Chariho Regional School District - Science Curriculum
September, 2016

CHEMISTRY CURRICULUM

Unit 1: Using Mathematics in Chemistry

OVERVIEW

Summary

Measurements are fundamental to the experimental sciences. It is important to be able to take measurements and decide whether measurements make sense, are correct and are represented properly. Students will be able to measure as accurately and precisely as possible, perform operations, calculate, and round the answers relevant to the context of the problems. In this unit, topics such as scientific notation, solving multi-step equations, rounding and order of operation will be reinforced in the context of chemistry problem solving.

Content to Be Learned

- Convert measurements into scientific notation.
- Distinguish among accuracy, precision, and error of a measurement.
- Determine the number of significant figures in a measurement and in a calculated answer.
- List Standard International (SI) Units of measurement and common SI prefixes.
- Solve multi-step problems.
- Interpret results and determine the appropriateness of their responses.

Practices

- Using Mathematics and Computational Thinking.

Crosscutting Concepts

- Scale, Proportion, and Quantity.
- Patterns.

Essential Questions

- Why is it important for scientists to measure accurately and precisely when conducting scientific investigations?
- What are some ways scientists communicate their results to peers effectively and accurately?

Common Core Standards

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

- CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.
- CCSS.MATH.PRACTICE.MP4 Model with mathematics.
- CCSS.MATH.CONTENT.HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.
- CCSS.MATH.CONTENT.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Unit 2: Atomic Structure

OVERVIEW

Summary

Students will be introduced to the structure of an atom. Using a periodic table they will be able to determine the number of protons, neutrons and electrons of an element. Students will begin to see patterns (both horizontal and vertical) in the periodic table. Based on the number of electrons in the outer shell, students will gain an understanding of how an atom becomes charged and reacts with one another. This unit is a foundation for the unit on Chemical Bonding.

Content to Be Learned

- Structure of an atom (protons, neutrons, electrons).
- The arrangement of the periodic table is by number of protons and similarity of chemical protons, and patterns of outer electron states.
- Chemical processes can be described and predicted based on knowledge of chemical properties and conservation of atoms.
- Periodic table orders elements horizontally based on number of protons in an atom's nucleus, and places elements with similar properties in columns. This pattern reflects patterns of outer electron states.

Practices

- Developing and using models.
- Constructing explanations and designing solutions.
- Planning and carrying out investigations.
- Obtaining, evaluating and communicating information.

Crosscutting Concepts

- Patterns.
- Energy and matter.
- Structure and function.

Essential Questions

- How can the periodic table be used to predict the properties of elements?
- How does the periodic table show patterns in valance electrons of elements?
- How can the structure of an object infer information about the strength of the forces between its particles?
- Why is the molecular-level structure important in the functioning of designed materials?

Next Generation Science Standards

HS-PS1-1 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.LS1.C

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B**

Common Core State Standards Connections:

ELA/Literacy -

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

HS-PS1-3 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-3. **Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*]

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

Science and Engineering Practices

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.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

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

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.ESS2.C

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS2.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS1-3)*

Mathematics -

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

HS-PS2-6 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

HS-PS2-6. **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [*Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**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.	**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.

Connections to other DCIs in this grade-level: N/A

Articulation of DCIs across grade-bands:
MS.PS2.B

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS2-6)*
WHST.11-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS2-6)*

Mathematics -

HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-PS2-6)*
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-6)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS2-6)*

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

Unit 3: Chemical Bonding

OVERVIEW

Summary

Chemical Bonding is the electrostatic interaction of charged atoms which leads to chemical bonding. Students will be introduced to the measures used to determine the strength of these bonds based on the ability of these atoms to compete for electrons. This knowledge will ultimately lead to an understanding of the physical and chemical properties of substances.

Content to Be Learned

- Determine the number of valence electrons in an atom of a representative element.
- Explain how the octet rule applies to atoms of metallic and nonmetallic elements.
- Describe how cations and anions form.

