Chemical Reactions](#): Students demonstrate how to balance a chemical equation.

#### Links to Free and Low Cost Instructional Resources

*Note- The majority of the student sense-making experiences found at these links predate the NGSS. Most will need to be modified to include science and engineering practices, disciplinary core ideas, and cross cutting concepts. [The EQulP Rubrics for Science](#) can be used as a blueprint for evaluating and modifying instructional materials.*

- ï American Association for the Advancement of Science: <http://www.aaas.org/programs>
- ï American Chemical Society: <http://www.acs.org/content/acs/en/education.html>
- ï Concord Consortium: Virtual Simulations: <http://concord.org/>
- ï International Technology and Engineering Educators Association: <http://www.iteaconnect.org/>
- ï National Earth Science Teachers Association: <http://www.nestanet.org/php/index.php>
- ï National Science Digital Library: <https://nsdl.oercommons.org/>
- ï National Science Teachers Association: <http://ngss.nsta.org/Classroom-Resources.aspx>
- ï North American Association for Environmental Education: <http://www.naaee.net/>
- ï Phet: Interactive Simulations <https://phet.colorado.edu/>
- ï Science NetLinks: <http://www.aaas.org/program/science-netlinks>



## Appendix A: NGSS and Foundations for the Unit

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-PS1-2)*

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.] (HS-PS1-7)*

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.] (HS-LS1-5)*

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.] (HS-LS1-7)*

Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.] (HS-LS1-6)*

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (HS-ETS1-2)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Developing and Using Models</b>	<b>PS1.B: Chemical Reactions</b>	<b>Energy and Matter</b>
<ul style="list-style-type: none"> <li>Use a model based on evidence to illustrate the</li> </ul>	<ul style="list-style-type: none"> <li>The fact that atoms are conserved, together</li> </ul>	<ul style="list-style-type: none"> <li>Changes of energy and matter in a system can</li> </ul>

<p>relationships between systems or between components of a system. (HS-LS1-5),(HS-LS1-7)</p> <p><b>Constructing Explanations and Designing Solutions</b></p> <p>ï Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)</p>	<p>with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2)</p> <p><b>ESS2.D: Weather and Climate</b></p> <ul style="list-style-type: none"> <li>Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</li> <li>Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</li> </ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <p>ï Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)</p> <p><b>ETS1.A: Defining and Delimiting Engineering Problems</b></p> <p>ï Criteria and constraints also include satisfying</p>	<p>be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6)</p> <p>ï Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)</p>
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	<p>any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)</p> <p>ï Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)</p> <p>•</p> <p><b>LS1.A: Structure and Function</b></p> <p>ï Systems of specialized cells within organisms help them perform the essential functions of life. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6)</p> <p>ï All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6)</p> <p>ï Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6)</p> <p>ï Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback</p>	
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	<p>mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (secondary to HS-LS1-4, HS-LS1-5, HS-LS1-6)</p> <p><b>ETS1.B: Developing Possible Solutions</b></p> <p>ï When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</p> <p>ï Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</p> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <p>ï Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)</p> <p>ï</p> <p><b>LS1.B: Growth and Development of Organisms</b></p> <p>ï In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells,</p>	
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	<p>with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)</p> <p><b>LS1.C: Organization for Matter and Energy Flow in Organisms</b></p> <p>ï The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)</p> <p>ï The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6)</p> <p>ï As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6),(HS-LS1-7)</p> <p>ï As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to</p>	
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	the surrounding environment. (HS-LS1-7)	
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### Embedded English Language Arts/Literacy and Mathematics Standards

#### *English Language Arts/Literacy*

<b>RST.9-10.7</b>	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1)
<b>WHST.9-12.5</b>	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)
<b>RST.11-12.1</b>	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5) (HS-LS1-6)
<b>WHST.9-12.9</b>	Draw evidence from informational texts to support analysis, reflection and research (HS-LS1-6)
<b>RST.11-12.7</b>	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)
<b>RST.11-12.8</b>	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)
<b>RST.11-12.9</b>	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)

**WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-5)

**WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6)

## Unit Summary

***How is energy transferred within a system?***

***How do organisms obtain and use the energy they need to live and grow?***

Students will understand energy as a quantitative property of a system—a property that depends on the motion and interactions of matter and radiation within that system. They will also understand that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy, at both the macroscopic and the atomic scales, can be accounted for as motions of particles or as energy associated with the configurations (relative positions) of particles.

In this unit of study, students *develop and using models, plan and conduct investigations, use mathematical thinking, and construct explanations and design solutions* as they develop an understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Students also apply an understanding of the process of *optimization and engineering design* to chemical reaction systems. The crosscutting concepts of *patterns, energy and matter, and stability and change* are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in *developing and using models, planning and conducting investigations, using mathematical thinking, and constructing explanations and designing solutions*.

## Student Learning Objectives

**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-PS1-4)*

**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-PS1-5)*

**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-PS1-6)*

**Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.] (HS-LS1-5)*

**Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.] (HS-LS1-7)*

**Part A (3 days):** *Does thermal energy always transfer or transform in predictable ways?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>ï When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.</li> <li>ï Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.</li> <li>ï Uncontrolled systems always move toward more stable states—that is, toward a more uniform energy distribution.</li> <li>ï Although energy cannot be destroyed, it can be converted into less useful forms—for example, to thermal energy in the surrounding environment.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>ï Plan and conduct an investigation individually or collaboratively to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined.</li> <li>ï Use models to describe a system and define its boundaries, initial conditions, inputs, and outputs.</li> <li>ï Design an investigation to produce data on transfer of thermal energy in a closed system that can serve as a basis for evidence of uniform energy distribution among components of a system when two components of different temperatures are combined, considering types, how much, and the accuracy of data needed to produce reliable measurements.</li> <li>ï Consider the limitations of the precision of the data collected and refine the design accordingly</li> </ul>

<b>Part B (10 days): How does energy flow in a chemical reaction?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>The total amount of energy in closed systems is conserved.</li> <li>The total amount of energy in a chemical reaction system is conserved.</li> <li>Changes of energy in a system can be described in terms of how energy flows into, out of, and within that system.</li> <li>Changes of energy in a chemical reaction system can be described in terms of how energy flows into, out of, and within that system.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Use the fact that energy is conserved to describe and predict energy flow in chemical reactions.</li> <li>Describe changes of energy and matter in a chemical reaction system in terms of how energy flows into, out of, and within that system.</li> </ul>

<b>Part C (5 days): What is different inside a heat pack and a cold pack?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>A stable molecule has less energy than the same set of atoms separated; at least this much energy must be provided in order to take the molecule apart.</li> <li>Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.</li> <li>Changes of energy and matter in a chemical reaction system can be described in terms of collisions of molecules and the rearrangements of atoms into new molecules, with subsequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</li> <li>Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Explain the idea that a stable molecule has less energy than the same set of atoms separated.</li> <li>Describe changes of energy and matter in a chemical reaction system in terms of energy and matter flows into, out of, and within that system.</li> <li>Describe chemical processes, their rates, and whether or not they store or release energy in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</li> <li>Develop a model based on evidence to illustrate the relationship between the release or absorption of energy from a chemical reaction system and the</li> </ul>

the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	changes in total bond energy.
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**Part D (10 days):** *Is it possible to change the rate of a reaction or cause two elements to react that do not normally want to?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</li> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</li> <li>Patterns in the effects of changing the temperature or concentration of the reacting particles can be used to provide evidence for causality in the rate at which a reaction occurs.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Use the number and energy of collisions between molecules (particles) to explain the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.</li> <li>Use patterns in the effects of changing the temperature or concentration of the reactant particles to provide evidence for causality in the rate at which a reaction occurs.</li> <li>Apply scientific principles and multiple and independent student-generated sources of evidence to provide an explanation of the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.</li> </ul>

