SUPPORT GUIDE 3.0
FOR CHEMISTRY

SOUTH CAROLINA ACADEMIC STANDARDS
AND PERFORMANCE INDICATORS FOR SCIENCE

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INTRODUCTION TO CHEMISTRY STANDARDS

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. This document, *South Carolina Academic Standards and Performance Indicators for Science*, contains the academic standards in science for the state's students in kindergarten through grade twelve.

As science educators we must take a 3 dimensional approach in facilitating student learning. By addressing content standards, science and engineering practices and crosscutting concepts, students are able to have relevant and evidence based instruction that can help solve current and future problems. For more information please see: https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts.

ACADEMIC STANDARDS

In accordance with the South Carolina Education Accountability Act of 1998 (S.C. Code Ann. § 59-18-110), the purpose of academic standards is to provide the basis for the development of local curricula and statewide assessment. Consensually developed academic standards describe for each grade and high school core area the specific areas of student learning that are considered the most important for proficiency in the discipline at the particular level.

Operating procedures for the review and revision of all South Carolina academic standards were jointly developed by staff at the State Department of Education (SCDE) and the Education Oversight Committee (EOC). According to these procedures, a field review of the first draft of the revised South Carolina science standards was conducted from March through May 2013. Feedback from that review and input from the SCDE and EOC review panels was considered and used to develop these standards.

The academic standards in this document are not sequenced for instruction and do not prescribe classroom activities; materials; or instructional strategies, approaches, or practices. The *South Carolina Academic Standards and Performance Indicators for Science* is not a curriculum.

THE PROFILE OF THE SOUTH CAROLINA GRADUATE

The *2014 South Carolina Academic Standards and Performance Indicators for Science* support the *Profile of the South Carolina Graduate. The Profile of the South Carolina Graduate* has been adopted and approved by the South Carolina Association of School Administrators (SCASA), the South Carolina Chamber of Commerce, the South Carolina Council on Competitiveness, the Education Oversight Committee (EOC), the State Board of Education (SBE), and the South Carolina Department of Education (SCDE) in an effort to identify the knowledge, skills, and characteristics a high school graduate should possess in order to be prepared for success as they enter college or pursue a career. The profile is intended to guide all that is done in support of college- and career-readiness.

Profile of the South Carolina Graduate

World Class Knowledge

- Rigorous standards in language arts and math for career and college readiness
- Multiple languages, science, technology, engineering, mathematics (STEM), arts and social sciences

World Class Skills

- Creativity and innovation
- Critical thinking and problem solving
- Collaboration and teamwork
- Communication, information, media and technology
- Knowing how to learn

Life and Career Characteristics

- Integrity
- Self-direction
- Global perspective
- Perseverance
- Work ethic
- Interpersonal skills

Approved by SCASA Superintendents Roundtable and SC Chamber of Commerce SC Education Oversight Committee, SC State Board of Education, SC Department of Education, SC General Assembly, SC Council on Competitiveness, TransformSC, & SC Arts in Basic Curriculum Steering Committee

SCIENCE AND ENGINEERING PRACTICES

In addition to the academic standards, each grade level or high school course explicitly identifies *Science and Engineering Practice* standards, with indicators that are differentiated across grade levels and core areas. The term "practice" is used instead of the term "skill," to emphasize that scientists and engineers use skill and knowledge simultaneously, not in isolation. These eight science and engineering practices are:

1. Ask questions and define problems
2. Develop and use models
3. Plan and conduct investigations
4. Analyze and interpret data
5. Use mathematical and computational thinking
6. Construct explanations and design solutions
7. Engage in scientific argument from evidence
8. Obtain, evaluate, and communicate information

Students should engage in scientific and engineering practices as a means to learn about the specific topics identified for their grade levels and courses. It is critical that educators understand that the Science and Engineering Practices are *not* to be taught in isolation. There should *not* be a distinct "Inquiry" unit at the beginning of each school year. Rather, the practices need to be employed *within the content* for each grade level or course.

Additionally, an important component of all scientists and engineers' work is communicating their results both by informal and formal speaking and listening, and formal reading and writing. Speaking, listening, reading and writing is important not only for the purpose of sharing results, but because during the processes of reading, speaking, listening and writing, scientists and engineers continue to construct their own knowledge and understanding of meaning and implications of their research. Knowing how one's results connect to previous results and what those connections reveal about the underlying principles is an important part of the scientific discovery process. Therefore, students should similarly be reading, writing, speaking and listening throughout the scientific processes in which they engage.

For additional information regarding the development, use and assessment of the *2014 Academic Standards and Performance Indicators for Science* please see the official document that is posted on the SCDE science web page https://ed.sc.gov/scdoe/assets/file/agency/ccr/Standards-Learning/documents/South_Carolina_Academic_Standards_and_Performance_Indicators_for_Science_2014.pdf.

Support for the guidance, overviews of learning progressions, and explicit details of each SEP can be found in the Science and Engineering Support Document https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf.

CROSSCUTTING CONCEPTS

Seven common threads or themes are presented in *A Framework for K-12 Science Education* (2012). These concepts connect knowledge across the science disciplines (biology, chemistry, physics, earth and space science) and have value to both scientists and engineers because they identify universal properties and processes found in all disciplines. These crosscutting concepts are:

1. Patterns
2. Cause and Effect: Mechanism and Explanation
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, Cycles, and Conservation
6. Structure and Function
7. Stability and Change

These concepts should not to be taught in isolation but reinforced in the context of instruction within the core science content for each grade level or course.

The link http://www.nap.edu/read/13165/chapter/8 provides support from the framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) that gives further guidance on each crosscutting concept.

1. **Patterns:** The National Research Council (2012) states that "observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them" (p. 84).
2. **Cause and Effect: Mechanism and Explanation:** The National Research Council (2012) states that "events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts" (p. 84).
3. **Scale, Proportion, and Quantity:** The National Research Council (2012) states that "in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance" (p. 84).
4. **Systems and Systems Models:** The National Research Council (2012) states that "Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering" (p. 84).
5. **Energy and Matter:** Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. **Structure and Function:** The National Research Council (2012) states that "the way in which an object or living thing is shaped and its substructure determine many of its properties and functions" (p. 84).
7. **Stability and Change:** The National Research Council (2012) states that "For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study" (p. 84).

DECIPHERING THE STANDARDS

Kindergarten
Life Science: Exploring Organisms and the Environment

Standard K.L.2: The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.

K.L.2A. Conceptual Understanding: The environment consists of many types of organisms including plants, animals, and fungi. Organisms depend on the land, water, and air to live and grow. Plants need water and light to make their own food. Fungi and animals cannot make their own food and get energy from other sources. Animals (including humans) use different body parts to obtain food and other resources needed to grow and survive. Organisms live in areas where their needs for air, water, nutrients, and shelter are met.

Performance Indicators: Students who demonstrate this understanding can:

K.L.2A.1 Obtain information to answer questions about different organisms found in the environment (such as plants, animals, or fungi).

Figure 1: Example from the Kindergarten Standards

The code assigned to each performance indicator within the standards is designed to provide information about the content of the indicator. For example, the **K.L.2A.1** indicator decodes as the following:

K: The first part of each indicator denotes the grade or subject. The example indicator is from Kindergarten. The key for grade levels are as follows:

K: Kindergarten
1: First Grade
2: Second Grade
3: Third Grade
4: Fourth Grade
5: Fifth Grade
6: Sixth Grade
7: Seventh Grade
8: Eighth Grade
H.B: High school Biology I
H.B: High School Chemistry I
H.P: High school Physics I
H.E: High School Earth Science

L: After the grade or subject, the content area is denoted by an uppercase letter. The L in the example indicator means that the content covers Life Science. The key for content areas are as follows:
E: Earth Science
EC: Ecology
L: Life Science
P: Physical Science

S: Science and Engineering Practices
2: The number following the content area denotes the specific academic standard. In the example, the 2 in the indicator means that it is within the second academic standard with the Kindergarten science content.

A: After the specific content standard, the conceptual understanding is denoted by an uppercase letter. The conceptual understanding is a statement of the core idea for which students should demonstrate understanding. There may be more than one conceptual understanding per academic standard. The A in the example means that this is the first conceptual understanding for the standard. Additionally, the conceptual understandings are novel to the *2014 South Carolina Academic Standards and Performance Indicators for Science*.

1: The last part of the code denotes the number of the specific performance indicator. Performance indicators are statements of what students can do to demonstrate knowledge of the conceptual understanding. The example discussed is the first performance indicator within the conceptual understanding.

Core Areas of Chemistry

- Atomic Structure and Nuclear Processes
- Bonding and Chemical Formulas
- States of Matter
- Solutions, Acids and Bases
- Chemical Reactions
- Thermochemistry and Chemical Kinetics

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CONTENT SUPPORT GUIDE
FOR CHEMISTRY
SOUTH CAROLINA ACADEMIC STANDARDS AND PERFORMANCE INDICATORS

INTRODUCTION

Local districts, schools and teachers may use this document to construct standards-based science curriculum, allowing them to add or expand topics they feel are important and to organize content to fit their students' needs and match available instructional materials. The support document includes standard, conceptual understanding, performance indicator, science and engineering practices, crosscutting concepts, essential learning experiences, extended learning experiences, assessment guidelines, learning connections, and in some cases note to teacher.

FORMAT OF THE CONTENT SUPPORT GUIDE

The format of this document is designed to be structurally uniformed for each of the academic standards and performance indicators. For each, you will find the following sections--

Standard
- This section provides the standard being explicated.

Conceptual Understanding
- This section provides the overall understanding that the student should possess as related to the standard. Additionally, the conceptual understandings are novel to the *2014 South Carolina Academic Standards and Performance Indicators for Science*.

Performance Indicator
- This section provides a specific set of content with an associated science and engineering practice for which the student must demonstrate mastery.

Science and Engineering Practices (SEPs)
- This section lists the specific science and engineering practice that are paired with the content in the performance indicator. Educators should reference the chapter on this specific science and engineering practice in the *Science and Engineering Practices Support Guide.*
- Educators have the freedom to enhance SEPs addressed during instruction.
- SEPs Support Guide https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Crosscutting Concepts (CCCs)
- Cross Cutting Concepts (http://www.nap.edu/read/13165/chapter/8) This link provides support from the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012).
- Educators have the freedom to enhance CCCs addressed during instruction.

Essential Learning Experiences

- This section illustrates the knowledge of the content contained in the performance indicator for which it is fundamental for students to demonstrate mastery.

Note to Teacher

- If necessary or appropriate, this section provides additional instructional guidance.

Extended Learning Experiences

- This section provides educators with topics that will enrich students' knowledge related to topics learned with the explicated performance indicator.

Assessment Guidelines

- This section provides guidelines for educators and assessors to check for student mastery of content utilizing interrelated science and engineering practices.

Learning Connections

- This section provides a list of academic content along with the associated academic standard that students will have received in prior or will experience in future grade levels.

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2A. Conceptual Understanding: The existence of atoms can be used to explain the structure and behavior of matter. Each atom consists of a charged nucleus, consisting of protons and neutrons, surrounded by electrons. The interactions of these electrons between and within atoms are the primary factors that determine the chemical properties of matter. In a neutral atom the number of protons is the same as the number of electrons.	
Performance Indicator	**H.C.2A.1:** Obtain and communicate information to describe and compare subatomic particles with regard to mass, location, charge, electrical attractions and repulsions, and impact on the properties of an atom.
Science and Engineering Practice	**S.1A.8:** Obtain and evaluate informational texts, observations, data collected, or discussions to (1) generate and answer questions, (2) understand phenomena, (3) develop models, or (4) support explanations, claims, or designs. Communicate observations and explanations using the conventions and expectations of oral and written language.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information, see page 6. Patterns Systems and System Models Scale, Proportion, and Quantity

Essential Learning Experiences:
It is essential that students obtain and communicate data related to subatomic particles and their role in determining properties of an atom.

- Atoms are comprised of three subatomic particles. The mass of proton and neutron are similar, yet much larger than that of the electron. The protons and neutrons comprise the nucleus. The electrons are located within an electron cloud outside of the nucleus. Refer to chart for charges.
- Atoms have a positively charged nucleus (made from protons and neutrons) surrounded by negative electrons. The atom is mostly empty space.
- Atomic number gives identity to atom, mass is determined mostly by number of protons and neutrons, and chemical properties are determined by valence electrons.
- Isotopes are atoms with the same number of protons but different numbers of neutrons. They are different forms of an element because of their different atomic masses. Isotope notation (C-14; ^{14}C; $^{14}_{6}C$) should be used to write isotopes.

