SOUTH CAROLINA
DEPARTMENT OF EDUCATION

Chemistry Performance Targets

for the
South Carolina College- and Career-Ready Science Standards 2021

For use 2025-2026

July 2025

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State Superintendent of Education

Contents

Purpose and Use

Science is a way of understanding the physical universe using observation and experimentation to explain natural phenomena. Science also refers to an organized body of knowledge that includes core ideas to the disciplines and common themes that bridge the disciplines. As science educators we must take a 3-dimensional approach in facilitating student learning. By addressing content, science and engineering practices and crosscutting concepts, students can have relevant and evidence-based instruction that can help solve current and future problems.

This document is intended as a guide for discerning and describing features of students and their work who have met the stated Performance Expectation (PE). This document is not intended to be read from cover to cover, but to be used, when needed, to support teacher professional learning and curriculum decisions. This is not intended for student use, and thus is not written in student-friendly language. This is not a curriculum or a means to limit instruction in the classroom. Although each PE states a dedicated Science and Engineering Practice (SEP) and Crosscutting Concept (CCC), students will need to use the whole range of SEPs and CCCs to achieve success by the end of instruction.

Three-dimensional science learning requires discipline specific communication skills. This means that effective science learning occurs when students are expected to speak, listen, read, and write in ways that are appropriate to science. With each Performance Target, there are question/sentence stems and terminology to support student discourse about phenomena to help teachers facilitate the acquisition of science discourse. Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding. The terms and stems in this section are intended to provide a baseline for teachers, neither list is exhaustive nor complete.

In addition to the doing (SEP), thinking (CCC), and learning of science knowledge (Disciplinary Core Ideas) outlined here, students will also require a working knowledge of grade-level appropriate tools and techniques of science. Students should know and recognize how scientists and engineers use these tools and techniques, not just identify them. Students should be able to use these tools to gather data, describe how these tools gather data, and/or interpret data sampled from them. Students will need to understand and apply the conventions of scientific notation when working with extremely large or small quantities of measurement and their calculations.

Document Updates

July 2025

- All Performance Expectation statements have been reformatted to call out each of the dimensions as follows:
  - Science and Engineering Practice – **bold**
  - Crosscutting Concept – *italicize*
  - Disciplinary Core Idea – regular
- The watermark from previous versions of this resource has been replaced with the wording “For use 2025-2026” on the title page and in the footer. This change was made to improve accessibility of this resource.
- Because scientific notation is no longer an expectation of the math standards, the following statement was added to the purpose and use page to support the teaching and understanding of scientific notation: “Students will need to understand and apply the conventions of scientific notation when working with extremely large or small quantities of measurement and their calculations.”

June 2024

- Updated watermark to 2024-2025.
- Adjusted formatting and grammar.

PS1 – Matter and Its Interactions

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.	**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.	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena.

Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students use a model (limited to Periodic Table of the Elements) and identify the components of the model that are relative to their predictions, including:
        i. elements and their arrangement in the periodic table,
        ii. a positively charged nucleus composed of protons and neutrons, surrounded by negatively charged electrons,
        iii. valence electrons,
        iv. number of protons,
        v. number of neutrons, and
        vi. shielding of core electrons.
2. **Relationships**

a. Students use a model to describe the relationships between components, including:
    i. arrangement of the main groups reflects the valence electron pattern and
    ii. elements are arranged by the number of protons.

3. **Connections**
    a. Students use a model to predict the patterns or elemental behavior based on the attraction and repulsion between electrically charged particles and the reactivity of an atom (pattern of valence electrons).
    b. Students predict patterns and properties including:
        i. number and types of bonds formed by and between elements,
        ii. number and charges in stable ions that form atomic groups,
        iii. reactivity and electronegativity trends in groups and periods based on attractions of valence electrons to the nucleus, and
        iv. relative sizes of atoms across periods and in groups.

