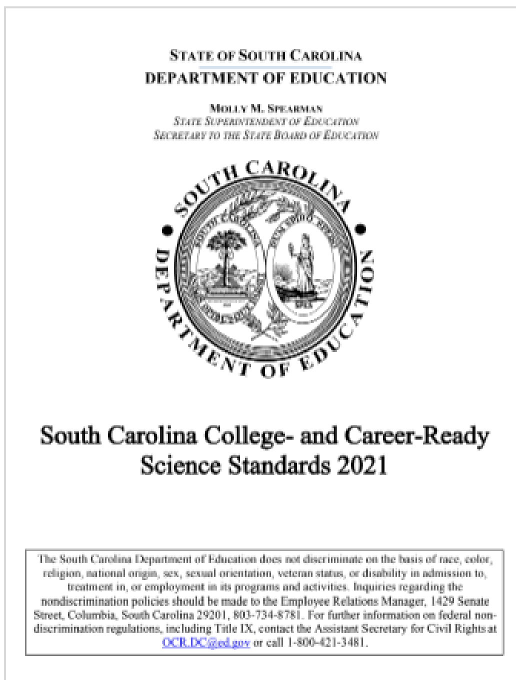
Chemistry 1



STATE OF SOUTH CAROLINA
DEPARTMENT OF EDUCATION

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SOUTH CAROLINA DEPARTMENT OF EDUCATION

South Carolina College- and Career-Ready Science Standards 2021

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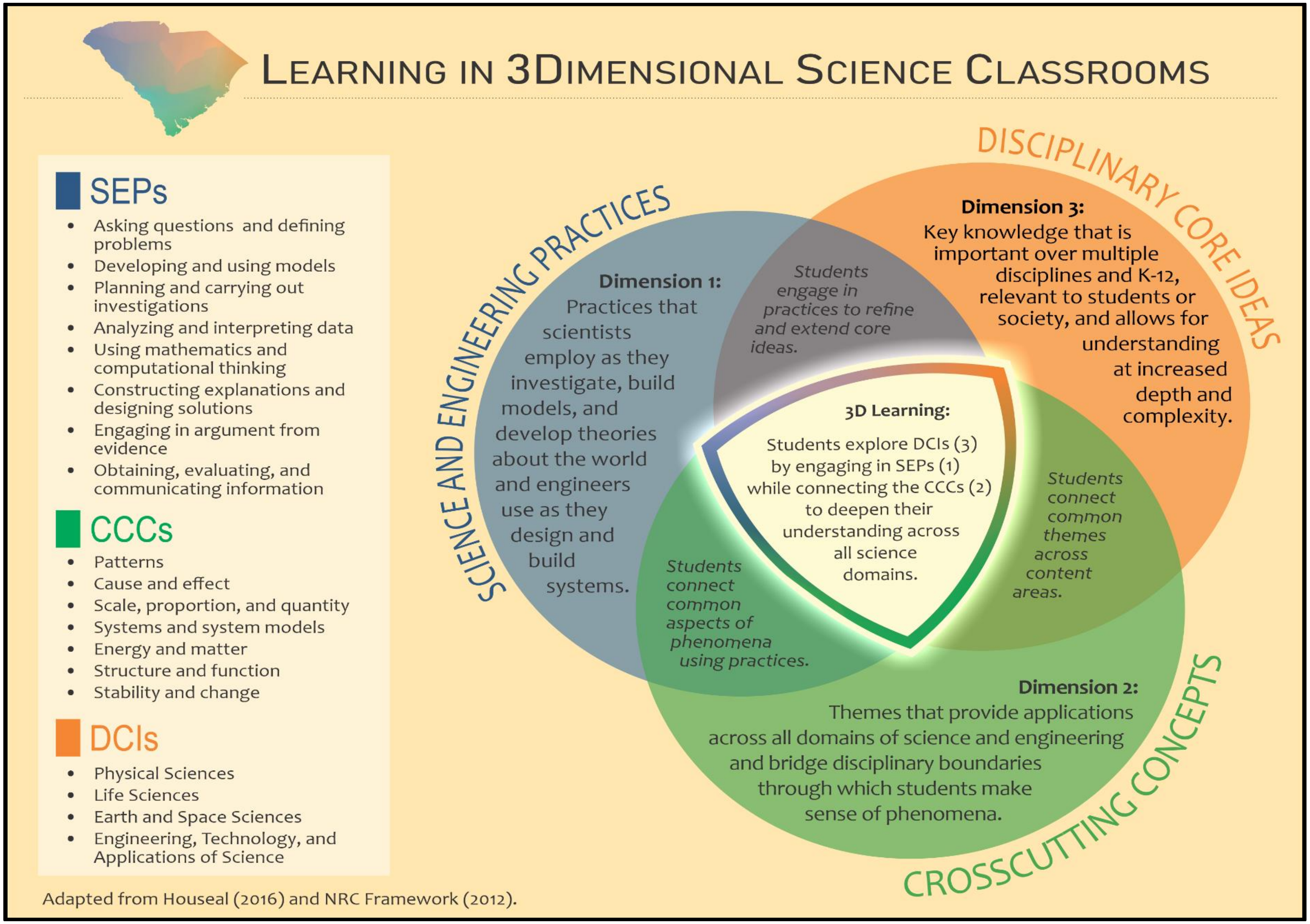
Learning in 3 Dimensional Science Classrooms