Subatomic Particle	Symbol	Atomic mass (amu)	Atomic Charge	Location
Proton	p^+	1.0073	+1	Nucleus
Neutron	n^0	1.0078	0	Nucleus
Electron	e^-	0.005485	-1	Electron cloud

- Explain the following atomic characteristics and properties (in terms of atomic structure) and understand what variables influence the magnitude of the characteristics or properties for a given element.
    - Electron configuration
    - Ionization energy
    - Electron Affinity
    - Atomic Radius

NOTE TO TEACHER: Information here is basic to all other indicators. Calculations using this information are a part of H.C.6A.4.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.
- Investigate ionic size to determine patterns in ionic size and how ionic size can affect characteristics or properties of a given ion.
- Research the experiment and scientists lead to the current atomic model.
- Research Coulomb's Law ($F=kq_1q_2/r^2$) a physics connection.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections

Previous Learning Connections (6-8):
7.P.2A.2: Obtain and use information about elements (including chemical symbol, atomic number, atomic mass, and group or family) to describe the organization of the periodic table.

High School Learning Connections (9-12):
Biology
H.B.2A.1: Construct explanations of how the structures of carbohydrates, lipids, proteins, and nucleic acids (including DNA and RNA) are related to their functions in organisms.

	Earth Science **H.E.3A.5:** Analyze and interpret data to describe the physical and chemical properties of minerals and rocks and classify each based on the properties and environment in which they were formed.

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2A. Conceptual Understanding: The existence of atoms can be used to explain the structure and behavior of matter. Each atom consists of a charged nucleus, consisting of protons and neutrons, surrounded by electrons. The interactions of these electrons between and within atoms are the primary factors that determine the chemical properties of matter. In a neutral atom the number of protons is the same as the number of electrons.	
Performance Indicator	**H.C.2A.2:** Use the Bohr and quantum mechanical models of atomic structure to exemplify how electrons are distributed in atoms.
Science and Engineering Practice	**H.C.1A.2:** Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information, see page 6. Systems and System Models

Essential Learning Experiences:
It is essential that students use models of the atom to explain the structure and behavior of matter. Students should also be able to identify the limitations of models.

- The Bohr model of the atom can be utilized to explain the arrangement of electrons within the hydrogen atom. The Bohr model is not sufficient in regard to explaining all electron arrangements.
- The quantum mechanical model can be utilized to describe the arrangement and probable location of electrons. Electron configuration can be utilized to identify the approximate location of electrons.
- Understand orbital types and number of orbitals within an energy level; two electrons can occupy an orbital.
- Utilize electron configuration (standard) notation, orbital notation, and electron dot structures using Hund's rule, Aufbau's principle and Pauli's exclusion principle.

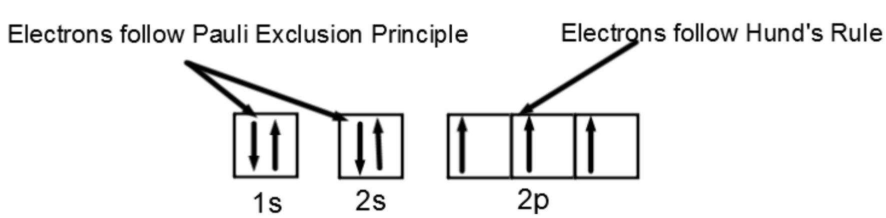


Figure 2. Paulі and Hund (SCDE, 2018).

- Be able to draw electron-dot structure for representative elements.
- The Representative Elements are the first two families (Groups I and II on the far left) and the last six groups (on the right) of the Periodic Table.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Write electron configurations using noble gas configuration.
- Determine the four quantum numbers of an electron within an atom.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

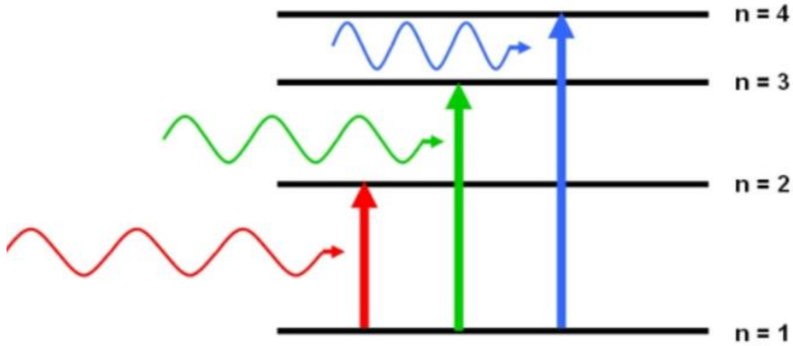
Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.1:** Obtain and use information about elements (including chemical symbol, atomic number, atomic mass, and group or family) to describe the organization of the periodic table. **High School Learning Connections (9-12):** **Biology** **H.B.2A.1:** Construct explanations of how the structures of carbohydrates, lipids, proteins, and nucleic acids (including DNA and RNA) are related to their functions in organisms. **Earth Science** **H.E.3A.5:** Analyze and interpret data to describe the physical and chemical properties of minerals and rocks and classify each based on the properties and environment in which they were formed.

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2A. Conceptual Understanding: The existence of atoms can be used to explain the structure and behavior of matter. Each atom consists of a charged nucleus, consisting of protons and neutrons, surrounded by electrons. The interactions of these electrons between and within atoms are the primary factors that determine the chemical properties of matter. In a neutral atom the number of protons is the same as the number of electrons.	
Performance Indicator	**H.C.2A.3:** Analyze and interpret absorption and emission spectra to support explanations that electrons have discrete energy levels.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Structure and Function Energy and Matter

Essential Learning Experiences:
It is essential that students analyze and interpret absorption and emission spectra to support explanations that electrons have discrete energy levels which is evident when electrons gain or absorb energy causing movement between energy levels.

- Electrons move between energy levels.
- When electrons absorb energy, they move from a position of low energy to a position of higher energy. They absorb a specific amount of energy leaving a black space in a continuous spectrum. The resulting spectrum is called an absorption spectrum.
- When electrons release (emit) energy, electrons move from a higher energy (specific frequency, specific wavelength). The emission corresponds to a band of energy (light) in the emission spectrum.
- Transitions that electrons make between the same levels result in the same amount of energy.



Swinburne University of Technology (2015). Photon Energies.
Retrieved from http://astronomy.swin.edu.au/cosmos/A/Absorption+Line

- An element's emission spectra can be utilized to identify the element. Emission spectra are produced by thin gases in which the atoms do not experience many collisions because of low density. The emission lines (bright area) correspond to photons of discrete energies that are emitted when in excited states. Flame tests, using primarily metal ions, can be used to see characteristic emission spectra.
- Emission spectra are produced by low pressure gases so the atoms do not experience many collisions. The emission lines (bright area) correspond to discrete energies that are emitted when an electron returns to the ground state (a lower energy level) from an excited state (a higher energy level).

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Use E = h (h is Planck's constant 6.626 X 10^{-34} Js) to calculate either energy (E) in joules or frequency () in hertz (Hz).
- Use the formula c=λ to determine wavelength and frequency of light.
- Compare emission and absorption spectra with continuous spectra.
- Explore how atomic spectra are used to identify materials on earth and in space.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.1:** Obtain and use information about elements (including chemical symbol, atomic number, atomic mass, and group or family) to describe the

	organization of the periodic table. **8.P.3A2:** Develop and use models to exemplify the basic properties of waves (including frequency, amplitude, wavelength, and speed). **High School Learning Connections (9-12):** **Physics** **H.P.3F.5:** Obtain information to communicate the similarities and differences among the different bands of the electromagnetic spectrum (including radio waves, microwaves, infrared, visible light, ultraviolet, and gamma rays) and give examples of devices or phenomena from each band.

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2B. Conceptual Understanding: In nuclear fusion, lighter nuclei combine to form more stable heavier nuclei and in nuclear fission heavier nuclei are split to form lighter nuclei. The energies in fission and fusion reactions exceed the energies in usual chemical reactions	
Performance Indicator	**H.C.2B.1:** Obtain and communicate information to compare alpha, beta, and gamma radiation in terms of mass, charge, penetrating power, and their practical applications (including medical benefits and associated risks).
Science and Engineering Practice	**H.C.1A.8:** Obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Energy and Matter

Essential Learning Experiences:
It is essential that students obtain and communicate information about alpha, beta, and gamma radiation.

See chart.

Type of Radiation Emitted and Symbol	Nature of the Radiation	Nuclear Symbol	Penetrating Power, and what will Block it	Effect of Release of Particles from the Nucleus	Risks, Benefits and Real-World Applications
α Alpha	a helium nucleus of 2 protons and 2 neutrons, mass = 4 charge = +2	${}^{4}_{2}He$	Low penetration stopped by a few cm of air or thin sheet of paper	Reduces the atomic mass number by 4 Reduces the atomic number by 2	Used in smoke detectors. Specifically, Americium releases alpha rays. Risks: Not considered dangerous because alpha rays DO NOT penetrate human skin.
β Beta	high kinetic energy electrons, mass = 1/1850 of alpha, charge = -1	${}^{0}_{-1}e$	Moderate penetration, most stopped by a few mm of metals like aluminum	Is the result of neutron decay and will increase the atomic number by 1 but will not change the mass number	Used to treat eye and bone cancers. Also, used in manufacturing to measure thickness of products. Risks: Dangerous to living cells. Can penetrate human skin.
γ Gamma	very high frequency electromagnetic radiation, mass = 0, charge = 0	${}^{0}_{0}\gamma$	Very highly penetrating, most stopped by a thick layer of steel or concrete, but even a few cm of dense lead doesn't stop all of it!	Is electromagnetic radiation released from an excited nucleus. The atomic number and mass number do not change.	Used to treat various other cancers. Used for CT-Scans. Also, used to sterilize and test equipment. Risks: Could harm DNA and cause mutations in cell growth or Cancer. Like beta rays can penetrate the skin.

Figure 3. Radiation chart (SCDE, 2005).

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Write nuclear equations for beta decay, positron emission, and electron capture.
- Balance nuclear equations.
- Research parts of a nuclear reactor to produce electricity.
- Rank nuclear particles according to size, penetrating ability, and danger.
- Study proton therapy as a treatment for cancer and other possible uses.
- Investigate how nuclear materials are mined.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

<table>
<tr>
<td>Learning Connections</td>
<td>Previous Learning Connections (6-8):
7.P.2A.1: Obtain and use information about elements (including chemical symbol, atomic number, atomic mass, and group or family) to describe the organization of the periodic table._

High School Learning Connections (9-12):
Physics
H.P.3G.4::Use mathematical and computational thinking to predict the products of radioactive decay (including alpha, beta, and gamma decay).
H.P.3G.5: Obtain information to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers).
Earth Science:
H.E.4A.5: Develop and use models of various dating methods (including index fossils, ordering of rock layers, and radiometric dating) to estimate geologic time.
H.E.4A.6: Use mathematical and computational thinking to calculate the age of Earth materials using isotope ratios (actual or simulated).</td>
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</table>

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2B. Conceptual Understanding: In nuclear fusion, lighter nuclei combine to form more stable heavier nuclei and in nuclear fission heavier nuclei are split to form lighter nuclei. The energies in fission and fusion reactions exceed the energies in usual chemical reactions	
Performance Indicator	**H.C.2B.2:** Develop models to exemplify radioactive decay and use the models to explain the concept of half-life and its use in determining the age of materials (such as radiocarbon dating or the use of radioisotopes to date rocks).
Science and Engineering Practice	**H.C.1A.2:** Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Energy and Matter

Essential Learning Experiences:
It is essential that students develop and use models that explain radioactive decay and use those models to explain half-life. Students could use simulations of radioactive decay and half-life to determine the age of fossils.

- Radioactive decay is the spontaneous breakdown of an atomic nucleus resulting in the release of energy and matter from the nucleus.
- Half-life is the time required for half of the entity's matter to decay. For example, Carbon-14 is an isotope of the element Carbon. It has a half-life of 5,730 years. An initial sample of 100g would have only 50 g remaining after this time.
- Carbon-14 is an example of how radioactive decay can be used to estimate the age of carbon-bearing materials.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate the half-life of an isotope.
- Calculate the mass of an isotope remaining after a given number of half-lives.
- Balance nuclear decay equations.
- Complete a half-life lab.
- Calculate the time required for a certain amount of mass to decay.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.1:** Obtain and use information about elements (including chemical symbol, atomic number, atomic mass, and group or family) to describe the organization of the periodic table._ **High School Learning Connections (9-12):** **Physics** **H.P.3G.4:**:Use mathematical and computational thinking to predict the products of radioactive decay (including alpha, beta, and gamma decay). **H.P.3G.5:** Obtain information to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers). **Earth Science** **H.E.3A.1:** Analyze and interpret data to explain the differentiation of Earth's internal structure using (1) the production of internal heat from the radioactive decay of unstable isotopes, (2) gravitational energy, (3) data from seismic waves, and (4) Earth's magnetic field. **H.E.4A.5:** Develop and use models of various dating methods (including index fossils, ordering of rock layers, and radiometric dating) to estimate geologic time. **H.E.4A.6:** Use mathematical and computational thinking to calculate the age of Earth materials using isotope ratios (actual or simulated).