- Describe the physical and chemical properties of ionic, covalent, and metallic compounds.
- Describe the information provided by a chemical formula.
- Compare and contrast the relative positions that electrons take in ionic, covalent, and metallic bonding.
- Describe how atoms form single, double, and triple covalent bonds.
- Describe how electronegativity determine the distribution of charge in a polar molecule.
- Describe how the magnitude of the electronegative difference determines the type of chemical bond.
- Evaluate the strength of intermolecular attractions in ionic, covalent, metallic bonds.

Practices

- Developing and using models.
- Constructing explanations and designing solutions.
- Planning and carrying out investigations.

Crosscutting Concepts

- Patterns.

Essential Questions

- How does the atomic structure affect interactions between atoms?
- How does the type of chemical bond affect the physical and chemical properties of a compound?
- How does the knowledge of chemical bonding allow chemists to design chemicals with specific properties?
- Why does matter organize itself?

Next Generation Science Standards

HS-PS1-1 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

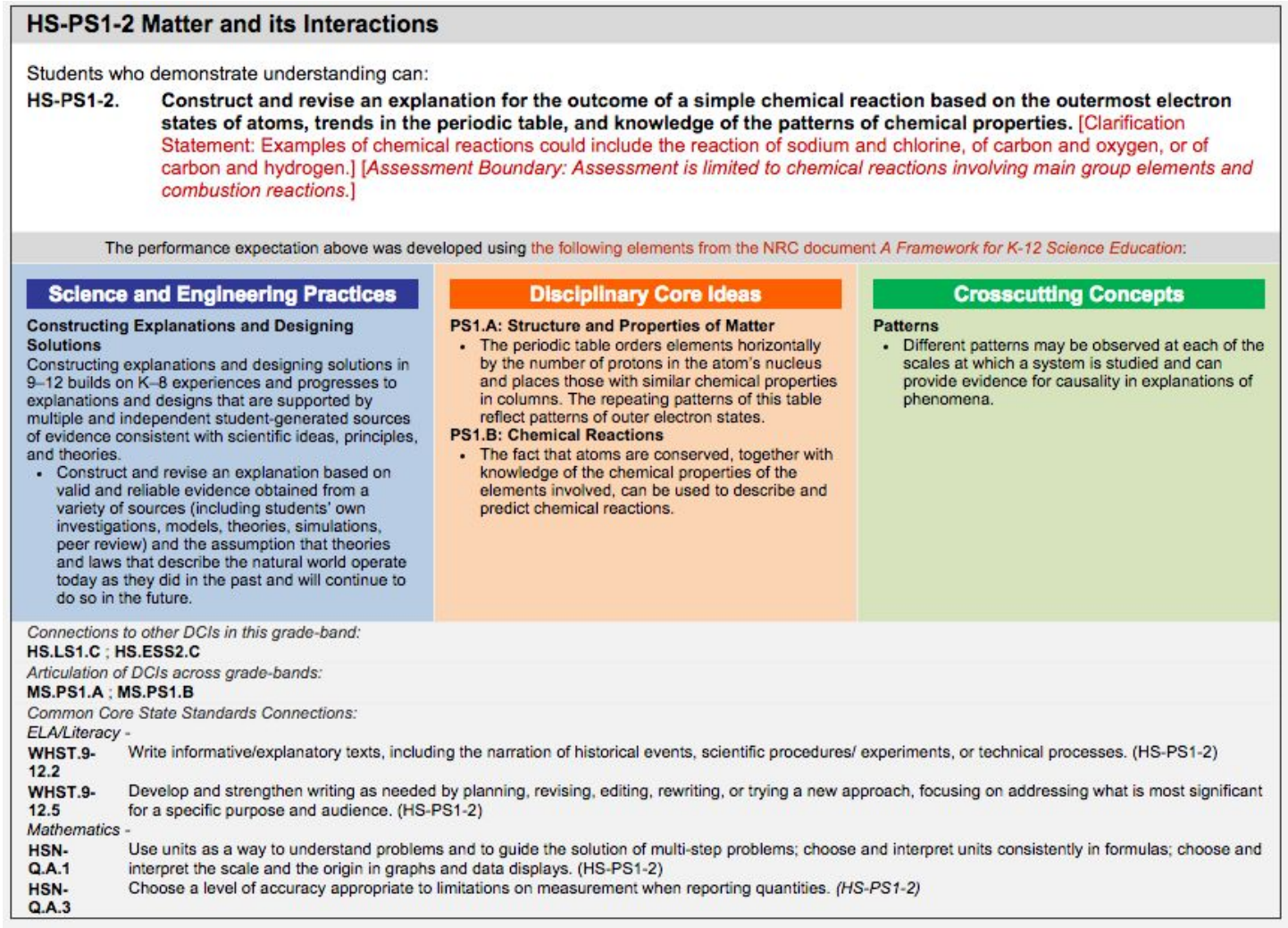
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.LS1.C
Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B**
Common Core State Standards Connections:
ELA/Literacy -
RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. *(HS-PS1-1)*