Dimension 1: Science and Engineering Practices

The **Science and Engineering Practices (SEPs)** are the major practices that scientists apply as they investigate and build models and theories about the world, and that engineers use as they design and build systems. Students should not learn about these practices secondhand, in an isolated unit, or apart from the other two dimensions. While one **SEP** is identified to be assessable and represents the student performance goal for the end of instruction, other **SEPs** should be applied by students to support their progress leading up to the end of instruction. This is vital, as the fields of science and engineering are related and mutually supportive through the eight **SEPs** that students **DO** (NRC Framework, 2012, p. 50-53).

Asking Questions and Defining Problems

Scientists ask and refine questions about phenomena that lead to explanations of how the natural and designed world(s) works.
Engineers ask questions to define the problems, identify constraints, and determine criteria for an effective solution.

Use Mathematical and Computational Thinking

Scientists use mathematics and computation as tools for representing physical variables and their relationships.
Engineers use mathematical and computational representations of established relationships and principles as an integral part of design.

Developing and Using Models

Scientists construct and use models to help develop and understand explanations about natural phenomena.
Engineers use models as helpful tools to test proposed systems and to recognize strengths and limitations of new designs.

Constructing Explanations and Designing Solutions

Scientists construct logically coherent explanations of phenomena that are consistent with the available evidence.
Engineers' designs are based on scientific knowledge and models of the material world.

Planning and Carrying out Scientific Investigations

Scientists use observations and data collected to test existing theories and explanations or to revise and develop new ones.
Engineers use investigations to gain data to specify design criteria and to test their designs.

Engaging in Argument from Evidence

Scientists identify the strengths and weaknesses of a line of reasoning to engage in argument for finding the best explanation of a natural phenomenon.
Engineers engage in argument from evidence to find the best possible solution to a problem.

Analyzing and Interpreting Data

Scientists use a range of tools to identify the significant features and patterns in data.
Engineers use a range of tools and analyze data collected in the tests of their designs and investigations.

Obtaining, Evaluating, and Communicating Information

Scientists derive meaning from texts and evaluate the validity of information to then communicate ideas.
Engineers derive meaning from other's work and texts and evaluate the information, to apply it usefully to express their ideas.

Link to the grounding research for the **SEPs** from the NRC Framework.

Dimension 2: Crosscutting Concepts

The **Crosscutting Concepts** (**CCCs**) represent seven themes that span across science domains (Physical, Life, Earth and Space, and Engineering, Technology, and Applications of Science) and have value to both scientists and engineers as they identify and connect universal properties and processes found in all domains. Students should not learn about these concepts secondhand, in an isolated unit, or apart from the other two dimensions. While one **CCC** is identified to be assessable and represents the student performance goal for the end of instruction, other **CCCs** could be applied by students to support their progress leading up to the end of instruction. The **CCCs** give students an organizational framework for connecting knowledge from the various disciplines into a coherent and scientific based view of the world (NRC Framework, 2012, 83-102).

