*Unit 2. Ionic and Covalent Compounds

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Unit Summary

Atoms in ionic compounds are held together by chemical bonds formed by the attraction of oppositely charged ions. Ions are formed when atoms gain or lose valence electrons to achieve a stable octet electron configuration (noble gas electron configuration). Oppositely charged ions attract each other, forming electrically neutral ionic compounds. In written names and formulas for ionic compounds, the cation appears first, followed by the anion. Metals form crystal lattices and can be modeled as cations surrounded by a “sea” of freely moving valence electrons. Atoms in covalent compounds are held together by chemical bonds formed by the sharing of valence electrons. Atoms gain stability when they share electrons and form covalent bonds. Specific rules are used when naming binary covalent compounds and binary acids and oxoacids. Structural formulas show the relative positions of atoms within a molecule. The VSEPR theory is used to determine molecular shape. A chemical bond’s character is related to each atom’s attraction for the electrons in the bond

Enduring Understandings

1. The properties of atomic particles affect the interactions of those atoms.
2. Forces attract, hold together or repel matter.

Essential Questions

1. Why do bonds form?
2. What are the major similarities and differences between ionic and covalent bonds?
3. How do shape, electronegativity, and polarity relate to one another?
4. How can the shape, bond angles, and polarity be predicted using VSEPR theory?
5. How does metallic bonding structure affect the properties of a metal?
6. How does crystal lattice structure affect the properties of an ionic compound?
7. What are the rules for ionic, covalent, and acid naming and formula writing?
8. What are the rules for naming simple organic compounds and functional groups?
9. How do intermolecular forces between particles explain the bulk properties of substances?

10. What is the relationship between intramolecular forces (bonding) and intermolecular forces?

Student Learning Objectives (PE, SEP, DCI, CCC) & Aligned Standards

Performance Expecations

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

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

HS-PS1-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Science and Engineering Practices

Developing and Using Models

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

- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Planning and Carrying Out Investigations

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS1-1, HS-PS1-2, HS-PS1-8)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
· Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)
· The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6))

PS2.B: Types of Interactions
·Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.(HS-PS2-6) (secondary to HS-PS1-1),(secondary to HS-PS1-3)

ETS1.C: Optimizing the Design Solution
· Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)(secondary to HS-PS1-6)

Crosscutting Concepts

Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1, HS-PS1-3)

Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—

including energy, matter, and information flows— within and between systems at different scales(HS-PS1-1, HS-PS1-1, HS-PS1-3)

Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)

Literacy Standards

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

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3), (HS-PS2-6)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source following a standard format for citation. (HS-PS1-3)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-3)

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Concepts & Skills

Concepts and Skills:

IONIC

- describe the formation of an ionic bond.
- describe the formation of an anion or cation from its neutral atom.
- state and apply the octet rule.
- draw Lewis dot structures for any element based on the number of valence electrons present.
- name and write formulas for ionic compounds using IUPAC nomenclature (naming) rules.
- determine the correct ratio of cations to anions needed to form a neutral ionic compound.
- identify the properties of an ionic compound, including melting point, boiling point, lattice energy, and hardness.
- understand that ionic compounds conduct electricity if they are in an aqueous or molten state.
- explain the electron sea model and the role that delocalized electrons play in determining the physical properties of metals (malleable, conductors of electricity/heat, luster, and ductile).
- understand that alloys are a mixture of elements that have metallic properties.
- explain the difference between a monoatomic and polyatomic ion.
- understand that a formula unit represents one particle of an ionic compound.
- distinguish between the term electrolyte and nonelectrolyte.

COVALENT

- describe the formation of a covalent bond.
- explain the differences between single, double and triple bonds based on number of electrons shared (length and strength).
- understand that a molecule represents one particle of a covalent compound.
- predict the molecular shape of a molecule using VSEPR theory (bent, linear, trigonal planar, trigonal pyramidal, and tetrahedral
- determine the polarity of molecules based on their shape if they have the same terminal ends.
- name and write formulas for binary molecular compounds.
- draw Lewis structures for various covalent compounds, including polyatomic ions.

OVERALL

- distinguish among ionic, molecular, and metallic substances given their properties.

- explain chemical bonding in terms of the behavior of electrons.
- distinguish between ionic compounds and binary molecular compounds.
- use electronegativity values to predict bond type (nonpolar covalent, mostly covalent, polar covalent, and ionic).
- name binary acids and oxoacids.
- Naming simple organic compounds and functional groups.
- distinguish the various intermolecular forces of attraction found in molecules and compounds (ion-ion, hydrogen bonding, dipole-dipole, and dispersion)

Vocabulary:

anion, cation, chemical bond, crystal lattice, electrolyte, ionic bond, ionic compound, lattice energy, formula unit, monoatomic, oxidation number, oxyanion, polyatomic ion, alloy, delocalized electrons, electron sea model, metallic bond, covalent bond, Lewis structure, molecule, sigma bond, pi bond, VSEPR theory, intramolecular forces, intermolecular forces, electrostatic force of attraction, hydrogen bonding, dipole-dipole forces, dispersion forces, electronegativity. Alkane, alkene, alkyne, alcohol, ether, ester, carboxylic acid, aldehyde, ketone, saturated.