C-PS1-1 Academic Language

Question/Sentence Stems

- The structures present in _______ result in the properties of _______.
- The properties of _______ are a direct result of their _______ [structures or substructures].
- Each substructure behaves _______ in the model affecting the properties of _______.
- The patterns present in _______ are a direct result of ______.
- Why does the shape of _______ matter for its function?
- Does the pattern in the data support the conclusion that ________ is related to ______? Why or why not?
- Together, the parts of the_______ (system) work together to ______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- anion
- atom
- atomic number
- atomic radius
- atomic symbol
- atomic weight
- boiling point
- cation
- chemical formula
- chemical property
- core electrons
- covalent bond
- electron
- electron affinity
- electron configuration
- electronegativity
- element
- family
- filled shell
- gas
- group (vertical column)
- ion
- ionic bond
- isotope
- liquid
- matter
- melting point
- metal
- metalloid
- molar mass
- molecule
- neutron
- nonmetal
- nucleus
- period (horizontal row)
- periodic table
- periodic trends
- physical property
- proton
- pure substance
- s, p, d, f orbitals
- shielding
- single, double, triple bond(s)
- solid
- transition metal
- valence electrons
- valence shell

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 [models, peer review, simulations, theories, students' own investigations]) 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.	**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. **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.	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena.

Observable features of student performance by the end of the course:

1. **Articulating the explanation of phenomena**
    a. Students construct an explanation of the outcome of a chemical reaction, including:
        i. That the total number of atoms of each element present in the reactants and products is the same.
        ii. The numbers and types of bonds (limited to covalent, ionic) that each atom forms, as determined by valence electron states and electronegativity.
        iii. The valence electron state of the atoms of the reactants and products based on their positions on the periodic table.
        iv. How to use patterns of attraction to predict the type of reaction that occurs.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. Identification of the products and reactants, including their chemical formulae and their valence electron arrangement.
        ii. Identification that the number and types of atoms/ions are the same both before and after a reaction.
        iii. Identification of the numbers and types of bonds in both the reactants and products.
        iv. Patterns of reactivity (for example: the high reactivity of alkali metals, etc.) at the macroscopic level as determined by using the periodic table.
        v. Valence electron configuration and the relative electronegativity of the atoms of the reactants and products based on their position in the periodic table.
3. **Reasoning**
    a. Students use a chain of reasoning to connect the evidence and support, refute, or revise and explanation about how the patterns of valence electrons and the electronegativity of elements can be used to predict the number and types of bonds each element forms.
    b. Students describe/explain the relationship between the observable patterns of reactivity of elements in the periodic table relative to the patterns of valence electrons and electronegativity.
    c. Students revise or expand the explanation about the products of a chemical reaction given new evidence or context.

C-PS1-2 Academic Language

Question/Sentence Stems

- The pattern(s) of _______ are observed in the data presented above in the [table, chart, graph, model output].
- The pattern in the data supports the conclusion that _______ is caused by _______, because _______.
- The mathematical function that best fits the pattern of data is _______.
- One way the _______ can be classified or grouped is to create groups of _______ that are similar to each other because _______.
- Some similarities and differences among the ________ are _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- alkali metal
- atom
- atomic mass
- chemical bond
- chemical properties
- chemical reaction
- combustion
- compound
- concentration
- covalent bond
- decomposition
- double replacement reaction
- electron
- electron affinity
- electron sharing
- electron transfer
- electronegativity
- element
- endothermic reaction
- energy level
- equilibrium
- exothermic reaction
- flame test
- flammability
- gas
- halogen
- ion
- ionic bond
- Law of Conservation of Mass
- Lewis dot structures
- liquid
- mass
- molecule
- neutron
- noble gas
- octet
- outer electron state
- oxidation-reduction reaction
- periodic trends
- precipitate
- product
- proton
- reactant
- reactivity
- rearrangement
- reversible
- shielding
- single replacement reaction
- solid
- stable
- synthesis reaction
- valence electrons
- yield(s)

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.	**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. **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.	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena.

