High School Chemistry

Scope and Sequence

Unit of Study 1: Properties and Structure of Matter

Standards that appear this unit: HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS2-6*, HS-ETS1-3, HS-ETS1-4

HS. Structure and Properties of Matter

Students who demonstrate understanding can:

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

The performance expectations 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
Developing and Using Models 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. ▪ Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)	**PS1.A: Structure and Properties of Matter** ▪ Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) ▪ 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) **PS2.B: Types of Interactions** ▪ 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)*	**Patterns** ▪ 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)

Connections to other DCIs in this grade-band: **HS.LS1.C** (HS-PS1-1)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-1); **MS.PS1.B** (HS-PS1-1)

Common Core State Standards Connections:

ELA/Literacy –

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. *(HS-PS1-1)*

HS. Chemical Reactions
Students who demonstrate understanding can: **HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]
The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ 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)	**PS1.A: Structure and Properties of Matter** ▪ 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-PS1-2) *(Note: This Disciplinary Core Idea is also addressed by HS-PS1-1.)* **PS1.B: Chemical Reactions** ▪ The fact that atoms are conserved, together with knowledge of the chemical properties of the elements, can be used to describe and predict chemical reactions. (HS-PS1-2)	**Patterns** ▪ 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-PS1-2)

Connections to other DCIs in this grade-band: **HS.LS1.C** (HS-PS1-2); **HS.ESS2.C** (HS-PS1-2)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-2); **MS.PS1.B** (HS-PS1-2)

Common Core State Standards Connections:

ELA/Literacy –

WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)

Mathematics –

HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-2)*

HS. Structure and Properties of Matter		
Students who demonstrate understanding can: **HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]		
The performance expectations 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**
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. ▪ 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)	**PS1.A: Structure and Properties of Matter** ▪ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3) **PS2.B: Types of Interactions** ▪ 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-PS1-3)*	**Patterns** ▪ 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-PS1-3)
Connections to other DCIs in this grade-band: **HS.ESS2.C** (HS-PS1-3)		
Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-3); **MS.PS2.B** (HS-PS1-3)		
Common Core State Standards Connections: *ELA/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-PS1-3) **WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3) **WHST.11-12.8** 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) **WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS1-3)* *Mathematics –* **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-PS1-3)* **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-3)*		

HS. Structure and Properties of Matter		
Students who demonstrate understanding can: **HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]		
The performance expectations 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**
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ 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)	**PS1.A: Structure and Properties of Matter** ▪ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. *(secondary to HS-PS2-6)* **PS2.B: Types of Interactions** ▪ 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. (HS-PS2-6)	**Structure and Function** ▪ 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)
Connections to other DCIs in this grade-band: N/A		
Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS2-6); **MS.PS2.B** (HS-PS2-6)		
Common Core State Standards Connections: *ELA/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-PS2-6)* **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS2-6)* *Mathematics –* **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-PS2-6)* **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-6)* **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS2-6)*		

HS. Engineering Design

Students who demonstrate understanding can:

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

The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ 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)	**ETS1.B: Developing Possible Solutions** ▪ 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)	***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ 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-ETS1-3)

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:
Physical Science: HS-PS2-3, HS-PS3-3
Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:
Earth and Space Science: HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6
Connections to HS-ETS1.C: Optimizing the Design Solution include:
Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-3); **MS.ETS1.B** (HS-ETS1-3)

Common Core State Standards Connections:

ELA/Literacy –

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

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-ETS1-3)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(HS-ETS1-3)*

MP.4 Model with mathematics.(HS-ETS1-3)

HS. Engineering Design		
Students who demonstrate understanding can: **HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**		
The performance expectations 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**
Using Mathematics and Computational Thinking 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. ▪ 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)	**ETS1.B: Developing Possible Solutions** ▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)	**Systems and System Models** ▪ 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)
Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include: **Physical Science:** HS-PS2-3, HS-PS3-3 *Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:* **Earth and Space Science:** HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6 *Connections to HS-ETS1.C: Optimizing the Design Solution include:* **Physical Science:** HS-PS1-6, HS-PS2-3		
Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-4); **MS.ETS1.B** (HS-ETS1-4); **MS.ETS1.C** (HS-ETS1-4)		
Common Core State Standards Connections: *Mathematics –* **MP.2** Reason abstractly and quantitatively. *(HS-ETS1-4)* **MP.4** Model with mathematics. (HS-ETS1-4)		