Resources

Links to Free and Low Cost Instructional Resources

Note-*The majority of the student sense-making experiences found at these links predate the NGSS. Most will nee science and engineering practices, disciplinary core ideas, and cross cutting concepts. The EQuIP Rubrics for S blueprint for evaluating and modifying instructional materials.*

- American Association for the Advancement of Science: *http://www.aaas.org/programs*
- American Association of Physics Teachers: *http://www.aapt.org/resources/*
- American Chemical Society: *http://www.acs.org/content/acs/en/education.html*
- Concord Consortium: Virtual Simulations: *http://concord.org/*
- International Technology and Engineering Educators Association: *http://www.iteaconnect.org/*
- National Earth Science Teachers Association: *http://www.nestanet.org/php/index.php*
- National Science Digital Library: *https://nsdl.oercommons.org/*
- National Science Teachers Association: http://ngss.nsta.org/Classroom-Resources.aspx
- North American Association for Environmental Education: *http://www.naaee.net/*
- Phet: Interactive Simulations*https://phet.colorado.edu/*
- Physics Union Mathematics (PUM): *http://pum.rutgers.edu/*
- Science NetLinks: *http://www.aaas.org/program/science-netlinks*

Assessments

Possible Assessment Tasks:

- Practice Worksheets for each section
- Molecule Shapes (phet simulation- online- HTML5) https://phet.colorado.edu/en/simulation/molecule-shapes (HS-PS1-1, HS-PS1-2) or Molecule Shapes: Basic (phet simulation-online-HTML5) https://phet.colorado.edu/en/simulation/molecule-shapes-basics or Molecular Polarity(phet simulation-online-Java) https://phet.colorado.edu/en/simulation/legacy/molecule-polarity
- Molecular Shapes Lab
- Making Compounds/ Formula Writing Activity
- Bonding- Solids Properties POGIL
- Bonding- Solids Properties- Lab Activity

The Science Classroom

In this unit of study, students begin by building their understanding of the law of conservation of energy by planning and conducting investigations of thermal energy transfer. Students should investigate and describe a system focusing specifically on thermal energy transfer in a closed system. These investigations will provide opportunities for students to use models that can be made of a variety of materials, such as student-generated drawings and/or digital simulations, such as those available from PhET. These models can be used to describe a system, and define its boundaries, initial conditions, inputs, and outputs.

Students should have the opportunity to ask and refine questions, using specific textual evidence, about the energy distribution in a system. Students should collect relevant data from several sources, including their own investigations, and synthesize their findings into a coherent understanding.

Using the knowledge that energy cannot be created or destroyed, students should create computational or mathematical models to calculate the change in the energy in one component of a system when the change in energy of the other component(s) and energy flows in and out of the systems are known. In order to do this, students should manipulate variables in specific heat calculations. For example, students can use data collected from simple Styrofoam calorimeters to investigate the mixing of water at different initial temperatures or the adding of objects at different temperatures to water to serve as a basis for evidence of uniform energy distribution among components of a system. Students might conduct an investigation using different materials such as various metals, glass, and rock samples. Using the specific heat values for these substances, students could create mathematical models to represent the energy distribution in a system, identify important quantities in energy distribution, map relationships, and analyze those relationships mathematically to draw conclusions.

These investigations will allow students to collect data to show that energy is transported from one place to another or transferred between systems, and that uncontrolled systems always move toward more stable states with more uniform energy distribution. Students should also observe during investigations that energy can be converted into less useful forms, such as thermal energy released to the surrounding environment. During the design and implementation of investigations, students must consider the precision and accuracy appropriate to limitations on measurement of the data collected and refine their design accordingly.

This unit will also focus on the planning and conducting of mechanical and chemical investigations of water. Properties to be investigated should include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks. This focus is particularly important since water's abundance on Earth's surface, and its unique combination of physical and chemical properties, are central to the planet's dynamics.

The functions and properties of water and water systems can be inferred from the overall structure, the way components are shaped and used, and the molecular substructure. Investigations will emphasize the mechanical and chemical processes involved in the interactions between the hydrological cycle and solid materials. Examples of mechanical investigations include stream transportation and deposition, erosion, and frost wedging. Examples of chemical investigations include chemical weathering, recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids). When investigating the properties of water and their effects on Earth materials and surface processes, students should report quantities using a level of accuracy appropriate to limitations on measurement.