**Part E (10 days):** *What can we do to make the products of a reaction stable?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>Much of science deals with constructing explanations of how things change and how they remain stable.</li> <li>In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Construct explanations for how chemical reaction systems change and how they remain stable.</li> <li>Design a solution to specify a change in conditions that would produce increased amounts of products at equilibrium in a chemical system based on</li> </ul>

<ul style="list-style-type: none"> <li>Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed.</li> <li>Explanations can be constructed explaining how chemical reaction systems can change and remain stable.</li> </ul>	<p>scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</p> <ul style="list-style-type: none"> <li>Break down and prioritize criteria for increasing amounts of products in a chemical system at equilibrium.</li> <li>Refine the design of a solution to specify a change in conditions that would produce increased amounts of products at equilibrium in a chemical system based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</li> </ul>
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**Part F (2 days):** How do photosynthesis and cellular respiration result in a net transfer of energy?

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>The process of photosynthesis converts light energy to stored energy by converting carbon dioxide plus water into sugars plus released oxygen.</li> <li>Changes of energy in a system can be described in terms of how energy flows into, out of, and within a system.</li> <li>As energy flows through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.</li> <li>As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another.</li> <li>Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.</li> <li>Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Provide a mechanistic explanation for how photosynthesis transforms light energy into stored chemical energy.</li> <li>Use their understanding of energy flow and conservation of energy to illustrate the inputs and outputs of matter and the transformation of energy in photosynthesis.</li> <li>Construct an evidence-based model, to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.</li> <li>Use their understanding of energy flow and conservation of energy to illustrate the inputs and outputs of the process of cellular respiration.</li> </ul>

**Assessments**
**\*Formative Assessments provided for each subsection.**

Summative Assessments	Benchmark assessments	Alternative Assessments
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<ul style="list-style-type: none"> <li>● Chapter/Unit Tests</li> <li>● Writing Assignments</li> <li>● Lab Reports/Quizzes</li> </ul>	<ul style="list-style-type: none"> <li>● New Jersey Student Learning Assessment Science (NJSLA)</li> <li>● Quarterlies</li> <li>● Performance Assessments</li> </ul>	<ul style="list-style-type: none"> <li>● Oral Presentation</li> <li>● Video Recording</li> <li>● Virtual Labs</li> </ul>
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#### What It Looks Like in the Classroom

This unit of study looks at energy flow and matter but with emphasis on photosynthesis, cellular respiration, and polymerization. Students should use models such as diagrams, chemical equations, and conceptual models to illustrate how matter and energy flow through different organizational levels of living systems, from microscale to macroscale.

Models should use evidence to illustrate how photosynthesis transforms light energy into stored chemical energy; how cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy; and to illustrate the inputs and outputs of matter and the transformations of energy in both processes. Models could include chemical equations, flow diagrams, manipulatives, and conceptual models. Models should also illustrate that energy cannot be created or destroyed, and that it moves only between one place and another, between objects, or between systems.

This unit also expands student understanding of the conservation of energy within a system by emphasizing the key idea that a stable molecule has less energy than the same set of atoms when separated. To support this concept, students might look at the change in energy when bonds are made and broken in a reaction system. Students might also analyze molecular-level drawings and tables showing energies in compounds with multiple bonds to show that energy is conserved in a chemical reaction.

In addition to conservation of energy, students should explore energy flow into, out of, and within systems (including chemical reaction systems). Students might be given data and asked to graph the relative energies of reactants and products to determine whether energy is released or absorbed. They should also conduct simple chemical reactions that allow them to apply the law of conservation of energy by collecting data from their own investigations. Students should be able to determine whether reactions are endothermic and exothermic, constructing explanations in terms of energy changes. These experiences will allow them to develop a model that relates energy flow to changes in total bond energy. Examples of models might include molecular-level drawings, energy diagrams, and graphs.

Students should expand their study of bond energies by relating this concept to kinetic energy. This can be understood in terms of the collisions of molecules and the rearrangement of atoms into new molecules as a function of their kinetic energy content. Students should also study the effect on reaction rates of changing the temperature and/or concentration of a reactant (Le Chatelier's principle). Students might explore the concept of equilibrium through investigations, which may include manipulations of variables such as temperature and concentration. Examples of these investigations may include the iodine clock reaction, the ferrous cyanide complex, as well as computer simulations such as those located at [www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/equil/equil.htm](http://www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/equil/equil.htm). Using results from these investigations, students should develop an explanation about the effects of changing the temperature or concentration of the reacting particles on

the rate at which a reaction occurs and on equilibrium. Students should be able cite evidence from text to support their explanations after conducting research.

Finally, in order to meet the engineering requirement for Unit 3, students should design a solution to specify a change in conditions that would produce increased amounts of products at equilibrium. As they consider their design, students should keep in mind that much of science deals with constructing explanations for how things change and how they remain stable. Through investigations and practice in changing reaction conditions (as mentioned above), as well as through teacher demonstrations such as MOM to the Rescue/Acid–Base Reaction (Flinn Scientific), students should come to understand that in many situations, a dynamic and condition dependent balance between a reaction and the reverse reaction determines the number of all types of molecules present. Examples of designs that students could refine might include different ways to increase product formation. Designs should include methods such as adding reactants or removing products as a means to change equilibrium. Students will base these design solutions on scientific knowledge, student-generated sources of evidence from prior investigations, prioritized criteria, and tradeoff considerations. They will do this in order to produce the greatest amount of product from a reaction system.

*Integration of engineering -*

The engineering performance expectation HS-PS1-1 calls specifically for a connection to HS-ETS1.C. To meet this requirement, HS-ETS1-2 has been identified as appropriate for this unit, since it directs students to design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Students will design a solution to specify a change in conditions that would produce increased amounts of products at equilibrium.

**Connecting with English Language Arts/Literacy**

*English Language Arts/Literacy*

- Make strategic use of digital media in presentations to enhance understanding of how photosynthesis transforms light energy into stored chemical energy.
- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations showing that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy to enhance understanding of findings, reasoning, and evidence and to add interest.
- Cite specific textual evidence to support the concept that changing the temperature or concentration of the reacting particles affects the rate at which a reaction occurs.
- Develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Construct short as well as more sustained research projects to answer how to increase amounts of products at equilibrium in a chemical system. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

*Mathematics*

- Use a mathematical model to explain how the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols.
- Use units as a way to understand an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. Choose and interpret units consistently in formulas representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. Choose and interpret the scale and the origin in graphs and data displays representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Use a mathematical model to explain how to increase amounts of products at equilibrium in a chemical system. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

### Modifications

*Teacher Note: Teachers identify the modifications that they will use in the unit.*

#### ï ELL

- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Audio books, movies, and other digital media in lieu of print versions
- Native language texts and native language to English dictionary

#### ï Special Education and 504's

- Modified assignments (ex: fewer problems per page)
- Response to Intervention (RTI) ([www.help4teachers.com](http://www.help4teachers.com))
- Follow all IEP modifications/504 plan
- Oral Instructions

- Ë Record lessons instead of taking notes
- Ë Outlines of lessons
- Ë Study Guides with answers
- Ë Word processor to type notes
- Ë Frequent breaks
- Ë Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Ë 504:
- Ë Utilize graphic organizers to help provide a purpose for reading and increase comprehension
- Ë Assign peer tutor
- Ë Provide clear and specific directions
- Ë Provide class notes ahead of time to allow students to preview material and increase comprehension
- Ë Provide extended time
- Ë Simplify written and verbal instructions

## Ï Gifted and Talented

- Ë Peer Tutoring
- Ë Cooperative Learning Groups
- Ë Differentiated Instruction
- Ë Use project-based science learning to connect science with observable phenomena.
- Ë Structure the learning around explaining or solving a social or community-based issue.