HS-PS1-2 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct 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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.LS1.C ; **HS.ESS2.C**
Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B**
Common Core State Standards Connections:
ELA/Literacy -
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)
WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)
Mathematics -
HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-2)*

Unit 4: Chemical Reactions

OVERVIEW

Summary

Chemical reactions have many applications that make life possible. The Law of Conservation of Mass states that the total mass of the reactants will equal the total mass of the products. Students will learn to identify, name, and balance chemical reactions. They will learn about the various types of reactions and how to predict their products. They will be introduced to stoichiometry and the importance of balancing reactions.

Content to Be Learned

- Identify the reactants and products in a chemical reaction.
- Describe the steps for writing a balanced chemical equation.
- Describe the major types of reactions.
- Predict the products of the major types of reactions.

- Describe the information found in a net ionic equation.
- Determine how a chemical reaction satisfies the law of conservation of mass.
- Identify redox reactions, oxidizing agents, and reducing agents.
- Predict the amount of a precipitate in a double replacement reaction.
- Explain how balanced equations apply to both chemistry and everyday situations.
- Interpret balanced chemical equations in terms of moles, representative particles, mass and gas volumes at STP.
- Calculate stoichiometric quantities from balanced chemical equations using units of moles, mass, representative particles, and volumes of gases at STP.
- Identify the limiting reagent in a reaction.

Practices

- Using mathematics and computational thinking.
- Developing and using models.
- Constructing explanations and designing solutions.

Crosscutting Concepts

- Patterns.
- Energy and matter.
- Stability and change.

Essential Questions

- How can the outcome of a chemical reaction be predicted based on knowledge of chemical properties and patterns of the periodic table?
- What relationship exists between bond energy and the release or absorption of energy in a reaction?
- How does changing the temperature or concentration of reactants influence the rate of a reaction?
- How can conservation of mass be applied to chemical reactions?
- What variable need to be changed, and in what ways, to increase amounts of product in a chemically balanced system (equilibrium)?

HS-PS1-2 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct 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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

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

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B**

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)

Mathematics -

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-2)*

HS-PS1-5 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

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

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.PS3.A

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.PS2.B** ; **MS.PS3.A** ; **MS.PS3.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS1-5)*

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS1-5)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-PS1-5)*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-5)*

HS-PS1-6 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-6. **Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [*Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