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2B. Conceptual Understanding: In nuclear fusion, lighter nuclei combine to form more stable heavier nuclei and in nuclear fission heavier nuclei are split to form lighter nuclei. The energies in fission and fusion reactions exceed the energies in usual chemical reactions	
Performance Indicator	**H.C.2B.3:** Obtain and communicate information to compare and contrast nuclear fission and nuclear fusion and to explain why the ability to produce low energy nuclear reactions would be a scientific breakthrough.
Science and Engineering Practice	**H.C.1A.8:** Obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect

Essential Learning Experiences:
It is essential that students obtain and communicate information to compare nuclear fusion and fission. Students should also be able to evaluate information available on research and applications of low energy nuclear reactions.

- Processes of nuclear fission
    - Nuclear fission occurs when a heavy nucleus, such as the U-235 nucleus, splits into two or more parts, and a large amount of energy is released. The penetration of a large nucleus (such as U-235) by a neutron is one way to initiate a fission reaction. When an atom with a large nucleus undergoes fission, atoms that have smaller nuclei result. In the process smaller particles such as neutrons may be ejected from the splitting nucleus. If one or more ejected neutron strikes another U-235 nucleus, another fission reaction may occur. The continuation of this process is called a chain reaction. There must be a certain critical mass of fissionable material in close proximity for a chain reaction to occur.
    - Fission is the type of nuclear reaction that occurs in nuclear power plants and other nuclear applications (weapons, submarines, etc.).
    - Mass of the products of a fission reaction is less than the mass of the reactants. This lost mass (m) is converted into energy (E) and is called mass defect. The equation $E = mc^2$ shows the relationship of this "lost mass" (mass

defect, m) to the energy produced (E). The conversion of mass to energy during a nuclear reaction involves far more energy than the amount of energy involved in a chemical reaction. (It is not essential for students to use this equation.)

- Processes of nuclear fusion
    - Nuclear fusion occurs when light nuclei (such as hydrogen) fuse, or combine, to form a larger single nucleus (such as helium).
    - In fusion reactions the mass of the products is less than the mass of the reactants and the "lost mass" (mass defect) is converted to energy.
        - Fusion is the type of nuclear reaction that occurs on the sun (and other stars)
        - Forcing small nuclei to fuse requires huge amounts of energy; however, when fusion reactions occur on the sun, more energy is released than the amount of energy required to produce the reaction.
        - Using fusion for human applications is still in the developmental stage.
- Because the extreme temperatures required for nuclear fusion make these processes impractical for use, the ability to do so at low energy levels (LENR/cold fusion) would be groundbreaking in the scientific community.
    - Being able to contain the reaction would be phenomenal because - there are no greenhouse hydrocarbon emissions, no dangerous radiation produced during operation, and no potentially harmful byproducts associated with LENR/cold fusion.
    - The scientific community has invested time and effort in this area due to the potential benefits associated with LENR/cold fusion but there has been little practical success as a result of their efforts.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Research the pros and cons of nuclear power.
- Balance nuclear reactions.
- Discuss the pros and cons of fusion and fission.
- Explore methods for containing nuclear waste.
- Study the benefits and challenges of renewable energy resources.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

	Previous Learning Connections (6-8): Nuclear fission, nuclear fusion, and low energy nuclear reactions have not been addressed in previous grades.

Learning Connections	**High School Learning Connections (9-12):** **Physics:** **H.P.3G.4:** Use mathematical and computational thinking to predict the products of radioactive decay (including alpha, beta, and gamma decay). **H.P.3G.5:** Obtain information to communicate how radioactive decay processes have practical applications (such as food preservation, cancer treatments, fossil and rock dating, and as radioisotopic medical tracers). **Earth Science:** **H.E.2A.3:** Construct explanations for how elements are formed using evidence from nuclear fusion occurring within stars and/or supernova explosions. **H.E.3A.1:** Analyze and interpret data to explain the differentiation of Earth's internal structure using (1) the production of internal heat from the radioactive decay of unstable isotopes, (2) gravitational energy, (3) data from seismic waves, and (4) Earth's magnetic field. **H.E.4A.5:** Develop and use models of various dating methods (including index fossils, ordering of rock layers, and radiometric dating) to estimate geologic time. **H.E.4A.6:** Use mathematical and computational thinking to calculate the age of Earth materials using isotope ratios (actual or simulated).

Atomic Structures and Nuclear Processes

Standard H.C.2: The student will demonstrate an understanding of atomic structure and nuclear processes.	
H.C.2B. Conceptual Understanding: In nuclear fusion, lighter nuclei combine to form more stable heavier nuclei and in nuclear fission heavier nuclei are split to form lighter nuclei. The energies in fission and fusion reactions exceed the energies in usual chemical reactions	
Performance Indicator	**H.C.2B.4:** Use mathematical and computational thinking to explain the relationship between mass and energy in nuclear reactions ($E=mc^2$).
Science and Engineering Practice	**H.C.1A.5:** Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Energy and Matter

Essential Learning Experiences:
It is essential that students use mathematical and computational thinking to explain the relationship between mass, energy and the speed of light in nuclear reactions.

- Mass-Energy relationship is the concept that the mass of a system is associated with the energy contained in the system.
    - The relationship between mass and energy means mass can be converted to energy just as energy can be converted to mass and is explained by Einstein's famous equation $E=mc^2$ (c is the speed of light 3.00×10^8 m/s).
- Students should be able to identify that mass is converted into energy in a nuclear reaction.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate mass defect.
- Use the equation $e=mc^2$ to relate mass defect to the amount of energy released.
- Investigate how energy and work are related.
- Explore the use of simple machines to create complex machines.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** The relationship between mass and energy in nuclear reactions has not been addressed in previous grades. **High School Learning Connections (9-12):** **Physics** **H.P.3F.4:** Use mathematical and computational thinking to analyze problems that relate the frequency, period, amplitude, wavelength, velocity, and energy of light. **Earth Science** **H.E.2A.3:** Construct explanations for how elements are formed using evidence from nuclear fusion occurring within stars and/or supernova explosions.

Bonding and Chemical Formulas

Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.1:** Construct explanations for the formation of molecular compounds via sharing of electrons and for the formation of ionic compounds via transfer of electrons.
Science and Engineering Practice	**H.C.1A.6:** Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect

Essential Learning Experiences:
It is essential that students construct explanations for how molecular and ionic compounds are formed. Students could use the periodic table to compare the types of elements used in chemical bonding through the use of models and use these models to explain why ionic and covalent bonds are formed differently.

- Bonding occurs in order to achieve chemical stability (octet rule) in low energy state.
    - The octet rule states that elements gain or lose electrons to attain an electron configuration of the nearest noble gas.
    - The type of bond formed can be predicted by an element's location on the Periodic Table.
- Atoms form bonds through the sharing or transfer of electrons to achieve noble gas configuration in their valence shells (octet rule).
- Valence electrons are shared between nonmetals to form molecular/covalent bonds.
- Covalent bonds are common between two nonmetal elements, each having one or more orbitals in the outer energy level containing only one electron.

- Ionic bonds are formed from the transfer of electrons, creating ions. These ionic bonds are based on the electrostatic forces (positive ion attracted to a negative ion).
    - Metals lose electrons to form cations (positive ions).
    - Nonmetals gain electrons to form anions (negative ions).
- Identify substances as molecular or ionic compounds by type of elements in the compound.
    - Ionic compounds contain metals and nonmetals.
    - Molecular compounds contain nonmetals.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Investigate exceptions to the octet rule (odd electron species, incomplete octets, expanded octets).
- Explain why metals tend to form cations (in terms of electronic structure).
- Explain why nonmetals tend to form anions (in terms of electronic structure).
- Investigate which ionic compounds are used to treat roads in preparation for snow and ice storms and how those compounds affect the environment.
- Investigate covalent compounds used in cleansers that may be toxic for humans and other organisms.
- Explore alternatives to widely used covalent compounds found in cleansers.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.4:** Construct explanations for how compounds are classified as ionic (metal bonded to nonmetal) or covalent (nonmetals bonded together) using chemical formulas. **High School Learning Connections (9-12):** **Biology** **H.B.2A.1:** Construct explanations of how the structures of carbohydrates, lipids, proteins, and nucleic acids (including DNA and RNA) are related to their functions in organisms. **Earth Science:** **H.E.3A.5:** Analyze and interpret data to describe the physical and chemical properties of minerals and rocks and classify each based on the properties and environment in which they were formed.

Bonding and Chemical Formulas

Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.2:** Use the periodic table to write and interpret the formulas and names of chemical compounds (including binary ionic compounds, binary covalent compounds, and straight-chain alkanes up to six carbons).
Science and Engineering Practice	**H.C.1A.6:** Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns

Essential Learning Experiences:
It is essential that students construct explanations for how the formulas and names of chemical compounds are determined. Students could create a set of rules for naming and writing formulas based on patterns.

- Binary Ionic compounds
    - Binary ionic compounds consist of metals and nonmetals. Binary ionic compounds composed of main group elements (groups 1,2 and 13-18) are named with metal element (cation) first, then nonmetal (anion) with the ending –ide. Examples: $MgCl_2$ is named magnesium chloride and Li_2O named lithium oxide.
- The chemical formula for ionic compounds is the lowest ratio of ions that create a neutral compound. This means that the total charges of the cations and anions must be equal.
- Binary molecular compounds
    - Greek prefixes are used to write chemical names. The subscript identifies the number atoms of that element in the compound. Examples: H_2O, dihydrogen monoxide and CO_2 Carbon dioxide.

- To write the names of binary molecular compounds, the subscript identifies the prefix used in the name. Mono- is generally not used for the first element of in a binary compound.

Prefix	Meaning
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6

- Single Chain Alkanes (C_nH_{2n+2})
    - Single chain alkanes are named based on the number of carbons in the chain. Examples: CH_4 methane and C_2H_6 ethane.

NOTE TO TEACHER: Binary ionic compounds with transition metals and polyatomic ions will be used in chemical reactions, H.C.6A.1. Consideration may need to be given to introducing these types of compounds here. The information has been included in Extended Learning Experiences. Polyatomic ions are part of essential learning in H.C.3A.3. Alkenes and alkynes are included in the essential learning in H.C.3A.5.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Binary Ionic Compounds with transition metals
    - Binary ionic compounds with transition metals are named like binary ionic compounds, with the cation first and then the anion with -ide added to it. However, because transition metals can have more than one variation of ion (multivalent ion), Roman numerals in parentheses must be added following the cation to differentiate between the variations. The Roman numeral indicates the change on the metal. This type of naming convention, using Roman numerals, is known as the Stock naming system. Examples: FeO is iron (II) oxide and Fe_2O_3 is iron (III) oxide.
- Ionic compounds containing polyatomic ions
    - Ionic compounds containing polyatomic ions are compounds made up of a polyatomic ion (two or more atoms bonded together) and another ion.
    - The name of the cation is written first and the name of the anion is written second. Examples: LiOH is lithium hydroxide and $CaCO_3$ is calcium carbonate.

- If more than one polyatomic ion is needed, a parentheses and a subscript are used to make the total charges of the cations and anions equal. Examples: $Ca(OH)_2$ is calcium hydroxide and $Ca_3(PO_4)_2$.
- Polyatomic ions

Ammonium	NH_4^+	Hydroxide	OH^-
Acetate	$C_2H_3O_2^-$	Nitrate	NO_3^-
Carbonate	CO_3^{2-}	Nitrite	NO_2^-
Chlorate	ClO_3^-	Phosphate	PO_4^{3-}
Chromate	CrO_4^{2-}	Sulfate	SO_4^{2-}
Cyanide	CN^-	Sulfite	SO_3^{2-}

- Name and write formulas for binary acids and ternary acids (oxyacids),
- Name alkenes and alkynes

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.4:** Construct explanations for how compounds are classified as ionic (metal bonded to nonmetal) or covalent (nonmetals bonded together) using chemical formulas. **High School Learning Connections (9-12):** **Biology** **H.B.2A.1:** Construct explanations of how the structures of carbohydrates, lipids, proteins, and nucleic acids (including DNA and RNA) are related to their functions in organisms. **Earth Science** **H.E.3A.5:** Analyze and interpret data to describe the physical and chemical properties of minerals and rocks and classify each based on the properties and environment in which they were formed. **H.E.4A.1:** Construct scientific arguments to support claims that the physical conditions of Earth enable the planet to support carbon-based life.