Observable features of student performance by the end of the course:

1. **Identifying the phenomenon under investigation**
    a. Students identify the purpose of the investigation involving the relationship between measurable properties of a substance and the magnitude of attractive forces between the particles of that substance.

2. **Identifying the evidence to address the purpose of the investigation**
    a. Students describe the data that will be collected and the evidence to be derived from the data, including:
        i. Bulk properties that would allow inferences to be made about the electrical forces between particles, including the following descriptions:
            1. spacing of particles can change as a result of the experimental procedure even if the identity of the particles does not change,
            2. kinetic energy affects the magnitude of attraction between particles; as more energy is added to the system, attractive forces between particles can no longer keep them close together,
            3. patterns of interactions between particles at the molecular scale are reflected in the patterns of observable behavior, and/or
            4. patterns observed at multiple scales can provide evidence of the relationships between the magnitude of attractive forces between particles and the structure of substances.
3. **Planning the investigation**
    a. Students provide a rationale for the choice of substances to compare and describe the composition of those substances at the atomic scale.
    b. Students determine and describe the experimental design, including:
        i. identifying variables and controls,
        ii. experimental procedure,
        iii. trial number, and
        iv. necessary equipment, materials, and techniques.
4. **Refining the experimental design**
    a. Students evaluate the investigation, including:
        i. assessing the accuracy and precision of the data collected,
        ii. limitations of the investigation, and
        iii. strength of the data.
    b. Students refine the investigation to provide more accurate, precise, and useful data.

C-PS1-3 Academic Language

Question/Sentence Stems

- The pattern(s) of _______ is (are) observed in the data presented above in the [table, chart, graph, model output].
- The pattern in the data supports the conclusion that _______ is caused by _______, because _______.
- The mathematical function that best fits the pattern of data is _______.
- One way the _______ can be classified or grouped is to create groups of _______ that are similar to each other because _______.
- Using mathematics, the data was summarized to help see the patterns of _______ more clearly and helped to show that _______ causes or does not cause _______.
- Some similarities and differences among the _______ are _______.
- _____ are [highly or slightly] [similar or different] at the [microscopic or macroscopic] scale.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- accuracy
- atomic mass
- atomic radius
- atomic weight
- boiling point
- composite
- Coulomb's law
- covalent bond
- dipole
- dipole-dipole
- dissolve
- electrical conductivity
- electron
- electron cloud
- electron distribution
- electronegativity
- electrostatic force
- gas
- hydrogen bond
- intermolecular force
- intramolecular force
- ionic bond
- lattice energy
- liquid
- London dispersion forces
- melting point
- metallic bonding
- neutron
- nucleus
- permanent polarity
- phase change
- polarity
- polarize
- polymer
- precision
- proton
- solid
- soluble
- solute
- solvent
- state of matter
- surface area
- surface tension
- temporary polarity (including dipole)
- van der Waals forces
- vapor pressure

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.	**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. **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.	**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.

Observable features of student performance by the end of the course:

1. **Components of the model**
   a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components, including:
      i. the investigative system, including:
         1. the chemical reaction and
         2. the surroundings,
      ii. the bonds broken during the reaction,
      iii. the bonds formed during the reaction,
      iv. the energy transfer between:
         1. the systems and their components and/or
         2. the system and the surroundings,
      v. the relative potential energies of reactants and products, and
      vi. the transformation of kinetic energy to potential energy by molecular collisions.
2. **Relationships**
   a. Students develop/use a model to describe the relationships between components, including:
      i. the net change of energy within the system is the result of bonds that broken and formed during the reactions,
      ii. the energy transfer between the system and surroundings by molecular collisions,
      iii. the total energy change of the chemical reaction is matched by an equal but opposite energy change in the surroundings, and
      iv. the release or absorption of energy depends on changes (increase or decrease) in relative potential energies of the reactants and products.
3. **Connections**
   a. Students develop/use a model to demonstrate:
      i. The energy change within the system is accounted for by the change in bond energies of reactants and products.
      ii. Breaking bonds requires an input of energy from the system and/or surroundings.
      iii. Forming bonds releases energy to the system and/or the surroundings.
      iv. The energy transfer between the system and the surroundings is the bond energy difference between the reactants and products.
      v. The total energy of a system and the surroundings is conserved during a reaction.
      vi. Energy transfer occurs during molecular collisions.
      vii. The relative potential energies of the reactants and products are accounted for by the changes in bond energy.