To gain a more complete understanding, students might conduct short or more sustained research projects to determine how the properties of water affect Earth materials and surface processes. Once students have an understanding of the conservation of energy and the properties of water that allow it to absorb, store, and release large amounts of energy, the unit will transition to an engineering design problem.

Working from the premise that all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs, risks, and benefits, students will use cost–benefit ratios to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources.

For example, students might investigate the real-world technique of using hydraulic fracturing to extract natural gas from shale deposits versus other traditional means of acquiring energy from natural resources. Students will synthesize information from a range of sources into a coherent understanding of competing design solutions for extracting and utilizing energy and mineral resources. As students evaluate competing design solutions, they should consider that new technologies could have deep impacts on society and the environment, including some that were not anticipated. Some of these impacts could raise ethical issues for which science does not provide answers or solutions. In their evaluations, students should make sense of quantities and relationships associated with developing, managing, and utilizing energy and mineral resources. Mathematical models can be used to explain their evaluations. Students might represent their understanding by conducting a Socratic seminar as a way to present opposing views. Students should consider and discuss decisions about designs in scientific, social, and cultural contexts.

Connecting with English Language Arts Literacy and Mathematics

English Language Arts/Literacy

- Ask and refine questions to support uniform energy distribution among the components in a system when two components of different temperature are combined, using specific textual evidence.
- Conduct short as well as more sustained research projects to determine energy distribution in a system when two components of different temperature are combined.
- Collect relevant data across a broad spectrum of sources about the distribution of energy in a system and assess the strengths and limitations of each source.
- Synthesize findings from experimental data into a coherent understanding of energy distribution in a system.
- Conduct short as well as more sustained research projects to determine how the properties of water affect Earth materials and surface processes.
- Cite specific textual evidence to evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios.
- Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
- Integrate and evaluate multiple design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios in order to reveal meaningful patterns and trends.
- Evaluate the hypotheses, data, analysis, and conclusions of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios, verifying the data when possible and corroborating or challenging conclusions with other design solutions.
- Synthesize data from multiple sources of information in order to create data sets that inform design decisions and create a coherent understanding of developing, managing, and utilizing energy and mineral resources.

Mathematics

- Use symbols to represent energy distribution in a system when two components of different temperature are combined, and manipulate the representing symbols. Make sense of quantities and relationships in the energy distribution in a system when two components of different temperature are combined.
- Use a mathematical model to describe energy distribution in a system when two components of different temperature are combined. Identify important quantities in energy distribution in a system when two components of different temperature are combined and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and

improving the model if it has not served its purpose.

- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the properties of water and their effects on Earth materials and surface processes.
- Use symbols to represent an explanation of the best of multiple design solutions for developing, managing, and utilizing energy and mineral resources and manipulate the representing symbols. Make sense of quantities and relationships in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources symbolically and manipulate the representing symbols.
- Use a mathematical model to explain the evaluation of multiple design solutions for developing, managing, and utilizing energy and mineral resources. Identify important quantities in cost–benefit ratios for multiple design solutions for developing, managing, and utilizing energy and mineral resources and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit.

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning

Middle- and high-school student thinking about chemical change tends to be dominated by the obvious features of the change. For example, some students think that when something is burned in a closed container, it will weigh more because they see the smoke that was produced. Further, many students do not view chemical changes as interactions. They do not understand that substances can be formed by the recombination of atoms in the original substances. Rather, they see chemical change as the result of a separate change in the original substance, or changes, each one separate, in several original substances. For example, some students see the smoke formed when wood burns as having been driven out of the wood by the flame (NSDL, 2015).

Prior Learning

By the end of Grade 8, students know that:

Physical science

- Substances are made from different types of atoms, which combine with one another in various ways.
- Atoms form molecules that range in size from two atoms to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others.
- In a gas, they are widely spaced except when they happen to collide.
- In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Substances react chemically in characteristic ways.
- In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.
- These physical and chemical properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting point of rocks.

Connections to Other Courses

Physical science

- Each atom has a charged substructure consisting of a nucleus made of protons and neutrons and surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the nucleus of each element's atoms and places elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- A stable molecule has less energy than does the same set of atoms separated; at least this much energy is required in order to take the molecule apart.
- Chemical processes, their rates, and whether or not they store or release energy can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved in chemical reactions, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the energy stored in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

Life Science

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

Connections to NJSLS ELA & MATH

ELA/Literacy -

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

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3),(HS-PS1-5)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2),*(HS-PS1-5)*

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

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3),*(HS-PS1-6)*

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS1-3)*

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

Mathematics -

MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)

MP.4 Model with mathematics. *(HS-PS1-4),(HS-PS1-8)*

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),*(HS-PS1-3),(HS-PS1-4),(HS-PS1-5)*,(HS-PS1-7),(HS-PS1-8)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),*(HS-PS1-7)*,(HS-PS1-8)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)*