**Students at Risk of School Failure:**

- Extended Time
- Flexible Grouping
- Small Group Instruction
- Peer Buddies
- Tiered Activities
- Manipulatives
- Graphic Organizers



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**Career Readiness Standards**

- 9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth.
- 9.2.12.CAP.5: Assess and modify a personal plan to support current interests and postsecondary plans.

**Research on Student Learning**

Students' meaning for "energy" both before and after traditional instruction is considerably different from its scientific meaning. In particular, students believe energy is associated only with humans or movement, is a fuel-like quantity which is used up, or is something that makes things happen and is expended in the process. Students rarely think energy is measurable and quantifiable.

Students tend to think that energy transformations involve only one form of energy at a time. Although they develop some skill in identifying different forms of energy, in most cases their descriptions of energy change focus only on forms that have perceivable effects. The transformation of motion to heat seems to be difficult for students to accept, especially in cases with no obvious temperature increase. Finally, it may not be clear to students that some forms of energy, such as light, sound, and chemical energy, can be used to make things happen.

Some students of all ages have difficulty in identifying the sources of energy for plants and also for animals. Students tend to confuse energy and other concepts such as food, force, and temperature. As a result, students may not appreciate the uniqueness and importance of energy conversion processes like respiration and photosynthesis. Although specially designed instruction does help students correct their understanding about energy exchanges, some difficulties remain. [10] Careful coordination between The Physical Setting and The Living Environment benchmarks about conservation of matter and energy and the nature of energy may help alleviate these difficulties ([NSDL, 2015](#)).

**Prior Learning***Physical science*

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

- The changes of state that occur with variations in temperature or pressure can be described and predicted using models of matter. Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy; others store energy.
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively).
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively).
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions. Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

*Life science*

- Plants, algae (including phytoplankton), and many microorganisms use energy from light to make sugars (food) from carbon dioxide from the atmosphere and

water, through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules to support growth or to release energy.

#### *Earth and space sciences*

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

### Connections to Other Courses

#### *Physical science*

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position) of the particles. In some cases, the relative position of energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

*Life science*

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

**Sample of Open Education Resources**

[Dynamic Equilibrium](#): Students will define what is meant by dynamic equilibrium.

[Equilibrium and LeChatlier's Principle](#): Students identify the factors that affect equilibrium and how the system responds to the change.

[Collision Theory and Rates of Reaction](#): Students use the virtual simulation to observe how a chemical reaction occurs.

[Control a Haber-Bosch Ammonia Plant](#): You will learn about the economics of operating a chemical factory as you try to optimize the process of a simulated Haber-Bosch process ammonia fertilizer plant.

**Links to Free and Low Cost Instructional Resources**

*Note- The majority of the student sense-making experiences found at these links predate the NGSS. Most will need to be modified to include science and engineering practices, disciplinary core ideas, and cross cutting concepts. [The EQulP Rubrics for Science](#) can be used as a blueprint for evaluating and modifying instructional*

*materials.*

- American Association for the Advancement of Science: <http://www.aaas.org/programs>
- American Chemical Society: <http://www.acs.org/content/acs/en/education.html>
- Concord Consortium: Virtual Simulations: <http://concord.org/>
- International Technology and Engineering Educators Association: <http://www.iteaconnect.org/>
- National Earth Science Teachers Association: <http://www.nestanet.org/php/index.php>
- National Science Digital Library: <https://nsdl.oercommons.org/>
- National Science Teachers Association: <http://ngss.nsta.org/Classroom-Resources.aspx>
- North American Association for Environmental Education: <http://www.naaee.net/>
- Phet: Interactive Simulations <https://phet.colorado.edu/>
- Science NetLinks: <http://www.aaas.org/program/science-netlinks>

#### Appendix A: NGSS and Foundations for the Unit

**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-PS1-4)*

**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-PS1-5)*

**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-PS1-6)*

**Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.] (HS-LS1-5)*

**Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** *[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.] (HS-LS1-7)*

**Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** (HS-ETS1-2)

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Developing and Using Models</b></p> <ul style="list-style-type: none"> <li>ï Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4),(HS-PS1-8)</li> <li>ï Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)</li> </ul> <p><b>Planning and Carrying Out Investigations</b></p> <ul style="list-style-type: none"> <li>ï Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types,</li> </ul>	<p><b>PS1.A: Structure and Properties of Matter</b></p> <ul style="list-style-type: none"> <li>ï A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4)</li> </ul> <p><b>PS1.B: Chemical Reactions</b></p> <ul style="list-style-type: none"> <li>ï Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of</li> </ul>	<p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>ï Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2),(HS-PS1-3),(HS-PS1-5)</li> </ul> <p><b>Energy and Matter</b></p> <ul style="list-style-type: none"> <li>ï The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)</li> <li>ï Changes of energy and matter in a system can be described in terms of energy and matter</li> </ul>

<p>how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)</p> <p><b>Using Mathematics and Computational Thinking</b></p> <p>ï Use mathematical representations of phenomena to support claims. (HS-PS1-7)</p> <p><b>Constructing Explanations and Designing Solutions</b></p> <p>ï Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)</p> <p>ï Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)</p> <p>ï Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)</p> <p><b>Asking Questions and Defining Problems</b></p> <p>ï Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)</p> <p><b>Using Mathematics and Computational Thinking</b></p> <p>ï Use mathematical models and/or computer simulations to predict the effects of a design</p>	<p>molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5)</p> <p>ï In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6)</p> <p>ï The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)</p> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <p>ï Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)</p> <p><b>ETS1.A: Defining and Delimiting Engineering Problems</b></p> <p>ï Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)</p> <p>ï Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-</p>	<p>flows into, out of, and within that system. (HS-PS1-4)</p> <p><b>Stability and Change</b></p> <p>ï Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)</p> <p>-----</p> <p><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b></p> <p>ï Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)</p> <p><b>Energy and Matter</b></p> <p>ï Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6)</p> <p>ï Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)</p>
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<p>solution on systems and/or the interactions between systems. (HS-ETS1-4)</p> <p><b>Constructing Explanations and Designing Solutions</b></p> <p>ï Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)</p> <p>ï Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)</p>	<p>ETS1-1)</p> <p><b>ETS1.B: Developing Possible Solutions</b></p> <p>ï When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</p> <p>ï Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</p> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <p>ï Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)</p> <p><b>LS1.C: Organization for Matter and Energy Flow in Organisms</b></p> <p>ï The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)</p> <p>ï The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based</p>	
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	<p>molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6)</p> <p>ï As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6),(HS-LS1-7)</p> <p>ï As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. (HS-LS1-7)</p> <p>ï</p>	
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**Embedded English Language Arts/Literacy and Mathematics**

