NGSS Alignment Guide for High School Chemistry

This guide outlines how the Khan Academy high school chemistry course aligns with the Next Generation Science Standards (NGSS). NGSS is built around a three-dimensional approach:

Performance Expectations (PEs) Each unit is aligned with specific PEs that blend all three dimensions—DCIs, SEPs, and CCCs—into meaningful, assessable learning goals that reflect what students should know and be able to do.		
Science and Engineering Practices (SEPs)	**Disciplinary Core Ideas (DCIs)**	**Crosscutting Concepts (CCCs)**
Describe the behaviors that scientists engage in as they investigate the natural world and that engineers use to design and build solutions. These practices go beyond "skills"—they involve applying content knowledge in purposeful ways.	Help students make connections across the different domains of science. By making these ideas explicit, instruction helps students build a coherent, transferable understanding of science that they can apply in new and unfamiliar contexts.	Key ideas that are central to understanding the physical sciences, life sciences, Earth and space sciences, and engineering. These ideas have broad relevance across scientific disciplines and build in complexity across grade levels.

Quick navigation to unit standards

Unit 1: Atoms, isotopes, and ions

Unit 2: Atomic models and periodicity

Unit 3: Chemical bonding

Unit 4: Chemical reactions

Unit 5: Stoichiometry and the mole

Unit 6: States of matter

Unit 7: Thermochemistry

Unit 8: Solutions, acids, and bases

Unit 9: Reaction rates and equilibrium

Unit 10: Nuclear chemistry

NGSS Unit guides

Looking for tools and support for implementing Khan Academy chemistry in your classroom? Check out our NGSS high school chemistry unit guides! These guides are designed to support the implementation of Khan Academy as a supplement to your existing science curriculum.

Designed *by* educators *for* educators, these NGSS-aligned guides blend pedagogy with content support for all teachers. Whether you're new to the course or a seasoned educator, you'll find resources to build confidence, inspire new ideas, and enhance classroom implementation.

Unit 1: Atoms, isotopes, and ions (link to unit)

Performance expectations (PEs)

- **HS-PS1-1:** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

Disciplinary core ideas (DCIs)

- **HS-PS1.A.1:** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- **HS-PS1.A.2:** 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.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Using mathematics and computational thinking: Students progress 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.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students define and describe different models of atoms.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students connect atomic structure to elemental identity and properties of matter.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students identify patterns in the periodic table related to atomic structure and elemental properties.

Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students consider the movement of subatomic particles into or out of the atom.

Unit 2: Atomic models and periodicity (link to unit)

Performance expectations (PEs)

- **HS-PS1-1:** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- **HS-ESS1-2:** 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.

Disciplinary core ideas (DCIs)

- **HS-PS1.A.1:** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- **HS-ESS1.A.2:** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- **HS-PS4.B.1:** 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.
- **HS-PS1.A.2:** 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.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.



Engaging in argument from evidence: Students progress to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that	Students define and describe different models of atoms.

are applicable throughout science and engineering.	
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students connect atomic structure to elemental identity, properties, and behavior of matter.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students consider the movement of energy into and out of the atom to produce atomic emission spectra.

Unit 3: Chemical bonding (link to unit)

Performance expectations (PEs)

- **HS-PS1-1:** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- **HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Disciplinary core ideas (DCIs)

- **HS-PS1.A.2:** 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.A.3:** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.



Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students apply patterns in the periodic table to predict bonding behavior, write chemical formulas, and name compounds.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students make connections between atomic structure, chemical bonding, and macroscopic properties of

	substances.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students predict bonding patterns based on an atom's tendency to achieve greater stability by completing its valence shell.
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students describe and apply different models of chemical bonding.

Unit 4: Chemical reactions (link to unit)

Performance expectations (PEs)

- **HS-PS1-1:** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- **HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Disciplinary core ideas (DCIs)

- **HS-PS1.A.2:** 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.A.3:** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.



Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students apply patterns in the periodic table to predict bonding behavior, write chemical formulas, and name compounds.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students make connections between atomic structure, chemical bonding, and macroscopic properties of

	substances.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students predict bonding patterns based on an atom's tendency to achieve greater stability by completing its valence shell.
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students describe and apply different models of chemical bonding.

Unit 5: Stoichiometry and the mole (link to unit)

Performance expectations (PEs)

- **HS-PS1-7:** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Disciplinary core ideas (DCIs)

- **HS-PS1.B.3:** 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.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Using mathematics and computational thinking: Students progress 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.



Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students apply conservation of mass to predict theoretical yields and to determine amounts of reactants required to make desired amounts of products.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students use patterns in reactivity to predict the outcomes of chemical reactions.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students observe changes from reactants to products and represent them with balanced chemical

	equations.
Scale, proportion, and quantity: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.	Students recognize that the incredibly small size of atoms means only incredibly large numbers of them are easily measured, which requires the application of Avogadro's number and molar mass.

Unit 6: States of matter (link to unit)

Performance expectations (PEs)

- **HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS2-6:** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Disciplinary core ideas (DCIs)

- **HS-PS1.A.3:** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- **HS-PS2.B.3:** 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.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.



Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students connect molecular structure to intermolecular forces and macroscopic properties of substances.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students consider relative amounts of energy required to weaken or break intramolecular and intermolecular forces within samples of different substances.

Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students model the behavior of gases using the kinetic molecular theory and the gas laws.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students predict how gas pressure will change in response to changes in volume, temperature, or moles of particles in a gas sample.

Unit 7: Thermochemistry (link to unit)

Performance expectations (PEs)

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

Disciplinary core ideas (DCIs)

- **HS-PS3.A.2:** 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.
- **HS-PS3.A.3:** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- **HS-PS3.A.4:** These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.
- **HS-PS3.B.1:** 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.
- **HS-PS3.B.2:** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- **HS-PS3.B.3:** 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.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Using mathematics and computational thinking: Students progress 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.

Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students define systems in order to study thermal energy transfer within and between systems.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students predict, observe, and quantify thermal energy transfer into, out of, and within systems.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students observe and analyze changes as systems reach thermal equilibrium.
Cause and effect (Mechanism and explanation): Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Students explain how the transfer of thermal energy occurs via the mechanism of particle collisions.

Unit 8: Solutions, acids, and bases (link to unit)

Performance expectations (PEs)

- **HS-PS1-2:** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
- **HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Disciplinary core ideas (DCIs)

- **HS-PS1.A.3:** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- **HS-PS1.B.1:** 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.
- **HS-PS1.B.3:** 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-PS2.B.3:** 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.

Science and engineering practices (SEPs)

Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students use molecular structure and distribution of charge to determine the relative strengths of interactions between solute and solvent particles.

Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students explain how changes in temperature affect the solubility of solids and gases in aqueous solutions.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students observe changes from reactants to products and represent them with balanced chemical equations.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students use patterns in reactivity to predict the outcomes of chemical reactions.

Unit 9: Reaction rates and equilibrium (link to unit)

Performance expectations (PEs)

- **HS-PS1-4:** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- **HS-PS1-5:** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- **HS-PS1-6:** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

Disciplinary core ideas (DCIs)

- **HS-PS1.B.1:** 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.
- **HS-PS1.B.2:** 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-PS3.B.4:** The availability of energy limits what can occur in any system.

Science and engineering practices (SEPs)



Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.



Planning and carrying out investigations: Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.



Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.



Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that	Students describe and apply a collision model to explain changes in reaction systems.

are applicable throughout science and engineering.	
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students predict how changes in different factors affect chemical reaction rates and systems at equilibrium.
Energy and matter (Flows, cycles, and conservation): Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students predict, observe, and quantify the flow of thermal energy and/or matter into, out of, and within systems as matter undergoes chemical reactions.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students use patterns in reactivity to predict the outcomes of chemical reactions.

Unit 10: Nuclear chemistry (link to unit)

Performance expectations (PEs)

- **HS-PS1-8:** 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.
- **HS-ESS1-1:** 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.
- **HS-ESS1-3:** Communicate scientific ideas about the way stars, over their life cycle, produce elements.
- **HS-ESS1-6:** 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.

Disciplinary core ideas (DCIs)

- **HS-PS1.C.1:** 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.C.2:** 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.
- **HS-ESS1.A.1:** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
- **HS-ESS1.A.4:** 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-PS3.D.4:** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

Science and engineering practices (SEPs)

Developing and using models: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

Using mathematics and computational thinking: Students progress 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.

Analyzing and interpreting data: Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Constructing explanations and designing solutions: Students progress to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Crosscutting concepts (CCCs)

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students utilize models of nuclear changes to explain what happens during nuclear decay and nuclear reactions.
Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	Students evaluate the mass loss that occurs during nuclear reactions to explain why fission and fusion release large amounts of energy.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Students investigate how radioisotopes undergo nuclear changes to become stable.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students recognize patterns in the decay rates of radioisotopes and use the concept of half-life to make predictions about the remaining quantity of a substance over time, the age of geological and archaeological samples, and the stability of different isotopes.