Patterns

Students observe patterns of forms and events to guide organization and classification. Patterns prompt student questions about the factors that influence cause-and-effect relationships and are useful as evidence to support student explanations and arguments.

Systems and System Models

Students define the system(s) under study by specifying its boundaries and making explicit a model of the system(s). By doing so, the students are provided tools for understanding and testing ideas that are applicable throughout science and engineering.

Cause and Effect

Students investigate and explain causal relationships and the mechanisms by which they are mediated. Events have causes, some simple, some multifaceted and complex. Students can test such mechanisms across given contexts and the mechanisms can be used to predict and explain events in new contexts.

Energy and Matter

Students understand the system's possibilities and limitations by tracking fluxes of energy and matter into, out of, and within systems.

Scale, Proportion, Quantity

Students, while considering phenomena, come to recognize what is relevant at different measures of size, time, and energy, and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Structure and Function

Students observe an object or living thing's structure and shape to determine many of its properties and functions. The functioning of natural and built systems both depend on the shapes and relationships of certain key parts and on the properties of the materials from which they are made.

Stability and Change

Students recognize the conditions of stability and rates of change for natural and built systems to develop an understanding of how the system operates and causes for changes in systems.

Link to the grounding research for the **CCCs** from the [NRC Framework.]()

Dimension 3: Disciplinary Core Ideas

Disciplinary Core Ideas (**DCIs**) are a set of four science and engineering domains for K–12 science that have broad importance across multiple science and engineering disciplines. The **DCIs** provide a tool for understanding or investigating more complex ideas and solving problems, relate to the interests and life experiences of students, and are learnable over multiple grades at increasing levels of depth and sophistication. Students should not memorize or learn isolated facts about the **DCIs** secondhand or apart from the other two dimensions (NRC Framework, 2012, p. 31).

Physical Science (PS)

PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

Students gain awareness of the structure of matter, interactions occurring in terms of the forces between objects, related energy transfers, and their consequences to understand the physical and chemical basis of a system. Chemistry and physics underlie all natural and human-created phenomena and helps students see the mechanisms of cause and effect in all systems and processes that are understood through a common set of physical and chemical principles.

Life Science (LS)

LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity

Students focus on patterns, processes, and relationships of living organisms. The study of life ranges over scales from single molecules, organisms, and ecosystems, to the biosphere. A core principle of the life sciences is that organisms are related through common ancestry and that processes of natural selection have led to the tremendous diversity on Earth. Students in life science courses explore all aspects of living things and the environments they live in.

Earth and Space Science (ESS)

ESS1: Earth's place in the universe
ESS2: Earth's systems
ESS3: Earth and human activity

Students investigate processes that operate on Earth and address Earth's place in the universe. Earth and space science involve phenomena that range in scale from unimaginably large to invisibly small. Earth and space sciences also provide students opportunities to understand how the atmosphere, geosphere, and biosphere are interconnected.

