KANSAS SCIENCE STANDARDS

High School Chemistry

Unpacked Standards

KANSAS STATE DEPARTMENT OF EDUCATION

Kansas leads the world in the success of each student.

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Contents

Overview

Purpose of the Tool

The science unpacked standards serve as a tool for teachers and school leaders to provide clarity and consistency around implementing the Kansas State Science Standards.

This tool removes the need for teachers to individually "unpack" each standard, and instead provides key experiences, ideas, and concepts to support the work of standards alignment. This tool intentionally breaks down each standard into the three dimensions of science and engineering practices, disciplinary core ideas, and cross cutting concepts to promote three dimensional instruction and assessment.

There is a need for teachers to intentionally work with and make sense of standards. For each standard, it is encouraged to use the "Student-Standard Alignment Tool" on page 11 to intentionally plan for how the standards can be aligned to the students in each unique class. This tool was developed as a way to incorporate analysis of the students' interests and abilities.[1]

The organization of this document follows the recommended scope and sequence that may be found in the Science Graduation Guidance High School Science Scope and Sequence.[2]

The information for this document came from three locations:

- Disciplinary Core Idea Appendix[1]
- Cross Cutting Concepts Appendix[3]
- Science and Engineering Appendix[3]

Kansas Science Standards

The Kansas State standards reflect what students should know and be able to do at each grade level. We do not recommend prioritizing standards at the exclusion of other standards. High quality instruction includes teaching all standards for all students at the appropriate depth and rigor and includes reteaching standards that students have not mastered.

The Next Generation Science Standards (NGSS) standards document and its appendices are the board adopted standards and should supersede this tool. This tool is intended to provide an outline of the vertical alignment of all three dimensions of each standard in this course and to provide clarity in expectations of each standard to ensure appropriate rigor of content.

Kansas NGSS are three-dimensional standards. The Performance Expectation (PE) and its supporting elements are considered the standard. Each standard consists of a Science and Engineering Practice (SEP), a Disciplinary Core Idea (DCI), and a Cross Cutting Concept (CCC). Science is a multi-dimensional discipline and all three dimensions must be considered and taught. Throughout this document, the vertical alignment, K-12, of each dimension is provided for every single standard. The full appendix for the SEPs, DCIs, and CCCs were used to create this document.

1 https://docs.google.com/document/d/1N2ciKuxcglyEhD4s1RwmO_GBvjsLv2dAwrqFFI8JFTY/edit

2 https://community.ksde.gov/LinkClick.aspx?fileticket=wmQyOpyeCBs%3d&tabid=5675&mid=13857

3 https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

OVERVIEW

Unpacked Science Standards

The KSDE science team has unpacked each standard for the 3-dimensions of content. There should not be an expectation for an individual teacher to do the work of unpacking standards in science, but instead to engage deeply with the unpacked science standards to consider how to best plan instruction and assessment of the students in their classrooms. Below is an overview of the process used to systematically identify the key ideas, experiences, and concepts a student needs to show mastery of a standard.

1. Identify the Standards
    - Performance Expectation (PE) and its supporting elements are considered the standard.
        - Each standard consists of a Science and Engineering Practice (SEP), a Disciplinary Core Idea (DCI), and a Cross Cutting Concept (CCC).
        - Students need access to each of the three dimensions of the standard to be successful
    - The standards have been arranged into Standards Bundles that are aligned to KSDE's 2023 Science HS Scope and Sequence Guidance
2. Closely examine **vertical alignment** of the elements of the standard.
    - For each dimension of the standard (DCI, SEP, CCC) the elements from grades K-8 that specifically build towards each specific high school standard have been included in this document.
        - For the DCI elements, the foundational concepts that bridge the gap between prior grade level standards and the grade 9-12 standard were identified as the key information that must be taught before reaching the intent of the standard.
        - For the SEP and CCC dimensions, the differences between prior grade level elements and the 9-12 elements were identified.
3. Determine the key experiences, ideas, and concepts necessary to show mastery
    - Only content that is explicitly indicated in the standard (in the performance expectation and/or defined elements) is included and expected of students.
    - Each standard has key experiences, ideas, and concepts that are necessary to meet the full standard.
        - The key experiences are aligned to the Science and Engineering Practices (SEPs).
        - The key ideas are aligned to the Disciplinary Core Ideas (DCIs).
        - The key concepts are aligned to the Cross Cutting Concepts (CCCs).
4. Identify any additional information needed to understand the unpacked standard
    - This could include decisions that were made about what to include and/or not include in the key experiences, ideas, or concepts.
    - This could include clarification around the intention of the standard as determined during the unpacking process
    - This could include clarification needed

Note: Engineering and Technology Standards (ETS)

ETS are included in NGSS, however each is explicitly tied to an additional performance expectation aligned to either life, physical, or earth and space science and are not intended to be taught in isolation.

The ETS standards were not unpacked in this document. However, components of engineering design were considered when unpacking standards that are linked to ETS and are included in multiple SEPs.

Recommended High School Chemistry Standards Alignment

The graduation requirements outlined by the Kansas Department of Education state that students should earn three credits in the areas of science that include concepts of Life Science (LS), Physical Science (PS) and Earth/ Space Science (ESS). The intent is that all the standards in these areas are mapped to courses at the local level and KSDE does not dictate which courses are required and we recognize that the scope and sequence of courses vary greatly across the state.

Historically across the nation a sequence including the Physics, Biology, and Chemistry has been identified as the most common. for this reason we have bundled the high school standards to align to these three courses and incorporated the Earth and Space standards into discipline courses where it best aligns. The standards included in this document would be most commonly associated with the introductory course called "Chemistry" with course code 03101.

We recognize that student choice and agency is important and as such intend for the recommended standards' bundles to only serve as guidance while making decisions at the local level.

The shaded area below shows an overview of the recommended chemistry standards bundles.

Chemistry (03101)

PERIODIC TABLE AND BONDING

HS-PS1-1

HS-PS1-2

INTERMOLECULAR FORCES

HS-PS1-3

HS-PS2-6

HS-ESS2-5

CHEMICAL REACTIONS and BOND ENERGY

HS-PS1-4

HS-LS1-7

HS-LS1-5

HS-LS2-3

CYCLING AND CONSERVATION OF MATTER

HS-PS1-7

HS-LS1-6

HS-LS2-5

HS-ESS2-6

KINETICS AND EQUILIBRIUM

HS-PS1-6

HS-PS1-5

HS-PS3-4

NUCLEAR ENERGY

HS-ESS1-2

HS-ESS1-1

HS-ESS1-3

HS-PS1-8

Student Standard Alignment Process

(Analyze Students' Interests and Identities.[4])

The standards are the expectation for every student in the state of Kansas. However, we acknowledge that Kansas students are a diverse population. Teachers should think intentionally about how the ideas and experiences that students bring to the classroom relate to the science standards in order to plan for the unique students in your classroom.

Question	Ideas and Experiences
What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?	
Where are students using and experiencing these ideas, practices, and concepts outside of the classroom?	
What questions may students have related to these ideas about how the world works?	
What scaffolding might my students need to fully understand this particular standard?	
What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?	

4 https://dpi.wi.gov/science

Kansas Standards for Science

BUNDLE: Periodic Table and Bonding

Standards included:

HS-PS1-1
HS-PS1-2

FOCUS SEPs:

Constructing Explanations and Designing Solutions
Developing and Using Models

FOCUS DCIs:

PS1.A Structure and Properties of Matter
PS1.B Chemical Reactions
PS1.C Nuclear Processes

FOCUS CCCs:

Patterns
Scale, Proportion and Quantity

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model – based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Use a model to predict the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Look at patterns of atomic structure including number protons, number of electrons, number of electron energy levels, and how the periodic table is organized based on these patterns.
- Explain how the periodic table is a model of subatomic structure which allows prediction and explanation of properties of elements based on an element's location.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.A: Structure of Matter (Includes PS1.C Nuclear Processes)

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.
Grades 3-5	• Matter exists as particles that are too small to see, and so matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.
Grades K-2	• Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.

9-12 GRADE LEVEL ELEMENT(S)

- The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes. Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy to take the molecule apart.

  Foundational concepts necessary for success that are not covered in previous grade bands:

  - Subatomic particles – charges, location, function
  - Electron energy levels, ordering of
  - Types of bonds (ionic, polar covalent, nonpolar covalent, etc.) – types of elements involved and how electrons are transferred or shared
  - How metals and nonmetals react – losing or gaining electrons
  - Valence electrons
  - Atomic radius/size

  Key ideas that students need to apply in order to be successful:

  - Using knowledge of valence electrons to predict number of bonds formed, or to predict ionic charge
  - Using periodic table to identify number of valence electrons in main group elements
  - Using periodic table to predict if an element will be a metal, nonmetal, or metalloid
  - Use periodic table to predict bond type between two elements based on their relative location to one another
  - Explain how properties are either similar (reactivity), same (ionic charge, bonds with oxygen), or dissimilar based on a group of elements' locations on the periodic table.
  - Using periodic table to predict atomic radius/size in order to predict relative metal reactivity
  - Explain why valence electrons are responsible for various properties (reactivity, types of bonds formed, number of bonds formed)
  - Identify when patterns of properties will be similar/same and when they will change
    - In main group, same column = same charge
    - Same column, elements react in similar ways but likelihood of reactivity changes
    - As you go across the periodic table, properties gradually change
      - Ionization energy (reactivity, types of bonds)
      - Electronegativity (reactivity, types of bonds)

TARGET CROSS CUTTING CONCEPT PROGRESSION

Scale, Proportion and Quantity

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns can be used to identify cause and effect relationships.
Grades 3-5	• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.
Grades K-2	• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Patterns can exist across the components of a system.
- The patterns at different scales can be used as evidence of the cause/effect relationship.
- The patterns are used to explain the phenomenon (as opposed to describe).