C-PS1-4 Academic Language

Question/Sentence Stems

- Energy is transferred into the system when _______. This is evidenced by______.
- Energy is transferred out of the system when _______. This is evidenced by_______.
- The system contains energy in the forms of _______.
- When bonds are broken, energy is _______(released/absorbed).
- When bonds are formed, energy is_______(released/absorbed).
- Energy is ___(released/absorbed) during the chemical reaction because ______.
- Before the reaction occurs the chemical bonds in the _______ possess _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- activation energy
- atom
- atomic arrangement
- bond energy
- calorimetry
- chemical reaction rate
- chemical system
- combustion
- conversion
- endothermic
- enthalpy ($H=E+PV$)
- exothermic
- heat energy
- ion
- kinetic energy
- Law of Conservation of Energy
- molecule
- oxidation
- photosynthesis
- potential energy
- product
- reactant
- recombination
- reduction
- release of energy
- respiration
- stable
- transfer
- unstable
- $\Delta H=ms\Delta T$

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.	**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.	**Patterns** Different patterns may be observed at which a system is studied and can provide evidence for causality in explanations of phenomena.

Observable features of student performance by the end of the course:

1. **Articulating the explanations of phenomena**
    a. Students articulate a statement describing/explaining relationships between energy and reactions rates, including:
        i. as the kinetic energy of colliding particles increases, the reaction rate increases,
        ii. as the number of collisions between particles increases, the reaction rate increases, and/or
        iii. not all collisions result in a rearrangement of atoms (reaction) due to insufficient kinetic energy.

2. **Evidence**
    a. Students identify and describe evidence (for example: data table, graph, etc.) to construct the explanation, including that:
        i. increases in concentration increases the reaction rate and/or
        ii. increases in thermal energy, as measured by temperature, usually increases the reaction rate.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. A molecule that collides can break bonds and form new bonds, resulting in a new molecule.
        ii. The probability of bonds breaking during a collision is dependent upon the kinetic energy of the collision since bond breaking requires energy.
        iii. Collisions are more likely to occur at a higher temperature (a measurement of thermal energy) because particles are moving faster.
        iv. Because temperature is a measure of average kinetic energy, a higher temperature indicates that molecular collisions will, on average, be more likely to break bonds and form new bonds.
        v. At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often.
        vi. A higher concentration means there are more molecules in a given volume, thus more collisions per unit of time at the same temperature.

C-PS1-5 Academic Language

Question/Sentence Stems

- The pattern(s) of _______ is (are) observed in the data presented above in the [table, chart, graph, model output].
- The pattern in the data supports the conclusion that _______ is caused by _______, because _______.
- The mathematical function that best fits the pattern of data is _______.
- One way the _______ can be classified or grouped is to create groups of _______ that are similar to each other because _______.
- Using mathematics, the data was summarized to help see the patterns of _______ more clearly and helped to show that _______ causes or does not cause _______.
- Some similarities and differences among the _______ are _______.
- ____ are [highly or slightly] [similar or different] at the [microscopic or macroscopic] scale.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- acid-base reaction
- activation energy
- atomic energy
- atomic mass
- atomic motion
- average reaction rate
- biocatalytic factors
- boiling point
- catalyst
- closed system
- collision theory
- concentration
- covalent bond
- dilute
- endothermic
- enzyme
- exothermic
- ion
- ionic bond
- kinetic energy
- Law of Conservation of Mass
- Le Chatelier's Principle
- melting point
- molecule
- oxidation
- oxidation-reduction reaction
- particle size
- pH
- production
- reactant
- solute
- solution
- solvent
- surface area
- temperature
- thermal energy

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.	**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*)	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

Observable features of student performance by the end of the course:

1. **Using scientific knowledge to generate design solutions**
    a. Students identify and describe changeable components of a given chemical reaction system that will increase products at equilibrium. Students explicitly use Le Chatelier's principle.