*English Language Arts/Literacy*

- RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1)
- WHST.9-12.5** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)
- RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5) (HS-LS1-6)

- WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection and research (HS-LS1-6)
- RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)
- RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)
- RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-5)
- WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6)
- SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)
- Mathematics -*
- MP.2** Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7),(HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)
- MP.4** Model with mathematics. (HS-PS1-4), (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)
- HSF-IF.C.7** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-LS1-4)
- HSF-BF.A.1** Write a function that describes a relationship between two quantities. (HS-LS1-4)
- HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
- HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7)

**HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7)

**Unit Summary*****What happens in stars?***

In this unit of study, energy and matter are studied further by investigating the processes of nuclear fusion and fission that govern the formation, evolution, and workings of the solar system in the universe. Some concepts studied are fundamental to science and demonstrate *scale, proportion, and quantity*, such as understanding how the matter of the world formed during the Big Bang and within the cores of stars over the cycle of their lives.

In addition, an important aspect of Earth and space sciences involves understanding the concept of *stability and change* while making inferences about events in Earth's history based on a data record that is increasingly incomplete the farther one goes back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record.

The crosscutting concepts of *energy and matter; scale, proportion, and quantity; and stability and change* are called out as organizing concepts for this unit. Students are expected to demonstrate proficiency in *developing and using models; constructing explanations and designing solutions; using mathematical and computational thinking; and obtaining, evaluating, and communicating information*; and they are expected to use these practices to demonstrate understanding of the core ideas.

**Student Learning Objectives**

**Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.] (HS-PS1-8)*

**Communicate scientific ideas about the way stars, over their life cycle, produce elements.** *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.] (HS-ESS1-3)*

**Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.] (HS-ESS1-1)*

**Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** *[Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen*

and 1/4 helium).] (HS-ESS1-2)

Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.] (HS-ESS1-6)

**Part A (8 days):** Why is fusion considered the Holy Grail for the production of electricity?

Why aren't all forms of radiation harmful to living things?

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy.</li> <li>The total number of neutrons plus protons does not change in any nuclear process.</li> <li>In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.</li> <li>Use simple qualitative models based on evidence to illustrate the scale of energy released in nuclear processes relative to other kinds of transformations.</li> <li>Develop models based on evidence to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays.</li> </ul>

**Part B (8 days):** How do stars produce elements?

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than the hydrogen and helium formed at the time of the Big</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Communicate scientific ideas in multiple formats (including orally,</li> </ul>

<p>Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.</p> <ul style="list-style-type: none"> <li>In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</li> </ul>	<p>graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements.</p> <ul style="list-style-type: none"> <li>Communicate scientific ideas about the way nucleosynthesis, and therefore the different elements it creates, vary as a function of the mass of a star and the stage of its lifetime.</li> <li>Communicate scientific ideas about how in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</li> </ul>
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**Part C (8 days):** *Is the life span of a star predictable?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.</li> <li>Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.</li> <li>The significance of the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth is dependent on the scale, proportion, and quantity at which it occurs.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core in releasing energy that eventually reaches Earth in the form of radiation.</li> <li>Develop a model based on evidence to illustrate the relationships between nuclear fusion in the sun's core and radiation that reaches Earth.</li> </ul>

**Part D (8 days):** *If there was nobody there to Tweet about it, how do we know that there was a Big Bang?*

Concepts	Formative Assessment
<ul style="list-style-type: none"> <li>The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.</li> <li>The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.</li> <li>Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.</li> <li>Construct an explanation of the Big Bang theory based on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar</li> </ul>

<p>including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.</p> <ul style="list-style-type: none"> <li>• Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.</li> <li>• Energy cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems.</li> <li>• Science and engineering complement each other in the cycle known as research and development (R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise.</li> <li>• Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future.</li> <li>• Science assumes the universe is a vast single system in which basic laws are consistent.</li> <li>• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.</li> </ul>	<p>gases (from the spectra of electromagnetic radiation from stars).</p> <ul style="list-style-type: none"> <li>• Construct an explanation based on valid and reliable evidence that energy in the universe cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems.</li> </ul>
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**Part E (8 days):** *How can chemistry help us to figure out ancient events?*

<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>• Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.</li> <li>• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>• Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.</li> <li>• Use available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6</li> </ul>

<p>ages of rocks and other materials.</p> <ul style="list-style-type: none"> <li>Much of science deals with constructing explanations of how things change and how they remain stable.</li> </ul>	<p>billion years ago.</p> <ul style="list-style-type: none"> <li>Apply scientific reasoning to link evidence from ancient Earth materials, meteorites, and other planetary surfaces to claims about Earth's formation and early history, and assess the extent to which the reasoning and data support the explanation or conclusion.</li> <li>Use available evidence within the solar system to construct explanations for how Earth has changed and how it remains stable.</li> </ul>
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<b>Assessments</b> *Formative Assessments provided for each subsection.		
Summative Assessments	Benchmark assessments	Alternative Assessments
<ul style="list-style-type: none"> <li>Chapter/Unit Tests</li> <li>Writing Assignments</li> <li>Lab Reports/Quizzes</li> </ul>	<ul style="list-style-type: none"> <li>New Jersey Student Learning Assessment Science (NJSLA)</li> <li>Quarterlies</li> <li>Performance Assessments</li> </ul>	<ul style="list-style-type: none"> <li>Oral Presentation</li> <li>Video Recording</li> <li>Virtual Labs</li> </ul>

What It Looks Like in the Classroom
<p>This unit of study continues looking at energy flow and matter but with a new emphasis on Earth and space science in relation to the history of Earth starting with the Big Bang theory. Students will also explore the production of elements in stars and radioactive decay. Students should develop and use models to illustrate the processes of fission, fusion, and radioactive decay and the scale of energy released in nuclear processes relative to other kinds of transformations, such as chemical reactions. Models should be qualitative, based on evidence, and might include depictions of radioactive decay series such as Uranium-238, chain reactions such as the fission of Uranium-235 in reactors, and fusion within the core of stars. Students could also explore the PhET nuclear fission inquiry lab and graphs to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of alpha, beta, and gamma radioactive decays. When modeling nuclear processes, students should depict that atoms are not conserved, but the total number of protons plus neutrons is conserved. Models should include changes in the composition of the nucleus of atoms and the scale of energy released in nuclear processes.</p> <p>The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process</p>



releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. Because atoms of each element emit and absorb characteristic frequencies of light, the presence of an element can be detected in stars and interstellar gases. Students should develop an understanding of how analysis of light spectra gives us information about the composition of stars and interstellar gases. Communication of scientific ideas about how stars produce elements should be done in multiple formats, including orally, graphically, textually, and mathematically. The conservation of the total number of protons plus neutrons is important in their explanations, and students should cite supporting evidence from text.