Unit of Study 2: Energy and Its Applications (non-living)

Standards that appear this unit: HS-PS3-4, HS-ESS2-5, HS-ESS3-2*, HS-ETS1-3

HS. Energy

Students who demonstrate understanding can:

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
[Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

The performance expectations 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
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. ▪ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4)	**PS3.B: Conservation of Energy and Energy Transfer** ▪ Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-4) ▪ Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4) **PS3.D: Energy in Chemical Processes** ▪ Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-4)	**Systems and System Models** ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)

Connections to other DCIs in this grade-band: **HS.ESS1.A** (HS-PS3-4); **HS.ESS2.A** (HS-PS3-4); **HS.ESS2.D** (HS-PS3-4)

Articulation to DCIs across grade-bands: **MS.PS3.B** (HS-PS3-4)

Common Core State Standards Connections:

ELA/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-PS3-4)*

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-4)

WHST.11-12.8 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-PS3-4)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS3-4)*

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS3-4)

MP.4 Model with mathematics. *(HS-PS3-4)*

HS. Earth's Systems		
Students who demonstrate understanding can: **HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]		
The performance expectations 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**
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. ▪ 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-ESS2-5)	**ESS2.C: The Roles of Water in Earth's Surface Processes** ▪ The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)	**Structure and Function** ▪ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5)
Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS2-5); **HS.PS1.B** (HS-ESS2-5); **HS.PS3.B** (HS-ESS2-5); **HS.ESS3.C** (HS-ESS2-5)		
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS2-5); **MS.PS4.B** (HS-ESS2-5); **MS.ESS2.A** (HS-ESS2-5); **MS.ESS2.C** (HS-ESS2-5); **MS.ESS2.D** (HS-ESS2-5)		
Common Core State Standards Connections: *ELA/Literacy –* **WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ESS2-5) *Mathematics –* **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-5)		

HS. Human Sustainability

Students who demonstrate understanding can:

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

The performance expectations 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
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ▪ Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS-ESS3-2)	**ESS3.A: Natural Resources** ▪ All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2) **ETS1.B. Designing Solutions to Engineering Problems** ▪ 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. *(secondary to HS-ESS3-2)*	***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** ▪ Engineers continuously modify these systems to increase benefits while decreasing costs and risks. (HS-ESS3-2) ▪ Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2) --- ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World** ▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2) ▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2) ▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)

Connections to other DCIs in this grade-band: **HS.PS3.B** (HS-ESS3-2); **HS.PS3.D** (HS-ESS3-2); **HS.LS2.A** (HS-ESS3-2); **HS.LS2.B** (HS-ESS3-2); **HS.LS4.D** (HS-ESS3-2); **HS.ESS2.A** (HS-ESS3-2)

Articulation of DCIs across grade-bands: **MS.PS3.D** (HS-ESS3-2); **MS.LS2.A** (HS-ESS3-2); **MS.LS2.B** (HS-ESS3-2); **MS.LS4.D** (HS-ESS3-2); **MS.ESS3.A** (HS-ESS3-2); **MS.ESS3.C** (HS-ESS3-2)

Common Core State Standards Connections:	
ELA/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-ESS3-2)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS3-2)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-ESS3-2)

HS. Engineering Design

Students who demonstrate understanding can:

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

The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ 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)	**ETS1.B: Developing Possible Solutions** ▪ 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)	***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ 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-ETS1-3)

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:
Physical Science: HS-PS2-3, HS-PS3-3
Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:
Earth and Space Science: HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6
Connections to HS-ETS1.C: Optimizing the Design Solution include:
Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-3); **MS.ETS1.B** (HS-ETS1-3)

Common Core State Standards Connections:
ELA/Literacy –

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

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-ETS1-3)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(HS-ETS1-3)*

MP.4 Model with mathematics.(HS-ETS1-3)

Unit of Study 3: Bonding and Chemical Reactions

Standards that appear this unit: HS-PS1-7, HS-PS1-4, HS-PS1-5, HS-PS1-6*, HS-ETS1-2

HS. Chemical Reactions

Students who demonstrate understanding can:

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

The performance expectations 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
Using Mathematical and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 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. ▪ Use mathematical representations of phenomena to support claims. (HS-PS1-7)	**PS1.B: Chemical Reactions** ▪ 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-PS1-7)	**Energy and Matter** ▪ The total amount of energy and matter in closed systems is conserved. (HS-PS1-7) ▪ 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) --------------------------------------- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ▪ Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