2. **Describing criteria and constraints, including quantification when appropriate**
    a. Students describe and quantify criteria, including:
        i. cost,
        ii. energy inputs,
        iii. hazardous nature of reactants and products,
        iv. chemical properties of reactants and products, and/or
        v. resource availability.
3. **Evaluating, refining, and/or optimizing the design solution**
    a. Students refine the given system by prioritizing the criteria and making tradeoffs to increase the amount of product obtained from the system.

C-PS1-6 Academic Language

Question/Sentence Stems

- The forward and reverse rates _______ as equilibrium is reached.
- When a substance in the system is ________ (increased/decreased) the system will run in a direction to ________ (use it up/replace it)
- ________ (Adding/Removing) a ________(reactant/product) will cause the reaction to favor formation of more _______(reactants/products) at the new equilibrium.
- The pattern(s) of _______ were observed in the way that the system changes over time.
- The forward rate ____ while the revers rate _______ as the system reaches equilibrium.
- A potential cause for the system to become unstable or imbalanced is _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- arrangement
- bond energy
- catalyst
- chemical bond
- chemical process
- chemical reaction rate
- closed system
- compound
- concentration
- concentration change
- conservation of matter
- dynamic
- dynamic equilibrium
- element
- endothermic
- equilibrium
- equilibrium constant (K)
- exothermic
- heat energy
- inert gas
- Le Chatelier's principle
- mole
- molecular level
- open system
- pressure change
- product
- reactant
- recombination of chemical elements
- reversible reaction
- stable
- stressors
- surface area of reactants
- temperature
- temperature change
- thermal energy
- transfer

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.	**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.	**Energy and Matter** The total amount of energy and matter in closed systems is conserved.

Observable features of student performance by the end of the course:

1. **Representation**
    a. Students develop/use a mathematical model (for example: numerical calculation, graphs, other depictions of quantitative information) and identify the relevant components, including:
        i. quantities of reactants and products of a chemical reaction in terms of:
            1. atoms,
            2. moles, and
            3. mass,
        ii. molar mass of all components of the reaction,
        iii. use of balanced chemical equation(s), and
        iv. the claim that atoms, and therefore mass, are conserved during a chemical reaction.
2. **Mathematical modeling**
    a. Students use the mole to convert between the atomic and macroscopic scales for the analysis.
    b. Students develop/use a mathematical model to:
        i. predict the relative number of atoms in the reactants versus products and the atomic scale and
        ii. calculate the mass of any component of a reaction, given any other component.
3. **Analysis**
    a. Students develop/use a mathematical model (for example: stoichiometric calculations) and describe how to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
    b. Students describe how the mass of a substance can be used to determine the number of atoms, molecules, or ions using moles and mole relationships.

C-PS1-7 Academic Language

Question/Sentence Stems

- When matter moves within the system it _______ (describe movement, change, and interactions).
- When matter leaves the system it _______ (describe where the matter goes).
- _______________ (name reactants) in the system rearrange to form _______ (list products formed).
- The _______(element) atoms start in the _______ (molecule name) molecule before the chemical reaction and end in the _______ (molecule name) molecule.
- Other molecules involved in this chemical reaction are _______.
- The fact that the mass of_______ does not change is evidence that matter is conserved during the changes.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- acid
- atomic mass
- balanced chemical reaction
- base
- chemical equations
- chemical formulae
- coefficient
- compounds
- conserved
- conversion factor
- dimensional analysis
- Law of Conservation of Mass
- matter
- molar mass
- molarity
- mole
- pH
- product
- product
- reactant
- solution
- solution concentration
- solution pH
- stoichiometry
- subscripts
- unbalanced chemical reaction