Students should also use the sun as a model for the lifecycle of a star. This model should also illustrate the relationship between nuclear fusion in the sun's core and energy that reaches the Earth in the form of radiation. Students could construct a mathematical model of nuclear fusion in the sun's core, identifying important quantities and factors that affect the life span of the sun. They should also be able to use units and consider limitations on measurement when describing energy from nuclear fusion in the sun's core that reaches the Earth. For example, students should be able to quantify the amounts of energy in joules when comparing energy sources. In this way, students will develop an understanding of how our sun changes and how it will burn out over a lifespan of approximately 10 billion years.

This unit continues with a study of how astronomical evidence ("red shift/blue shift," wavelength relationships to energy, and universe expansion) can be used to support the Big Bang theory. Students should construct an explanation of the Big Bang theory based on evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. Students should explore and cite evidence from text of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of primordial radiation that still fills the universe. The concept of conservation of energy should be evident in student explanations. Students should also be aware that a scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. Students should also know that if new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of the new evidence.

Students should be able to cite specific evidence from text to support their explanations of the life cycle of stars, the role of nuclear fusion in the sun's core, and the Big Bang theory. In their explanations, they should discuss the idea that science assumes the universe is a vast single system in which laws are consistent.

This unit concludes with the application of scientific reasoning and the use of evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of the Earth's formation and early history. For example, students will use examples of spontaneous radioactive decay as a tool to determine the ages of rocks or other materials (K-39 to Ar-40). Students should make claims about Earth's formation and early history supported by data while considering appropriate units, quantities and limitations on measurement. Students might construct graphs showing data on the absolute ages and composition of Earth's rocks, lunar rocks, and meteorites. Using available evidence within the solar system, students should construct explanations for how the earth has changed and how it has remained stable in its 4.6 billion year history.

#### Connecting with English Language Arts/Literacy and Mathematics

*English Language Arts/Literacy*

- RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-1)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)
- SL.11-12.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)

*Mathematics*

- MP.2** Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) ,(HS-PS1-8)
- MP.4** Model with mathematics. (HS-ESS1-1)
- HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2)
- HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2)
- HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2)
- HSA-SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1)
- HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2)
- HSA-CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2)

**Modifications**

*Teacher Note: Teachers identify the modifications that they will use in the unit.*

ï ELL

- o Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).

- o Audio books, movies, and other digital media in lieu of print versions
- o Native language texts and native language to English dictionary

ï Special Education

- o Modified assignments (ex: fewer problems per page)
- o Response to Intervention (RTI) ([www.help4teachers.com](http://www.help4teachers.com))
- o Follow all IEP modifications
- o Oral Instructions
- o Record lessons instead of taking notes
- o Outlines of lessons
- o Study Guides with answers
- o Word processor to type notes
- o Frequent breaks
- o Provide students with multiple choices for how they can represent their understanding (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).

**504:**

- o Utilize graphic organizers to help provide a purpose for reading and increase comprehension
- o Assign peer tutor
- o Provide clear and specific directions
- o Provide class notes ahead of time to allow students to preview material and increase comprehension
- o Provide extended time
- o Simplify written and verbal instructions

ï Gifted and Talented

- o Peer Tutoring
- o Cooperative Learning Groups
- o Differentiated Instruction

- o Use project-based science learning to connect science with observable phenomena.
- o Structure the learning around explaining or solving a social or community-based issue.

**Students at Risk of School Failure:**

- Extended Time
- Flexible Grouping
- Small Group Instruction
- Peer Buddies
- Tiered Activities
- Manipulatives
- Graphic Organizers

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**Career Readiness Standards**

- 9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth.
- 9.2.12.CAP.5: Assess and modify a personal plan to support current interests and postsecondary plans.

**Research on Student Learning**

N/A

**Prior Learning***Physical science*

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

#### *Earth and space science*

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.
- Earth and its solar system are part of the Milky Way Galaxy, which is one of many galaxies in the universe.
- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted probabilistically.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

## Connections to Other Courses

*Physical science*

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- When two objects interacting through a field change relative position, the energy stored in the field is changed.
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength

electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.

- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

#### *Earth and space science*

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

#### Sample of Open Education Resources

- ï [Stellar Spectra](#): Students analyze bright line spectra of stars for evidence of a red shift.
- ï [Spectrum Simulator](#): Allows you to simulate various spectra for discussion.
- ï [Spectrum Simulation](#): Interactive periodic table where students can see the emission spectrum for each element.
- ï [Analysis of Spectral Lines Inkewriter](#): Interactive story based on a [pogil](#) for students to evaluate how a bright line spectrum is produced and how it can be used to identify elements.
- ï [Nuclear Fission PhET Simulation](#): Online interactive simulator for nuclear fission, chain reactions and nuclear reactors.
- ï [EM Spectrum Module](#):
- ï [Hydrogen Atom Simulator](#): Model the interactions of a hydrogen atom with light to discuss the quantum nature of absorption and emission.
- ï [3 views spectrum demonstrator](#): View the difference in spectra between a hot incandescent light bulb and a cold, thin, gas cloud.
- ï [Online Simulation of a Nuclear Reactor](#)
- ï [Extrasolar Planet Radial Velocity Demonstrator](#): View the shift in spectrum as a planet and star orbit their center of mass.

- ï [Doppler Shift Simulator](#)
- ï [Nuclear Fission Simulation](#): Shoot a neutron at a nucleus of uranium-235. The nucleus splits and you can discuss how the number of protons and neutrons were conserved as two different elements were formed from the original nucleus.
- ï [Nuclear Fusion Simulation](#)
- ï [Nuclear Chain Reaction simulation](#): Simulates both a controlled and an uncontrolled chain reaction within a nuclear reactor.

#### Links to Free and Low Cost Instructional Resources

*Note- The majority of the student sense-making experiences found at these links predate the NGSS. Most will need to be modified to include science and engineering practices, disciplinary core ideas, and cross cutting concepts. [The EQULP Rubrics for Science](#) can be used as a blueprint for evaluating and modifying instructional materials.*

- ï American Association for the Advancement of Science: <http://www.aaas.org/programs>
- ï American Chemical Society: <http://www.acs.org/content/acs/en/education.html>
- ï Concord Consortium: Virtual Simulations: <http://concord.org/>
- ï International Technology and Engineering Educators Association: <http://www.iteaconnect.org/>
- ï National Earth Science Teachers Association: <http://www.nestanet.org/php/index.php>
- ï National Science Digital Library: <https://nsdl.oercommons.org/>
- ï National Science Teachers Association: <http://ngss.nsta.org/Classroom-Resources.aspx>
- ï North American Association for Environmental Education: <http://www.naaee.net/>
- ï Phet: Interactive Simulations <https://phet.colorado.edu/>
- ï Science NetLinks: <http://www.aaas.org/program/science-netlinks>



## Appendix A: NGSS and Foundations for the Unit

**Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** *[Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.] (HS-PS1-8)*

**Communicate scientific ideas about the way stars, over their life cycle, produce elements.** *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.] (HS-ESS1-3)*

**Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.] (HS-ESS1-1)*

**Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** *[Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).] (HS-ESS1-2)*

**Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** *[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.] (HS-ESS1-6)*

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Developing and Using Models</b>	<b>PS1.C: Nuclear Processes</b>	<b>Energy and Matter</b>
Modeling in 9–12 builds on K–8 and progresses to	<ul style="list-style-type: none"> <li>Nuclear processes, including fusion, fission, and</li> </ul>	<ul style="list-style-type: none"> <li>In nuclear processes, atoms are not conserved,</li> </ul>