Bonding and Chemical Formulas

Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.3:** Analyze and interpret data to predict the type of bonding (ionic or covalent) and the shape of simple compounds by using the Lewis dot structures and oxidation numbers.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical Analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns. Cause and Effect System and System Models Structure and Function

Essential Learning Experiences:
It is essential that students analyze and interpret data to identify a compound's type of bonding and molecular shape. This could include using periodic tables, ball and stick models, and computer simulations to construct explanations of shapes associated with VSEPR theory.

- Molecular compounds:
  - The structure of molecules is the result of nonmetals sharing electrons (covalent bonds) in order to form stable outer-energy-level configuration (octet rule).
  - Draw single, double, and triple bonds using Lewis structures, including the presence of nonbonding electron pairs, multiple bonds, polyatomic ions.
  - The "s" and "p" orbitals in the outer energy level (valence electrons) of each atom provide possible bonding sites (except for the element which achieve He structure).

  - Molecular geometries to be studied are linear, bent (angular), trigonal planar, trigonal pyramidal, and tetrahedral.
  - Explain the shape of-molecules with no more than four bonds such as methane, water and carbon dioxide using VSEPR (valence shell electron pair repulsion).

- Ionic compounds:
  - Crystalline structure is the result of the ionic bonding of positive and negative ions, forming a neutral compound.
  - Some covalently bonded groups of atoms (similar in structure to molecules) act like single atoms in forming ions. These charged groups of covalently bonded atoms are called polyatomic ions. They may be positive or negative.
  - Oxidation numbers
    - The sum of the oxidation numbers in the formula of any neutral compound is zero.
    - The sum of the oxidation numbers in a polyatomic ion is equal to its charge.
    - The oxidation number of a monatomic ion is equal to the charge of its ion.
    - The oxidation number of the monatomic ions formed from elements in the following groups of the periodic table:
      - Group 1, +1
      - Group 2, +2
      - Group 16, -2
      - Group 17, -1

NOTE TO TEACHER: Single, double, and triple bonds are also part of content in H.C.3A5.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.
- Use VSEPR Theory to predict molecular geometries for polyatomic ions and structure of organic molecules (having more than one carbon atom). Hybridization occurs in single, double, triple bonds, and delocalized pi bonds.
- Draw resonance structures of molecules and polyatomic ions.
- Assign oxidation numbers to atoms in molecular compounds.
- Identify how double and triple bonds change the geometry around the central atom.
- Predict the hybridization given a Lewis dot structure.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.4:** Construct explanations for how compounds are classified as ionic (metal bonded to nonmetal) or covalent (nonmetals bonded together) using chemical formulas. **High School Learning Connections (9-12):** **Biology** **H.B.3A.3:** Construct scientific arguments to support claims that chemical elements in the sugar molecules produced by photosynthesis may interact with other elements to form amino acids, lipids, nucleic acids or other large organic molecules.

Bonding and Chemical Formulas

Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.4:** <u>Plan and conduct controlled scientific investigations</u> to generate data on the properties of substances and analyze the data to infer the types of bonds (including ionic, polar covalent, and nonpolar covalent) in simple compounds.
Science and Engineering Practice	**H.C.1A.3:** <u>Plan and conduct controlled scientific investigations</u> to answer Questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns. Cause and Effect System and System Models Structure and Function

Essential Learning Experiences:
<u>It is essential</u> that students to plan and conduct controlled scientific investigations to identify physical and chemical properties of ionic and covalently bonded compounds. Students could design, conduct, and present data from an experiment to answer the question "How do properties of ionic compounds differ from covalent compounds?" Data from the experiment could also be used to predict the type of bond within simple compounds.

- Ionic and covalent compounds include ionic, polar covalent, and nonpolar covalent. Ionic and covalent bonds differ in properties include melting point, boiling point, conductivity in aqueous solution, and solubility in water and nonpolar solvents.

- Ionic bond and covalent bond are relative terms. Most bonds that are characterized as ionic or covalent actually have a character that lies somewhere between 100% ionic and 100% covalent. Diatomic molecules are however, 0% ionic.
- Electronegativity trends and electronegativity differences should also be used to help identify the bond type. For example:

Type of Bond	Electronegativity Difference
Nonpolar Covalent	0 → 0.4
Polar Covalent	0.5 → 1.9
Ionic	2.0 → 4.0

- "Like dissolves like" – polar and ionic compounds will dissolve best in polar solvents such as water, while nonpolar substances will dissolve best in nonpolar solvents, such as oil – and that aqueous solutions with ionic solutes are electrically conductive.
    - Polar molecules are attracted to one another, but the attraction is not a chemical bond so it is broken easily. These substances usually have moderate melting and boiling points
    - Polar molecules are attracted to one another and to ionic substances as well.

Ionic Characteristics	Covalent Characteristics
electron transfer virtually complete	electrons are shared with the most electronegative element having the greater pull on the electrons
generally stronger bonds	generally weaker bonds
high melting and boiling points	may be polar or nonpolar

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Infer the types of intermolecular attractions present (hydrogen bonding, dipole-dipole, and London dispersion forces.

IMF (Intermolecular Force)	Strength	Found in	Caused by
Van der Waals London dispersion	Low Increases with molar mass and surface area	All molecules important if nonpolar	Attractions of polarizable electron clouds
Dipole	medium	Polar molecules	Electrostatic attraction between +end of one molecule and - end of another molecule
Hydrogen bond	1/10 strength of covalent bond	Molecules with H attached to a small electronegative atom like O, N or F	Attraction between H attached to a N, O or F and the unshared pair of e- on an O, N or F.

Stronger IMF raises melting point and boiling point. You must put energy into overcome the forces holding the particles together. Stronger forces require more energy.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.4:** Construct explanations for how compounds are classified as ionic (metal bonded to nonmetal) or covalent (nonmetals bonded together) using chemical formulas. **7.P.2B.1:** Analyze and interpret data to describe substances using physical properties (including state, boiling/melting point, density, conductivity, color, hardness, and magnetic properties) and chemical properties (the ability to burn or rust). **7.P.2B.4:** Plan and conduct controlled scientific investigations to answer questions about how physical and chemical changes affect the properties of different substances, hardness, and magnetic properties) and chemical properties (the ability to burn or rust).

	High School Learning Connections (9-12): **Biology** **H.B.2C.3:** Analyze and interpret data to explain the movement of molecules (including water) across a membrane.

Bonding and Chemical Formulas

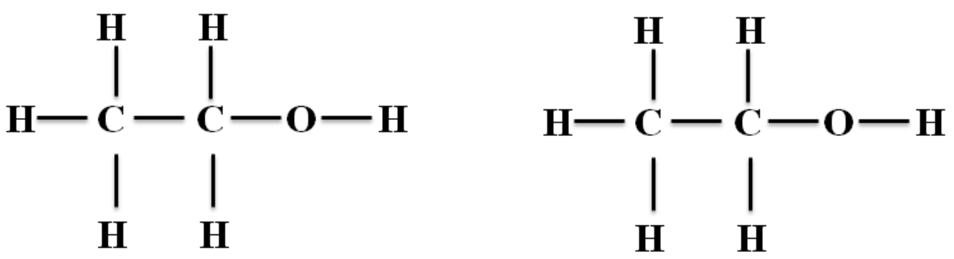
Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.5:** Develop and use models (such as Lewis dot structures, structural formulas, or ball-and-stick models) of simple hydrocarbons to exemplify structural isomerism.
Science and Engineering Practice	**H.C.1A.2:** Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns. Structure and Function

Essential Learning Experiences:
It is essential to develop and use models to understand or represent phenomena, processes and relationships that include arrangement and structure of simple hydrocarbons. Students could design simple diagrams, constructs, and computer generated models using teacher provided materials to illustrate isomerism in branch and chain hydrocarbons.

- Hydrocarbons are molecular compounds made of carbon and hydrogen. Hydrogens may be substituted with other atoms or functional groups (called substituents).
- Describe hybridization of simple molecules like alkanes and alcohols up to 6 carbons.
  - Atomic orbitals are reorganized to form hybrid orbitals that have different geometries and bond angles.
  - New properties my result from the formation of hybrid orbitals.
- Explain how the capacity to form four covalent bonds results in several bonding possibilities for carbon, including
  - Single bonds involve carbons that form four bonds with other atoms.
  - Multiple bonds (double or alkenes and triple or alkynes) involve carbons that are closer together than if they were singly bonded. Additional overlap is caused by the overlap of unhybridized orbitals.

- Ring structures (aromatics) can involve single or double bonds between carbons.
- Covalent network of carbons involve all types of bonds. Carbon is unique in the fact that it bonds to itself multiple times.

- Isomers are compounds with the same molecular formulas, but different molecular structures.
  Examples of isomers: These following compounds have the chemical formula C_2H_6O.



Ethanol **Dimethylether**

Figure 4. Isomers (SCDE, 2018).

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Use IUPAC nomenclature to name isomers.
- Draw Lewis dot structures for possible isomers.
- Draw Lewis dot structures to illustrate alkenes and alkynes.
- Explore and explain aromatics and basic carbon rings.
- Study uses of aromatics to make perfumes and cough syrups.
- Explore current alternative medicine practices using aromatics (aromatherapy)

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.4:** Construct explanations for how compounds are classified as ionic (metal bonded to nonmetal) or covalent (nonmetals bonded together) using chemical formulas. **High School Learning Connections (9-12):**

	Biology **H.B.3A.3:** Construct scientific arguments to support claims that chemical elements in the sugar molecules produced by photosynthesis may interact with other elements to form amino acids, lipids, nucleic acids or other large organic molecules. **H.E.3B.1:** Obtain and communicate information to explain how the formation, availability, and use of ores and fossil fuels impact the environment.

Bonding and Chemical Formulas

Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.6**: Construct explanations of how the basic structure of common natural and synthetic polymers is related to their bulk properties.
Science and Engineering Practice	**H.C.1A.6:** Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page number 6. Structure and Function

Essential Learning Experiences:
It is essential that students construct explanations of how polymer structure is related to its properties. Students could compare diagrams of synthetic hydrocarbons, such as polyethylene or nylon, and naturally occurring polymers, such as proteins or carbohydrates and use the information to explain, using evidence from the diagrams, why each polymer has different functions based on structure.

- Polymers are compounds having a molecular structure that is composed of a large number of similar units, called monomers, are bonded together.
  - The properties of a polymer depend on its molecular structure.
  - Structural factors that can impact the properties of a polymer include cross-linking, hydrogen bonding, branches, and polarity.
- Explain the structure, schematics and function biological, natural (ex. cellulose, silk, wool), and synthetic polymers (ex. polyvinyl chloride/PVC and polytetrafluoroethylene/Teflon).

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Explore and explain how the properties of common polymers, such as plastics are used in various industries.
- Relate the structures of biological polymers (ex. nucleic acids, lipids, proteins, carbohydrates), with their functions in living systems.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.4:** Construct explanations for how compounds are classified as ionic (metal bonded to nonmetal) or covalent (nonmetals bonded together) using chemical formulas. **7.P.2B.4:** Plan and conduct controlled scientific investigations to answer questions about how physical and chemical changes affect the properties of different substances. **High School Learning Connections (9-12):** **Biology** **H.B.2A.1:** Construct explanations of how the structures of carbohydrates, lipids, proteins, and nucleic acids (including DNA and RNA) are related to their functions in organisms.