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 Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**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.	**Energy and Matter** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components, including:
        i. identification of an element by the number of protons,
        ii. number of protons and neutrons before and after decay,
        iii. identity of emitted particle (limited to alpha, beta – both electrons and positrons, and gamma), and
        iv. scale of energy changes associated with nuclear processes, relative to the scale of energy changes associated with chemical processes.

2. **Relationships**
    a. Students develop/use at least 5 distinct models to describe the relationships between components for each of the following nuclear processes:
        i. fission,
        ii. fusion,
        iii. alpha decay,
        iv. beta decay, and
        v. gamma decay.
    b. Students develop/use a model to describe the following features:
        i. The total number of neutrons plus protons is the same both before and after the nuclear process, although the total number of protons and the total number of neutrons may be different before and after.
        ii. The scale of energy changes in a nuclear process is much larger (hundreds of thousands to millions of times larger) than the scale of energy changes in a chemical process.
3. **Connections**
    a. Students develop/use a fusion model to demonstrate:
        i. Fusion is a process in which two nuclei merge to form a single, larger nucleus.
        ii. The resulting nucleus has a larger number of protons than were found in either of the two original nuclei.
    b. Students develop/use a fission model to demonstrate:
        i. Fission is a process in which a nucleus splits into two or more fragments.
        ii. Each resulting fragment has a smaller number of protons than the original nucleus.
    c. Students develop/use a fusion or fission model to describe that these processes may release or absorb energy for the reaction to initiate.
    d. Students develop/use a model of radioactive decay to demonstrate:
        i. The differences in energy type (for example: kinetic, electromagnetic) and particle type (for example: alpha, beta) released during alpha, beta, and gamma decay.
        ii. Any changes from one element to another that result from the process.
        iii. That alpha particle emission is a type of fission reaction, but beta and gamma emission are not.

C-PS1-8 Academic Language

Question/Sentence Stems

- The forms of energy involved in this system are _______.
- The nucleus in an atom is changed by __________ because ________.
- When ___ decay occurs, a ____ particle is released from the nucleus and the changes to the nucleus are ____.
- The energy transformations that take place during the chemical change are _______.

Terminology to Support Student Discourse about Phenomena

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- absorption
- alpha decay
- alpha particle
- atomic mass
- atomic number
- beta emission
- beta particle
- daughter nuclei
- decay rate
- electromagnetic radiation
- fission
- fusion
- gamma radiation
- Geiger counter
- half-life
- heat
- heavy nucleus
- ionizing radiation
- island of stability
- kinetic energy
- light nuclei
- neutron
- nonionizing radiation
- nuclear mass
- nuclear process
- nuclear reaction
- nuclear reactor
- nuclear stability
- nucleus
- particle emission
- positron
- positron emission
- proton
- radiation
- radioactive
- radioactive decay
- solar energy
- spontaneous nuclear reaction
- stable
- transformation
- unstable

PS2 – Motion and Stability: Forces and Interactions

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).	**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. **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. **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*)	**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.

Observable features of student performance by the end of the course:

