

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)*

Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. *[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along*

with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.] (HS-ESS1-6)

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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	Formative Assessment
<ul style="list-style-type: none"> 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. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> 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	Formative Assessment
<ul style="list-style-type: none"> 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 electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) about the way stars, over their life cycles, produce elements. Communicate scientific ideas about the way nucleosynthesis, and therefore

<p>stage and explode.</p> <ul style="list-style-type: none"> In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. 	<p>the different elements it creates, vary as a function of the mass of a star and the stage of its lifetime.</p> <ul style="list-style-type: none"> Communicate scientific ideas about how in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
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Part C: Is the life span of a star predictable?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. 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. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> 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. Develop a model based on evidence to illustrate the relationships between nuclear fusion in the sun's core and radiation that reaches Earth.

Part D: If there was nobody there to Tweet about it, how do we know that there was a Big Bang?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> 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. 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. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> 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. 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). 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.

<ul style="list-style-type: none"> • Energy cannot be created or destroyed, only moved between one place and another place, between objects and/or fields, or between systems. • Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. • 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. • Science assumes the universe is a vast single system in which basic laws are consistent. • 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. 	
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Part E: How can chemistry help us to figure out ancient events?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • 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. • 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. • Much of science deals with constructing explanations of how things change and how they remain stable. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • 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. • 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. • 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. • Use available evidence within the solar system to construct explanations for how Earth has changed and how it remains stable.

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)
- 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.

Research on Student Learning

N/A

Prior Learning

Physical science

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

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Earth and space science

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

Connections to Other Courses

Physical science

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object

to another and between its various possible forms.

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- When two objects interacting through a field change relative position, the energy stored in the field is changed.
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

Earth and space science

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

Links to Free and Low Cost Instructional Resources

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

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

Appendix A: NGSS and Foundations for the Unit

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

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

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

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

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

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Developing and Using Models</p> <p>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</p>	<p>PS1.C: Nuclear Processes</p> <ul style="list-style-type: none"> 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 	<p>Energy and Matter</p> <ul style="list-style-type: none"> 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)

<p>designed worlds.</p> <ul style="list-style-type: none"> Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8),(HS-ESS1-1) <p>Constructing Explanations and Designing Solutions</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"> 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) 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) <p>Using Mathematical and Computational Thinking</p> <p>Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric 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"> Use mathematical or computational 	<p>change in any nuclear process. (HS-PS1-8)</p> <ul style="list-style-type: none"> Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.(secondary (HS-ESS1-6) <p>ESS1.A: The Universe and Its Stars</p> <ul style="list-style-type: none"> The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) 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) 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) 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) <p>PS3.D: Energy in Chemical Processes and Everyday Life</p> <ul style="list-style-type: none"> Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary) (HS-ESS1-1) <p>PS4.B: Electromagnetic Radiation</p>	<ul style="list-style-type: none"> 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) <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1) 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) In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. <p>Stability and Change</p> <ul style="list-style-type: none"> Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6) <p>-----</p> <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2),(HS-ESS1-4) <p>-----</p>
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<p>representations of phenomena to describe explanations. (HS-ESS1-4)</p> <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> 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) 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) 	<ul style="list-style-type: none"> 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) <p>ESS1.B: Earth and the Solar System</p> <ul style="list-style-type: none"> 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) <p>ESS1.C: The History of Planet Earth</p> <ul style="list-style-type: none"> 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. 	<p>Connections to Nature of Science</p> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p> <ul style="list-style-type: none"> 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) Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2) <p>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</p> <ul style="list-style-type: none"> 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)
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<p style="text-align: center;">Embedded English Language Arts/Literacy and Mathematics</p>	
<p><i>English Language Arts/Literacy -</i></p>	
<p>RST.11-12.1</p>	<p>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)</p>
<p>WHST.9-12.2</p>	<p>Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-3),(HS-ESS1-2)</p>
<p>SL.11-12.4</p>	<p>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)</p>

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)