<p>using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.</p> <ul style="list-style-type: none"> <li>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1)</li> </ul> <p><b>Constructing Explanations and Designing Solutions</b></p> <p>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2)</li> <li>Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6)</li> </ul> <p><b>Using Mathematical and Computational Thinking</b></p> <p>Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric</p>	<p>radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)</p> <ul style="list-style-type: none"> <li>Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.(secondary (HS-ESS1-6)</li> </ul> <p><b>ESS1.A: The Universe and Its Stars</b></p> <ul style="list-style-type: none"> <li>The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1)</li> <li>The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2),(HS-ESS1-3)</li> <li>The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2)</li> <li>Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2),(HS-ESS1-3)</li> </ul> <p><b>PS3.D: Energy in Chemical Processes and Everyday</b></p>	<p>but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-ESS1-1)</p> <ul style="list-style-type: none"> <li>Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)</li> </ul> <p><b>Scale, Proportion, and Quantity</b></p> <ul style="list-style-type: none"> <li>The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)</li> <li>Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4)</li> <li>In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</li> </ul> <p><b>Stability and Change</b></p> <ul style="list-style-type: none"> <li>Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)</li> </ul> <p>-----</p> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Interdependence of Science, Engineering, and Technology</b></p> <ul style="list-style-type: none"> <li>Science and engineering complement each other in the cycle known as research and development</li> </ul>
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<p>functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4)</li> </ul> <p><b>Obtaining, Evaluating, and Communicating Information</b></p> <ul style="list-style-type: none"> <li>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-ESS1-6)</li> <li>Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3)</li> </ul>	<p><b>Life</b></p> <ul style="list-style-type: none"> <li>Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (HS-ESS1-1)</li> </ul> <p><b>PS4.B: Electromagnetic Radiation</b></p> <ul style="list-style-type: none"> <li>Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.(secondary)HS-ESS1-2)</li> </ul> <p><b>ESS1.B: Earth and the Solar System</b></p> <ul style="list-style-type: none"> <li>Kepler’s laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)</li> </ul> <p><b>ESS1.C: The History of Planet Earth</b></p> <ul style="list-style-type: none"> <li>Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth’s formation and early history.</li> </ul>	<p>(R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2),(HS-ESS1-4)</p> <p>-----</p> <p><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b></p> <ul style="list-style-type: none"> <li>Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2)</li> <li>Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2)</li> </ul> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-ESS1-2)</li> </ul>
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**Embedded English Language Arts/Literacy and Mathematics**

- RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-1)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)
- SL.11-12.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)

*Mathematics -*

- MP.2** Reason abstractly and quantitatively. (HS-ESS1-1), (HS-ESS1-2) ,(HS-ESS1-3) ,(HS-PS1-8)
- MP.4** Model with mathematics. (HS-ESS1-1)
- HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-1),(HS-ESS1-2)
- HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1), (HS-ESS1-2)
- HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1), (HS-ESS1-2)
- HSA-SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-1)
- HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-1), (HS-ESS1-2)
- HSA-CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-ESS1-1),(HS-ESS1-2)

## Unit Summary

***How do Earth's geochemical processes and human activities affect each other?***

In this unit of study, students use *cause and effect* to *develop models and explanations* for the ways that feedbacks among different Earth systems control the appearance of Earth's surface. Central to this is the tension between internal systems, which are largely responsible for creating land at Earth's surface (e.g., volcanism and mountain building), and the sun-driven surface systems that tear down the land through weathering and erosion. Students begin to examine the ways that human activities cause feedbacks that create changes to other systems. Students understand the *system interactions* that control weather and climate, with a major emphasis on the mechanisms and implications of climate change. Students model the flow of energy and matter between different components of the weather system and how this affects chemical cycles such as the carbon cycle. Engineering and technology figure prominently here, as students use mathematical thinking and the analysis of geoscience data to examine and construct solutions to the many challenges facing long-term human sustainability on Earth. Here students will use these geoscience data to explain climate change over a wide range of timescales, including over one to ten years: large volcanic eruption, ocean circulation; ten to hundreds of years: changes in human activity, ocean circulation, solar output; tens of thousands to hundreds of thousands of years: changes to Earth's orbit and the orientation of its axis; and tens of millions to hundreds of millions of years: long-term changes in atmospheric composition).

Note: This unit may be assessed by a performance based assessment (project, debate, presentation, etc.).

## Student Learning Objectives

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-ESS2-4)*

**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.] (HS-ESS2-6)*

**Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** *[Clarification Statement: See Three-Dimensional Teaching and Learning Section for examples.] (HS-ETS1-1)*

**Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** *[Note: See Three-Dimensional Teaching and Learning Section for examples.] (HS-ETS1-2)*

**Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.** *[Note: See Three-Dimensional Teaching and Learning Section for*

*examples.]* (HS-ETS1-3)

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. *[Note: See Three-Dimensional Teaching and Learning Section for examples.]* (HS-ETS1-4)

**Part A (10 days):** *What happens if we change the chemical composition of our atmosphere?*

Concepts	Formative Assessment
<p>ï The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.</p> <p>ï Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.</p> <p>ï The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.</p> <p>ï Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.</p> <p>ï Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</p> <p>ï Science arguments are strengthened by multiple lines of evidence supporting a single explanation.</p>	<p><i>Students who understand the concepts are able to:</i></p> <p>ï Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.</p> <p>ï Use empirical evidence to differentiate between how variations in the flow of energy into and out of Earth's systems result in climate changes.</p> <p>ï Use multiple lines of evidence to support how variations in the flow of energy into and out of Earth's systems result in climate changes.</p>

<b>Part B (10 days): How does carbon cycle among the hydrosphere, atmosphere, geosphere, and biosphere?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<ul style="list-style-type: none"> <li>ï Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.</li> <li>ï Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.</li> <li>ï The total amount of energy and matter in closed systems is conserved.</li> <li>ï The total amount of carbon cycling among and between the hydrosphere, atmosphere, geosphere, and biosphere is conserved.</li> </ul>	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> <li>ï Develop a model based on evidence to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.</li> <li>ï Develop a model based on evidence to illustrate the biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere, providing the foundation for living organisms.</li> </ul>

<b>What It Looks Like in the Classroom</b>
<p>This unit of study continues looking at matter and energy, with a focus on weather and climate, carbon cycling, and the cause-and-effect relationships between human activity and Earth's systems. Students will examine causes of variations in the flow of energy into and out of Earth's systems and how climate is affected by these variations. They will also determine how the amount of carbon cycling in Earth's systems has changed over time, and how humans are influenced by resource availability, natural hazards, and climate change.</p> <p>Students should develop an understanding of how the foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. They should also examine how cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. Students might conduct research to locate and analyze data sets showing these phenomena.</p> <p>In order to determine how changes in the atmosphere due to human activity have increased the carbon dioxide concentrations and affected climate, students should</p>

look at cycles of differing timescales and their effects on climate. Geoscience data should be used to explain climate change over a wide-range of timescales, including one to ten years: large volcanic eruptions, ocean circulation; ten to hundreds of years: changes in human activity, ocean circulation, solar output; tens of thousands to hundreds of thousands of years: changes to Earth's orbit and the orientation of its axis; and tens of millions to hundreds of millions of years: long-term changes in atmospheric composition. Students might also explore Earth's climate history through an analysis of datasets such as the Keeling Curve or Vostok ice core data.