Key ideas that students need access in order to be successful:

- Finding/recognizing patterns in data sets (e.g., periodic table showing common charges, showing atomic radius, showing electronegativity, etc.).
- Looking at patterns in atomic structure as represented on the periodic table as evidence of causality (e.g., radius and number of valence electrons changes across a row which impacts reactivity).

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-PS1-2

Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, itrends 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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
Grades 3-5	• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
Grades K-2	• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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.

What ideas or skills are truly unique to this grade band?

- Explanations are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Students determine best evidence sources to support their explanation
- Evidence can include models, theories, simulations, peer review
- Revision of explanations based on further evidence or peer review
- Student developed evidence can include investigations, models, theories, simulations, peer review

Key experiences students need access to in order to be successful:

- Evaluate multiple sources of evidence (provided or student generated) for each source's relevance to the explanation requested.
- Write explanations of phenomena or observed data.
- Revise explanations of phenomena or observed data – both peer review and revision after obtaining new evidence.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.A: Structure and Properties of Matter and PS1.B: Chemical Reactions

PS1.A Structure and Properties of Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.
Grades 3-5	• Matter exists as particles that are too small to see, and so matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.
Grades K-2	• Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

PS1.B Chemical Reactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.
Grades 3-5	• Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.
Grades K-2	• Heating and cooling substances cause changes that are sometimes reversible and sometimes not.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Subatomic particles – charges, location, function
- Electron energy levels, ordering of types of bonds (ionic, polar covalent, nonpolar covalent, etc.) – types of elements involved and how electrons are transferred or shared
- How metals and nonmetals react – losing or gaining electrons
- Valence electrons
- Atomic radius/size

Key ideas that students need to apply in order to be successful

- Predict binary ionic formulas using main group elements.
- Predict binary covalent formulas using main group elements.
- Justify predictions with explanation based on knowledge of valence electrons, periodic trends, observed chemical properties.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns can be used to identify cause and effect relationships.
Grades 3-5	• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.
Grades K-2	• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Patterns can exist across the components of a system.
- The patterns at different scales can be used as evidence of the cause/effect relationship.
- The patterns are used to explain the phenomenon (as opposed to describe).

Key ideas that students need access in order to be successful:

- Finding/recognizing patterns in data sets (e.g., periodic table showing common charges, showing electronegativity, number of valence electrons etc)
- Looking at patterns in atomic structure as represented on the periodic table as evidence of causality (e.g., radius and number of valence electrons changes across a row which impacts reactivity)
- Patterns in types of elements and resulting bond types they can form (ionic vs. covalent)
- Compare/contrast elements with the same number of valence electrons and how they can participate in both ionic and covalent bonds depending on the other element involved.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Intermolecular Forces

Standards included:

HS-ESS2-5
HS-PS1-3
HS-PS2-6

FOCUS SEPs:

Obtaining, Evaluating, and Communicating Information
Planning and Carrying Out Investigations

FOCUS DCIs:

ESS2.C	The Roles of Water in Earth's Surface Processes
PS1.A	Structure and Properties of Matter
PS2.B	Types of Interactions

FOCUS CCCs:

Patterns
Structure and Function

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).*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Planning and Carrying Out Investigations

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
Grades 3-5	• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
Grades K-2	• With guidance, plan and conduct an investigation in collaboration with peers (for K). • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or skills are truly unique to this grade band?

- Decide on types and accuracy of data needed to produce reliable measurements
- Consider limitations on the precision of the data (e.g., number of trials, cost, risk, time)
- Refine the design based on the limitations identified.
- Planning design to account for:
  - Accuracy of data
  - Reliability of measurements
  - Limitations on precision of data
- Refining experimental design as needed

Key experiences students need access to in order to be successful:

- Identify the purpose of the investigation in order to effectively plan
- Experience planning an investigation where the procedure is justified to explain the methods of data collection to account for accuracy and reliability and acknowledge any limitations.
- Experience collecting both qualitative and quantitative data in order to analyze the data and make connections between water's properties and the physical changes evident on earth.
- Writing procedures/directions for activities that use only the provided materials and that can be followed by anyone, not just partners or themselves.
- Conduct the investigation following the procedures/directions as planned
- Experience with laboratory investigations specifically related to the DCI that include chemical and mechanical investigations of the properties of water.
    - Examples of mechanical investigations could 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 could 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).

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS2.C: The Roles of Water in Earth's Surface Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of sea water drive interconnected ocean currents. Water movement causes weathering and erosion, changing landscape features.
Grades 3-5	• Most of Earth's water is in the ocean and much of the Earth's freshwater is in glaciers or underground.
Grades K-2	• Water is found in many types of places and in different forms on Earth.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Water properties including:
    - Water's high heat capacity properties
    - Water density differences in solid and liquid states
    - Water's ability to transmit sunlight
    - Polarity
    - Water property of expanding upon freezing,
    - Water's ability to dissolve and transport materials
    - Water's ability to lower the viscosities and melting points of rocks.
- The properties of water related to energy transfer impacts temperature and weather patterns
- Landscape features can be changed through the movement and deposition of materials as water flows.

Key ideas that students need to apply in order to be successful:

- Water's high heat capacity influences Earth's surface in many ways

    - Coastal areas have a more temperate climate based on latitude than they otherwise would because the large body of water takes a lot of energy to heat/cool
    - Desert areas have a large fluctuation in daytime and nighttime temperatures because the lack of water in the local area does not allow the air to retain the sun's heat when it sets
    - When lava/melted rocks hit water, the water is able to absorb large amounts of heat rapidly cooling the rocks lowering their viscosity and as a result slowing their flow
- Moving water can carry solids, either dissolved or not
    - Moving water will deposit solids at various points changing the land surface
- Water can dissolve many ionic and polar substances
    - Many rocks and landforms are made of ionic minerals that will dissolve in water
    - As running water dissolves the substances the surface of the Earth changes
    - The longer the water runs through an area, the larger and more permanent the change
    - If/when the water evaporates the dissolved substances may deposit in large quantities in the area.
- Water density changes based on temperature
    - Liquid water is more dense than solid – Water expands upon freezing
    - Water freezing on/in land can result in landform changes due to the expansion of the water
    - Sea ice that melts will not cause a rise in sea levels because liquid water is less dense than ice
    - Landform ice that melts and runs into the oceans will cause an increase in sea levels because it is not currently in the ocean
- Explain how water's various properties including polarity, density, deposition, capillary action, etc, influences the structure of Earth at and below the surface.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Structure and Function

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.
Grades 3-5	• Different materials have different substructures, which can sometimes be observed. • Substructures have shapes and parts that serve functions.
Grades K-2	• The shape and stability of structures of natural and designed objects are related to their function(s).

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Molecular structure of materials in objects and/or systems.
- Properties of natural objects are based on structure.
- Information about the function and/or properties of a natural object can be inferred from their structure including different components of the object and/or the molecular substructure of the object.

Key ideas that students need access in order to be successful:

- Students need to be able to identify and describe key components of earth's surface structure and how that structure can change or has changed over time.
- Infer how the molecular structure of water explains water's properties.
- Infer how the properties of water explain the water processes that change earth's surface.
- Make connections between water processes and the structure of earth's surface.
- Identify how water processes can change earth's surface.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Planning and Carrying Out Investigations

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
Grades 3-5	• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
Grades K-2	• With guidance, plan and conduct an investigation in collaboration with peers (for K). • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

  What ideas or skills are truly unique to this grade band?

  - Decide on types and accuracy of data needed to produce reliable measurements
  - Consider limitations on the precision of the data (e.g., number of trials, cost, risk, time)
  - Refine the design based on the limitations identified.
  - Planning design to account for:
    - Accuracy of data
    - Reliability of measurements
    - Limitations on precision of data
  - Refining experimental design as needed.

Key experiences students need access to in order to be successful:

- Identify the purpose of the investigation in order to effectively plan
- Experience planning an investigation where the procedure is justified to explain the methods of data collection to account for accuracy and reliability and acknowledge any limitations.
- Experience with laboratory activities where data is highly variable among students so that they see the need for accuracy, reliability, or reproducibility in their own experimental design
- Writing procedures/directions for activities that use only the provided materials and that can be followed by anyone, not just partners or themselves.
- Experience in planning investigations that must be refined/modified after initial data collection.
    - Students need to know that they can go back and do more, try something else if they don't get enough or the type of data they initially thought they would.
- Experience with laboratory investigations specifically related to the Disciplinary Core Idea so that they have an idea of types of things that can reasonably be done in their specific classroom situation
    - Example: testing surface tension, melting substances and measuring temperature or time, boiling/evaporating substances, etc.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.A: Structure and Properties of Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.
Grades 3-5	• Matter exists as particles that are too small to see, and so matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.
Grades K-2	• Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.