Connections to other DCIs in this grade-band: **HS.PS3.B** (HS-PS1-7); **HS.LS1.C** (HS-PS1-7); **HS.LS2.B** (HS-PS1-7)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-7); **MS.PS1.B** (HS-PS1-7); **MS.LS1.C** (HS-PS1-7); **MS.LS2.B** (HS-PS1-7); **MS.ESS2.A** (HS-PS1-7)

Common Core State Standards Connections:

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS1-7)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-7)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS1-7)*

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

HS. Chemical Reactions		
Students who demonstrate understanding can: **HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]		
The performance expectations 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**
Developing and Using Models 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. ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4)	**PS1.A: Structure and Properties of Matter** ▪ 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) **PS1.B: Chemical Reactions** ▪ 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-PS1-4)	**Energy and Matter** ▪ 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)
Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-PS1-4); **HS.PS3.B** (HS-PS1-4); **HS.PS3.D** (HS-PS1-4); **HS.LS1.C** (HS-PS1-4)		
Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-4); **MS.PS1.B** (HS-PS1-4); **MS.PS2.B** (HS-PS1-4); **MS.PS3.D** (HS-PS1-4); **MS.LS1.C** (HS-PS1-4)		

HS. Chemical Reactions

Students who demonstrate understanding can:

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)	**PS1.B: Chemical Reactions** ▪ 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-PS1-5)	**Patterns** ▪ 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-PS1-5)

Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-PS1-5)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-5); **MS.PS1.B** (HS-PS1-5); **MS.PS2.B** (HS-PS1-5); **MS.PS3.A** (HS-PS1-5); **MS.PS3.B** (HS-PS1-5)

Common Core State Standards Connections:

ELA/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-PS1-5)

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

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS1-5)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-PS1-5)*

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

<table>
<tr><td colspan="3">HS. Chemical Reactions</td></tr>
<tr><td colspan="3">Students who demonstrate understanding can:
HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* [Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]</td></tr>
<tr><td colspan="3">The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</td></tr>
<tr><td>Science and Engineering Practices
Constructing Explanations and Designing Solutions
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.
▪ 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)</td><td>Disciplinary Core Ideas
PS1.B: Chemical Reactions
▪ 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)
ETS1.C: Optimizing the Design Solution
▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)</td><td>Crosscutting Concepts
Stability and Change
▪ Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)</td></tr>
<tr><td colspan="3">Connections to other DCIs in this grade-band: HS.PS3.B (HS-PS1-6)</td></tr>
<tr><td colspan="3">Articulation to DCIs across grade-bands: MS.PS1.B (HS-PS1-6)</td></tr>
<tr><td colspan="3">Common Core State Standards Connections:
ELA/Literacy –
WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6)</td></tr>
</table>

HS. Engineering Design		
Students who demonstrate understanding can: **HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**		
The performance expectations 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**
Constructing Explanations and Designing Solutions 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. ▪ 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)	**ETS1.C: Optimizing the Design Solution** ▪ 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)	N/A
Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include: **Physical Science:** HS-PS2-3, HS-PS3-3 *Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:* **Earth and Space Science:** HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6 *Connections to HS-ETS1.C: Optimizing the Design Solution include:* **Physical Science:** HS-PS1-6, HS-PS2-3		
Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-2); **MS.ETS1.B** (HS-ETS1-2); **MS.ETS1.C** (HS-ETS1-2)		
Common Core State Standards Connections: *Mathematics –* **MP.4** Model with mathematics. (HS-ETS1-2)		

Unit of Study 4: Transfer of Energy and Its Applications (living)

Standards that appear this unit: HS-LS1-5, HS-LS1-7, HS-LS1-6, HS-LS1-6, HS-LS1-7

HS. Matter and Energy in Organisms and Ecosystems		
Students who demonstrate understanding can: **HS-LS1-5.** **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]		
The performance expectations 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**
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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. ▪ Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5)	**LS1.C: Organization for Matter and Energy Flow in Organisms** ▪ The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)	**Energy and Matter** ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5)
Connections to other DCIs in this grade-band: **HS.PS1.B** (HS-LS1-5); **HS.PS3.B** (HS-LS1-5)		
Articulation across grade-bands: **MS.PS1.B** (HS-LS1-5); **MS.PS3.D** (HS-LS1-5); **MS.LS1.C** (HS-LS1-5); **MS.LS2.B** (HS-LS1-5)		
Common Core State Standards Connections: *ELA/Literacy –* **SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-LS1-5)*		