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

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

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)*

Crosscutting Concepts

Stability and Change

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

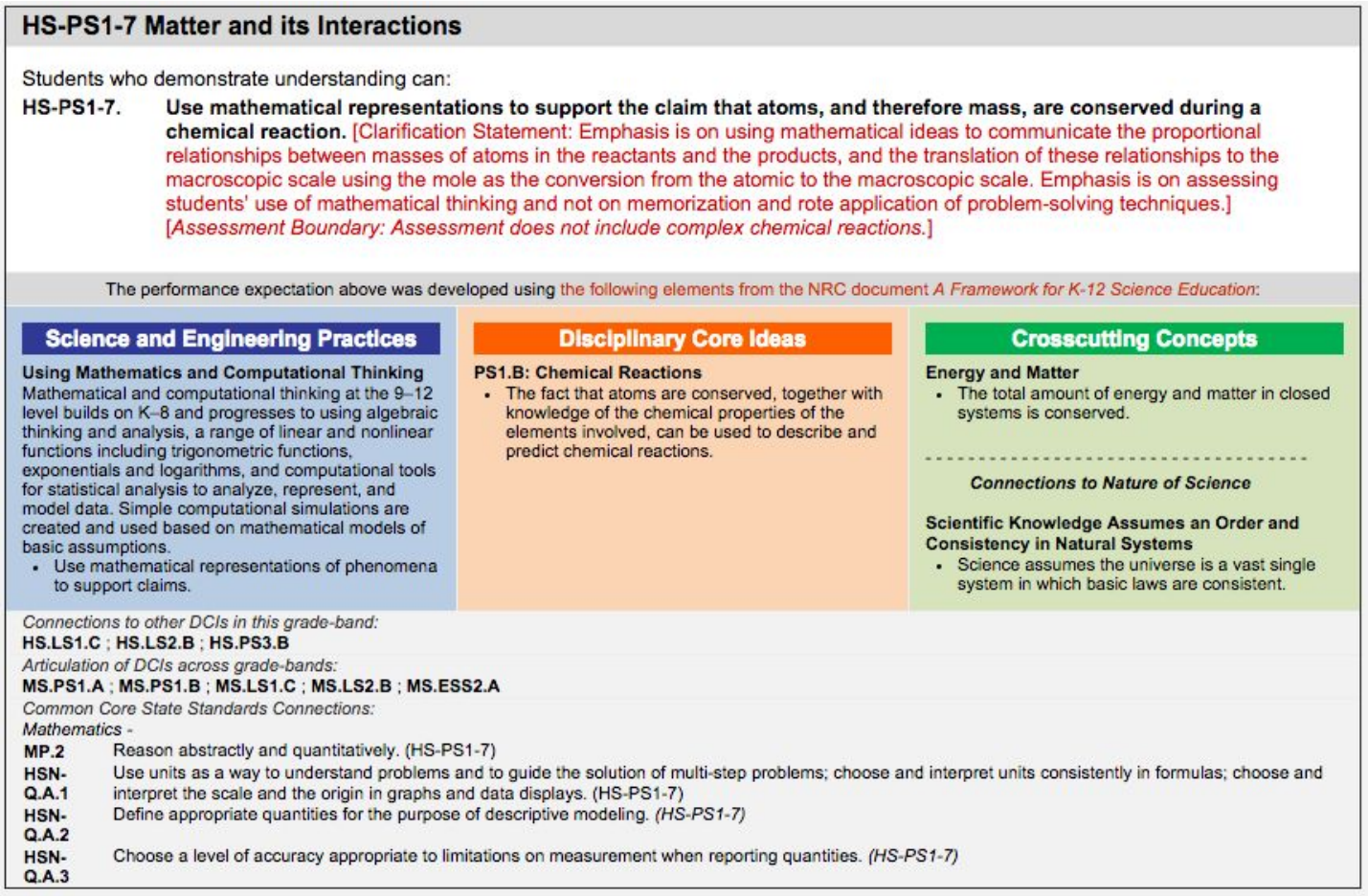
Connections to other DCIs in this grade-band:
HS.PS3.B

Articulation of DCIs across grade-bands:
MS.PS1.B

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS1-6)*



HS-PS1-7 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical representations of phenomena to support claims.

Disciplinary Core Ideas

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.

Crosscutting Concepts

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

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes the universe is a vast single system in which basic laws are consistent.

Connections to other DCIs in this grade-band:
HS.LS1.C ; **HS.LS2.B** ; **HS.PS3.B**
Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.LS1.C** ; **MS.LS2.B** ; **MS.ESS2.A**
Common Core State Standards Connections:
Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS1-7)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-7)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS1-7)*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-7)*

Unit 5: Thermodynamics

OVERVIEW

Summary

Thermodynamics is the study of potential and kinetic energy transformations; especially heat during chemical reactions. Students will be introduced to the concepts of enthalpy, entropy and Gibbs free energy. These formulations are quantifiable and are essential components in determining the spontaneity of chemical reactions.