Bonding and Chemical Formulas

Standard H.C.3: The student will demonstrate an understanding of the structures and classification of chemical compounds.	
H.C.3A. Conceptual Understanding: Elements are made up of only one kind of atom. With increasing atomic number, a predictable pattern for the addition of electrons exists. This pattern is the basis for the arrangement of elements in the periodic table. The chemical properties of an element are determined by an element's electron configuration. Elements can react to form chemical compounds/molecules that have unique properties determined by the kinds of atoms combined to make up the compound/molecule. Essentially, the ways in which electrons are involved in bonds determines whether ionic or covalent bonds are formed. Compounds have characteristic shapes that are determined by the type and number of bonds formed.	
Performance Indicator	**H.C.3A.7:** Analyze and interpret data to determine the empirical formula of a compound and the percent composition of a compound.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical Analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page number 6. Patterns Scale, Proportion and Quantity

Essential Learning Experiences:
It is essential that students analyze and interpret data collected from investigations
- The empirical formula is the simplest ratio possible between atoms in a compound.
- Analyze and use data to determine that a molecular formula is the same as, or a multiple of, the empirical formula, and is based on the actual number of atoms of each type in the compound.
- Calculate molar mass given the formula for a compound.
- The percent composition of a component in a compound is the percent of the total molar mass of the compound that is due to that component.
- Derive empirical formulas, molecular formulas, and percent composition (given formula or masses).
- Calculate empirical formula from percent composition or mass of each element in a compound or determine molecular formula from given empirical formula, given the compound's molar mass.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate percent composition and empirical formulas of hydrates.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.1:** Develop and use simple atomic models to illustrate the components of elements (including the relative position and charge of protons, neutrons, and electrons). **7.P.2A.2:** Obtain and use information about elements (including chemical symbol, atomic number, atomic mass, and group or family) to describe the organization of the periodic table. **High School Learning Connections (9-12):** **Biology** **H.B.3A.3:** Construct scientific arguments to support claims that chemical elements in the sugar molecules produced by photosynthesis may interact with other elements to form amino acids, lipids, nucleic acids or other large organic molecules.

States of Matter

Standard H.C.4 The student will demonstrate an understanding of the structure and behavior of the different states of matter.	
H.C.4A Conceptual Understanding: Matter can exist as a solid, liquid, or gas, and in very high-energy states, as plasma. In general terms, for a given chemical, the particles making up the solid are at a lower energy state than the liquid phase, which is at a lower energy state than the gaseous phase. The changes from one state of matter into another are energy dependent. The behaviors of gases are dependent on the factors of pressure, volume, and temperature.	
Performance Indicator	**H.C.4A.1:** Develop and use models to explain the arrangement and movement of the particles in solids, liquids, gases, and plasma as well as the relative strengths of their intermolecular forces.
Science and Engineering Practice	**H.C.1A.2:** Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Systems and System Models Energy and Matter

Essential Learning Experiences:
It is essential that students develop and use models to understand or represent phenomena, processes and relationships (arrangement, movement of particles and intermolecular forces of matter). This could include the design of simple diagrams, constructs, computer generated models or simulations using teacher provided materials to illustrate particle arrangement of solids, liquids and gases and communicate the relationship between the arrangement, movement and intermolecular forces to the states of matter.

- All matter is made up of atoms that are in constant random motion.
- The speed of the molecules depends on temperature. Intermolecular forces affect a substance's state of matter.
- Matter exists in four different states of matter: Solid, liquid, gas, and plasma. Each state of matter has specific properties. Basic properties of each are as follows:

Solids	• The particles of solids are closely packed together due to strong intermolecular forces holding them together • The particles of solids are constantly vibrating, but they do not readily slip past one another. • Because the particles vibrate in place and do not readily slip past one another, a solid has a definite shape. • Particles are usually arranged in a regular pattern.
Liquids	• The particles of liquids are in contact with each other because intermolecular forces holding them together. • The particles of liquids have enough energy to partially overcome the intermolecular forces of the surrounding particles. Liquid particles can slip past surrounding particles and slide over one another. Because the particles slip past one another, a liquid does not have a definite shape and so takes the shape of the container. • Particles have no regular arrangement.
Gases	• The particles of gases are far enough apart so there are no intermolecular forces. • The particles of gases are moving randomly, in straight lines until they bump into other particles or into the wall of the container. When a particle hits another particle or the container, it bounces off and continues to move. (elastic collisions) • Because gas particles move independently, the particles move throughout the entire container. The forces between the particles are not strong enough to prevent the particles from spreading to fill the container in which the gas is located. (diffusion) • Particles have no regular arrangement.
Plasma	• Plasma is matter consisting of positively and negatively charged particles, stripped from atoms creating charged particles. • A substance is converted to the plasma phase at very high temperatures, such as those in stars (such as the sun). High temperature means that the particles of a substance are moving at high speeds. At these speeds, collisions between particles result in electrons being stripped from freely moving atoms and ions. • Plasma is the most common state of matter in the universe, found not only in stars, but also in lightning bolts, Van Allen radiation belts, neon and fluorescent light tubes and auroras.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Explain how specific intermolecular forces affect a substance's melting and boiling points.
- Investigate how heat is used to treat water in water processing plants.

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.1:** Analyze and interpret data to describe substances using physical properties (including state, boiling/melting point, density, conductivity, color, hardness, and magnetic properties) and chemical properties (the ability to burn or rust). **High School Learning Connections (9-12):** **Earth Science** **H.E.3A.1:** Analyze and interpret data to explain the differentiation of Earth's internal structure using (1) the production of internal heat from the radioactive decay of unstable isotopes, (2) gravitational energy, (3) data from seismic waves, and (4) Earth's magnetic field.

States of Matter

Standard H.C.4 The student will demonstrate an understanding of the structure and behavior of the different states of matter.	
H.C.4A Conceptual Understanding: Matter can exist as a solid, liquid, or gas, and in very high-energy states, as plasma. In general terms, for a given chemical, the particles making up the solid are at a lower energy state than the liquid phase, which is at a lower energy state than the gaseous phase. The changes from one state of matter into another are energy dependent. The behaviors of gases are dependent on the factors of pressure, volume, and temperature.	
Performance Indicator	**H.C.4A.2:** Analyze and interpret heating curve graphs to explain that changes from one state of matter to another are energy dependent.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical Analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Energy and Matter Stability and Change

Essential Learning Experiences:
It is essential that students analyze and interpret data from an investigation to determine how variation in heat and energy affect phase change.

- Temperature is a term used to describe the average kinetic energy of the particles in a substance. The faster particles are moving the higher the temperature.
- When energy (such as heat) is added to a substance, the energy of the particles of the substance increases. Evidence of this would be that the temperature of the substance increases or a phase change.
- Phase change can be explained in terms of The Kinetic Molecular Theory
    - Phase change is due to changing the movement (energy) of the particles. Phase changes occur when the potential energy changes.
    - The freezing or melting point is the temperature where a phase change occurs between a liquid and a solid. If heat is being added to a solid at this temperature, intermolecular forces between particles will break and a solid will melt. For an ionic compound, bonds are broken. For a covalent (molecular) compound, intermolecular forces are overcome. This is why ionic solids, in general, have higher melting points than covalent compounds. If heat is being taken away intermolecular forces will cause particles to attract and a liquid will freeze.

- The boiling point is the temperature where a liquid is changing to a gas throughout the liquid. This phase change can occur at any temperature. This temperature is when the vapor pressure of the liquid equals the atmospheric pressure. Boiling occurs when bubbles of the vapor are formed and is dependent on atmospheric pressure.
- There is no temperature change during a phase change.

- Heat is added to a solid and the particles will move faster and the temperature will increase until the temperature of the solid reaches its melting point.
    - When the temperature of a solid is equal to the melting point and more heat is added to the substance the temperature will not change. The extra heat will be used to overcome some of the intermolecular forces between the molecules of the solid and change the phase to a liquid.

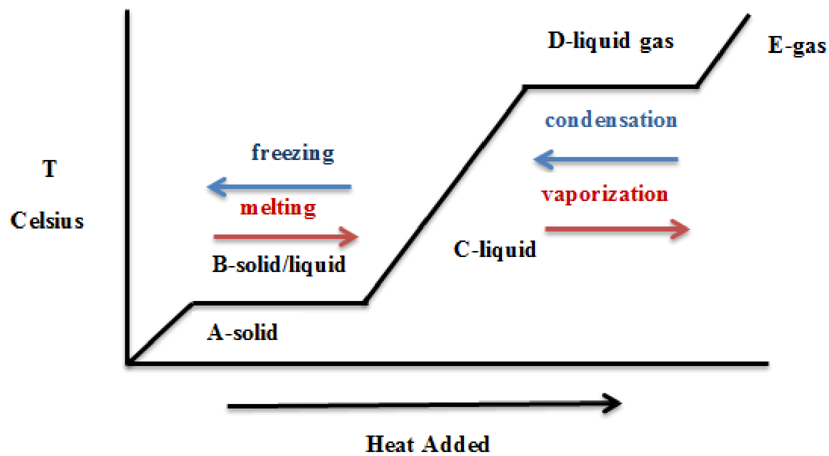

Figure 5. Phase change (SCDE, 2018).

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate energy absorbed or released using phase diagram.
- Analyze a phase diagram (temperature vs. pressure)
    - Explain triple point as the temperature and pressure at which solid, liquid and gas all exist in equilibrium.
    - Critical point or critical state is the point at which the two phases of a substance become indistinguishable. This occurs at the end point phase of equilibrium curve with critical pressure and temperature so there is no phase boundary.
- Create and analyze a graph of temperature vs time which illustrates the heating or cooling of a substance over the range of phase change.

- Explain the shape of the graph in terms of kinetic energy, potential energy, and heat transfer.
- Given a specific set of conditions, use the following equations to calculate the amount of heat involved. $\Delta H = mc\Delta T; H = mL_f ; \Delta H = mLv$

Assessment Guidelines:
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https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections: (6-8):** **7.P.2B.1:** Analyze and interpret data to describe substances using physical properties (including state, boiling/melting point, density, conductivity, color, hardness, and magnetic properties) and chemical properties (the ability to burn or rust). **7.P.2B.4:** Plan and conduct controlled scientific investigations to answer questions about how physical and chemical changes affect the properties of different substances.

States of Matter

<table>
<tr><td colspan="2">Standard H.C.4 The student will demonstrate an understanding of the structure and behavior of the different states of matter.</td></tr>
<tr><td colspan="2">H.C.4A Conceptual Understanding: Matter can exist as a solid, liquid, or gas, and in very high-energy states, as plasma. In general terms, for a given chemical, the particles making up the solid are at a lower energy state than the liquid phase, which is at a lower energy state than the gaseous phase. The changes from one state of matter into another are energy dependent. The behaviors of gases are dependent on the factors of pressure, volume, and temperature.</td></tr>
<tr><td>Performance Indicator</td><td>H.C.4A.3: <u>Conduct controlled scientific investigations</u> and use models to explain the behaviors of gases (including the proportional relationships among pressure, volume, and temperature).</td></tr>
<tr><td>Science and Engineering Practice</td><td>H.C.1A.3: <u>Plan and conduct controlled scientific investigation</u>s to answer Questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.</td></tr>
<tr><td>Crosscutting Concepts</td><td>The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6.

Cause and Effect
Stability and Change</td></tr>
</table>

Essential Learning Experiences:
It is essential that students plan and conduct controlled scientific investigations to determine how variation in pressure, volume, and temperature affect the behavior of gases.

- The Kinetic Molecular Theory attempts to explain the behavior of the physical systems and depends on combined actions of the particles in the system.
  - Kelvin is the SI unit of temperature.
  - Absolute zero is 0 K, which is equal to -273.15°C.
  - Pressure is force per unit area and is the physical force exerted on or against an object by something in contact with it. Pressure can be measured in Pa, kPa, mm of Hg, atm, or torr.
  - Standard Temperature and Pressure (STP) is a defined set of conditions: 1.0 atm of pressure and 0°C.
- Charles's law states the relationship between volume and temperature.
  - (V/T=k; $\frac{V_1}{T_2} = \frac{V_2}{T_2}$)

- Boyle's law states the relationship between pressure and volume.
  - (PV=k; $P_1 V_1 = P_2 V_2$)
- The combined gas law explains the relationship between volume, pressure, and temperature.
  - (PV/T=k; $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$)
- The ideal gas law equation (PV = nRT) is the mathematical relationship among pressure, volume, temperature, or number of moles. The ideal gas constant, R has various values and must be consistent with the units for the other variables. The standard molar volume of a gas at STP is 22.4 L.
- Solve problems mathematically using Charles's law, Boyle's law and combined gas law.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Relate number of particles and volume using Avogadro's principles.
- Relate the amount of gas present to it pressure, temperature, and volume using the ideal gas law.
- Use the ideal gas law to determine the density of a gas. (PV = nRT)
- Explain the difference between real gases and ideal gases.
- Solve problems mathematically using the ideal gas law.
- Solve problems mathematically using Gay Lussac's Law.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **6.P.3A.2:** Develop and use models to exemplify the conservation of energy as it is transformed from kinetic to potential (gravitational and elastic) and vice versa. **7.P.2B.1:** Analyze and interpret data to describe substances using physical properties (including state, boiling/melting point, density, conductivity, color, hardness, and magnetic properties) and chemical properties (the ability to burn or rust). **7.P.2B.4:** Plan and conduct controlled scientific investigations to answer questions about how physical and chemical changes affect the properties of different substances.

	High School Learning Connections (9-12): **Biology** **H.B.2A.2:** Plan and conduct investigations to determine how various environmental factors (including temperature and pH) affect enzyme activity and the rate of biochemical reactions.