HS. Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

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

The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)	**LS1.C: Organization for Matter and Energy Flow in Organisms** ▪ The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6) ▪ As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6)	**Energy and Matter** ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-6)

Connections to other DCIs in this grade-band: **HS.PS1.B** (HS-LS1-6)

Articulation across grade-bands: **MS.PS1.A** (HS-LS1-6); **MS.PS1.B** (HS-LS1-6); **MS.PS3.D** (HS-LS1-6); **MS.LS1.C** (HS-LS1-6); **MS.ESS2.E** (HS-LS1-6)

Common Core State Standards Connections:

ELA/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-LS1-6)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-6)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-6)

HS. Matter and Energy in Organisms and Ecosystems		
Students who demonstrate understanding can: **HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]		
The performance expectations 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**
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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. ▪ Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-7)	**LS1.C: Organization for Matter and Energy Flow in Organisms** ▪ As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-7) ▪ As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. (HS-LS1-7)	**Energy and Matter** ▪ Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.(HS-LS1-7)
Connections to other DCIs in this grade-band: **HS.PS1.B** (HS-LS1-7); **HS.PS2.B** (HS-LS1-7); **HS.PS3.B** (HS-LS1-7)		
Articulation across grade-bands: **MS.PS1.B** (HS-LS1-7); **MS.PS3.D** (HS-LS1-7); **MS.LS1.C** (HS-LS1-7); **MS.LS2.B** (HS-LS1-7)		
Common Core State Standards Connections: *ELA/Literacy –* **SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-LS1-7)*		

Unit of Study 5: Nuclear Energy

Standards that appear this unit: HS-PS1-8, HS-ESS1-3, HS-ESS1-1, HS-ESS1-2, HS-ESS1-6

HS. Structure and Properties of Matter

Students who demonstrate understanding can:

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. [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.]

The performance expectations 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
Developing and Using Models 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. ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8)	**PS1.C: Nuclear Processes** ▪ 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)	**Energy and Matter** ▪ In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)

Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-PS1-8); **HS.PS3.B** (HS-PS1-8); **HS.PS3.C** (HS-PS1-8); **HS.PS3.D** (HS-PS1-8); **HS.ESS1.A** (HS-PS1-8); **HS.ESS1.C** (HS-PS1-8)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-8); **MS.PS1.B** (HS-PS1-8); **MS.PS1.C** (HS-PS1-8); **MS.ESS2.A** (HS-PS1-8)

Common Core State Standards Connections:

Mathematics –

MP.4	Model with mathematics. *(HS-PS1-8)*
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-8)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-8)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-8)*

HS. Space Systems

Students who demonstrate understanding can:

HS-ESS1-3. **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.]

The performance expectations 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
Obtaining, Evaluating, and Communicating Information 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. ▪ 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)	**ESS1.A: The Universe and Its Stars** ▪ The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-3) ▪ 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-ESS1-3)	**Energy and Matter** ▪ In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-ESS1-3)

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS1-3); **HS.PS1.C** (HS-ESS1-3)

Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS1-3); **MS.ESS1.A** (HS-ESS1-3)

Common Core State Standards Connections:

ELA/Literacy –

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-ESS1-3)*

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-ESS1-3)

HS. Space Systems		
Students who demonstrate understanding can: **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.** [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 sub-atomic processes involved with the sun's nuclear fusion.]		
The performance expectations 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**
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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 world(s). ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS1-1)	**ESS1.A: The Universe and Its Stars** ▪ The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (HS-ESS1-1) **PS3.D: Energy in Chemical Processes and Everyday Life** ▪ Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. *(secondary to HS-ESS1-1)*	**Scale, Proportion, and Quantity** ▪ The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-ESS1-1)
Connections to other DCIs in this grade-band: **HS.PS1.C** (HS-ESS1-1); **HS.PS3.A** (HS-ESS1-1)		
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS1-1); **MS.PS4.B** (HS-ESS1-1); **MS.ESS1.A** (HS-ESS1-1); **MS.ESS2.A** (HS-ESS1-1); **MS.ESS2.D** (HS-ESS1-1)		

Common Core State Standards Connections:
ELA/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)*

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-ESS1-1)
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)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-1)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-1)
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)*
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-ESS1-1)*

HS. Space Systems

Students who demonstrate understanding can:

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. [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).]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

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.