9-12 GRADE LEVEL ELEMENT(S)

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Subatomic particles – charges, location, function
- Electron energy levels, ordering of:
    - Types of bonds (ionic, polar covalent, nonpolar covalent, etc.) – types of elements involved and how electrons are transferred or shared
    - How metals and nonmetals react – losing or gaining electrons.
    - Valence electrons
    - How ions are formed
- Attraction vs. repulsion of atoms, ions, molecules, and networked materials
- Describe bulk properties like melting point, boiling point, vapor pressure, surface tension, etc.

Key ideas that students need access in order to be successful:

- Identify which bulk scale properties are related to strength of particle attraction in a material
- Identify relative strength of attraction among a list/group of materials based on bulk scale property data – order items from weakest to strongest attraction of particles.
- Describe like materials and dissimilar materials attractions in terms of bulk properties AND particle attraction
  - Example: two samples at room temperature, one is liquid and one is solid, the liquid is polar and the solid is non-polar. However, by definition of being solid the nonpolar material has stronger attraction between its particles than the polar liquid.
- Use measured bulk scale properties to identify strength of electrical forces between the particles in the material
  - Example: Materials with a higher melting/boiling point will have stronger attraction between particles in the material.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Patterns

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns can be used to identify cause and effect relationships.
Grades 3-5	• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.
Grades K-2	• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Patterns can exist across the components of a system
- The patterns at different scales can be used as evidence of the cause/effect relationship
- The patterns are used to explain the phenomenon (as opposed to describe).

Key concepts that students need access in order to be successful:

- Asked to make connections between what is observed at the bulk scale and what is happening at the atomic scale.
- Make observations at the bulk scale.
- Finding/recognizing patterns in data to determine which observations can serve as evidence of strength of intermolecular forces at the atomic scale.
- Explain what is happening at the atomic scale using the patterns identified from observations.
- Explain the patterns in bulk properties (i.e., melting/boiling points) using information about particle level attractions (i.e., bond types).

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Obtaining, Evaluating, and Communicating Information

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.
Grades 3-5	• Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.
Grades K-2	• Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.

9-12 GRADE LEVEL ELEMENT(S)

- 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 oral, graphical, textual and mathematical).

What ideas or skills are truly unique to this grade band?

- Communicating in multiple formats
- Communication can be mathematical

Key experiences students need access to in order to be successful:

- Supports for organizing thinking to identify key ideas before communicating.
- Determining best methods of communication for the ideas related to the topic and intended audience.
  - Students need to choose at least two different formats to communicate information about the structure, properties, and design of chosen materials.
  - Formats can include: oral, graphical, textual, mathematical.
- Technical writing experiences.
  - As needed graphic organizers and/or other scaffolds for organizing thinking.
- Oral presentation experiences.
  - As needed graphic organizers and/or other scaffolds for organizing thinking.
- Organizing information graphically.
  - i.e., if using a slide style or infographic format having it organized in a visually engaging manner that is accessible to all who will be receiving the information; or ensuring all graphics are correct, legible, relevant, proper citations, in a poster or paper presentation etc.
- Students cite information used as appropriate.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS2.B: Types of Interactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.
Grades 3-5	• The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.
Grades K-2	• Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Atomic scale structure
- Attraction and repulsion as descriptors of force direction.
- Properties of different types of compounds.
- Chemical reactions change properties of matter.
- Intermolecular forces
- Macroscale forces related to electrostatic interactions.
- Comparing materials
- Electrons can move freely between atoms of conductive metals.
- Effects that attractive and repulsive electrical forces between particles have on the arrangement (structure) of the chosen designed material(s) of compounds (e.g., solids, liquids, gasses, network solid, polymers).

Key ideas that students need to apply in order to be successful:

- Making connections between the structures at atomic scale and forces seen at the macroscale
- Given a specific molecular structure students identify the attractive and repulsive forces present at an intermolecular level
- Given a specific molecular structure students identify the expected properties based on structure
- Explain how the structure and properties of a material contribute to the designed function of the material (i.e.: flexibility, conductivity, etc.)
- Explain how the structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material(s)
- How the material's properties make it suitable for use in its designed function.
- Describe how the molecular structure of the chosen designed material(s) (using a representation appropriate to the specific type of communication — e.g., geometric shapes for drugs and receptors, ball and stick models for long-chained molecules) will explain interactions of the material.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Structure and Function

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.
Grades 3-5	• Different materials have different substructures, which can sometimes be observed. • Substructures have shapes and parts that serve functions.
Grades K-2	• The shape and stability of structures of natural and designed objects are related to their function(s).

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Investigating or designing new systems or structures require a detailed examination
- Connections of the components reveal its function and/or solve a problem.

Key concepts that students need access in order to be successful:

- Identify the design component(s) necessary for the desired function of the material
- Identify how the properties and structure of the material support the function of the material (i.e., Power cords are metal and plastic (or fabric), the metal is what carries the electricity and the plastic/fabric is there to protect me from electrocution but both have to be flexible to have a usable function)
- Describe how the function of the material solves a design problem or need.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Chemical Reactions and Bond Energy

Standards included:

HS-PS1-4
HS-LS1-7
HS-LS1-5
HS-LS2-3

FOCUS SEPs:

Developing and Using Models
Constructing Explanations and Designing Solutions

FOCUS DCIs:

LS1.C	Organization for Matter and Energy Flow in Organisms
LS2.B	Cycles of Matter and Energy Transfer in Ecosystems
PS1.A	Structure and Properties of Matter and
PS1.B	Chemical Reactions

FOCUS CCCs:

Energy and Matter

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Information defining system and surroundings during photosynthesis.
- Experience with making and using diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is converted and conserved
- Model the chemical process of photosynthesis to show changes in energy and types of energy.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

LS1.C: Organization for Matter and Energy Flow in Organisms

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.
Grades 3-5	• Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.
Grades K-2	• Animals obtain food they need from plants or other animals. Plants need water and light.

9-12 GRADE LEVEL ELEMENT(S)

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Activation energy is needed to start a chemical reaction
- Chemical energy is potential energy stored in a compound that has the potential to be released as heat in a future chemical reaction that would result in more stable products
- Energy is conserved through energy transfer and conversions.

Key concepts that students need access in order to be successful:

- Students need to show that the sun's energy is needed to convert carbon dioxide and water into glucose and oxygen by using energy to break the bonds of these stable reactant molecules (CO_2 and H_2O)
- The formation of glucose and oxygen releases less energy than was provided by the sun because these products have a higher potential energy than the reactants (chemical energy).
- Students need to explain that some of the sun's energy is converted into chemical energy which is stored potential energy for future chemical reactions

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces,be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Energy (and matter) flows into and out of a system

Key concepts that students need access in order to be successful:

- Tracking changes in energy throughout a chemical reaction.
- Identifying when energy is being converted and stored by the system of a chemical reaction
- Clear identification of system vs. surroundings in a chemical reaction (i.e., the container, the room, you, the thermometer, are all surroundings)

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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**.]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Information defining system and surroundings during cellular respiration.
- Per the DCI above, the system is the interacting molecules, the surroundings by default are everything else (body, the environment, etc.)
- Experience with making and using diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is converted and conserved
- Model the (simplified) chemical process of cellular respiration to show changes in energy and types of energy.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

LS1.C: Organization for Matter and Energy Flow in Organisms

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.
Grades 3-5	• Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.
Grades K-2	• Animals obtain food they need from plants or other animals. Plants need water and light.

9-12 GRADE LEVEL ELEMENT(S)

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Cellular respiration is a series of complex chemical reactions that are represented by the simplified, net reaction of the combustion of glucose: $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$
- Oxygen as a reactant for cellular respiration
- Energy is used to maintain body temperature and to perform functions of life
- Breaking bonds requires energy and forming bonds releases energy
- Bond energy is the amount of energy needed to break the bond
- Relative bond strength of reactants and products determines if a reaction releases or absorbs energy

Key concepts that students need access in order to be successful:

- Identify bond energy of various molecules involved in cellular respiration – ex: glucose, oxygen, carbon dioxide, water
- Identify that molecules with higher bond energy (water and carbon dioxide) are more stable
- Identify that the formation of the more stable carbon dioxide and water molecules releases energy
- Describe the process of how cellular respiration releases energy – ex: glucose and oxygen bonds are broken and the formation of carbon dioxide and water (products) releases excess energy to the surroundings in the organism
- Heat that is released from this chemical process is used to maintain body temperature as the body constantly "loses" heat to the surroundings.

Additional information:

- Because cellular respiration is actually a series of complex chemical reactions high school students will not be able to accurately calculate the energy released by cellular respiration.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces,be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- Energy cannot be created or destroyed - it only moves between one place and another place, between objects and/or fields, or between systems.

What ideas or concepts are truly unique to this grade band?

- Energy (and matter) flows into and out of a system
- Energy cannot be destroyed

Key concepts that students need access in order to be successful:

- Tracking the energy flow into and out of the system of the net cellular respiration chemical reaction.
- Identifying when energy is being converted and stored or released by the system of a chemical reaction
- During the interim chemical steps in the cellular respiration process some energy is transferred through the formation of a new molecule that can be used as fuel for cellular processes.
- Some energy is converted to heat for maintaining body temperature, however it is not “lost” as it still exists in some form in the surroundings.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students’ interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-LS2-3

Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. [*Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.*] [**Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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. • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events.
Grades 3-5	• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
Grades K-2	• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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.

What ideas or skills are truly unique to this grade band?