Content to Be Learned

- Explain how energy, heat and work are related.
- Classify processes as either exothermic or endothermic.
- Chemical reactions release or absorb energy as chemical bonds are broken and formed.
- Explain why a catalyst is not considered a reactant or product.
- Describe the forms s of energy that can come from chemical reactions.
- Identify the units used in heat transfer.
- Distinguish between heat and specific heat.
- Describe how calorimeters are used to measure heat flow.
- Construct thermochemical equations.

- Classify and/or solve for the enthalpy change that occurs when a substance melts, freezes, boils, condenses, or dissolves.

Practices

- Constructing and revise an explanation based on valid and reliable evidence.

Crosscutting Concepts

- Energy and matter flow into, out of, and within a system.

Essential Questions

- How do you determine if a chemical reaction is endothermic or exothermic?
- How do you determine if a chemical reaction will create more or less disorder?
- How are the natural tendencies of the universe reflected in the meaning of the signs of enthalpy and entropy,?
- Why are catalysts needed for chemical reactions?

Next Generation Science Standards

HS-PS1-4 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-4. **Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

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.

Crosscutting Concepts

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.

Connections to other DCIs in this grade-band:
HS.PS3.A ; **HS.PS3.B** ; **HS.PS3.D** ; **HS.LS1.C**

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.PS2.B** ; **MS.PS3.D** ; **MS.LS1.C**

Common Core State Standards Connections:

ELA/Literacy -

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS1-4)*

Mathematics -

MP.4 Model with mathematics. *(HS-PS1-4)*

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-PS1-4)*

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-4)*

HS-PS1-2 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct 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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

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

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B**

Common Core State Standards Connections:

ELA/Literacy -

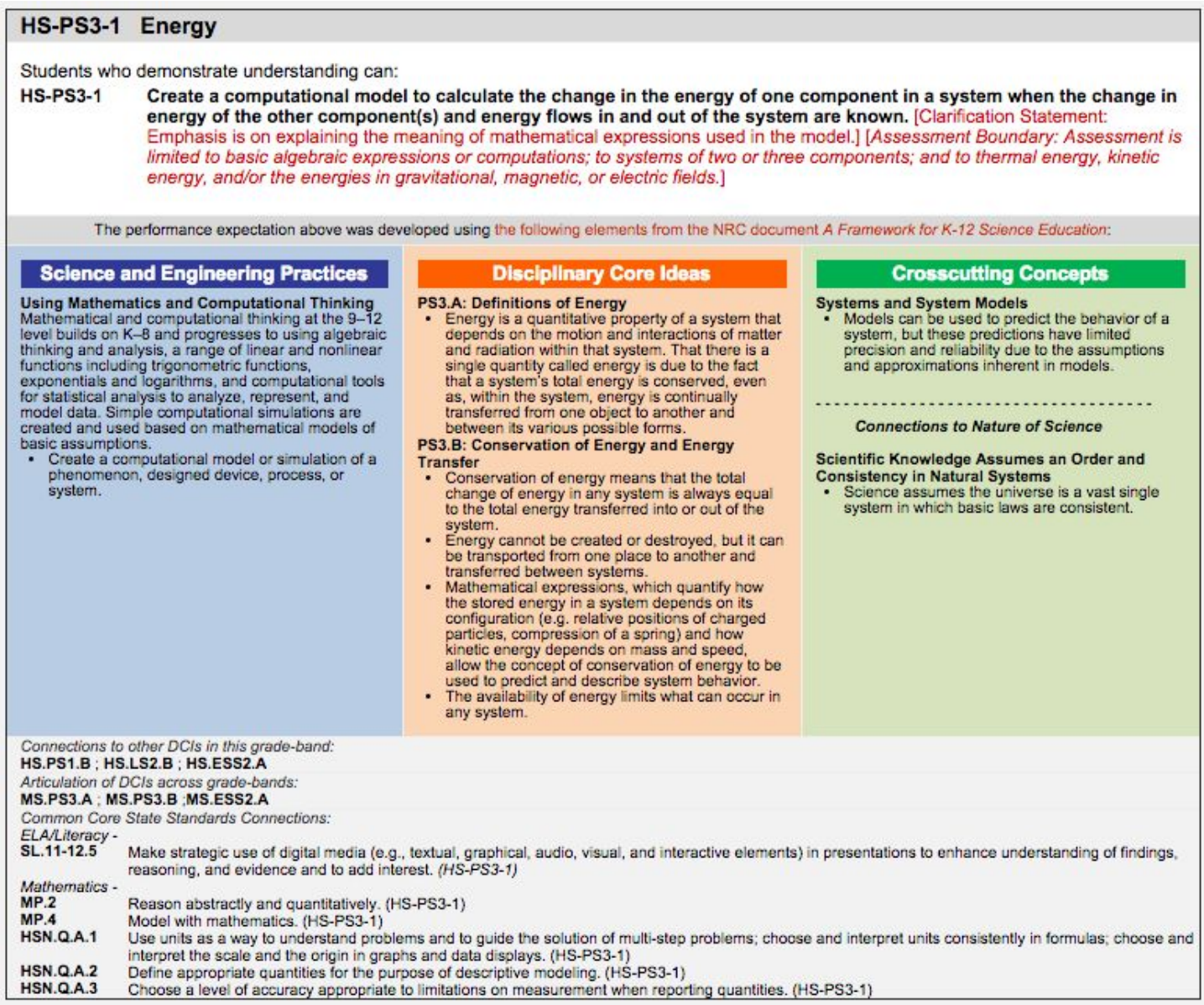
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)