- Construct 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-ESS1-2)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- 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)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- 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)
- 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)

PS4.B Electromagnetic Radiation

- 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 to HS-ESS1-2)*

Crosscutting Concepts

Energy and Matter

- 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)

Connection to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- 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)

Connection to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- 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)

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS1-2); **HS.PS1.C** (HS-ESS1-2); **HS.PS3.A** (HS-ESS1-2); **HS.PS3.B** (HS-ESS1-2); **HS.PS4.A** (HS-ESS1-2)

Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS1-2); **MS.PS4.B** (HS-ESS1-2); **MS.ESS1.A** (HS-ESS1-2)

Common Core State Standards Connections:	
ELA/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-ESS1-2)*
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-2)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-ESS1-2)
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-ESS1-2)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-ESS1-2)*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-2)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. *(HS-ESS1-2)*
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-ESS1-2)*
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-ESS1-2)*

HS. History of Earth

Students who demonstrate understanding can:

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. [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.]

The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ 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) -- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ 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-ESS1-6) ▪ Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (HS-ESS1-6)	**ESS1.C: The History of Planet Earth** ▪ 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. (HS-ESS1-6) **PS1.C: Nuclear Processes** ▪ 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 to HS-ESS1-6)*	**Stability and Change** ▪ Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)

Connections to other DCIs in this grade-band: **HS.PS2.A** (HS-ESS1-6); **HS.PS2.B** (HS-ESS1-6)

Articulation of DCIs across grade-bands: **MS.PS2.B** (HS-ESS1-6); **MS.ESS1.B** (HS-ESS1-6); **MS.ESS1.C** (HS-ESS1-6); **MS.ESS2.A** (HS-ESS1-6); **MS.ESS2.B** (HS-ESS1-6)

Common Core State Standards Connections:

ELA/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-ESS1-6)*

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ESS1-6)

WHST.9-12.1 Write arguments focused on *discipline-specific content.* (HS-ESS1-6)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-ESS1-6),

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-ESS1-6)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling *(HS-ESS1-6)*

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities (HS-ESS1-6)

HSF-IF.B.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. *(HS-ESS1-6)*

HSS-ID.B.6 Represent data on two quantitative variables on a scatter plot, and describe how those variables are related. *(HS-ESS1-6)*

Unit of Study 6: Chemistry and Human Impact

Standards that appear this unit: HS-ESS2-4, HS-ESS2-6, HS-ETS1-1, HS-ETS1-2, HS-ETS1-3, HS-ETS1-4

HS. Weather and Climate

Students who demonstrate understanding can:

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

The performance expectations 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
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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 world(s). ▪ Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4) --------------------------- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4)	**ESS1.B: Earth and the Solar System** ▪ Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(secondary to HS-ESS2-4)* **ESS2.A: Earth Materials and Systems** ▪ The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) **ESS2.D: Weather and Climate** ▪ The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-4), *(secondary to HS-ESS2-2)* ▪ Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-4)	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)

Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-ESS2-4); **HS.PS3.B** (HS-ESS2-4); **HS.LS2.C** (HS-ESS2-4); **HS.ESS1.C** (HS-ESS2-4); **HS.ESS3.C** (HS-ESS2-4); **HS.ESS3.D** (HS-ESS2-4)

Articulation of DCIs across grade-bands: **MS.PS3.A** (HS-ESS2-4); **MS.PS3.B** (HS-ESS2-4); **MS.PS3.D** (HS-ESS2-4); **MS.PS4.B** (HS-ESS2-4); **MS.LS1.C** (HS-ESS2-4); **MS.LS2.B** (HS-ESS2-4); **MS.LS2.C** (HS-ESS2-4); **MS.ESS2.A** (HS-ESS2-4); **MS.ESS2.B** (HS-ESS2-4); **MS.ESS2.C** (HS-ESS2-4); **MS.ESS2.D** (HS-ESS2-4); **MS.ESS3.C** (HS-ESS2-4); **MS.ESS3.D** (HS-ESS2-4)

Common Core State Standards Connections:	
ELA/Literacy –	
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-ESS2-4)*
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-ESS2-4)
MP.4	Model with mathematics. (HS-ESS2-4)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS2-4)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-4)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-4)