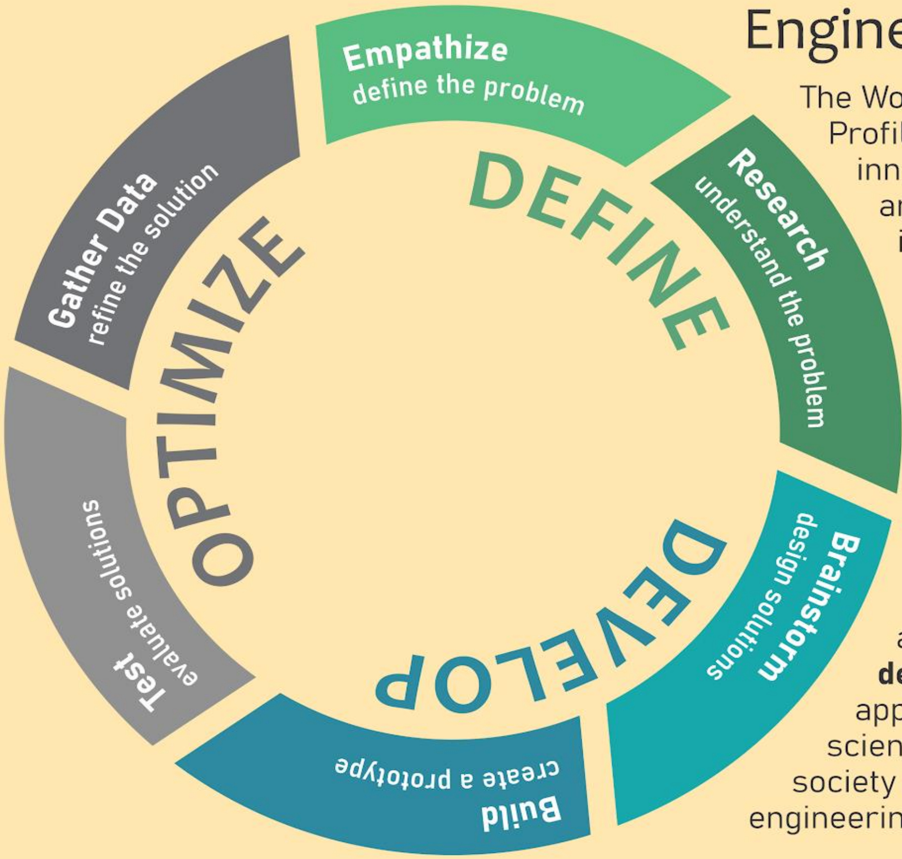
Engineering, Technology, and Applications of Science (ETS)

ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society

Students learn how science is utilized, through the engineering design process, and have the opportunity to appreciate the distinctions and relationships between engineering, technology, and applications of science alongside the physical, life, and Earth and space sciences of other science domains. Science-based designs of technologies and systems affect the ways in which people interact with each other and with the environment, indicating how these designs deeply influence society.

Link to the grounding research for the **DCIs** from the NRC Framework: PS, LS, ESS, and ETS.

Engineering, Technology, and Applications of Science: Engineering Design Process



Engineering Design Process:

The World Class Skills as articulated in the Profile of the SC Graduate: creativity and innovation, critical thinking, collaboration and teamwork, and communication are infused in the **engineering design process** to support student development of both individual and cooperative engineering practices. During the iterative process, students **define** problems to **develop** and **optimize** solutions to local, national, and global issues. The fields of science and engineering are related and mutually supportive and by engaging students in the knowledge and practices related to the **engineering design process**, students establish an appreciation for the interdependence of science, engineering, and technology within society and the natural world and view engineering as a possible career path.

ETS1: This icon found within the PE aligns to ETS1 and notes where students engage directly in the engineering design process.

ETS2: This icon found within the DCI box shows learning connections to ETS2 - Links Among Engineering, Technology, and Society.

Link to the grounding research for the **ETS** from the NRC Framework.

Chemistry

South Carolina chemistry students engage in thinking and solving problems the way scientists and engineers do to help them better see how science is relevant to their lives. To capitalize on the natural curiosity all students have about the world around them, learning experiences are built around the three dimensions of science: **Science and Engineering Practices (SEPs)**, **Crosscutting Concepts (CCCs)**, and **Disciplinary Core Ideas (DCIs)**. This three-dimensional approach to teaching and learning helps educators provide meaningful learning experiences that offer varied entry points for students from diverse backgrounds.

The **performance expectations** in chemistry help students engage in inquiry questions such as, **but not limited to:**

How can one explain the structure and properties of matter? Using the patterns in the periodic table, students predict properties of elements, substructure of atoms and trends.