Solutions, Acids and Bases

H.C.5 The student will demonstrate an understanding of the nature and properties of various types of chemical solutions.	
H.C.5A Conceptual Understanding: Solutions can exist in any of three physical states: gas, liquid, or solid. Solution concentrations can be expressed by specifying the relative amounts of solute and solvent. The nature of the solute, the solvent, the temperature, and the pressure can affect solubility. Solutes can affect such solvent properties as freezing point, boiling point, and vapor pressure. Acids, bases, and salts have characteristic properties. Several definitions of acids and bases are used in chemistry.	
Performance Indicator	**H.C.5A.1:** Obtain and communicate information to describe how a substance can dissolve in water by dissociation, dispersion, or ionization and how intermolecular forces affect solvation.
Science and Engineering Practice	**H.C.1A.8:** Obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect

Essential Learning Experiences:
It is essential that students obtain and evaluate information from investigations, computer simulations, and virtual labs to obtain evidence regarding how factors like dissociation, dispersion, or ionization affect solvation. The information could communicate the cause and effect relationships that affect solvation using presentations, discussions, digital publications, and digital media.

- Solvation is the process of a solute molecule being surrounded by a solvent molecule, which in regard to this standard is water and causes solute to break into individual parts (expanding solute) overcoming molecular forces (expanding solvent) to form solution.
- Substances can dissolve in water in three different ways: dissociation, dispersion, and ionization. Intermolecular forces affect how substances dissolve in water.
- Dissociation is the separation of an ionic compound into ions in solution.
- Dispersion occurs when particles are suspended throughout the dispersion medium, but do not ionize.

- Ionization is the formation of ions in solution from a molecular solute when dissolved in water.

Properties of Aqueous Solutions

Solution	Uniformity	Particle	Gravity
solution	homogenous	ions, atoms, small molecules	stable/does not separate
colloid	heterogeneous	large molecules/particles	stable does not separate
suspension	heterogeneous	large particles/aggregates	sediment form/unstable

Substances Dissolve in Water 3 Ways

Type	Behavior
Dissociation	separation of ionic compounds into ions
Dispersion	particles suspended in solvent without ionization
Ionization	ions formed when molecule dissolves

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.
- Distinguish among strong electrolytes, weak electrolytes, and nonelectrolytes
- Solve stoichiometry calculations based on reactions involving aqueous solutions, write net ionic equations, calculate the solubility of a compound from its solubility product constant, and determine equilibrium concentrations of reactants and products.
- Investigate the use of electrolytes by the human body.
- Create an apparatus to filter/clean (remove substances from) water for drinking.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.3:** Analyze and interpret data to describe and classify matter as pure substances (elements or compounds) or mixtures (heterogeneous or homogeneous) based on composition. **High School Learning Connections (9-12):** **Biology** **H.B.2C.2:** Ask scientific questions to define the problems that organisms face in maintaining homeostasis within different environments (including water of varying solute concentrations).

Solutions, Acids and Bases

H.C.5 The student will demonstrate an understanding of the nature and properties of various types of chemical solutions.	
H.C.5A Conceptual Understanding: Solutions can exist in any of three physical states: gas, liquid, or solid. Solution concentrations can be expressed by specifying the relative amounts of solute and solvent. The nature of the solute, the solvent, the temperature, and the pressure can affect solubility. Solutes can affect such solvent properties as freezing point, boiling point, and vapor pressure. Acids, bases, and salts have characteristic properties. Several definitions of acids and bases are used in chemistry.	
Performance Indicator	**H.C.5A.2:** Analyze and interpret data to explain the effects of temperature and pressure on the solubility of solutes in a given amount of solvent.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical Analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect

Essential Learning Experiences:
It is essential that students analyze and interpret data regarding how temperature and pressure affect the solubility of solid, liquid, and gas solutes in solvents. Data from solubility experiments should be presented graphically and the graphs analyzed for relationships between temperature or pressure and solubility,

- The solubility of most solids in a liquid is directly proportional to temperature of that system; however the degree to which temperature affects the solubility of a solid varies with the structure and amount of the solid.
- The solubility of most gases in a liquid is inversely proportional to temperature of that system.
- The solubility of most gases in a liquid is directly proportional to the pressure of that system.
- Explain the terms saturated, supersaturated, unsaturated, dilute, and concentrated with respect to solubility.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Use the Kinetic Molecular Theory to explain the solubility behavior of gases with respect to temperature and pressure.
- Explain why a salt will dissolve in water.
- Explain why a soda fizzes when the container is opened.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2A.3:** Analyze and interpret data to describe and classify matter as pure substances (elements or compounds) or mixtures (heterogeneous or homogeneous) based on composition. **High School Learning Connections (9-12):** **Biology** **H.B.2C.2:** Ask scientific questions to define the problems that organisms face in maintaining homeostasis within different environments (including water of varying solute concentrations).

Solutions, Acids and Bases

H.C.5 The student will demonstrate an understanding of the nature and properties of various types of chemical solutions.	
H.C.5A Conceptual Understanding: Solutions can exist in any of three physical states: gas, liquid, or solid. Solution concentrations can be expressed by specifying the relative amounts of solute and solvent. The nature of the solute, the solvent, the temperature, and the pressure can affect solubility. Solutes can affect such solvent properties as freezing point, boiling point, and vapor pressure. Acids, bases, and salts have characteristic properties. Several definitions of acids and bases are used in chemistry.	
Performance Indicator	**H.C.5A.3:** Use mathematical representations to analyze the concentrations of unknown solutions in terms of molarity and percent by mass.
Science and Engineering Practice	**H.C.1A.5:** Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Scale, Proportion and Quantity

Essential Learning Experiences:
It is essential that students use mathematical and computational thinking using experimentally acquired data, to calculate and express relationships among concentration, mass, and volume in terms of molarity and percent by mass.

- The concentration of solutions can characterized in terms of molarity (M) and percent by mass.
- Molarity (M) of a solution is measured in (moles/liter).
- $M = \frac{moles\ of\ solute}{liters\ of\ solution}$
- Percent by mass is another way to calculate the concentration of a solution. This is calculating by mass of solute per mass of solution x 100%.
- $\%\ by\ mass = \frac{mass\ of\ solute}{mass\ of\ solution}$

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Use different units to describe concentration.
- Calculate the volumes needed to dilute solutions ($M_CV_C=M_DV_D$), and explain methods for diluting solutions.

- Calculate molality ($\frac{moles\ solute}{kg\ solvent}$ = m) and mole fraction ($\chi_A = \frac{moles\ A}{total\ moles\ in\ solution}$).

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.3:** Analyze and interpret data to compare the physical properties, chemical properties (neutralization to form a salt, reaction with metals), and pH of various solutions and classify solutions as acids or bases. **High School Learning Connections (9-12):** **Biology** **H.B.2C.3:** Analyze and interpret data to explain the movement of molecules (including water) across a membrane.

Solutions, Acids and Bases

H.C.5 The student will demonstrate an understanding of the nature and properties of various types of chemical solutions.	
H.C.5A Conceptual Understanding: Solutions can exist in any of three physical states: gas, liquid, or solid. Solution concentrations can be expressed by specifying the relative amounts of solute and solvent. The nature of the solute, the solvent, the temperature, and the pressure can affect solubility. Solutes can affect such solvent properties as freezing point, boiling point, and vapor pressure. Acids, bases, and salts have characteristic properties. Several definitions of acids and bases are used in chemistry.	
Performance Indicator	**H.C.5A.4:** Analyze and interpret data to describe the properties of acids, bases, and salts.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical Analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect

Essential Learning Experiences:
It is essential that students analyze and interpret data obtained using a variety of methods to identify physical and chemical properties of acids, bases, and salts.

- Acids
  - The Arrhenius definition of an acid is a substance that ionizes or releases hydrogen ions (H^+) when it is mixed with water.
  - Acids are electrolytes.
  - The reaction of these acids with metals that are chemically active produce hydrogen gas.
  - Acids cause indicators to change colors (Litmus, Phenolphthalein, Methyl orange, and Bromothymol blue).
  - Neutralized by bases.
  - Water solutions of acids taste sour.
  - Have a pH less than 7.
- Bases
  - The Arrhenius Definition of a base is a substance that ionizes or releases hydroxide ions (OH-) when it is mixed with water.
  - Bases are electrolytes.

  - Bases cause indicators to change colors (Litmus, Phenolphthalein, Methyl orange, and Bromothymol blue).
  - Neutralized by acids.
  - Water solutions of bases taste bitter and feel slippery.
  - Have a pH greater than 7.
- Salts
  - Salts are defined as ionic compounds containing a positive ion other than the hydrogen ion, a negative ion other than the hydroxide ion and are soluble in water.
  - They have high melting points.
  - They are good conductors of electric current either when molten or when dissolved in water.
  - Salts completely break up into ions when dissolved in water.
  - Salts are formed by the reaction of acids with bases (cation from base and anion from acid).

NOTE TO TEACHER: Indicator H.C.6A.1 requires students to predict the products of chemical reactions based on the movement of ions, protons, and electrons. It might be helpful to students to be introduced to the Bronsted-Lowry and Lewis acid-base theories at this point to aid in their understanding of chemical reactions.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Define acids and bases using the Bronsted-Lowry acid-base theory.
- Define acids and bases using the Lewis theory of acid-base reactions.
- Explain the relationship between the strengths of acids and bases and the values of their ionization constants.
- Calculate pH and pOH from hydrogen and hydroxide concentrations for strong acids and bases.
- Explain the relationship of hydrogen concentration and hydroxide concentration in $K_{W,}$ K_a, and K_b in relation to strong and weak acids and bases.
- Perform a titration to determine the concentration of an unknown solution.
- Calculate the amount of titrant needed to completely neutralize a given solution.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.3:** Analyze and interpret data to compare the physical properties, chemical properties (neutralization to form a salt, reaction with metals), and pH of various solutions and classify solutions as acids or bases. **High School Learning Connections (9-12):** **Biology** **H.B.2A.2:** Plan and conduct investigations to determine how various environmental factors (including temperature and pH) affect enzyme activity and the rate of biochemical reactions.

Chemical Reactions

H.C.6 The student will demonstrate an understanding of the types, the causes, and the effects of chemical reactions.	
H.C.6A. Conceptual Understanding: A chemical reaction occurs when elements and /or compounds interact, resulting in a rearrangement of the atoms of these elements and/or compounds to produce substance with unique properties. Mass is conserved in chemical reactions. Reactions tend to proceed in a direction that favors lower energies. Chemical reaction can be categorized using knowledge about the reactant to predict products. Chemical reactions are quantifiable. When stress is applied to a chemical system that is in equilibrium, the system will shift in a direction that reduces the stress.	
Performance Indicator	**H.C.6A.1:** Develop and use models to predict the products of chemical reactions (1) based upon movements of ions; (2) based upon movements of protons; and (3) based upon movements of electrons.
Science and Engineering Practice	**H.C.1A.2:** Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Stability and Change

Essential Learning Experiences:
It is essential that students develop and use models to illustrate types of reactions and use those models to predict the products of chemical reactions.

- Reactions based upon movements of ions:
    - For the purposes of this indicator, chemical reactions that involve the movement of ionic particles are limited to those that produce an insoluble solid (precipitate) from two aqueous solutions.
    - To model these reactions, students should first conceptualize the solutes of aqueous solutions as dissociated ions. The ions that form insoluble solids come together through electrostatic attraction and precipitate. Models should progress from particle drawings to traditional chemical equations that include phase notation.
    - Example: $MgSO_4(aq) + Na_2CO_3(aq) \rightarrow MgCO_3(s) + Na_2SO_4(aq)$

    - These reactions are usually referred as double replacement (AB + CD → AD + BC) and precipitation reactions. Memorization of solubility rules is not assessed. Students should be able to read a solubility table.

- Reactions based upon movements of protons
    - For the purposes of this indicator, chemical reactions based upon the movement of protons (H^+) are acid-base neutralization reactions; the reactions covered in this section are limited to those between Bronsted-Lowry acids and bases.
    - To model these reactions, students should conceptualize acids as proton donors (H^+) and bases as proton acceptors (H^+) and then progress to predicting products using traditional chemical reactions. Student models should demonstrate understanding of conjugate acid-base pairs.
    - Example: $NH_3 + NaOH \rightarrow NH_4^+ + OH^-$
    - These reactions are usually referred to as neutralization or double replacement reactions.