HS. Earth's Systems

Students who demonstrate understanding can:

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

The performance expectations 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
Developing and Using Models Modeling in 9–12 builds on K–8 experiences 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 world(s). ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-6)	**ESS2.D: Weather and Climate** ▪ Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6) ▪ Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6)	**Energy and Matter** ▪ The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6)

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS2-6); **HS.PS1.B** (HS-ESS2-6); **HS.PS3.D** (HS-ESS2-6); **HS.LS1.C** (HS-ESS2-6); **HS.LS2.B** (HS-ESS2-6); **HS.ESS3.C** (HS-ESS2-6); **HS.ESS3.D** (HS-ESS2-6)

Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS2-6); **MS.PS3.D** (HS-ESS2-6); **MS.PS4.B** (HS-ESS2-6); **MS.LS2.B** (HS-ESS2-6); **MS.ESS2.A** (HS-ESS2-6); **MS.ESS2.B** (HS-ESS2-6); **MS.ESS2.C** (HS-ESS2-6); **MS.ESS3.C** (HS-ESS2-6); **MS.ESS3.D** (HS-ESS2-6)

Common Core State Standards Connections:

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-ESS2-6)
MP.4	Model with mathematics. (HS-ESS2-6)
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-ESS2-6)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-6)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-6)

HS. Engineering Design

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

The performance expectations 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
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)	**ETS1.A: Defining and Delimiting Engineering Problems** ▪ 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) ▪ 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)	***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ 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)

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:
Physical Science: HS-PS2-3, HS-PS3-3
Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:
Earth and Space Science: HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6
Connections to HS-ETS1.C: Optimizing the Design Solution include:
Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-1)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. *(HS-ETS1-1)*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-ETS1-1)

MP.4 Model with mathematics. (HS-ETS1-1)

HS. Engineering Design		
Students who demonstrate understanding can: **HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**		
The performance expectations 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**
Constructing Explanations and Designing Solutions 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. ▪ 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)	**ETS1.C: Optimizing the Design Solution** ▪ 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)	N/A
Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include: **Physical Science:** HS-PS2-3, HS-PS3-3 *Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:* **Earth and Space Science:** HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6 *Connections to HS-ETS1.C: Optimizing the Design Solution include:* **Physical Science:** HS-PS1-6, HS-PS2-3		
Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-2); **MS.ETS1.B** (HS-ETS1-2); **MS.ETS1.C** (HS-ETS1-2)		
Common Core State Standards Connections: *Mathematics –* **MP.4** Model with mathematics. (HS-ETS1-2)		

HS. Engineering Design

Students who demonstrate understanding can:

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

The performance expectations 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
Constructing Explanations and Designing Solutions 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. ▪ 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)	**ETS1.B: Developing Possible Solutions** ▪ 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)	***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ 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-ETS1-3)

Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:

Physical Science: HS-PS2-3, HS-PS3-3

Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:

Earth and Space Science: HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6

Connections to HS-ETS1.C: Optimizing the Design Solution include:

Physical Science: HS-PS1-6, HS-PS2-3

Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-3); **MS.ETS1.B** (HS-ETS1-3)

Common Core State Standards Connections:

ELA/Literacy –

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

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-3)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-ETS1-3)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(HS-ETS1-3)*

MP.4 Model with mathematics.(HS-ETS1-3)

HS. Engineering Design		
Students who demonstrate understanding can: **HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**		
The performance expectations 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**
Using Mathematics and Computational Thinking 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. ▪ 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)	**ETS1.B: Developing Possible Solutions** ▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)	**Systems and System Models** ▪ 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)
Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include: **Physical Science:** HS-PS2-3, HS-PS3-3 *Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:* **Earth and Space Science:** HS-ESS3-2, HS-ESS3-4, **Life Science:** HS-LS2-7, HS-LS4-6 *Connections to HS-ETS1.C: Optimizing the Design Solution include:* **Physical Science:** HS-PS1-6, HS-PS2-3		
Articulation of DCIs across grade-bands: **MS.ETS1.A** (HS-ETS1-4); **MS.ETS1.B** (HS-ETS1-4); **MS.ETS1.C** (HS-ETS1-4)		
Common Core State Standards Connections: *Mathematics –* **MP.2** Reason abstractly and quantitatively. *(HS-ETS1-4)* **MP.4** Model with mathematics. (HS-ETS1-4)		