How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?
Students explain simple chemical reactions and patterns of chemical properties. Using chemical reactions, students conduct substance structure and particle force investigations, illustrate energy changes, explain reaction rates, refine a chemical system in equilibrium, support a claim of energy conservation and illustrate changes to nuclei composition.

How can one explain and predict interactions between objects and within systems of objects?
Students build an understanding of attraction and repulsion between electric charges at the atomic scale explaining the structure, properties and transformations of matter as well as electrostatic forces between objects.

How is energy transferred and conserved?
Students investigations concerning macroscopic and the subatomic energy can account for either motions of particles or energy associated with the configuration (relative positions) of particles.

How are waves/particles used to transfer energy and send and store information?
Students evaluate and communicate how wave/particle properties and the interactions of electromagnetic radiation with matter can transmit and capture information and energy.

***The PEs should be bundled to design classroom experiences. There are multiple ways to bundle the PEs to help students lead inquiry and see connections between ideas, and help teachers facilitate phenomenon-driven learning with efficient use of instructional time.**

Chemistry

Through the chemistry performance expectations, students demonstrate grade-appropriate proficiency in each of three dimensions. When students explore **Disciplinary Core Ideas** (Dimension 3), they will do so by engaging in **Science and Engineering Practices** (Dimension 1) and should be supported in making connections to the **Crosscutting Concepts** (Dimension 2) to link their understanding across the four disciplinary core domains.

Each performance expectation contains one **SEP** and one **CCC** to be assessable and represents the student performance goal for the end of instruction; however, other **SEPs** and **CCCs** should be applied by students to support their progress leading up to the end of instruction. In chemistry, these **end-of-instruction** **SEPs**, **DCIs**, and **CCCs** include:

SEPs	DCIs	CCCs
• Developing and Using Models • Planning and Carrying Out Investigations • Using Mathematics and Computational Thinking • Constructing Explanations and Designing Solutions • Obtaining, Evaluating, and Communicating Information	• Physical Science (PS1, PS2, PS3, PS4) • Engineering, Technology, and Applications of Science (ETS1, ETS2)	• Patterns • Cause and Effect • Systems and System Models • Energy and Matter • Structure and Function • Stability and Change

Hyperlinks within the Standards Document

SC Conceptual Vertical Articulation links: Hover over the above underlined and hyperlinked titles to view links for all SEPs, DCIs, and CCCs.

A Framework for K-12 Science Education links: Hover over titles found within the foundation boxes under each PE to link the guiding research for all SEPs, DCIs, and CCCs.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations. Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. NRC Framework Link	**LS1.C: Organization for Matter and Energy Flow in Organisms** All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. NRC Framework Link	**Patterns** Patterns in the natural and human designed world can be observed and used as evidence. NRC Framework Link

*Equity in science education requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; with access to quality space, equipment, and teachers to support and motivate that learning and engagement; and adequate time spent on science. In addition, the issue of connecting to students' interests and experiences is particularly important for broadening participation in science (NRC Framework, p. 28).

Matter and Its Interactions (PS1)		
C-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.* ***State Assessment Boundary:*** *Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Use a model to predict the relationships between systems or between components of a system. NRC Framework Link	**PS1.A: Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. 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. NRC Framework Link	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena. NRC Framework Link

Matter and Its Interactions (PS1)

C-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

Clarification Statement: *Examples of chemical reactions could include the reaction of sodium and chlorine, carbon and oxygen, carbon and hydrogen, or biochemical reactions.*
State Assessment Boundary: *Assessment is limited to chemical reactions involving main group elements and combustion reactions.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. NRC Framework Link	**PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. NRC Framework Link **PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. NRC Framework Link	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena. NRC Framework Link

Matter and Its Interactions (PS1)		
C-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at a bulk scale to infer the strength of various 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). Macroscopic properties of substances at the bulk scale could include the melting point and boiling point, vapor pressure, and surface tension.* ***State Assessment Boundary:*** *Assessment does not include Raoult's law calculations of vapor pressure.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. NRC Framework Link	**PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the broader level are determined by various forces within and between atoms. NRC Framework Link **PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. NRC Framework Link	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena. NRC Framework Link

