*Unit 1. Measurement & Modeling, Electrons and Periodic Table

Content Area: **Science**
Course(s):
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Unit Summary

The ancient Greeks tried to explain matter, but the scientific study of the atom began with John Dalton in the early 1800's. From there several atomic models were developed by Thomson, Rutherford, and Bohr. An atom is made of a nucleus containing protons and neutrons; electrons move around the nucleus. The number of protons and the mass number define the type of atom. Unstable atoms emit radiation to gain stability. Under certain conditions, some nuclei can emit alpha, beta, or gamma radiation. Unstable nuclei can break apart spontaneously, changing the identity of atoms. Fission, splitting of nuclei, and fusion, the combining of nuclei, release tremendous amounts of energy. Nuclear reactions have many useful applications, but they also have harmful biological effects.

Wavelike properties of electrons help relate atomic emission spectra, energy states of atoms, and atomic orbitals. Atomic emission spectrums were initially explained by the Bohr Theory, but atoms other than hydrogen required a further explanation covered in the quantum mechanical model. A set of three rules (Aufbau, Pauli Exclusion, and Hund) can be used to determine electron arrangement of an atom known as electron configuration. This will also include orbital diagrams, noble gas configurations, and electron dot diagrams. The periodic table evolved over time as scientists discovered more useful ways to compare and organize the elements (history of the periodic table up through Mosely). Elements are organized into different blocks (SPDF), in the periodic table, according to their electron configuration. Trends in the periodic table include metallic character (metals, metalloids, and nonmetals), atomic and ionic radius, electronegativity, ionization energy, and electron affinity

Enduring Understandings

1. The properties of elements determine how atoms and molecules interact.

2. Radioactivity and generation of nuclear energy involve the process of fission, fusion, and radioactive decay.

Essential Questions

1. What are the substructures of an atom and how do they influence the formation and abundance of the elements?

2. How can the substructure of an atom be used to explain the properties of substances?

3. How can the Periodic Table be used to explain and predict the properties of elements?

4. How is the nucleus changed (with respect to the number of neutrons and protons) during fission, fusion, and radioactive decay?

5. How is energy released during the process of fission, fusion, and radioactive decay?

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

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

HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

HS-PS4-3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.]

HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]

Science and Engineering Practices

Developing and Using Models

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

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8)
- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-1, HS-PS1-2, HS-PS1-8)

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)
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. (HS-PS1-1, HS-PS1-2, HS-PS1-8)

Using Mathematics and Computational Thinking

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

- Use mathematical representations of phenomena to support claims. (HS-PS4-1)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3)

Obtaining, Evaluating, and Communicating Information

- 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, HS-PS1-2)

The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1, HS-PS1-2)

PS1.C: Nuclear Processes

Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)

Spontaneous radioactive decay follows a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of materials. (HS-ESS1-5)

PS3.D: Energy in Chemical Processes and Everyday life

Nuclear fusion processes on the center of the sun releases the energy that ultimately reaches Earth as radiation.

(HS-ESS1-1)

PS4.A: Wave Properties

The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)

PS4.B: Electromagnetic Radiation

Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identifications of the presence for an element, even microscopic quantities (HS-ESS1-2)

Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)

When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)

Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

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-PS1-2)

Energy and Matter

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8, HS-ESS1-2, HS-ESS1-3)

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-PS1-2, HS-PS1-8, HS-PS4-3)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4)

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, HS-PS1-2, HS-PS1-8)

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-PS1-1, HS-PS1-2, HS-PS1-8)

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

Concepts & Skills

Concepts and Skills:

- compare the nucleus to the atom, and include size, mass and charge .
- describe the mass, charge, and location of the proton, neutron, and electron.
- understand the relationship and meaning of atomic number and mass number
- recognize isotopes of an element given number of subatomic particles, mass number, or shorthand notation
- identify an element when given the number of protons, neutrons, and electrons.
- calculate the atomic mass number given percent abundance of naturally occurring isotopes.
- explain the development of atomic theory and the quantum model of the atom, in terms of the relevance of the work of Dalton, Thomson, Bohr, and Rutherford.
- describe the radioactive decay process. Compare and contrast alpha, beta, and gamma radiation. Compare and contrast fission and fusion reactions.
- write balanced alpha, beta, positron, and electron capture decay reactions.
- understand the band of stability.
- calculate half-life problems using an equation and logical thinking.
- explain radioactive chemical dating.