- Explanations are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Students determine best evidence sources to support their explanation
- Evidence can include models, theories, simulations, peer review
- Revision of explanations based on further evidence or peer review
- Student developed evidence can include investigations, models, theories, simulations, peer review

Key experiences students need access to in order to be successful:

- Evaluate multiple sources of evidence (provided or student generated) for each source's relevance to the explanation requested.
- Write explanations of phenomena or observed data
- Revise explanations of phenomena or observed data – both peer review and revision after obtaining new evidence

TARGET DISCIPLINARY CORE IDEA PROGRESSION

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.
Grades 3-5	• Matter cycles between the air and soil and among organisms as they live and die.
Grades K-2	• [Content found in LS1.C and ESS3.A]

9-12 GRADE LEVEL ELEMENT(S)

- Cellular respiration (including anaerobic processes) provide most of the energy for life processes.[1]

Foundational concepts necessary for success that are not covered in previous grade bands:

- All matter is made of atoms
- Matter cannot be created or destroyed
- Anaerobic respiration occurs in oxygen deficient environment and
- Aerobic respiration is what we traditionally call cellular respiration and is done in the presence of oxygen
- The sugar molecule needed as a reactant for respiration comes from the process of photosynthesis
- The energy released through cellular respiration drives the chemical processes in living organisms
- The processes of life require atoms beyond the basic glucose molecule that is used to start respiration (i.e., nitrogen, phosphorus, sodium, potassium, etc.) that must come from food
- Breaking bonds requires energy and forming bonds releases energy
- Bond energy is the amount of energy needed to break the bond
- Bond strength of reactants and products determines if a reaction releases or absorbs energy

Key concepts that students need access in order to be successful:

- All forms of respiration (aerobic and anaerobic) produce energy that can be used by living things
- The energy produced in respiration can be traced back to energy from the sun.
- The stored chemical potential energy in glucose is transformed into a new molecule that can be used as fuel for cellular processes during respiration.
- The net aerobic reaction produces more stable products and thus more energy than the anaerobic reaction
- Aerobic respiration can be represented by the following equation: $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$
- Anaerobic respiration can be represented by the following equation: $C_6H_{12}O_6 \rightarrow C_3H_6O_3$.
- All living things are made of atoms that make up complex carbon-based molecules and the rearranging of atoms to form the molecules needed for life's processes is driven by the chemical potential energy stored as glucose.
- The atoms found in a living thing continue to go through chemical processes and rearrange to form different molecules for various life functions as long as there is sufficient energy.

1 The words "Photosynthesis" and" were deleted from the DCI sentence because nothing about the performance expectation discusses photosynthesis and it is not needed for either aerobic or anaerobic respiration.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. • Matter is transported into, out of, and within systems. Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces,be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- Energy drives the cycling of matter within and between systems.

What ideas or concepts are truly unique to this grade band?

- Energy drives the cycling of matter
- Matter can cycle between different systems

Key concepts that students need access in order to be successful:

- Students need the opportunity to visualize the role of energy in breaking bonds to allow atoms to rearrange into different molecules
- Describe that in order for matter to move or change energy must be supplied
- The energy that drives cellular respiration can be traced back to the sun
- Explain that when matter moves out of a system it transfers to a different system because matter is conserved.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Experimentation or information defining system and surroundings during chemical reactions.
- Experience with making and using molecular-level drawings and diagrams of reactions, graphs showing the relative bond energies of reactants and products, and representations showing energy is conserved
- Model different stages of chemical reactions to show changes in energy and types of energy.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.A: Structure and Properties of Matter and PS1.B: Chemical Reactions

PS1.A Structure and Properties of Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.
Grades 3-5	• Matter exists as particles that are too small to see, and so matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.
Grades K-2	• Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

PS1.B Chemical Reactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.
Grades 3-5	• Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.
Grades K-2	• Heating and cooling substances cause changes that are sometimes reversible and sometimes not.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

  Foundational concepts necessary for success that are not covered in previous grade bands:

  - Compounds are formed by chemically combining 2 or more elements.
  - A chemical reaction occurs when bonds are broken and/or new bonds are formed.
  - Clear understanding of system vs. surroundings in a chemical reaction (i.e., the container, the room, you, the thermometer, are all surroundings; the system is the individual particles that are reacting)
  - Different types of energy that can be transferred to and from in a chemical reaction (potential chemical energy, bond energy, kinetic energy, etc.)
  - Energy is conserved in a chemical reaction

Key concepts that students need access in order to be successful:

- Energy changes that are happening in a chemical reaction based on collected or presented data
  - If temperature rises, what must be the change in bond energy
  - How bond energy correlates to compound stability
  - How particle speed changes when breaking bonds vs. forming bonds.
  - How overall temperature change from beginning to end of a reaction can be used to deduce whether reactants or products were more stable (which had more or less bond energy)
  - Show the conservation of energy through different forms of energy

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces,be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Energy (and matter) flows into and out of a system

Key concepts that students need access in order to be successful:

- Tracking changes in energy throughout a chemical reaction.
- Identifying when energy is being released or absorbed by the system of a chemical reaction
- Clear identification of system vs. surroundings in a chemical reaction (i.e., the container, the room, you, the thermometer, are all surroundings)

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Cycling and Conversion of Matter

Standards included:

HS-ESS2-6
HS-LS1-6
HS-LS2-5
HS-PS1-7

FOCUS SEPs:

Constructing Explanations and Designing Solutions
Developing and Using Models
Using Mathematics and Computational Thinking

FOCUS DCIs:

ESS2.D	Weather and Climate
LS1.C	Organization for Matter and Energy Flow in Organisms
LS2.B	Cycles of Matter and Energy Transfer in Ecosystems
PS1.B	Chemical Reactions
PS3.D	Energy in Chemical Processes

FOCUS CCCs:

Energy and Matter
Systems and System Models

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.*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Multiple systems represented

Key experiences students need access to in order to be successful:

- Identifying how the different systems (biosphere, atmosphere, hydrosphere, and geosphere) interact.
- Modeling how carbon moves between two or more systems.
- Use evidence to show the relative concentration of carbon in each of the spheres.

Additional information:

- HS-LS2-5 is tangential for SEP and DCI and it is strongly recommended that these standards be taught together and can be assessed in one model

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS2.D: Weather and Climate

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. • Because these patterns are so complex, weather can only be predicted probabilistically. • The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.
Grades 3-5	• Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. • Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years.
Grades K-2	• Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.

9-12 GRADE LEVEL ELEMENT(S)

- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Carbon cycle
- Exchange among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- Photosynthesis
- Cellular respiration
- Combustion

Key concepts that students need access in order to be successful:

- Identify where carbon exists in molecules in each of the spheres
- Describe how carbon is converted between glucose and carbon dioxide, and back again, through cellular respiration and photosynthesis.
- Identify multiple ways that carbon cycles between the spheres which can include:
  - Carbon moves from the atmosphere (CO_2) to biosphere through the process of photosynthesis ($C_6H_{12}O_6$)
  - Carbon moves from the biosphere to the atmosphere through the process of respiration (CO_2)
  - Carbon is moved from the biosphere to the atmosphere when organic matter is burned (i.e., forest fires)
  - Carbon is moved from the biosphere to the atmosphere during decomposition of organic matter
  - Carbon moves from the atmosphere to the hydrosphere and back through diffusion of CO_2 between bodies of water and the air
  - Carbon moves from the biosphere to the geosphere through the formation of fossil fuels (time, heat, pressure needed)

    - Carbon moves from the geosphere to the atmosphere through the combustion of fossil fuels (coal, oil, gas)
    - Carbon moves from the geosphere to the atmosphere when stored carbon is released during permafrost thawing
    - Carbon dioxide in the atmosphere was released through cellular respiration and can be dissolved in water in oceans and other water sources.
    - Carbon dioxide moves from the geosphere to the atmosphere during volcanic eruptions
    - Carbon moves from the geosphere to the hydrosphere through the process of erosion
    - Carbon moves from the biosphere to geosphere through the rock cycle
- The carbon that can be stored in the geosphere as a carbon sink in the form of fossil fuels and biological waste is the product of photosynthesis that was stored in living organisms.
- Human use of fossil fuels has led to an increase in production of CO_2 since the industrial revolution.
- The relative concentration of CO_2 in the atmosphere has increased more than can be explained by population growth alone, therefore human actions must be causing increases in CO_2 in the atmosphere.
- The increase in carbon dioxide concentration in the atmosphere due to human activity has had an effect on climate.

Additional information:

- HS-LS2-5 is tangential for SEP and DCI and it is strongly recommended that these standards be taught together and can be assessed in one model.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
Grades 3-5	• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. • Matter is transported into, out of, and within systems.
Grades K-2	• Objects may break into smaller pieces,be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- The total amount of energy and matter in closed systems is conserved.

What ideas or concepts are truly unique to this grade band?

- Total amount of energy and matter is conserved
- Closed systems

Key concepts that students need access in order to be successful:

- The earth is considered a closed system with each sphere acting a component of the system
- Identifying how the different systems (biosphere, atmosphere, hydrosphere, and geosphere) interact.
- Modeling how the interaction between systems moves carbon (matter)
- Use evidence of photosynthesis and cellular respiration to model carbon (matter) moving between systems (spheres).
- If the relative abundance of carbon in one sphere changes, there must be an equal and opposite change to the abundance of carbon in the other sphere to maintain conservation of matter.
- The carbon used and released by humans can be traced through a cycle involving fossil fuels in the geosphere which are combusted by human activity and carbon is released to the atmosphere. Some of this carbon is then cycled into the hydrosphere when it is dissolved into the water.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
Grades 3-5	• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
Grades K-2	• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or skills are truly unique to this grade band?