Mathematics -

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-2)*



HS-PS3-1 Energy

Students who demonstrate understanding can:

HS-PS3-1 **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

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

Science and Engineering Practices

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Create a computational model or simulation of a phenomenon, designed device, process, or system.

Disciplinary Core Ideas

PS3.A: Definitions of Energy
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Crosscutting Concepts

Systems and System Models
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes the universe is a vast single system in which basic laws are consistent.

Connections to other DCIs in this grade-band:
HS.PS1.B ; HS.LS2.B ; HS.ESS2.A
Articulation of DCIs across grade-bands:
MS.PS3.A ; MS.PS3.B ;MS.ESS2.A
Common Core State Standards Connections:
ELA/Literacy -
SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. *(HS-PS3-1)*
Mathematics -
MP.2 Reason abstractly and quantitatively. (HS-PS3-1)
MP.4 Model with mathematics. (HS-PS3-1)
HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1)
HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1)
HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1)

Unit 6: States of Matter

OVERVIEW

Summary

Matter exists in many forms. The physical properties of crystals, solids, liquids, gases and plasma and their solutions, in conjunction with temperature and pressure, effect changes in the constitution of chemical reactions. Students will gain an in-depth knowledge of how physical properties interact with one another in the lab and the world at large. Students will learn about the gas laws that govern the movement of molecules and will understand and experience the relationships between temperature, pressure and volume of a gas. They will be able to predict how each of those variables would change when one is manipulated.

Content to Be Learned

- Describe the assumptions of the kinetic theory as it applies to physical states and chemical reactions.

- Describe particle movement in the four states of matter.
- Describe particle behavior at the melting and boiling points.
- Define the relationship between Kelvin temperature and average kinetic energy.
- Identify factors that determine physical properties of a liquid.
- Describe the equilibrium between solid, liquid, gas, and plasma.
- Evaluate the way particles are organized in solids, liquids, gases and plasmas.
- Explain Bernoulli's Principle.
- Identify the factors that determine the shape of a crystal.
- Identify the conditions necessary for sublimation.
- Describe how equilibrium conditions are represented in a phase change.
- Describe the three factors that affect gas pressure.
- Describe the interrelationships between temperature, pressure, and volume of a gas.
- Use Boyle's', Charles', Combined Gas Law, and the Ideal Gas Law to solve problems.
- Compare and contrast real and ideal gases.