- Reactions based upon movements of electrons:
    - For the purposes of this indicator, chemical reactions based upon movements of electrons are limited to simple oxidation-reduction reactions in which only one element is oxidized and another is reduced.
    - To model these reactions, students should first conceptualize one or more electrons moving from one species to another to form new products. Models should progress from particle drawings to traditional chemical equations that include phase notation.
    - These oxidation-reduction reactions are usually referred to in textbooks as synthesis (A + B → AB), decomposition (AB → A + B), and single replacement reactions (AB + C → AC + B).
        - Predicting the products of decomposition reactions should be limited to simple binary compounds decomposing to their elements.
        - "Oxidation" is defined as the process of losing electrons, "reduction" is defined as process of gaining electrons
            - A substance that is "oxidized" has lost electrons
            - A substance that is "reduced" has gained electrons
            - When a substance is oxidized, it "gives" electrons to another substance, causing that substance to gain electrons or be reduced.
                - A substance that causes another substance to be reduced is called a "reducing agent"
                - Any substance that is oxidized is a reducing agent
            - When a substance is reduced, it "takes" electrons from another substance, causing that substance to lose electrons or be oxidized.
                - A substance that causes another substance to be oxidized is called an "oxidizing agent"
                - Any substance that is reduced is called an oxidizing agent

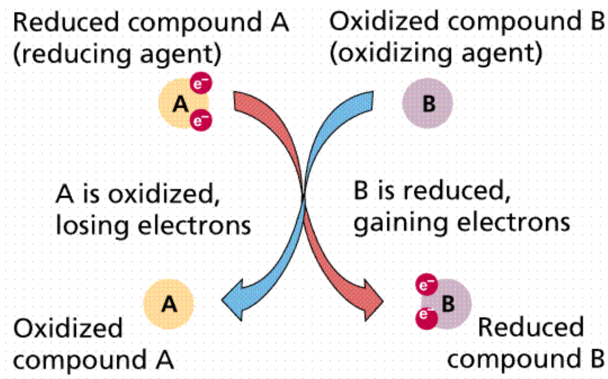

Figure 5. Compounds (SCDE, 2005).

- Examples:
  $Mg(s) + Br_2(l) \rightarrow MgBr_2(s)$
  $NaCl(s) \rightarrow Na(s) + Cl_2(g)$
  $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

NOTE TO TEACHER: There is a connection to content which may have been introduced with H.C.5A.4, Bronsted - Lowry theory of acids and bases. Any mention of protons and the movement of protons in this indicator refer to H^+. Teachers may want students to recognize combustion reactions as they are the primary content of H.C.7A.3.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Construct and use net ionic equations to model reactions involving the production of carbonic acid which subsequently decomposes to water and carbon dioxide.
- Obtain, evaluate, and communicate information regarding Lewis acid-base theory and hydrolysis.
- Develop and use models to identify oxidizing and reducing agents and write half-reactions.
- Write combustion reactions.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.5:** Develop and use models to explain how chemical reactions are supported by the law of conservation of matter. **High School Learning Connections (9-12):** **Biology** **H.B.3A.2:** Develop and revise models to describe how photosynthesis transforms light energy into stored chemical energy. **H.B.3A.4:** Develop models of the major inputs and outputs of cellular respiration (aerobic and anaerobic) to exemplify the chemical process in which the bonds of molecules are broken, the bonds of new compounds are formed and a net transfer of energy results.

Chemical Reactions

H.C.6 The student will demonstrate an understanding of the types, the causes, and the effects of chemical reactions.

H.C.6A. Conceptual Understanding: A chemical reaction occurs when elements and /or compounds interact, resulting in a rearrangement of the atoms of these elements and/or compounds to produce substance with unique properties. Mass is conserved in chemical reactions. Reactions tend to proceed in a direction that favors lower energies. Chemical reaction can be categorized using knowledge about the reactant to predict products. Chemical reactions are quantifiable. When stress is applied to a chemical system that is in equilibrium, the system will shift in a direction that reduces the stress.

Performance Indicator	**H.C.6A.2:** Use Le Châtelier's principle to <u>predict</u> shifts in chemical equilibria resulting from changes in concentration, pressure, and temperature.
Science and Engineering Practice	**H.C.1A.6:** <u>Construct explanations</u> of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Stability and Change

Essential Learning Experiences:
<u>It is essential</u> that students understand the concept of equilibrium as it applies to solubility and phase change. This knowledge should lead students to make claims about the influence of pressure, temperature, and concentration based on their knowledge and their observations. Students should also to be able to identify the cause and effect relationships change in pressure, temperature, and concentration have on equilibrium.

- Equilibrium is a dynamic condition in which two opposing changes occur at equal rates in a closed system.
- Le Chatelier's principle states that if a system is at equilibrium and is subjected to stress, the equilibrium is disturbed and shifts in the direction that relieves stress and returns to equilibrium.
- Apply Le Châtelier's Principle in reference to the following stresses:
  - A change in concentration - adding additional reactant to a system will shift the equilibrium to the right, towards the side of the products. Reducing the concentration of any product will also shift equilibrium to the right.

- A change in temperature has to do with the heat of reaction and changes K ($K = \frac{[P]}{[R]}$).
    - In exothermic reactions, increases in temperature will shift equilibrium to the left
    - In endothermic reactions, increases in temperature will shift equilibrium to the right
- A change in pressure will result in an attempt to restore equilibrium by creating more or fewer moles of gas.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Define and manipulate K_{sp} in order to predict solubility.
- Explain changes in equilibrium due to solubility, phase changes and reaction completion (the equilibrium shifts to offset the change).
- Conduct investigations changing volume or pressure which will restore equilibrium by varying moles of gas.
- Explain equilibrium shifts that occur in endothermic and exothermic reactions.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.5:** Develop and use models to explain how chemical reactions are supported by the law of conservation of matter. **High School Learning Connections (9-12):** **H.B.2C.1:** Develop and use models to exemplify how the cell membrane serves to maintain homeostasis of the cell through both active and passive transport processes.

Chemical Reactions

H.C.6 The student will demonstrate an understanding of the types, the causes, and the effects of chemical reactions.	
H.C.6A. Conceptual Understanding: A chemical reaction occurs when elements and /or compounds interact, resulting in a rearrangement of the atoms of these elements and/or compounds to produce substance with unique properties. Mass is conserved in chemical reactions. Reactions tend to proceed in a direction that favors lower energies. Chemical reaction can be categorized using knowledge about the reactant to predict products. Chemical reactions are quantifiable. When stress is applied to a chemical system that is in equilibrium, the system will shift in a direction that reduces the stress.	
Performance Indicator	**H.C.6A.3:** Plan and conduct controlled scientific investigations to produce mathematical evidence that mass is conserved in chemical reactions
Science and Engineering Practice	**H.C.1A.3:** Plan and conduct controlled scientific investigations to answer Questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Patterns Cause and Effect Stability and Change Systems and System Models

Essential Learning Experiences:
It is essential that students plan and conduct controlled scientific investigations to gather evidence of mass and moles before and after a chemical reaction. Students should design, conduct, and present data from an experiment to perform stoichiometric calculations, calculate the number of molecules, formula units, or ions in a given molar amount of a chemical compound.

- The Law of Conservation of Mass says that mass can neither created nor destroyed, but can be changed in form.
  - A balanced chemical reaction illustrates the law of conservation of mass.
  - The total mass of the material(s) before the reaction is the same as the total mass of material(s) after the reaction.

- In a chemical reaction, the number of atoms of each kind of element are the same on each side of an equation.
- Chemical reactions do not create or destroy atoms, only create different configurations of the same atoms.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Plan and conduct a chemical reaction then reverse that reaction to prove The Law of Conservation of Mass. This should include measurements and a balanced chemical reaction to support the law.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.4:** Plan and conduct controlled scientific investigations to answer questions about how physical and chemical changes affect the properties of different substances. **7.P.2B.5:** Develop and use models to explain how chemical reactions are supported by the law of conservation of matter. **High School Learning Connections (9-12):** **Biology** **H.B.3A.2:** Develop and revise models to describe how photosynthesis transforms light energy into stored chemical energy. **H.B.3A.4:** Develop models of the major inputs and outputs of cellular respiration (aerobic and anaerobic) to exemplify the chemical process in which the bonds of molecules are broken, the bonds of new compounds are formed and a net transfer of energy results.

Chemical Reactions

H.C.6 The student will demonstrate an understanding of the types, the causes, and the effects of chemical reactions.	
H.C.6A. Conceptual Understanding: A chemical reaction occurs when elements and /or compounds interact, resulting in a rearrangement of the atoms of these elements and/or compounds to produce substance with unique properties. Mass is conserved in chemical reactions. Reactions tend to proceed in a direction that favors lower energies. Chemical reaction can be categorized using knowledge about the reactant to predict products. Chemical reactions are quantifiable. When stress is applied to a chemical system that is in equilibrium, the system will shift in a direction that reduces the stress.	
Performance Indicator	**H.C.6A.4:** Use mathematical and computational thinking to predict the amounts of reactants required and products produced in specific chemical reactions.
Science and Engineering Practice	**H.C.1A.5:** Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Cause and Effect Stability and Change Systems and System Models Scale, Proportion, and Quantity

Essential Learning Experiences:
It is essential that students determine molar mass, formula mass, and molecular mass and convert between those mass and moles. Students should calculate the limiting and excess reactants in chemical reactions using experimentally acquired data.

- Convert grams, liters, and atomic mass units to moles.
- Convert moles to grams, liters, and atomic mass units.
- Use mole ratios (fractions) to convert moles to grams, to liters, and to atomic mass units.
- The quantity 6.02×10^{23} of any object is defined as a "mole" of the object.
- At standard temperature and pressure, the volume of one mole of a gas is 22.4 L.
- The atomic mass of a substance, as found on the periodic table, represents the average mass (in atomic mass units) of the naturally occurring isotopes of the element.
- The molar mass of a pure substance is the mass (in grams) of one mole of the substance (the molar mass of carbon atoms is the mass (in grams) of one mole of carbon atoms).
- The molar mass of an element (measured in grams) is numerically equal to the atomic mass of the element (measured in atomic mass units)

- The formula mass is the term used for ionic substances. It is the sum of the atomic masses of all of the elements contained in one formula unit of an ionic compound.
- The molecular mass is the term used for molecular compounds. It is the sum of the atomic masses of all of the elements in the molecular formula of the substance.
- Molar mass, formula mass, or molecular mass can be used to convert between mass in grams and amount in moles of a chemical compound.
- Reaction stoichiometry is used to identify the amount of reactants and products in moles or grams needed or required in a chemical reaction.
- Limiting reactant is the reactant that limits the amount of product that can be formed.

NOTE TO TEACHER:
The mole concept, atomic mass, and molar mass of an element may be introduced as a part of instruction in H.C.2A.1. These may be taught using cooking recipes for real-world connections.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal but can be used by teachers to extend the depth and rigor of student engagements.

- Calculate percent yield.
- Calculate limiting reagent and reagent in excess.

Assessment Guidelines:
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Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.4:** Plan and conduct controlled scientific investigations to answer questions about how physical and chemical changes affect the properties of different substances. **7.P.2B.5:** Develop and use models to explain how chemical reactions are supported by the law of conservation of matter. **High School Learning Connections (9-12):** **H.B.3A.2:** Develop and revise models to describe how photosynthesis transforms light energy into stored chemical energy. **H.B.3A.4:** Develop models of the major inputs and outputs of cellular respiration (aerobic and anaerobic) to exemplify the chemical process in which the bonds of molecules are broken, the bonds of new compounds are formed and a net transfer of energy results.

Thermochemistry and Chemical Kinetics

Standard H.C.2: H.C.7 -The student will demonstrate an understanding of the conservation of energy and energy transfer.	
H.C.7A Conceptual Understanding The first law of thermodynamics states that the amount of energy in the universe is constant. An energy diagram is used to represent changes in the energy of the reactants and products in a chemical reaction. Enthalpy refers to the heat content that is present in an atom, ion, or compound. While some chemical reactions occur spontaneously, other reactions may require that activation energy be lowered in order for the reaction to occur.	
Performance Indicator	**H.C.7A.1:** Analyze and interpret data from energy diagrams and investigations to support claims that the amount of energy released or absorbed during a chemical reaction depends on changes in total bond energy.
Science and Engineering Practice	**H.C.1A.4:** Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical Analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Energy and Matter Stability and Change Cause and Effect

Essential Learning Experiences:
It is essential that students analyze and interpret data to exemplify how energy is conserved during a chemical reaction. Student generated laboratory data or teacher provided data could be used to support that energy is conserved in a chemical reaction.