- Explanations are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Students determine best evidence sources to support their explanation
- Evidence can include models, theories, simulations, peer review
- Revision of explanations based on further evidence or peer review
- Student developed evidence can include investigations, models, theories, simulations, peer review

Key experiences students need access to in order to be successful:

- Evaluate multiple sources of evidence (provided or student generated) for each source's relevance to the explanation requested.
- Write explanations of phenomena or observed data
- Revise explanations of phenomena or observed data – both peer review and revision after obtaining new evidence.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

LS1.C: Organization for Matter and Energy Flow in Organisms

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.
Grades 3-5	• Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.
Grades K-2	• Animals obtain food they need from plants or other animals. Plants need water and light.

9-12 GRADE LEVEL ELEMENT(S)

- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Foundational concepts necessary for success that are not covered in previous grade bands:

- The carbon, hydrogen, and oxygen atoms from sugar molecules formed in or ingested by an organism and the atoms from the sugar can be the same atoms found in amino acids and other large carbon-based molecules.
- Chemical elements can bond to form molecules.
- Carbon can form large molecules with repeating patterns.
- Larger carbon-based molecules and amino acids can be a result of chemical reactions between sugar molecules (or their component atoms) and other atoms.
- Sugar molecules are composed of carbon, oxygen, and hydrogen atoms.
- Amino acids and other complex carbon-based molecules are composed largely of carbon, oxygen, and hydrogen atoms.
- In a chemical reaction bonds are broken, atoms rearrange, and new bonds are formed
- The overall chemical reaction used to represent cellular respiration is a simplified explanation for a complicated multi-step process.

Key concepts that students need access in order to be successful:

- Identify bond energy of various molecules involved in cellular respiration – ex: glucose, oxygen, carbon dioxide, water.
- Identify that molecules with higher bond energy (water and carbon dioxide) are more stable.
- Identify that the formation of the more stable carbon dioxide and water molecules releases energy.
- Describe the process of how cellular respiration releases energy – ex: glucose and oxygen bonds are broken and the formation of carbon dioxide and water (products) releases excess energy to the surroundings in the organism.
- Heat that is released from this chemical process is used to maintain body temperature as the body constantly "loses" heat to the surroundings.

Additional information:

- In the context of a chemistry classroom this PE is a conceptual application of conservation of matter (atoms):
  - The chemical processes involve complex multi-step chemical processes so we are focused on the type of atoms found in the starting (glucose) and ending molecules (larger carbon molecules like amino acids)
  - PS1-7 is the claim that atoms, and therefore mass, are conserved during a chemical reaction. This standard can be used as a conceptual application (used for formative assessment) of PS1-7

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes.
Grades 3-5	• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. • Matter is transported into, out of, and within systems.
Grades K-2	• Objects may break into smaller pieces,be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Changes of (energy) and matter

Key concepts that students need access in order to be successful:

- Molecules that make living organisms are made of the matter that enters the system
- Compare a macromolecule to a sugar molecule to identify similarities and differences
- Explain that the macromolecule's carbon, hydrogen, and oxygen come from sugars
- Describe that some of the matter in macromolecules can be tracked to sugar molecules that are broken down and rearranged in chemical processes
- Describe that if a macromolecule includes elements that are not carbon, hydrogen, or oxygen there must be an additional source other than glucose.

Additional information:

- Key experiences described for the CCC for this PE are focused on the flow of matter because the performance expectation is focused on the flow of matter.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

HS-LS2-5

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [*Clarification Statement: Examples of models could include simulations and mathematical models.*] [**Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]**

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Multiple systems represented

Key experiences students need access to in order to be successful:

- Identifying how the different systems (biosphere, atmosphere, hydrosphere, and geosphere) interact.
- Modeling how carbon moves between two or more systems.
- Create a model using the inputs and outputs of photosynthesis and cellular respiration to show carbon moving between systems (spheres).

Additional information:

- HS-ESS2-6 is tangential for SEP and DCI and it is strongly recommended that these standards be taught together and can be assessed in one model.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems and PS3.D: Energy in Chemical Processes

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.
Grades 3-5	• Matter cycles between the air and soil and among organisms as they live and die.
Grades K-2	

9-12 GRADE LEVEL ELEMENT(S)

- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

PS3.D: Energy in Chemical Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.
Grades 3-5	• Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food.
Grades K-2	• Sunlight warms Earth's surface.

9-12 GRADE LEVEL ELEMENT(S)

- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (Secondary).

  Foundational concepts necessary for success that are not covered in previous grade bands:

  - Carbon cycle
  - Exchange among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
  - Photosynthesis
  - Cellular respiration

  Key concepts that students need access in order to be successful:

  - Identify where carbon exists in each of the spheres
    - Ex: atmosphere carbon dioxide, methane; geosphere: fossil fuels, rocks; hydrosphere: carbon dioxide and shells; biosphere: glucose and carbon-based macromolecules
  - Describe how carbon is converted between glucose and carbon dioxide, and back again, through cellular respiration and photosynthesis.
  - In photosynthesis, the solar energy is converted and stored in the glucose created.
  - Solar energy is then passed along through the glucose during cellular respiration giving energy to organisms.

- Carbon dioxide in the atmosphere was released through cellular respiration and can be dissolved in water in oceans and other water sources.
- The carbon that can be stored in the geosphere as a carbon sink in the form of fossil fuels and biological waste is the product of photosynthesis that was stored in living organisms.

Additional information:

- HS-ESS2-6 is tangential for SEP and DCI and it is strongly recommended that these standards be taught together and can be assessed in one model

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy, matter, and information flows within systems.
Grades 3-5	• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions. • Develop and/or use models to describe and/or predict phenomena. 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.
Grades K-2	• Objects and organisms can be described in terms of their parts. • Systems in the natural and designed world have parts that work together.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Models can be physical, mathematical, or computer models
- Using models to consider different scales
- Models are used to simulate (vs. represent) a system and its interactions.

Key concepts that students need access in order to be successful:

- Identifying how the different systems (biosphere, atmosphere, hydrosphere, and geosphere) interact.
- Modeling how the interaction between systems moves carbon
- Use evidence of photosynthesis and cellular respiration to model carbon moving between systems (spheres).
- Using the scale of an individual chemical reaction to explain and represent what happens at a macroscale in the spheres.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Using Mathematics and Computational Thinking

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Use mathematical representations to describe and/or support scientific conclusions and design solutions.
Grades 3-5	• Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.
Grades K-2	• Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.

9-12 GRADE LEVEL ELEMENTS

- Use mathematical representations of phenomena to support claims.

What ideas or skills are truly unique to this grade band?

- Using mathematical representations of phenomena.
- Supporting claims

Key experiences students need access to in order to be successful:

- Have multiple experiences where students convert units and know when and how to use unit relationships appropriately.
- Describe and/or explain their own thinking for the multi-step process used to solve mathematical representations of the chemical reaction.
- Demonstrate using mathematical representations that atoms and therefore mass are conserved in a chemical reaction when defining reactants and/or products using any possible combination of units – moles, grams, particles.
- Describe how the mathematical representations support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
    - Ex: Perhaps using stoichiometry to calculate the amount of mass of a reaction that is converted to a gas to prove that matter is conserved.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.B: Chemical Reactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.
Grades 3-5	• Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.
Grades K-2	• Heating and cooling substances cause changes that are sometimes reversible and sometimes not.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- The mole is a unit of measurement at the macroscopic scale
- Avogadro's number is a constant used to convert between atoms (or particles) and moles
- Atomic Mass is a unit of measurement of atoms in a compound
- Molar Mass is a unit of measurement of a mole of atoms in a compound
- Chemical reactions can be represented by chemical equations and can be defined as balanced or unbalanced equations
- Mole conversions (grams to/from mole of a single substance, particles to/from mole of a single substance)

Key concepts that students need access in order to be successful:

- Explain how a balanced chemical equation shows conservation of atoms
- Explain how the mole is used to describe the macroscopic quantities of chemicals due to the small nature of atoms.
- Explain that since atoms have mass, if atoms are being conserved, then mass is being conserved, and the same if scaled up using moles.
- Explain how the ratios/coefficients of chemicals in a balanced equation can be used to predict quantities of chemical substances in the equation given a quantity of one of the chemical substances.
- Explain how you can use molar masses to predict quantities in a chemical reaction when given (or needing) the mass of one of the substances in the reaction
- Explain how you can use Avogadro's number to predict quantities in a chemical reaction when given (or needing) the number of particles of one substance in the reaction.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes.
Grades 3-5	• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. • The total weight of the substances does not change. This is what is meant by conservation of matter. • Matter is transported into, out of, and within systems.
Grades K-2	• Objects may break into smaller pieces, be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- The total amount of energy and matter in closed systems is conserved.

What ideas or concepts are truly unique to this grade band?

- A chemical reaction is a closed system (even if some products, like gasses, are not visible)

Key concepts that students need access in order to be successful:

- Experience analyzing chemical reactions to determine the amount of matter in the system
- Experience analyzing chemical reactions where conservation of matter is not readily observed or measured but can be proven mathematically
  - Ex: A reactant or a product is a gas
- Proving conservation of matter through both conservation of atoms and conservation of mass

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Kinetics and Equilibrium

Standards included:

HS-PS1-5
HS-PS1-6
HS-PS3-4

FOCUS SEPs:

Constructing Explanations and Designing Solutions
Planning and Carrying Out Investigations

FOCUS DCIs:

PS1.B Chemical Reactions
PS3.B Conservation of Energy and Energy Transfer
PS3.D Energy in Chemical Processes

FOCUS CCCs:

Patterns
Stability and Change
Systems and System Models

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
Grades 3-5	• Identify the evidence that supports particular points in an explanation.
Grades K-2	• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

What ideas or skills are truly unique to this grade band?