1. **Communication**
    a. Students use and cite at least two different formats (for example: oral, graphical, textual, mathematical, etc.) to communicate scientific and technical information about the design, properties and structure of a chosen material.
2. **Connections**
    a. Students identify and communicate evidence for how molecular level structure determines the functioning of designed materials, including:
        i. how the structure, properties, and molecular interactions at the atomic scale determine the function of a designed material and
        ii. how the material's properties make it suitable for its intended use.
    b. Students identify the molecular structure of a designed material using appropriate representations for the communication format (for example: geometric shapes for drugs and receptors, ball and stick models for long-chain molecules, etc.).
    c. Students identify and describe the relationship between a designed material's function and its macroscopic properties (for example: material strength, conductivity, reactivity, state of matter, durability, etc.) and each of the following:
        i. molecular structure,
        ii. intermolecular forces and polarity,
        iii. ability of electrons to move relatively freely in metals, and
        iv. types of bonds between atoms.
    d. Students identify and describe the role of electrical forces (attractive and repulsive) between molecules in the arrangement of the molecules in a designed material (for example: state, network solid, polymer, etc.)
    e. Students identify and describe that, for all materials, electrostatic forces on the atomic and molecular scales result in contact forces (for example: friction, normal forces, stickiness, etc.) on the macroscopic scale.

C-PS2-6 Academic Language

Question/Sentence Stems

- The structures present in _______ result in the properties of _______.
- The properties of _____ are a direct result of their ______ [structures or substructures].
- Each substructure behaves _______ in the model affecting the properties of _______.
- Together, the parts of the _______ (system) work together to _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- chemical property
- conductor
- covalent bond
- dipole
- dipole-dipole
- electronegativity
- electrostatic attraction
- heat conductivity
- Hydrogen (H) bonding
- hydrogen bond
- immiscible
- induced dipole
- insoluble
- insulator
- intermolecular attraction
- ionic bond
- magnetic property
- mechanical property
- metallic bond
- miscible
- monomer
- net charge
- nonpolar
- physical property
- polar
- polymer
- salts
- soluble
- valence electrons
- van der Waals forces

PS3 – Energy

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.	**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). **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.	**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.

Observable features of student performance by the end of the course:

1. **Identifying the phenomenon under investigation**
    a. Students identify the purpose of the investigation involving the transfer of thermal energy when two components at different temperatures are combined within a closed system, which results in a more uniform energy distribution among the components of the system (second law of thermodynamics).
2. **Identifying the evidence to address the purpose of the investigation**
    a. Students describe the data that will be collected and the evidence to be derived from the data, including:
        i. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object shows:
            1. thermal energy lost by the hot object is equal to the thermal energy gained by the cold object and
            2. the distribution of thermal energy is more uniform after the interaction of the hot and cold objects.
        ii. The heat capacity of the objects under investigation (obtained from scientific literature).
3. **Planning the investigation**
    a. Students determine and describe the experimental design, including:
        i. identifying variables and controls, including:
            1. how a nearly closed system will be constructed, including boundaries and initial conditions of the system,
        ii. the experimental procedure,
        iii. how the data will be collected, including:
            1. data necessary to calculate the change in thermal energy of the components of the system, including:
                a. masses of the components,
                b. initial temperatures, and
                c. final temperatures,
        iv. number of trials, and
        v. the necessary equipment, materials, and techniques
4. **Refining the experimental design**
    a. Students evaluate the investigation, including:
        i. assessing the accuracy and precision of the data collected, including:
            1. potential causes for the apparent loss of energy from a closed system,
        ii. limitations of the investigation, and
        iii. strength of the data.
    b. Students refine the investigation to provide more accurate, precise, and useful data.

C-PS3-4 Academic Language

Question/Sentence Stems

- The key components of the system are _______ and they work together by _______.
- In the system, _______ and _______ are shown in the model.
- In the system, _______ is not shown in the model. This is not shown because _______.
- The key assumptions to the model of my system are _______ this affects the reliability of the model because _______.
- The model was chosen to represent _______ because of _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- calorimetry
- closed system
- conservation of energy
- entropy
- First Law of Thermodynamics
- Gibbs free energy (G)
- heat conduction
- heat convection
- heat radiation
- irreversible process
- isolated system
- Joules (J)
- Kelvin (K)
- kinetic energy
- Law of Conservation of Energy
- macroscopic scale
- melting
- microscopic scale
- molecular energy
- open system
- reversible process
- Second Law of Thermodynamics
- specific heat
- specific heat capacity
- spontaneous reaction
- system surroundings
- temperature
- thermal energy
- vaporization

PS4 – Waves and Their Applications in Technologies for Information Transfer

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.	**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.	**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.