Practices

- Constructing and revise an explanation.
- Developing and using models.
- Using mathematics and computational thinking.

Crosscutting Concepts

- Energy and Matter.
- Stability and Change.
- Patterns.

Essential Questions

- How are force, area, and pressure related?
- What are the relationships between temperature and pressure in gas laws?
- How does pressure change as the velocity of a fluid increases?
- How does external pressure affect the boiling point of a liquid?
- How are kinetic energy and temperature related?

Next Generation Science Standards

HS-PS1-3 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-3. **Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*]

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

Science and Engineering Practices

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.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

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

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.ESS2.C

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS2.B**

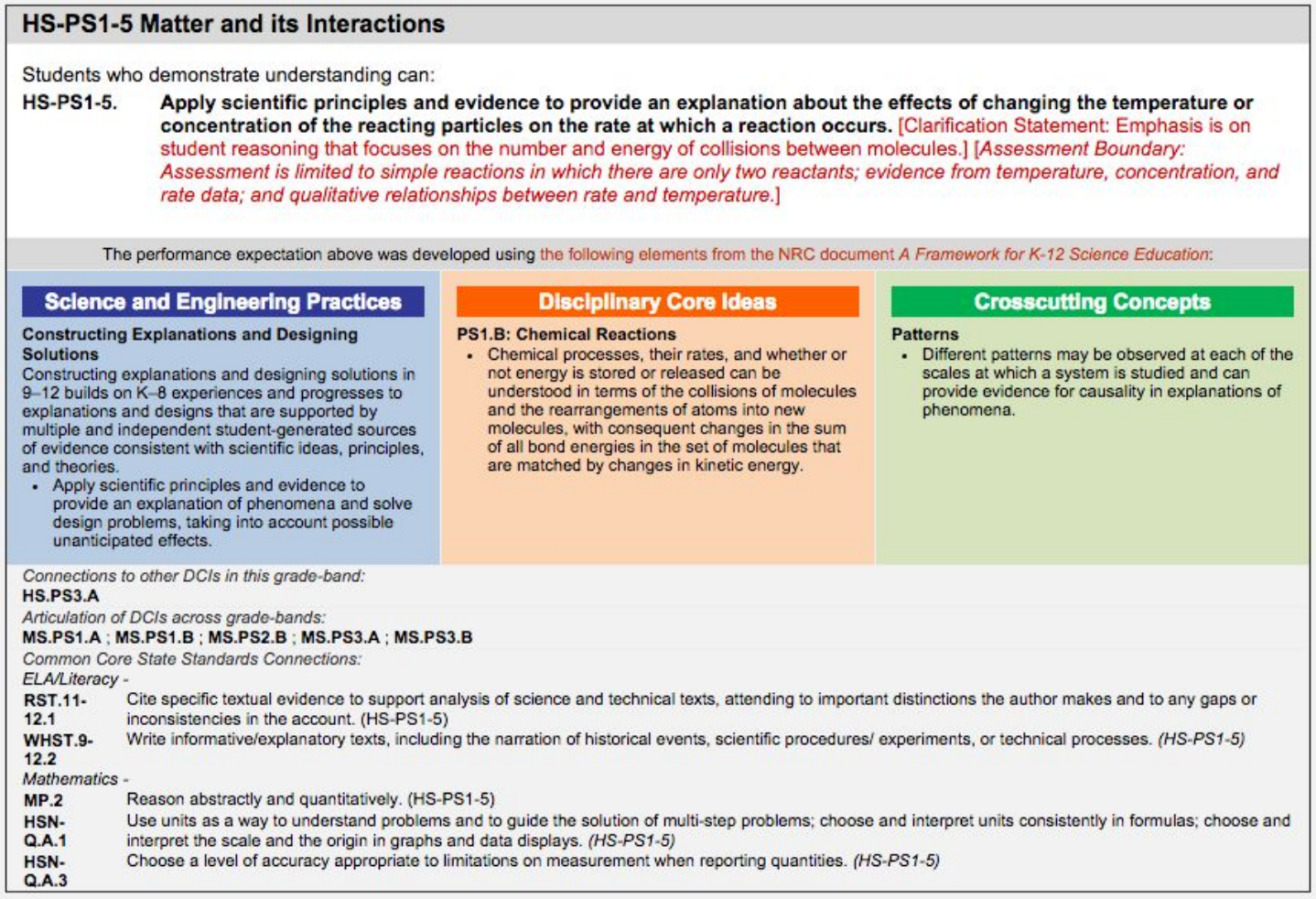
Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS1-3)*

