

**SALEM COUNTY VOCATIONAL TECHNICAL SCHOOLS**

**SALEM COUNTY CAREER AND TECHNICAL  
HIGH SCHOOL**



**Chemistry**

## **1. Course Description**

Chemistry is a rigorous college preparatory course which consists of a laboratory oriented, intensive study of chemistry which prepares students for the standard achievement test as well. In this course, students will learn the underlying principles that govern physical and chemical processes in the natural world. Students will learn the usefulness and relevance of chemistry in both their intended areas of study and in the everyday world, and will gain an appreciation of these processes from applications of chemical principles.

## **2. Course Philosophy**

This course is designed to meet the objectives of a high school general chemistry course. For this reason, both rigorous class work and laboratory exercises will enable students to attain a depth of understanding of fundamentals and competence in dealing with chemical problems. This course will contribute to the development of the students' abilities to think clearly and to express their ideas both orally and in written form.

### 3. Scope and Sequence

Unit 1: Structure and Properties of Matter

Instructional period: 40 days

Unit Summary
<p><b><i>How can the substructures of atoms explain the observable properties of substances?</i></b></p> <p>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. 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 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 <i>structure and function</i>, <i>patterns</i>, <i>energy and matter</i>, and <i>stability and change</i> are called out as the framework for understanding the disciplinary core ideas. Students use <i>developing and using models</i>, <i>planning and conducting investigations</i>, <i>using mathematical thinking</i>, and <i>constructing explanations and designing solutions</i>. Students are also expected to use the science and engineering practices to demonstrate proficiency with the core ideas.</p>
Student Learning Objectives
<p><b>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.</b> <i>[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.]</i> (<a href="#">HS-PS1-1</a>)</p>
<p><b>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.</b> <i>[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.]</i> (<a href="#">HS-PS1-2</a>)</p>

**Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** *[Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]* ([HS-PS1-3](#))

**Part A:** *How can a periodic table tell me about the subatomic structure of a substance?*

**Concepts**

- 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.
- Each atom has a charged substructure.
- An atom's nucleus is made of protons and neutrons and is surrounded by electrons.
- 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.
- The repeating patterns of this table reflect patterns of outer electron states.
- Patterns of electrons in the outermost energy level of atoms can provide evidence for the relative properties of elements at different scales.
- 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.

**Formative Assessment**

*Students who understand the concepts are able to:*

- 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.
- 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.

**Part B:** *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 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, 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>
<p><b>Part C:</b> <i>How can I use the properties of something (in bulk quantities) to predict what is happening with the subatomic particles?</i></p>	
<p><b>Concepts</b></p>	<p><b>Formative Assessment</b></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.</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>

**Part D:** 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</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</li> </ul>

important in the functioning of designed materials.	<p>repulsive forces that determine the functioning of the material.</p> <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>
<b>What It Looks Like in the Classroom</b>	
<p>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.</p> <p>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.</p>	

- ✓ 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.
- ✓ 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.

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.

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 that structure and interactions of matter at the bulk amount, and accuracy of data required producing reliable information and 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 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.

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, vapor pressure, and surface tension. Students might also plan and conduct an investigation using attraction and repulsion (charges—cations/anions) at the atomic scale to explain transformations of matter at the bulk scale—for example, collecting data to create cooling and heating curves.

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.

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. Molar mass, 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).

#### *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.

#### 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.
- 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.
- 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.
- 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 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 units as a simple way to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret units comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret the scale and origin in graphs and data displays comparing the structure of substances and the bulk scale and electrical forces between particles.
  - Determine a level of accuracy appropriate to limitations on measurements of the strength of electrical forces between particles.

#### Modifications

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

- Restructure lessons using Universal Design for Learning (UDL) principals ([http://www.cast.org/our-work/about-udl.html#.VXmoXcfD\\_UA](http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA))
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- 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).
- 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).

- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide English Language Learners students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

#### Connections to Other Courses

##### Biology

- 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.
- 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.

##### 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

[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.

[Shall We Dance? – Classifying Types of Chemical Reactions](#): Students identify and differentiate between four types of chemical reactions: synthesis, decomposition, single replacement and double replacement. Students also develop

models for chemical reactions and identify the limitations of the models using evidence.