- Apply scientific principles (i.e.: temperature is a measure of kinetic energy, causality)
- Take into account unanticipated effects

Key experiences students need access to in order to be successful:

- Exposure to the relevant scientific principles (i.e.: temperature is a measure of kinetic energy, causality, many reactions can be sped up or slowed down reactions occur based on collisions of particles)
- Gather or be given data or other evidence to analyze temperature and/or concentration and reaction rate.
- Students construct an explanation that uses reasoning to integrate the evidence and the scientific principle of collision theory in terms of how and why chemical reactions occur and at what rate.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.B: Chemical Reactions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.
Grades 3-5	• Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.
Grades K-2	• Heating and cooling substances cause changes that are sometimes reversible and sometimes not.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

  Foundational concepts necessary for success that are not covered in previous grade bands:

  - Reactant particles must collide with enough energy in the correct orientation for a chemical reaction to occur.
  - Reaction rates are determined by amount of collisions with the correct energy over a given time period to get reaction to completion
  - Temperature is a measurement of the average kinetic energy of particles in a substance
  - A more concentrated sample of a chemical has more particles in a given volume than a less concentrated sample.
  - A reaction that releases energy occurs when the bond energies of the products are higher than the bond energies of the reactants, and is called exothermic.
  - A reaction that absorbs energy occurs when the bond energies of the reactants is higher than the bond energies of the products, and is called endothermic.

  Key concepts that students need access in order to be successful:

  - As the kinetic energy of colliding particles increases and the number of productive collisions increases, the reaction rate increases.
  - As concentration of particles increases, the number of collisions increases, the reaction rate increases.
  - Raising temperature will result in a quicker reaction, faster reaction rate, less time to complete reaction, etc. (i.e., rate and time are inverse relationships) and vice versa
  - Increasing concentration will result in a quicker reaction, faster reaction rate, less time to complete reaction, etc
  - Exothermic reactions occur at a faster rate than thermodynamically neutral reactions or endothermic reactions because one of the products is heat, which in turn raises the temperature of the remaining reactants, increasing the reaction rate until one or more reactants is consumed.
  - Endothermic reactions occur with a slower reaction rate than thermodynamically neutral reactions or exothermic reactions because they absorb energy from the surroundings, which in turn lowers the temperature and requires a sustained input of energy to maintain the reaction.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Patterns

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns can be used to identify cause and effect relationships.
Grades 3-5	• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.
Grades K-2	• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Patterns can exist across the components of a system
- The patterns at different scales may be different from each other
- The patterns at different scales can be used as evidence of the cause/effect relationship
- The patterns are used to explain the phenomenon (as opposed to describe).

Key concepts that students need access in order to be successful:

- Asked to make connections between what is observed at the bulk scale and what is happening at the atomic scale (i.e., reaction happens because of particle collisions)
- Make observations about the reaction rate at the bulk scale
- Finding/recognizing patterns in data to determine which observations can serve as evidence of rate of successful collisions during a chemical reaction
- Explain what is happening at the atomic scale in terms of successful collisions in a chemical reaction using the patterns identified from observations
- Explain the patterns in bulk properties (i.e., reaction rate, temperature, concentration) using information about collision theory

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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 Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.*] [**Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.**]

***** The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.
Grades 3-5	• Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
Grades K-2	• Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem. • Generate and/or compare multiple solutions to a problem.

9-12 GRADE LEVEL ELEMENT(S)

- Refine a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.

What ideas or skills are truly unique to this grade band?

- Students refine a design solution
- The solution is designed to address a complex real world problem
- Changes to the designed solution are based on student generated evidence

Key experiences students need access to in order to be successful:

- Exposure to real world problems where reversible chemical reactions are a factor
- Exposure to real world problems where reversible chemical reactions need to be manipulated to produce more/less of a certain chemical
- Multiples trials of design challenges where changes are controlled and all variables are measured
- Results of trials are analyzed for efficacy or tradeoffs
- Final designs are chosen based on analyzed results and needs of the challenge and can support the choices made.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.B: Chemical Reactions and **ETS1.C**: Optimizing the Design Solution

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.
Grades 3-5	• Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.
Grades K-2	• Heating and cooling substances cause changes that are sometimes reversible and sometimes not.

9-12 GRADE LEVEL ELEMENT(S)

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.

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)

Foundational concepts necessary for success that are not covered in previous grade bands:

- Reversible chemical reactions are possible
- At dynamic equilibrium of a reversible reaction, both the forward and reverse reaction are occurring simultaneously
- The number of each molecule present (reactants and products) at any given time is dependent on conditions including temperature, pressure, concentration of one type molecule in the reaction.

Key concepts that students need access in order to be successful:

- Describe the effect of changing either the amount of reactants or products in a closed system
- Identify the conditions that, when changed, could cause a reversible reaction to shift
- Describe how changing one component of a system at equilibrium will cause a change in the other components.
- Describe that rate of reaction will change if the concentration of one component is changed until the system reaches equilibrium
- Describe that an equilibrium reaction appears stable at the macroscopic level because the forward and reverse reactions are occurring at the same rate at the particle level.

Additional Information

- The ETS element was not specifically unpacked in the DCI because the critical content of this ETS element is covered through the SEP for this standard.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Stability and Change

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. • Small changes in one part of a system might cause large changes in another part. • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. • Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.
Grades 3-5	• Change is measured in terms of differences over time and may occur at different rates. • Some systems appear stable, but over long periods of time will eventually change.
Grades K-2	• Some things stay the same while other things change. • Things may change slowly or rapidly

9-12 GRADE LEVEL ELEMENT(S)

- Much of science deals with constructing explanations of how things change and how they remain stable.

What ideas or concepts are truly unique to this grade band?

- Explanations include "the how" for change and stability

Key concepts that students need access in order to be successful:

- Once equilibrium is reached, a reversible reaction will remain stable while the forward and reverse reactions are occurring simultaneously unless some portion of the system is stressed.
- Stress could include: more reactants added, products removed, change in volume, temperature, or pressure, etc.
- If a portion of a reversible reaction is stressed, the change can be predicted based on that stressor.
- For example, if some product is removed, the reaction will shift toward making more product until equilibrium is again achieved.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Planning and Carrying Out Investigations

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
Grades 3-5	• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
Grades K-2	• With guidance, plan and conduct an investigation in collaboration with peers (for K). • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or skills are truly unique to this grade band?

- Decide on types and accuracy of data needed to produce reliable measurements
- Consider limitations on the precision of the data (e.g., number of trials, cost, risk, time)
- Refine the design based on the limitations identified.
- Planning design to account for:
  - Accuracy of data.
  - Reliability of measurements.
  - Limitations on precision of data.
  - Refining experimental design as needed.

Key experiences students need access to in order to be successful:

- Identify the purpose of the investigation in order to effectively plan
- Experience planning an investigation where the procedure is justified to explain the methods of data collection to account for accuracy and reliability and acknowledge any limitations.
- Experience collecting quantitative data in order to analyze the data and use mathematical thinking to quantitatively describe energy changes
- Experience with laboratory activities where data is highly variable among students so that they see the need for accuracy, reliability, or reproducibility in their own experimental design
- Writing procedures/directions for activities that use only the provided materials and that can be followed by anyone, not just partners or themselves.
- Experience in planning investigations that must be refined/modified after initial data collection.
    - Students need to know that they can go back and do more, try something else if they don't get enough or the type of data they initially thought they would.
- Experience with laboratory investigations specifically related to the DCI
- Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS3.B: Conservation of Energy and Energy Transfer and PS3.D: Energy in Chemical Processes

PS3.B: Conservation of Energy and Energy Transfer

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Kinetic energy can be distinguished from the various forms of potential energy. • Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.
Grades 3-5	• Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- 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).

PS3.D: Energy in Chemical Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.
Grades 3-5	• Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food.
Grades K-2	• Sunlight warms Earth's surface.

9-12 GRADE LEVEL ELEMENT(S)

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Energy cannot be created or destroyed.
- Systems evolve toward stability.
- Sometimes energy conversion is not 100% efficient because some energy often is converted to unintended energy forms (i.e., thermal energy, light, sound, etc.).

Key concepts that students need access in order to be successful:

- The thermal energy that exits one material is equal to the thermal energy that is absorbed by the other material in a closed system.
- That two objects at different temperatures will transfer thermal energy from the warmer object to the cooler object until they are the same final temperature due to uniform thermal energy (thermal equilibrium).
- Different materials have different specific heat capacities which influence how rapidly the temperature can be changed.
- The mass of material impacts how rapidly the temperature of an object can be changed.
- Temperature at equilibrium can be predicted based on knowing the initial temperature, heat capacity, and mass of objects being brought together.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Systems and System Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Models can be used to represent systems and their interactions - such as inputs, processes and outputs - and energy, matter, and information flows within systems. • Models are limited in that they only represent certain aspects of the system under study.
Grades 3-5	• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions.
Grades K-2	• Objects and organisms can be described in terms of their parts. • Systems in the natural and designed world have parts that work together.