Students can use a jigsaw activity to examine data for an assigned timescale and event to show cause-and-effect relationships among energy flow into and out of Earth's systems and the resulting in changes in climate.

Students should use models to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. Models should be supported by multiple lines of evidence, and students should use digital media in presentations to enhance understanding. Students might use mathematical models, and they should identify important quantities and map relationships using charts and graphs. Mathematical models should include appropriate units and limitations on measurement should be considered.

Students will continue their study of Earth's systems by examining the history of the atmosphere. Students should research the early atmospheric components and the changes that occurred due to plants and other organisms removing carbon dioxide and releasing oxygen. By studying the carbon cycle, students should revisit the idea that matter and energy within a closed system are conserved among the hydrosphere, atmosphere, geosphere, and biosphere. Students should extend their understanding of how human activity affects the concentration of carbon dioxide in the environment and therefore climate. Students' experiences should include synthesizing information from multiple sources and developing quantitative models based on evidence to describe the cycling of carbon among the ocean, atmosphere, soil, and biosphere.

Students should understand how biogeochemical cycles provide the foundation for living organisms. Once again, students might use a jigsaw activity to illustrate the relationships between these systems. Finally, making a connection to engineering, students will investigate the cause-and-effect relationships between the interdependence of human activities and Earth's systems. Students should construct an explanation based on evidence for relationships between human activity and changes in climate. Students can revisit the idea of renewable and nonrenewable resources touched upon in unit 4, and further investigate their availability. Examples of key natural resources should include access to fresh water, fertile soil, and high concentrations of minerals and fossil fuels. Students should also examine natural hazards including interior processes (volcanic eruptions and earthquakes); surface processes (tsunamis, mass wasting, and soil erosion); and severe weather (hurricanes, floods, and droughts). Additionally, other geologic events that have driven the development of human history (including populations and migrations) should also be researched. These geologic events include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised. Students must use empirical evidence to identify differences between cause and correlation in the relationship between climate changes and human activity. Students should also use empirical evidence to make claims about causes and effects of these interactions. The influence of major technological systems on modern civilizations should be emphasized. Because all the scientific and engineering practices and crosscutting concepts are necessary for mastery of the scientific content in this unit, it is an opportunity for students to engage in problem solving using the complete engineering design cycle. Research and



examination of data to determine relationships between global change and human activity will allow students to identify and analyze a major global challenge.

Students should take into account possible qualitative and quantitative criteria and constraints for solutions and examine the needs of society in response to the identified major global challenge. The students could then design a solution to this real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. They must then evaluate their solution based on prioritized criteria and tradeoffs (e.g., cost, safety, reliability, aesthetics, and possible social, cultural, and environmental impacts). Finally, students might use computer simulations along with mathematics and computational thinking to model the impact of their proposed solution. Their simulation must take into account the numerous criteria and constraints on interactions within and between systems relevant to the problem. For example, major global challenges might include ozone depletion, melting glaciers, rising sea levels, changes in climate and extreme weather, ocean acidification, aerosols and smog, melting permafrost, destruction of rainforests, and biome migration. Some local challenges students might consider include fishing industry quotas vs. economic impact on local fishing fleets (i.e., New Bedford, Galilee, Jerusalem); flood plain construction vs. housing restrictions on ocean beach fronts (i.e., Mantoloking, Seaside Heights); design of possible solutions to retard or prevent further beach erosion; and response to recent flooding in Rhode Island and flood plain restoration.

*Integration of engineering -*

The standards in this unit do not identify a connection to engineering; however, the nature of the content lends itself to real-world problem identification and solution design, testing, and modification. Students can use their understanding of energy and matter and system interactions from the previous units to guide their thinking about climate change, its effects on humans, the adverse effects of human activities, and potential solutions to contemporary issues regarding climate change. In this unit, students have the opportunity to complete the entire engineering cycle (ETS1-1, ETS1-2, ETS1-3, and ETS1-4) by analyzing a major global challenge related to climate change and human activity, designing and evaluating a possible solution to this problem, and further using a computer simulation to model the impact of the proposed solution.

**Connecting with English language arts/literacy and Mathematics**

*English Language Arts/Literacy-*

- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations describing how variations in the flow of energy into and out of Earth's systems result in changes in climate to enhance understanding of findings, reasoning, and evidence and to add interest.
- Cite specific textual evidence of the availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- Use empirical evidence to write an explanation for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

*Mathematics-*

- İ Represent symbolically an explanation for how variations in the flow of energy into and out of Earth's systems result in changes in climate, and manipulate the representing symbols. Use symbols to make sense of quantities and relationships about how variations in the flow of energy into and out of Earth's systems result in changes in climate, symbolically and manipulate the representing symbols.
- İ Use a mathematical model to explain how variations in the flow of energy into and out of Earth's systems result in changes in climate. Identify important quantities in variations in the flow of energy into and out of Earth's systems result in changes in climate and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- İ Use units as a way to understand problems and to guide the solution of multistep problems about how variations in the flow of energy into and out of Earth's systems result in changes in climate; choose and interpret units consistently in formulas representing how variations in the flow of energy into and out of Earth's systems result in changes in climate; choose and interpret the scale and the origin in graphs and data displays representing how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- İ Define appropriate quantities for the purpose of descriptive modeling of how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- İ Choose a level of accuracy appropriate to limitations on measurement when reporting quantities to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- İ Represent symbolically the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere, and manipulate the representing symbols. Make sense of quantities and relationships in the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- İ Use a mathematical model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. Identify important quantities in the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- İ Use units as a way to understand the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere; choose and interpret units consistently in formulas representing the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere; choose and interpret the scale and the origin in graphs and data displays representing the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- İ Define appropriate quantities for the purpose of descriptive modeling of the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- İ Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- İ Represent symbolically how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity, and manipulate the representing symbols. Make sense of quantities and relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- İ Use units as a way to understand the relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity. Choose and interpret units consistently in formulas to determine relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity. Choose and interpret the scale and the origin in graphs and data displays

representing relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.

- ï Define appropriate quantities for the purpose of descriptive modeling of relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.
- ï Choose a level of accuracy appropriate to limitations on measurement when reporting quantities showing relationships among availability of natural resources, occurrence of natural hazards, and changes in climate and their influence on human activity.

### Modifications

*Teacher Note: Teachers identify the modifications that they will use in the unit.*

- ï ELL
  - o Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
  - o Audio books, movies, and other digital media in lieu of print versions
  - o Native language texts and native language to English dictionary
- ï Special Education
- ï Modified assignments (ex: fewer problems per page)
  - o Response to Intervention (RTI) ([www.help4teachers.com](http://www.help4teachers.com))
  - o Follow all IEP modifications
  - o Oral Instructions
  - o Record lessons instead of taking notes
  - o Outlines of lessons
  - o Study Guides with answers
  - o Word processor to type notes
  - o Frequent breaks
  - o Provide students with multiple choices for how they can represent their understanding (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).