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>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</li> </ul>	<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 states. (HS-PS1-1),(HS-PS1-2)</li> <li>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary to HS-PS2-6)</li> </ul> <p><b>PS1.B: Chemical Reactions</b></p> <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. (HS-PS1-2)</li> </ul> <p><b>PS2.B: Types of Interactions</b></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> <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>they did in the past and will continue to 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>	<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),(secondary to HS-PS1-3)</i></li> </ul>	<p><b><i>Connections to Engineering, Technology, and Applications of Science</i></b> <b>Influence of Science, Engineering, and Technology on Society and the Natural World</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>
<b>Embedded English Language Arts/Literacy and Mathematics Standards</b>		
<p><i>English Language Arts/Literacy</i></p> <p><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-PS1-3)</p>		



<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-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-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-ETS1-3),(HS-ETS1-4)
<b>MP.4</b>	Model with mathematics. (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)

### 3. Scope and Sequence

Unit 2: Bonding and Chemical Reactions

Instructional period: 40 days

Unit Summary
<p><b><i>How can one explain the structure, properties, and interactions of matter?</i></b></p> <p>In this unit of study, students <i>develop and using models, plan and conduct investigations, use mathematical thinking, and construct explanations and design solutions</i> 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 <i>optimization and engineering design</i> to chemical reaction systems. The crosscutting concepts of <i>patterns, energy and matter, and stability and change</i> are the organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in <i>developing and using models, planning and conducting investigations, using mathematical thinking, and constructing explanations and designing solutions</i>.</p>
Student Learning Objectives
<p><b>Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. <i>[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</i></b></p>

<i>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)</i>	
<b>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.</b> <i>[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)</i>	
<b>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.</b> <i>[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)</i>	
<b>Part A: 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 energy and matter in closed systems is conserved.</li> <li>• The total amount of energy and matter in a chemical reaction system is conserved.</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 energy and 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 energy and matter in a chemical reaction system in terms of energy and matter flows into, out of, and within that system.</li> </ul>
<p><b>Part B:</b> <i>What is different inside a heat pack and a cold pack?</i></p>	
<p><b>Concepts</b></p>	<p><b>Formative Assessment</b></p>
<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> </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</li> </ul>

<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> </ul>	<p>changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</p> <ul style="list-style-type: none"> <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 changes in total bond energy.</li> </ul>
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### What It Looks Like in the Classroom

The *Bonding and Chemical Reaction* unit ties together the concepts developed in *Structure and Properties of Matter*. In this unit, students will develop an understanding that the total amount of energy and matter in a closed system (including chemical reaction systems) is conserved and that 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. 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 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.

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 (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

- 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.
- 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. The unneeded modifications can then be deleted from the list.

- Restructure lesson using UDL principals ([http://www.cast.org/our-work/about-udl.html#VXmoXcfD\\_UA](http://www.cast.org/our-work/about-udl.html#VXmoXcfD_UA))
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- 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).
- 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).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.



- Collaborate with after-school programs or clubs to extend learning opportunities.

## 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

- 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. 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.

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

- 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>

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>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>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>Using Mathematics and Computational Thinking</b></p> <ul style="list-style-type: none"> <li>Use mathematical representations of phenomena to support claims. (HS-PS1-7)</li> </ul> <p><b>Constructing Explanations and Designing Solutions</b></p> <ul style="list-style-type: none"> <li>Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)</li> </ul>	<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 states. (HS-PS1-1),(HS-PS1-2)</li> <li>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6)</li> <li>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>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>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>In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)</li> <li>The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)</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. (HS-PS1-4)</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-PS1-6)</li> </ul> <p>-----</p> <p><b><i>Connections to Nature of Science</i></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 do so in the future. (HS-PS1-2)</li> <li>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)</li> </ul> <p><b>Asking Questions and Defining Problems</b></p> <ul style="list-style-type: none"> <li>Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)</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><b>Constructing Explanations and Designing Solutions</b></p> <ul style="list-style-type: none"> <li>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)</li> </ul>	<p>molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5)</p> <ul style="list-style-type: none"> <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. (HS-PS1-6)</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. (HS-PS1-2),(HS-PS1-7)</li> </ul> <p><b>PS1.C: Nuclear Processes</b></p> <ul style="list-style-type: none"> <li>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. (HS-PS1-8)</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.(secondary to HS-PS1-1),(secondary to HS-PS1-3)</li> </ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <ul style="list-style-type: none"> <li>Criteria may need to be broken down into simpler ones that can be approached</li> </ul>	<p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b></p> <ul style="list-style-type: none"> <li>Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)</li> </ul>
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<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>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> <ul style="list-style-type: none"> <li>● 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>● 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>● 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</li> </ul>	
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	<p>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> <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 (trade-offs) may be needed. (HS-ETS1-2)</li></ul>	
<b>Embedded English Language Arts/Literacy and Mathematics</b>		
<i>English Language Arts/Literacy</i>		
<b>RST.9-10.7</b>	Translate quantitative or technical information expressed visually or r	
<b>RST.11-12.1</b>	Cite specific textual evidence to su and to any gaps or inconsistencies	
<b>RST.11-12.7</b>	Integrate and evaluate multiple so (multimedia) in order to address a c	
<b>RST.11-12.8</b>	Evaluate the hypotheses, data, and corroborating or challenging concl	