9-12 GRADE LEVEL ELEMENT(S)

- 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.

What ideas or concepts are truly unique to this grade band?

- Defining boundaries and initial inputs of the system
- Analyzing inputs and outputs of the system
- Investigation of systems

Key concepts that students need access in order to be successful:

- Experience with defining the system versus the surroundings, especially in complex systems.
- Experience with defining whether a system is a closed system or open system.
- Describe the limitations of the investigation when the system is not truly a closed system
    - Example: a bomb calorimeter is a closed system, a coffee cup calorimeter is technically not a closed system but can be treated as such, a soda can is not a closed system when doing calorimetry.
    - Depending on a particular setup, the system may have energy outputs that are not measurable because of thermal energy loss to surroundings.
- Multiple lab or mathematical experiences with data from different objects with different masses or different heat capacities and analyzing how those differences influence the system.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

BUNDLE: Nuclear Energy

Standards included:

HS-PS1-8
HS-ESS1-1
HS-ESS1-2
HS-ESS1-3

FOCUS SEPs:

Constructing Explanations and Designing Solutions
Developing and Using Models
Obtaining, Evaluating, and Communicating Information

FOCUS DCIs:

ESS1.A	The Universe and its Stars
PS1.C	Nuclear Processes
PS3.D	Energy in Chemical Processes and Everyday Life
PS4.B	Electromagnetic Radiation

FOCUS CCCs:

Energy and Matter
Scale, Proportion and Quantity

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**.]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.
- Use of an already developed and accepted model as a source of information.

Key experiences students need access to in order to be successful:

- Use information about energy released during nuclear processes as evidence to support developing a model.
- Experience modeling energy changes.
- Develop a model that shows that the energy released in a nuclear process is multitudes larger than the energy released in a chemical process.
- Develop simple models (drawing or diagrams) for each of the distinct nuclear processes (fusion, fission, radioactive decay).

TARGET DISCIPLINARY CORE IDEA PROGRESSION

PS1.C: Nuclear Processes

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• N/A
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- 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.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Subatomic particles
- Strong nuclear force is what holds protons and neutrons together in the nucleus
- The nucleus stores potential energy that is released in gamma decay
- Collision theory of particles
- Isotopes are atoms of an element that have different numbers of neutrons, and therefore different mass numbers
- Some isotopes are stable, some are radioactive
- Energy conversion between forms of energy
- An element is determined by the number of protons in the nucleus -- if there is a change to the number of protons, the element is changed. If there is a change to neutrons or electrons, the element is not changed.

Key concepts that students need access in order to be successful:

- Fusion is the combination of two (or more) nuclei into a new larger nucleus of a different element and the total number of protons and neutrons is the same as before the fusion
- Fission is the process where one nucleus splits apart into more than one smaller elements and the total number of protons and neutrons is the same as before the fission
    - Fission can occur spontaneously as in radioactive decay
    - Fission can occur due to bombardment with neutrons or smaller atoms
- Radioactive decay occurs spontaneously
    - Alpha decay releases a helium ion and results in a different element forming
        - Also considered fission
    - Beta decay releases either electrons or positrons
        - An electron is released when a neutron becomes a proton and a new element is created
        - A positron is released when a proton becomes a neutron and a new element is created
    - Gamma decay releases electromagnetic energy and does not result in a different element forming
- All nuclear processes release energy due to the strong nuclear force
- Scale of energy released in nuclear reactions is multitudes larger than energy changes in similar quantities used in chemical processes

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces, be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

What ideas or concepts are truly unique to this grade band?

- In nuclear processes atoms are not conserved.
- In nuclear processes the total number of protons plus neutrons is conserved.

Key concepts that students need access in order to be successful:

- In nuclear processes energy is released (created when matter is converted to energy in fusion and fission reactions) as a result in the changes in the nucleus
- Energy released in a nuclear process is multitudes greater than the energy released in a chemical reaction.
- See that nuclear structures can vary in numbers of neutrons and stay the same element
- See that nuclear structures can change and create different elements as long as all protons and neutrons are accounted for while having one atom become many or many atoms become one
- See measurements or see calculations of energy released during nuclear processes compared to a similar mass of a chemical process

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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 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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Developing and Using Models

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Develop or modify a model - based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.
Grades 3-5	• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena.
Grades K-2	• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).

9-12 GRADE LEVEL ELEMENT(S)

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

What ideas or skills are truly unique to this grade band?

- Use of models to show relationships between systems and components of systems, not just variables or phenomena.

Key experiences students need access to in order to be successful:

- Gather evidence about the structure and processes in the sun related to nuclear fusion and energy
- Gather evidence about other stars of other types to show how stars will change over their lifetime.
- Modeling systems that change over time
- Experience modeling the energy released from the process of nuclear fusion.
- Experience modeling the sun's layers and indication of where the fusion process occurs (the core).
- Model the changes the sun will go through during its lifespan as it uses up the hydrogen fuel for the nuclear fusion and what will happen to the layers during that time.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.A: The Universe and its Stars and PS3.D: Energy in Chemical Processes and Everyday Life

ESS1.A: The Universe and its Stars

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. • Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
Grades 3-5	• Stars range greatly in size and distance from Earth and this can explain their relative brightness.
Grades K-2	• Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.

9-12 GRADE LEVEL ELEMENT(S)

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

PS3.D: Energy in Chemical Processes and Everyday Life

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• N/A
Grades 3-5	• N/A
Grades K-2	• N/A

9-12 GRADE LEVEL ELEMENT(S)

- Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (Secondary)

Foundational concepts necessary for success that are not covered in previous grade bands:

Nuclear fusion of hydrogen to helium

- Energy can travel from the sun to Earth in the form of radiation
- The sun is changing due to using hydrogen to fuse into helium
- The sun will eventually burn out
- The sun has a lifespan of approximately 10 billion years

Key concepts that students need access in order to be successful:

- Describe how the reactions in the sun's core are nuclear changes, not chemical changes.
- Each packet of energy created (photon) travels through the layers of the Sun, radiative zone, convective zone, photosphere, and eventually reaches Earth as electromagnetic radiation, including visible light, over the course of 100,000+ years
- Describe how radiation is released during fusion and how radiation from the sun reaches Earth's system.
- Predict how relative proportions of hydrogen and helium will change as the sun ages
- Describe that as the sun goes through its lifecycle and uses up all available hydrogen, it will then fuse the helium into elements up to carbon and oxygen

TARGET CROSS CUTTING CONCEPT PROGRESSION

Scale, Proportion and Quantity

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
Grades 3-5	• Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. • Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.
Grades K-2	• Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). • Standard units are used to measure length.

9-12 GRADE LEVEL ELEMENT(S)

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

What ideas or concepts are truly unique to this grade band?

- Significance of scale for a given phenomena
- Quantity impacts significance of phenomena
- Proportions in a system impact significance of phenomena

Key concepts that students need access in order to be successful:

- Examine data about how other stars have changed over time
- Use patterns about different types of stars and their lifespans to make predictions about the sun.
- Compare the relative proportions of hydrogen and helium and make predictions about how these proportions will change over the lifespan of the sun
- Identify that the qualitative description of the scale of energy of fusion is larger than the qualitative description of energy from a chemical reaction.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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).*]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Constructing Explanations and Designing Solutions

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
Grades 3-5	• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
Grades K-2	• Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.

9-12 GRADE LEVEL ELEMENT(S)

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

What ideas or skills are truly unique to this grade band?

- Explanations are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
  - Example: Evidence can include students' own investigations, theories, simulations, peer review

Key experiences students need access to in order to be successful:

- Evaluate multiple sources of evidence for each source's relevance to the explanation requested.
- Synthesize multiple pieces of evidence to support a single claim about the Big Bang theory
- Use 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.

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.A: The Universe and its Stars and PS4.B: Electromagnetic Radiation

ESS1.A: The Universe and its Stars

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The solar system is part of the Milky Way, which is one of many billions of galaxies.
Grades 3-5	• Stars range greatly in size and distance from Earth and this can explain their relative brightness.
Grades K-2	• Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.

9-12 GRADE LEVEL ELEMENT(S)

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

PS4.B: Electromagnetic Radiation

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• The construct of a wave is used to model how light interacts with objects.
Grades 3-5	• Objects can be seen when light reflected from their surface enters our eyes.
Grades K-2	• Objects can be seen only when light is available to illuminate them.

9-12 GRADE LEVEL ELEMENT(S)

- 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).

Foundational concepts necessary for success that are not covered in previous grade bands:

- Each element produces a unique spectra of light that can be used to identify it.
- The study of stars' light spectra is used to identify compositional elements of stars.
- The shift in light spectra (red shift/blue shift – Doppler shift) can be used to identify stars' movements and distances from earth.
- The study of stars' brightness can be used to identify stars' movements and distances from earth
- Evidence that supports the Big Bang theory.
  - Observations of distant galaxies receding from our own (red shift/blue shift).
  - The measured composition of stars and interstellar gasses (light spectra).
  - The maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- The big bang had so much energy that some was converted to matter in the form of subatomic particles.
- The subatomic particles eventually became hydrogen.
- There was still so much energy left from the big bang that it allowed hydrogen to fuse into helium

outside of stars, which is why interstellar gas is approximately ¾ hydrogen and ¼ helium.
- Stars produce elements through nuclear fusion of hydrogen into larger nuclei releasing electromagnetic energy.
  - Some stars can produce elements up to iron.
  - Elements larger than iron are produced through supernova.