**504:**

- Utilize graphic organizers to help provide a purpose for reading and increase
- comprehension
- Assign peer tutor
- Provide clear and specific directions
- Provide class notes ahead of time to allow students to preview material and increase
- comprehension
- Provide extended time
- Simplify written and verbal instructions

**ï Gifted and Talented**

- Peer Tutoring
- Cooperative Learning Groups
- Differentiated Instruction
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- 

**Students at Risk of School Failure:**

- Extended Time
- Flexible Grouping
- Small Group Instruction
- Peer Buddies
- Tiered Activities
- Manipulatives
- Graphic Organizers

ï

**Career Readiness Standards**

- 9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth.
- 9.2.12.CAP.5: Assess and modify a personal plan to support current interests and postsecondary plans.

**Research on Student Learning**

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect.

The idea of energy conservation seems counterintuitive to middle- and high-school students who hold on to the everyday use of the term energy, but teaching heat dissipation ideas at the same time as energy conservation ideas may help alleviate this difficulty. Even after instruction, however, students do not seem to appreciate that energy conservation is a useful way to explain phenomena. A key difficulty students have in understanding conservation appears to derive from not considering the appropriate system and environment. In addition, middle- and high-school students tend to use their conceptualizations of energy to interpret energy conservation ideas. For example, some students interpret the idea that "energy is not created or destroyed" to mean that energy is stored up in the system and can even be released again in its original form. Or, students may believe that no energy remains at the end of a process, but may say that "energy is not lost" because an effect was caused during the process (for example, a weight was lifted). Although teaching approaches which accommodate students' difficulties about energy appear to be more successful than traditional science instruction, the main deficiencies outlined above remain despite these approaches (NSDL, 2015).

### Prior Learning

#### *Physical science-*

- ï Substances are made from different types of atoms, which combine with one another in various ways.
- ï Atoms form molecules that range in size from two to thousands of atoms.
- ï Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- ï Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- ï In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- ï Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- ï The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- ï Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- ï A system of objects may also contain stored (potential) energy, depending on the objects' relative positions.
- ï Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- ï When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- ï The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the

sample, and the environment.

- ï Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- ï When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- ï The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- ï A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- ï However, because light can travel through space, it cannot be a matter wave, like sound or water waves.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

*Life science-*

- ï Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.
- ï Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth or to release energy.
- ï Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
- ï Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- ï Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- ï Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans,

and geosphere through chemical, physical, geological, and biological processes.

- ï A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- ï Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- ï Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

*Earth and space science-*

- ï Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.
- ï Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- ï Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior.
- ï The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.
- ï The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.
- ï Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.
- ï The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and

transport materials, and lower the viscosities and melting points of rocks.

- ï The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
- ï Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- ï Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.
- ï Resource availability has guided the development of human society.
- ï All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.
- ï Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- ï Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
- ï Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- ï Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

#### Connections to Other Courses

##### *Physical science-*

- ï Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- ï The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- ï The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- ï A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
- ï Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- ï In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules



present.

- İ The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- İ Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- İ At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- İ These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.
- İ Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- İ Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- İ Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- İ The availability of energy limits what can occur in any system.
- İ Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- İ Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

*Life science-*

- İ The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- İ The sugar molecules thus formed contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.
- İ As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- İ As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration

also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

- ï Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- ï Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
- ï Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- ï A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, the ecosystem may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- ï Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

*Earth and space sciences-*

- ï Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.
- ï Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.
- ï The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- ï Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
- ï Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- ï Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

**Sample of Open Education Resources**

- ï [Carbon Cycle Lab from Annenberg Learner](#) : Simulation to model the carbon cycle and human impact on the cycle
- ï [Interactive Energy Lab from Annenberg Learner](#): Students manipulate the energy sources of the world to view how shifting from fossil fuels to renewables could affect the global energy budget.
- ï [Magma Interactive](#) : Students manipulate the temperature, pressure, and content settings of magma.
- ï [Interpreting Ozone Layer Data](#): Data analysis activity using ozone layer data

**Links to Free and Low Cost Instructional Resources**

*Note- The majority of the student sense-making experiences found at these links predate the NGSS. Most will need to be modified to include science and engineering practices, disciplinary core ideas, and cross cutting concepts. [The EQUIP Rubrics for Science](#) can be used as a blueprint for evaluating and modifying instructional materials.*

- ï American Association for the Advancement of Science: <http://www.aaas.org/programs>
- ï American Chemical Society: <http://www.acs.org/content/acs/en/education.html>
- ï Concord Consortium: Virtual Simulations: <http://concord.org/>
- ï International Technology and Engineering Educators Association: <http://www.iteaconnect.org/>
- ï National Earth Science Teachers Association: <http://www.nestanet.org/php/index.php>
- ï National Science Digital Library: <https://nsdl.oercommons.org/>
- ï National Science Teachers Association: <http://ngss.nsta.org/Classroom-Resources.aspx>
- ï North American Association for Environmental Education: <http://www.naaee.net/>
- ï Phet: Interactive Simulations <https://phet.colorado.edu/>

Science NetLinks: <http://www.aaas.org/program/science-netlinks>

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## Appendix A: NGSS and Foundations for the Unit

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-ESS2-4)*

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.] (HS-ESS2-6)*

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. *[Clarification Statement: See Three-Dimensional Teaching and Learning Section for examples.] (HS-ETS1-1)*

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. *[Note: See Three-Dimensional Teaching and Learning Section for examples.] (HS-ETS1-2)*

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. *[Note: See Three-Dimensional Teaching and Learning Section for examples.] (HS-ETS1-3)*

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. *[Note: See Three-Dimensional Teaching and Learning Section for examples.] (HS-ETS1-4)*

The Student Learning Objectives above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Developing and Using Models</b></p> <p>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-6)</p>	<p><b>ESS1.B: Earth and the Solar System</b></p> <p>Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of</p>	<p><b>Cause and Effect</b></p> <p>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)</p>

<p>İ Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4)</p> <p><b>Asking Questions and Defining Problems</b></p> <p>İ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)</p> <p><b>Using Mathematics and Computational Thinking</b></p> <p>İ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)</p> <p><b>Constructing Explanations and Designing Solutions</b></p> <p>İ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)</p>	<p>years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (<i>secondary to HS-ESS2-4</i>)</p> <p><b>ESS2.A: Earth Materials and Systems</b></p> <p>İ The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output or Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)</p> <p><b>ESS2.D: Weather and Climate</b></p> <p>İ The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. (HS-ESS2-4)</p> <p>İ Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6)</p> <p>İ Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)</p> <p><b>ETS1.A: Defining and Delimiting Engineering</b></p>	<p><b>Energy and Matter</b></p> <p>İ The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6)</p> <p><b>Systems and System Models</b></p> <p>İ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (HS-ETS1-4)</p> <p>-----</p> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <p>İ New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)</p> <p><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge is Based on Empirical Evidence</b></p> <p>İ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4)</p>
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	<p><b>Problems</b></p> <ul style="list-style-type: none"><li>ï Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)</li><li>ï Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)</li></ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"><li>ï When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</li><li>ï Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</li></ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <ul style="list-style-type: none"><li>ï Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority</li></ul>	
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	of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	
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<b>Embedded English Language Arts/Literacy and Mathematics</b>
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*English Language Arts/Literacy*

- RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)
- RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)
- RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)

*Mathematics*

- MP.2** Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7),(HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)
- MP.4** Model with mathematics. (HS-PS1-4), (HS-ETS1-1),(HS-ETS1-2),(HS-ETS1-3),(HS-ETS1-4)
- HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
- HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7)



**HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-4),(HS-PS1-5),(HS-PS1-7)