Observable features of student performance by the end of the course:

1. **Obtaining information**
    a. Students research at least two claims proposed in published material (citing at least two sources per claim) about the impact of absorbed electromagnetic radiation on matter, including at least one claim that deals with living tissue.

2. **Evaluating information**
    a. Students use reasoning about the data presented to analyze the reliability and validity of the claim, including:
        i. photon energy (limited to relative wavelengths) and
        ii. ionization probability.
    b. Students evaluate the information based on:
        i. the credibility, accuracy, and bias of each publication and the methods used to generate and collect the evidence and
        ii. the cause-and-effect reasoning in each claim, including extrapolations to larger scales (for example: extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the organism, etc.).

C-PS4-4 Academic Language

Question/Sentence Stems

- If _______ happens, I/we predict that ________ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- In order to conclude that _______ caused _______, the following evidence is needed _______.

Terminology to Support Student Discourse about Phenomena

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- absorption
- brightness
- cells
- denaturation
- diffraction
- electric potential
- emission
- frequency
- gamma ray
- infrared radiation
- interference
- ionize
- light scattering
- light transmission
- magnetic resonance imaging (MRI)
- media
- microwave
- mutagen
- mutation
- ohm
- organism
- phase
- photoelectric
- photoelectric effect
- photon
- photon energy
- radio wave
- refraction
- resonance
- semiconductor
- solar cell
- speed of light
- thermal imaging
- tissues
- transparent
- transverse wave
- ultraviolet
- ultraviolet (UV) radiation
- visible light
- vision
- wavelength
- x-ray

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).	**PS4.B: Electromagnetic Radiation** Photoelectric materials emit electrons when they absorb light of a high-enough frequency. **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. **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*) **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems. (*secondary*)	**Cause and Effect** Systems can be designed to cause a desired effect of energy interactions of matter.

Observable features of student performance by the end of the course:

1. **Communication**
    a. Students use and cite at least two different formats (for example: oral, graphical, textual, mathematical, etc.) to communicate scientific information about at least two devices and the physical principles upon which the devices depend. At least one device must depend on the electromagnetic spectrum for its operation.
2. **Connections**
    a. Students identify and communicate information about the devices, including:
        i. how each device operates,
        ii. the wave behavior utilized by the device, and
        iii. qualitatively describe how the basic physical principles were used through research and development to produce the functionality of the device (for example: absorbing electromagnetic energy and converting it to thermal energy to heat an object, etc.).
    b. Students discuss real-world problems or need each device addresses and how civilization depends on the device.
    c. Students identify and describe the cause-and-effect relationships that are used to produce the functionality of the device.

C-PS4-5 Academic Language

Question/Sentence Stems

- If _______ happens, I/we predict that ________ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- In order to conclude that _______ caused _______, the following evidence is needed _______.

Terminology to Support Student Discourse about Phenomena

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- angle of incidence
- antenna
- constructive wave
- demodulation
- destructive wave
- diffraction
- dispersion
- electromagnetic spectrum
- frequency
- gamma ray
- infrared
- intensity
- interference
- light emitting diode (LED)
- longitudinal wave
- magnetic resonance imaging (MRI)
- mechanical wave
- medium
- microwaves
- navigation
- nodes
- optical fiber
- oscillating electron
- periodic motion
- photon
- photon energy
- prism
- radar
- radio
- rarefaction
- real image
- receiver
- reflection
- refraction
- resonance
- restoring
- sonar
- sonography
- standing wave
- standing wave
- superposition
- transmitter
- transverse wave
- ultrasound
- ultraviolet (UV) ray
- velocity
- virtual image
- visible light
- wavelength
- weather monitoring
- Wi-Fi
- x-ray

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