Key concepts that students need access in order to be successful:

- Explain what each piece evidence proves is happening in space
  - Ex: the redshift of the spectra of stars/galaxies indicates they are moving further away from us, the further away the star/galaxy the larger the redshift, indicating it is receding at a faster rate.
  - Ex: the atomic emission spectra of a star and interstellar gasses indicates which elements compose each.
  - Ex: the existence of cosmic background radiation shows that there must have been a large release of energy across the entire universe at one point in time, and we can still measure it today as microwaves billions of years later.
- For each piece of evidence explain how it supports the Big Bang theory.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).
Grades 3-5	• Energy can be transferred in various ways and between objects.
Grades K-2	• Objects may break into smaller pieces, be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems.*(See additional information)

What ideas or concepts are truly unique to this grade band?

- Conservation of energy (and matter) (in typical chemical systems)
  - The Big Bang is not a chemical system, it is a nuclear creation system
  - This DCI hinges on the fact that energy was converted to mass during the Big Bang
  - This DCI hinges on the fact that nuclear fusion happened outside of the stars which released more energy through conversion of matter to energy
  - This process is the conservation of energy and matter as a system together
- Energy (and matter) transfer between systems

Key concepts that students need access in order to be successful:

- Explain how electromagnetic radiation observed from earth traveled from events in space
- When the observed energy from space is different than expected (red-shifted as compared to earth-based source) then the difference can be evidence of the continued movement of objects
- Explain that much of the helium exists outside of stars due to the fusion that happened after the Big Bang but before stars were formed.

Additional Information:

- This is the Cross Cutting Concept from NGSS. It is recognized that in the instance of nuclear processes, energy and matter together are conserved. While not represented in the selected Cross Cutting Concept, this was a consideration when unpacking.

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

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.**]

TARGET SCIENCE AND ENGINEERING PRACTICE PROGRESSION

Obtaining, Evaluating, and Communicating Information

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.
Grades 3-5	• Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.
Grades K-2	• Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.

9-12 GRADE LEVEL ELEMENT(S)

- 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).

What ideas or skills are truly unique to this grade band?

- Communicating ideas about a phenomenon.
- Communication can now include mathematical.
- Communicating about one topic in multiple formats.

Key experiences students need access to in order to be successful:

- Supports for organizing thinking to identify key ideas before communicating
- Determining best methods of communication for the ideas related to the phenomenon and intended audience
  - Students need to choose at least two different formats to communicate information about the structure, properties, and design of chosen materials
- Formats can include: oral, graphical, textual, mathematical
- Technical writing experiences with scaffolds for organizing thinking
- Oral presentation experiences with scaffolds for organizing thinking
- Organizing information graphically
  - i.e., if using a slide style or infographic format having it organized in a visually engaging manner that is accessible to all who will be receiving the information; or ensuring all graphics are correct, legible, relevant, proper citations, in a poster or paper presentation etc.
- Students cite information used as appropriate

TARGET DISCIPLINARY CORE IDEA PROGRESSION

ESS1.A: The Universe and its Stars

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. • Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
Grades 3-5	• Stars range greatly in size and distance from Earth and this can explain their relative brightness.
Grades K-2	• Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.

9-12 GRADE LEVEL ELEMENT(S)

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

Foundational concepts necessary for success that are not covered in previous grade bands:

- Light spectra of stars are used to identify composition of mixtures of elements present in the atmosphere of the star.
- Nuclear fusion creates larger elements and releases energy in the process
- Atoms are made of subatomic particles
  - Neutrons and protons are in the nucleus, electrons are not in the nucleus
  - Protons determine the identity of an element
  - Neutrons determine the stability of a nucleus
- Lifespan stages of stars is determined by the mass of the star
  - Low to average mass stars eventually become red giants and then white dwarfs
  - High mass stars eventually become supergiants and then either black hole or neutron star

Key concepts that students need access in order to be successful:

- Describe how a given spectrum can be used to describe a star
  - Describe that the width of the spectral lines can be used to identify how fast the material is moving
  - Describe that moving spectral lines show that a start might be orbiting another star, which helps identify mass and size of star
  - Use a given spectrum to identify the elements in a star.
- Describe how the characteristics of a star change in different stages
  - Star Mass
  - Elements Produced
    - Before stars exist -- protons and neutrons collide to make hydrogen and helium
    - Nuclear fusion in the core of stars produce elements up to iron (some stars only up to lithium)
    - Main sequence stars fuse hydrogen to helium in their core
    - When main sequence stars run out of hydrogen, some helium fusion happens but then the star expands to a giant where elements up to iron are then created in red giants and supergiants
    - Supernova explosions allow for fusion reactions that create elements larger than iron when white dwarfs collide with and/or accrete larger red stars in binary systems.

TARGET CROSS CUTTING CONCEPT PROGRESSION

Energy and Matter

BELOW GRADE LEVEL

Grades	Grade Level Elements
Grades 6-8	• Matter is conserved because atoms are conserved in physical and chemical processes.
Grades 3-5	• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems.
Grades K-2	• Objects may break into smaller pieces, be put together into larger pieces, or change shapes.

9-12 GRADE LEVEL ELEMENT(S)

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

What ideas or concepts are truly unique to this grade band?

- In nuclear processes atoms are NOT conserved
- Number of subatomic particles ARE conserved in nuclear processes
- While number of subatomic particles are conserved in nuclear processes, neutrons can be transformed into a protons through beta decay

Key concepts that students need access in order to be successful:

- Use nuclear reaction equations to prove conservation of protons and neutrons.
- Use nuclear reaction equations to prove that there is not a conservation of atoms in nuclear reactions with alpha and beta decay.
- See that nuclear structures can change and create different elements as long as all protons and neutrons are accounted for while having one atom become many or many atoms become one

ALIGNING THIS STANDARD TO YOUR STUDENTS:

- What everyday experiences or knowledge from other content areas might students bring to help them develop the targets from the SEP, DCI, and CCC?
- Where are students using and experiencing these ideas, practices, and concepts outside of the science classroom?
- What questions may students have related to these ideas about how the world works?
- What scaffolding might my students need to fully understand this particular standard?
- What phenomena could capture students' interest and provide opportunities to use the science covered in this standard to understand the phenomena?

Glossary of Terms

Cross Cutting Concept[2]

These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.

Disciplinary Core Idea[1]

The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

Elements[2]

The bulleted practices, disciplinary core ideas, and crosscutting concepts that are articulated in the foundation boxes of the standards as well as the in the NGSS appendices on each dimension.

Next Generation Science Standards (NGSS)[3]

K–12 science content standards. Standards set the expectations for what students should know and be able to do. Adopted in as Kansas Science Standards in 2013

Performance Expectation[2]

Each NGSS standard is written as a performance expectation that sets the learning goals for students, but does not describe how students get there. Each standard is not a daily standard but an expectation of what students should be able to do by the end of instruction (years or grade-bands).

Science and Engineering Practice[2]

The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

Standards[3]

End of instruction goals or benchmarks for student proficiency.

Standards Alignment[1]

Standards-Aligned instruction has clearly defined student learning expectations aligned to Kansas State Standards and supported with evidence-based instruction and materials.

2 *Next Generation Science Standards.* (n.d.). https://www.nextgenscience.org

3 Next Generation Science Standards. (n.d.). *NGSS Glossary*. https://www.nextgenscience.org/glossary

GLOSSARY OF TERMS

Standards Bundles[4]

Grouping elements or concepts from multiple PEs in lessons, units, and/or assessments that students can develop and use together to build toward proficiency on a set of PEs in a coherent manner.

Standards Unpacking

A systematic process of identifying the key ideas, experiences, and concepts that students need to demonstrate to show mastery of a standard.

Three-Dimensions[3]

These are the three strands of knowledge and skills that students should explicitly be able to use to explain phenomena and design solutions to problems. The three dimensions are the Disciplinary Core Ideas (DCIs), Crosscutting Concepts (CCCs), and Science and Engineering Practices (*"the Practices"* or SEPs).

Unpacked Standard

The key ideas, experiences, and concepts that are identified as necessary for a student to demonstrate to show mastery of a standard. An unpacked standard is intended to provide clarity on the expectations of the standard and intentionally does not include any ideas, concepts, or experiences beyond the standard.

4 Next Generation Science Standards. (n.d.). *Next Generation Science Standards.* https://www.nextgenscience.org/

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GLOSSARY OF TERMS

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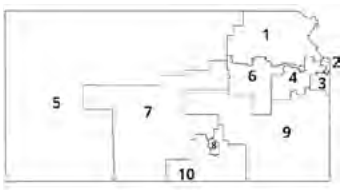

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SUCCESS DEFINED

A successful Kansas high school graduate has the

- Academic preparation,
- Cognitive preparation,
- Technical skills,
- Employability skills and
- Civic engagement

to be successful in postsecondary education, in the attainment of an industry recognized certification or in the workforce, without the need for remediation.

OUTCOMES

- Social-emotional growth
- Kindergarten readiness
- Individual Plan of Study
- Civic engagement
- Academically prepared for postsecondary
- High school graduation
- Postsecondary success

Kansans CAN

MISSION

To prepare Kansas students for lifelong success through rigorous, quality academic instruction, career training and character development according to each student's gifts and talents.

VISION

Kansas leads the world in the success of each student.

MOTTO

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