Matter and Its Interactions (PS1)

C-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 and is due to the absorption of energy when bonds are broken and the release of energy when new bonds are formed. 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. Examples could include photosynthesis and cell respiration.*
State Assessment Boundary: *Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Model Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system. NRC Framework Link	**PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. NRC Framework Link **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. NRC Framework Link	**Energy and Matter** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. NRC Framework Link

Matter and Its Interactions (PS1)

C-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. Examples could include enzymes or biocatalytic reactions.*
State 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.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. NRC Framework Link	**PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. NRC Framework Link	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena. NRC Framework Link

Matter and Its Interactions (PS1)

C-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, removing products, or chemical kinetics.*
State 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.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. NRC Framework Link	**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. NRC Framework Link **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)* NRC Framework Link	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. NRC Framework Link

Matter and Its Interactions (PS1)

C-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 (stoichiometry). Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem- solving techniques.*
State Assessment Boundary: *Assessment does not include complex chemical reactions.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 and experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical representations of phenomena to support claims. NRC Framework Link	**PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. NRC Framework Link	**Energy and Matter** The total amount of energy and matter in closed systems is conserved. NRC Framework Link

Matter and Its Interactions (PS1)

C-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.*
State Assessment Boundary: *Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Model Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system. NRC Framework Link	**PS1.C: Nuclear Processes** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. NRC Framework Link	**Energy and Matter** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. NRC Framework Link

Motion and Stability: Forces and Interactions (PS2)

C-PS2-6. Communicate scientific and technical information about why the molecular structure determines 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.*
State Assessment Boundary: *Assessment is limited to provided molecular structures of specific designed materials.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). NRC Framework Link	**PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the broader level are determined by various forces within and between atoms. NRC Framework Link **PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. NRC Framework Link **ETS1.C: Optimizing the Design Solution** Determining what constitutes "best," however, requires value judgments, given that one person's view of the optimal solution may differ from another's. *(secondary)* NRC Framework Link	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. NRC Framework Link

Energy (PS3)

C-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures 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.*
State Assessment Boundary: *Assessment is limited to investigations based on materials and tools provided to students.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. NRC Framework Link	**PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. 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). NRC Framework Link **PS3.D: Energy in Chemical Processes and Everyday Life** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. NRC Framework Link	**Systems and System Models** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. NRC Framework Link

Waves and Their Applications in Technologies for Information Transfer (PS4)		
C-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. ***Clarification Statement:*** *Emphasis is on the idea that particles associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.* ***State Assessment Boundary:*** *Assessment is limited to qualitative descriptions.*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. NRC Framework Link	**PS4.B: Electromagnetic Radiation** When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. Atoms of each element emit and absorb characteristic frequencies of light and nuclear transitions have distinctive gamma ray wavelengths, which allows identification of the presence of an element. NRC Framework Link	**Cause and Effect** Cause-and-effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. NRC Framework Link

Waves and Their Applications in Technologies for Information Transfer (PS4)

C-PS4-5. Communicate technical information about how some technological devices use the principles of the electromagnetic spectrum to cause matter to transmit and capture information and energy.

Clarification Statement: *Examples could include medical imaging and communications technology.*
State Assessment Boundary: *Assessments are limited to qualitative information. Assessments do not include band theory.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate technical information or 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). NRC Framework Link	**PS4.B: Electromagnetic Radiation** Photoelectric materials emit electrons when they absorb light of a high-enough frequency. NRC Framework Link **PS4.C: Information Technologies and Instrumentation** Multiple technologies based on the understanding of energy and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. NRC Framework Link **ETS2.A: Interdependence of Science, Engineering, and Technology** Science and engineering complement each other in the cycle known as research and development (R&D). *(secondary)* NRC Framework Link (continued next page)	**Cause and Effect** Systems can be designed to cause a desired effect of energy interactions of matter. NRC Framework Link

	ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World Modern civilization depends on major technological systems. *(secondary)* NRC Framework Link	