<b>RST.11-12.9</b>	Synthesize information from a range of sources to address a question or problem; identify a topic and textual evidence relevant to that topic; evaluate the relevance of the information; analyze how different pieces of information relate to each other; synthesize information from a range of sources to address a question or problem, resolving contradictions and discrepancies. (HS-PS1-5)
<b>WHST.9-12.2</b>	Write informative/explanatory texts in which they introduce a topic; state a purpose and a central idea or thesis; analyze a topic and select relevant facts, examples, and data; use relevant sources to support their analysis; provide a conclusion that follows from the analysis. (HS-PS1-5)
<b>WHST.9-12.7</b>	Conduct short as well as more sustained research projects based on focused questions, drawing on several print and digital sources, assessing the credibility of each source, comparing and contrasting the information gathered, and then synthesizing a list of relevant sources. (HS-PS1-5)
<b>SL.11-12.5</b>	Make strategic use of digital media and technology to research, connect, and collaborate with others. (HS-PS1-5)
<i>Mathematics -</i>	
<b>MP.2</b>	Reason abstractly and quantitatively. (HS-PS1-5)
<b>MP.4</b>	Model with mathematics. (HS-PS1-5)
<b>HSN-Q.A.1</b>	Use units as a way to understand problems and to guide the selection of appropriate units for the quantities involved; choose and interpret the meaning of the units used in formulas; choose and interpret the meaning of the units used in formulas. (HS-PS1-5)
<b>HSN-Q.A.2</b>	Define appropriate quantities for the situation at hand; choose a level of accuracy appropriate to the situation. (HS-PS1-5)
<b>HSN-Q.A.3</b>	Choose a level of accuracy appropriate to the situation. (HS-PS1-5)

### 3. Scope and Sequence

Unit 3: Nuclear Chemistry

Instructional period: 10 days

#### 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.

*Note: This unit can be taught in either Chemistry or as part of the Capstone Science Course.*

#### **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)**

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

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

**Concepts**

- Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy.
- The total number of neutrons plus protons does not change in any nuclear process.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

**Formative Assessment**

*Students who understand the concepts are able to:*

- 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.
- Use simple qualitative models based on evidence to illustrate the scale of energy released in nuclear processes relative to other kinds of transformations.
- 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.

**Part B:** *How do stars produce elements?*

**Concepts**

- 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 Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases

**Formative Assessment**

*Students who understand the concepts are able to:*

- Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements.

<p>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>	<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>
<b>Part C: Is the life span of a star predictable?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<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>
<b>Part D: If there was nobody there to Tweet about it, how do we know that there was a Big Bang?</b>	
<b>Concepts</b>	<b>Formative Assessment</b>
<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 including iron, and the process releases electromagnetic energy.</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 gases (from the spectra of electromagnetic radiation from stars).</li> </ul>

<p>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>	<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>
<b>Part E: <i>How can chemistry help us to figure out ancient events?</i></b>	
<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> </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> </ul>

<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.</li> <li>• Much of science deals with constructing explanations of how things change and how they remain stable.</li> </ul>	<ul style="list-style-type: none"> <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 billion years ago.</li> <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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### What It Looks Like in the Classroom

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.

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 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. The unneeded modifications can then be deleted from the list.*

- Restructure lesson using UDL principals ([http://www.cast.org/our-work/about-udl.html#VXmoXcfD\\_UA](http://www.cast.org/our-work/about-udl.html#VXmoXcfD_UA))



- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- 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).
- 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).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

#### 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.

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

- 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>

*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>  Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. <ul style="list-style-type: none"> <li>• Develop a model based on evidence to illustrate the relationships between systems</li> </ul>	<b>PS1.C: Nuclear Processes</b> <ul style="list-style-type: none"> <li>• 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. (HS-PS1-8)</li> <li>• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used</li> </ul>	<b>Energy and Matter</b> <ul style="list-style-type: none"> <li>• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3), (HS-PS1-8), (HS-ESS1-1)</li> <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>or between components of a system. (HS-PS1-8),(HS-ESS1-1)</p> <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</p>	<p>to determine the ages of rocks and other materials.(secondary (HS-ESS1-6)</p> <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 Life</b></p> <ul style="list-style-type: none"> <li>Nuclear Fusion processes in the center of the sun release the energy that ultimately</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 (R&amp;D). Many R&amp;D projects may</li> </ul>
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<p>to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric 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>reaches Earth as radiation. (secondary) (HS-ESS1-1)</p> <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>involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2),(HS-ESS1-4)</p> <p>-----</p> <p><b><i>Connections to Nature of Science</i></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		
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)

#### 4. Resource

Textbook: Chemistry: Matter and Change Glencoe 2013 ed.

Unit 1: Chapters 3, 4, 5, 6, and 12

Unit 2: Chapter 7, 8, and 9

Unit 3: Chapter 24