- The Law of Conservation of Energy states that the total energy of a system does not change.
  - For a chemical system, any energy transformations depend on changes in total bond energy.
- Enthalpy is a measure of the total energy of a system. The total enthalpy of a system cannot be measured directly, so the enthalpy change of a system is measured instead.
- The enthalpy change of a system can be conceptualized by $\Delta H = H_f - H_i$ where
  - ΔH is the change in enthalpy of the system.
  - H_f is the final enthalpy of the system.
  - H_i is the initial enthalpy of the system.
  - Each of these values is measured in Joules (J) or kilojoules (kJ) per mole of reactant.

- The heat of reaction, or ΔH_{rxn}, is the change in the enthalpy of a chemical reaction that occurs at a constant pressure.
    - If the chemical reaction is exothermic, the value of ΔH_{rxn} is negative;
    - If the chemical reaction is endothermic, the value of ΔH_{rxn} is positive.
- Energy diagrams are a useful means of visualizing the energy changes involved in chemical reactions.
    - The example below shows the energy changes typical of an exothermic and endothermic reaction.
    - Students should be able to identify the potential energy (PE) of the reactants, the PE of the products, the activation energy (E_a), and the heat of reaction (ΔH).
- Thermochemical equations include the word "energy" or the actual energy change, in kilojoules, in the chemical equation.
    - For endothermic reactions, the energy appears as a reactant, showing the absorption of energy from the surroundings.
    - For exothermic reactions, the energy appears as a product, showing a production or release of energy to the surroundings.
        - For example, the decomposition of water is shown as $2H_2O + \text{energy} \rightarrow 2H_2 + O_2$, while the formation of water from its elements would be shown as $2H_2 + O_2 \rightarrow 2H_2O + \text{energy}$.
- Every day and novel examples of endothermic and exothermic reactions include:
    - Everyday examples of endothermic reactions include baking bread, cooking an egg, and photosynthesis.
    - Examples of exothermic reactions in everyday life include burning wood, rusting, and cellular respiration.
    - Students should also be able to identify novel examples that clearly release or absorb energy, based upon common everyday experiences.

Extended Learning Experiences:

The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Interpret energy diagrams with respect to the reverse reaction.
- Calculate molar enthalpies of reaction using Hess' Law and/or tables of bond energies.
- Explain heat transfer through calorimetric calculations.
- Explain how specific heat of a substance affects how heat is transferred from one substance to another.

Assessment Guidelines:

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Learning Connections	**Previous Learning Connections (6-8):** **6.P.3A.5:** Develop and use models to describe and compare the directional transfer of heat through convection, radiation, and conduction. **High School Connections (9-12):** **Biology** **H.B.2A.2:** Plan and conduct investigations to determine how various environmental factors (including temperature and pH) affect enzyme activity and the rate of biochemical reactions. **H.B.3A.1:** Develop and use models to explain how chemical reactions among ATP, ADP, and inorganic phosphate act to transfer chemical energy within cells.

Thermochemistry and Chemical Kinetics

Standard H.C.2: H.C.7 -The student will demonstrate an understanding of the conservation of energy and energy transfer.	
H.C.7A Conceptual Understanding: The first law of thermodynamics states that the amount of energy in the universe is constant. An energy diagram is used to represent changes in the energy of the reactants and products in a chemical reaction. Enthalpy refers to the heat content that is present in an atom, ion, or compound. While some chemical reactions occur spontaneously, other reactions may require that activation energy be lowered in order for the reaction to occur.	
Performance Indicator	**H.C.7A.2:** Use mathematical and computational thinking to write thermochemical equations and draw energy diagrams for the combustion of common hydrocarbon fuels and carbohydrates, given molar enthalpies of combustion.
Science and Engineering Practice	**H.C.1A.5:** Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Energy and Matter Stability and Change Cause and Effect

Essential Learning Experiences:
It is essential that students use mathematical and computational thinking to analyze the amount of energy given off during the combustion of different fuels and draw energy diagrams.

- Combustion reactions are generally exothermic.
- Enthalpy of combustion (ΔH°_{comb}) is the change that occurs during the complete combustion of one mole of a substance.
- Enthalpy of combustion is defined by one mole of reactant (instead of reactants like enthalpy of formation).
- Examples of some thermal chemical equations for combustion are below:
  - $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + 889 kJ (energy)
  - $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ + 1300 kJ (energy)
  - $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ + 2220 kJ (energy)

- Draw energy diagram for combustion like the one shown below.

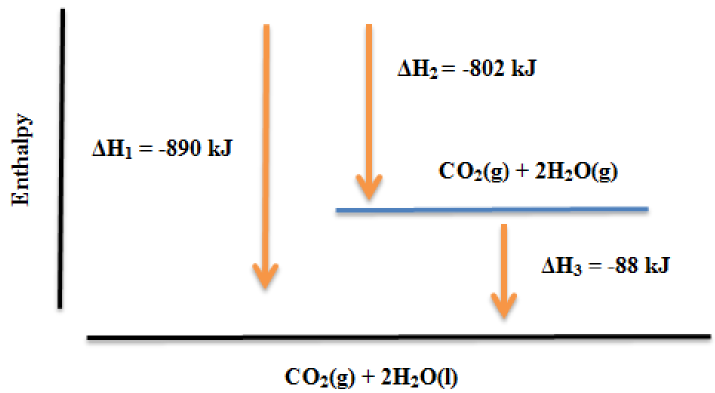

Figure 6. Combustion (SCDE, 2018).

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Use mathematical and computational thinking to write equations that can be balanced with multiple moles of fuel and or fractional moles of oxygen.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **6.P.3A.5:** Develop and use models to describe and compare the directional transfer of heat through convection, radiation, and conduction. **7.P.2B.5:** Develop and use models to explain how chemical reactions are supported by the law of conservation of matter. **High School Learning Connections (9-12):** **Biology** **H.B.3A.4:** Develop models of the major inputs and outputs of cellular respiration (aerobic and anaerobic) to exemplify the chemical process in which the bonds of molecules are broken, the bonds of new compounds are formed and a net transfer of energy results.

Thermochemistry and Chemical Kinetics

Standard H.C.2: H.C.7 -The student will demonstrate an understanding of the conservation of energy and energy transfer.	
H.C.7A Conceptual Understanding The first law of thermodynamics states that the amount of energy in the universe is constant. An energy diagram is used to represent changes in the energy of the reactants and products in a chemical reaction. Enthalpy refers to the heat content that is present in an atom, ion, or compound. While some chemical reactions occur spontaneously, other reactions may require that activation energy be lowered in order for the reaction to occur.	
Performance Indicator	**H.C.7A.3:** Plan and conduct controlled scientific investigations to determine the effects of temperature, surface area, stirring, concentration of reactants, and the presence of various catalysts on the rate of chemical reactions.
Science and Engineering Practice	**H.C.1A.3:** Plan and conduct controlled scientific investigations to answer Questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Energy and Matter Stability and Change Cause and Effect

Essential Learning Experiences:
It is essential that students plan and conduct controlled scientific investigations to determine how temperature, surface area, stirring, concentration of reactants, and catalyst affect the rate of chemical reactions.

- For many reactions, increases in temperature will increase reaction rates due to collisions between molecules having greater frequency and energy. Reactants not only need to collide with enough energy but they also must collide in the proper orientation.
- As the surface area of a solid reactant increases, the reaction rate will increase, due to more of the reactant being exposed to other reactants, causing more collisions.
- Stirring will keep the reactant particles in motion, increasing the frequency of collisions.
- As the concentration of a reactant increases, the frequency of collisions increases, due to the presence of more reactant molecules.
- The presence of a catalyst increases the rate of a reaction by reducing the activation energy required for the reaction to occur.

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Research and explain heterogeneous catalysts versus homogeneous catalysts.
- Research how catalysts are used in the human body.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.3:** Analyze and interpret data to compare the physical properties, chemical properties (neutralization to form a salt, reaction with metals), and pH of various solutions and classify solutions as acids or bases. **7.P.2B.5:** Develop and use models to explain how chemical reactions are supported by the law of conservation of matter. **High School Learning Connections (9-12):** **Biology** **H.B.2A.2:** Plan and conduct investigations to determine how various environmental factors (including temperature and pH) affect enzyme activity and the rate of biochemical reactions.

Thermochemistry and Chemical Kinetics

Standard H.C.2: H.C.7 -The student will demonstrate an understanding of the conservation of energy and energy transfer.	
H.C.7A Conceptual Understanding: The first law of thermodynamics states that the amount of energy in the universe is constant. An energy diagram is used to represent changes in the energy of the reactants and products in a chemical reaction. Enthalpy refers to the heat content that is present in an atom, ion, or compound. While some chemical reactions occur spontaneously, other reactions may require that activation energy be lowered in order for the reaction to occur.	
Performance Indicator	**H.C.7A.4:** Develop and use models to explain the relationships between collision frequency, the energy of collisions, the orientation of molecules, activation energy, and the rates of chemical reactions.
Science and Engineering Practice	**H.C.1A.2:** Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.
Crosscutting Concepts	The following Crosscutting Concepts may be applied to the content of this indicator. For more information see page 6. Energy and Matter Stability and Change Cause and Effect Systems and System Models

Essential Learning Experiences:
It is essential that students develop and use models to explain the relationship between collision energy and rate of reaction. Students should create energy diagrams to model how catalysts decrease the amount of energy needed for a chemical reaction to occur.

- Plan and carry out investigations using various compounds and catalysts to collect data. Use the graphs of data to explain behavior of particles and catalysts in a system.
- In order for a reaction to proceed, the reactant particles must collide. A chemical reaction only occurs if particles are oriented favorably. If the particles are not oriented correctly, a reaction will not occur.
- These collisions must have sufficient energy to break bonds of the reacting substances. The minimum amount of energy for a reaction to proceed is called the activation energy.
- A catalyst is a substance that increases the speed of a reaction but, is not consumed in the reaction.
- Catalysts allow for a different pathway with lower activation energy for a reaction to occur faster.
- Energy diagrams should be used to differentiate between reaction pathways with and without a catalyst.

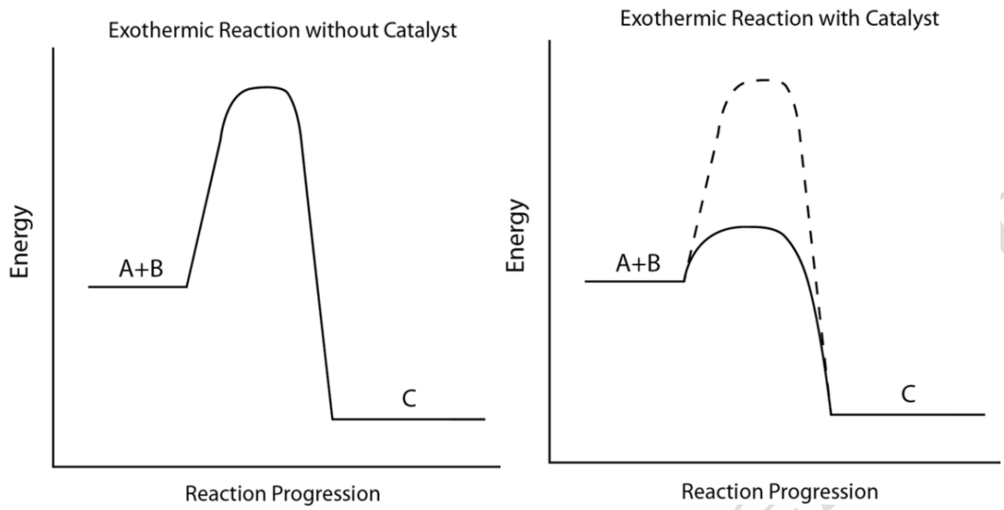

Figure 7. Exothermic (SCDE, 2018).

Extended Learning Experiences:
The following knowledge and learning experiences are not essential to the success of this learning goal, but can be used by teachers to extend the depth and rigor of student engagements.

- Investigate the lock and key hypothesis.
- Research the value of catalytic converters in cars.
- Compare and contrast heterogeneous catalysis, homogeneous catalysis, and surface catalysis.
- Investigate rates of chemical changes regulated by the endocrine system in the human body.

Assessment Guidelines:
Students should engage in multiple science and engineering practices when interacting with the content outlined in this performance indicator. For further information please see SEP Support Guide at:
https://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf

Learning Connections	**Previous Learning Connections (6-8):** **7.P.2B.3:** Analyze and interpret data to compare the physical properties, chemical properties (neutralization to form a salt, reaction with metals), and pH of various solutions and classify solutions as acids or bases. **High School Learning Connections (9-12):** **Biology** **H.B.2A.2:** Plan and conduct investigations to determine how various environmental factors (including temperature and pH) affect enzyme activity and the rate of biochemical reactions.

References

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