Mathematics -

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



HS-PS1-5 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

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

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.PS3.A

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.PS2.B** ; **MS.PS3.A** ; **MS.PS3.B**

Common Core State Standards Connections:

ELA/Literacy -

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5)

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

Mathematics -

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

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

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

Unit 8: Nuclear Chemistry

OVERVIEW

Summary

Nuclear chemistry is the study of the nucleus of an atom and its processes. Students will begin by learning about isotopes and how they differ from atoms of an element. They will then look at specific cases of isotopes, know as radioactive isotopes, and calculate their decay. Next, students will research the applications of radioactivity, including carbon dating, medical applications, and others. They will compare and contrast fission and fusion reactions, and will look at how fusion converts atoms inside the sun, which ultimately provides energy to Earth.

Content to Be Learned

- Identify the components of isotopes.
- Interpret the average atomic mass of an element.
- Define radioactivity.
- Contrast properties of radioactive and stable nuclei.

- Explain the strong force and contrast it to the electric force.
- Describe how an unstable nucleus releases energy.
- Describe the three main types of nuclear radiation.
- Determine the type of decay a radioisotope undergoes.
- Write the nuclear reactions for the half-life of a radioactive substance.
- Compare and contrast fission and fusion nuclear reactions.
- Explain what happens to the number of neutrons and protons in nuclear processes.
- Compare and contrast alpha, beta, and gamma radiation.
- Define the half-life of a radioactive material.
- Describe the process of radioactive dating.
- Discuss the ways in which radioactivity can be detected.
- Explain how nuclear fission can begin a chain reaction.
- Discuss how nuclear fusion occurs in the sun.
- Describe how radioactive tracers can be used to diagnose medical problems.
- Discuss how nuclear reactions are being used to help treat cancer.

Practices

- Constructing and revise an explanation.

Crosscutting Concepts

- Energy and matter.

Essential Questions

- How is mass number used to determine the nucleus of an isotope?
- How do fission, fusion, and radioactive decay each affect the composition of the nucleus and the energy released?
- How is nuclear chemistry used to help create geologic timelines?
- How are nuclear reactions and radioactivity used in medical applications?

Next Generation Science Standards

HS-PS1-7 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena to support claims.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Energy and Matter

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

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes the universe is a vast single system in which basic laws are consistent.

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

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B** ; **MS.LS1.C** ; **MS.LS2.B** ; **MS.ESS2.A**

Common Core State Standards Connections:

Mathematics -

MP.2	Reason abstractly and quantitatively. (HS-PS1-7)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-7)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS1-7)*
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-7)*

HS-PS1-1 Matter and its Interactions

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Connections to other DCIs in this grade-band:
HS.LS1.C

Articulation of DCIs across grade-bands:
MS.PS1.A ; **MS.PS1.B**

Common Core State Standards Connections:

ELA/Literacy -

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

HS-PS1-8 Matter and its Interactions

Students who demonstrate understanding can:

HS-PS1-8. **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

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

Disciplinary Core Ideas

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.

Crosscutting Concepts

Energy and Matter

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

Connections to other DCIs in this grade-band:

HS.PS3.A ; **HS.PS3.B** ; **HS.PS3.C** ; **HS.PS3.D** ; **HS.ESS1.A** ; **HS.ESS1.C** ; **HS.ESS3.A** ; **HS.ESS3.C**

Articulation of DCIs across grade-bands:

MS.PS1.A ; **MS.PS1.B** ; **MS.ESS2.A**

Common Core State Standards Connections:

Mathematics -

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