- describe the general structure of the atom, and explain how the properties are related to their structure.
- distinguish among principal energy levels, energy sublevels, and atomic orbital.
- explain how an atomic emission spectrum is used to identify a specific element.
- compare and contrast ground and excited states for the electron.
- use the Aufbau Principal, the Pauli Exclusion Principal, and Hund's Rule to write the electron configuration of the elements.
- determine the number of valence electrons for a given element from its electron configuration and/or position on the periodic table and use that information to help explain the chemical properties of the element.
- express the arrangement of electrons in atoms through electron configurations, noble gas configurations, orbital diagrams, and Lewis valence electron dot structures.
- identify the electron configuration of any element based on its position on the periodic table Periodic Table:
- explain the contributions of Lavoisier, Newlands, Meyer, Mendeleev, and Mosely to the development of the periodic table. And state the Periodic Law
- identify trends in ionization energy, electronegativity, and the relative sizes of atom and ions.
- identify the different parts of the Periodic Table: metals, nonmetals, metalloids, representative elements, alkali metals, alkaline earth metals, halogens, noble gases, transition metals, and the lanthanide and actinide series.
- predict the relative sizes of neutral atoms in comparison to their positive or negative ions.
- identify the number of valence electrons for a particular group of elements
- identify the probable charge on the ion of a main group elements based upon its position on the periodic table.
- understand that the drive for atoms to form bonds is based on the stability of the noble gases and the octet rule.

Vocabulary:

Atom, atomic number, mass number, ion, isotope, neutrons, protons, electrons, nucleus, atomic mass unit, atomic mass, cathode ray, alpha particle/radiation, beta particle/radiation, gamma ray, nuclear equation, nuclear reaction, radioactivity, radiation, radioactive decay, fission, fusion, band of stability, radioisotope, electron capture, positron, radioactive decay series, radiochemical dating, strong nuclear force, transmutation, Electron configuration, valence electron, atomic emission spectrum, Aufbau Principle, Pauli Exclusion Principle, Hund's Rule, electromagnetic spectrum (to explain atomic emission spectrum), photons, excited state, ground state, atomic orbital, principal quantum number, quantum mechanical model, electron dot structure, alkali metal, alkaline earth metals, transition metals, inner transition metals, halogens, noble gases, group, metal, period, metalloids, nonmetals, periodic law, representative elements, electronegativity, ionization energy, ions, octet rule

Resources

Build an Atom: This simulation allows students to create different illustrations of atoms and provides evidence that protons determine the identity of the element.

Periodic Table Trends: This is a virtual investigation of the periodic trends.

Path to Periodic Table: This investigation provides students with the opportunity to make sense of how and why the periodic table is organized the way that it is. Students will re-create the thought process that Dmitri Mendeleev and Julius Lothar Meyer went through to devise their early periodic tables.

Castle of Mendeleev: Students engage in a fantasy world that requires them to make claims, based on evidence, regarding the identity of unknown materials.

Shall We Dance? – Classifying Types of Chemical Reactions: Students identify and differentiate between four types of chemical reactions: synthesis, decomposition, single replacement and double replacement. Students also develop models for chemical reactions and identify the limitations of the models using evidence.

Assessments

Possible Assessment Tasks:

- Practice Worksheets for each section
- Build an atom (phet simulation- online- HTML5) https://phet.colorado.edu/en/simulation/build-an-atom (HS-PS1-1, HS-PS1-2)
- Calculating Average Atomic Mass Candium Lab
- Isotopes and atomic mass (phet simulation- online- HTML5) https://phet.colorado.edu/en/simulation/isotopes-and-atomic-mass (HS-PS1-1, HS-PS1-2)
- Atoms and theor Isotopes POGIL (HS-PS1-1, HS-PS1-2)
- Alpha Decay(phet simultions- on-line Java) https://phet.colorado.edu/en/simulation/legacy/alpha-decay , Beta Decay (phet simulations on-line Java) , Nuclear Fission(phet simulations on-line Java)

https://phet.colorado.edu/en/simulation/legacy/nuclear-fission (HS-PS1-8)

- Half Life Candium Lab (HS-PS1-8)
- Half life simulation lab. http://www.glencoe.com/sites/common_assets/science/virtual_labs/E18/E18.html (HS-PS1-8)
- Radioactive Dating Game (phet simulations on-line Java) https://phet.colorado.edu/en/simulation/legacy/radioactive-dating-game (HS-PS1-8)
- Microwaves (phet simulation online-Java) https://phet.colorado.edu/en/simulation/legacy/microwaves (HS-PS1-8)
- Spectroscopy and Flame Test Lab (HS-PS1-1)
- Periodic Table Puzzle Lab -Can you find the pattern?(HS-PS1-2)

The Science Classroom

In order to understand how the periodic table can be used as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms, students must first understand the idea that atoms have a charged substructure consisting of a nucleus that is composed of protons and neutrons surrounded by electrons. Students should use a variety of models to understand the structure of an atom. Examples may include computer simulations, drawings, and kits. Students can create models of atoms by calculating protons, neutrons, and electrons in any given atom, isotope, or ion.

In order to understand the predictive power of the periodic table, students should write electron configurations for main group elements, paying attention to patterns of electrons in the outermost energy level. Students should annotate the periodic table to determine its arrangement horizontally by number of protons in the atom's nucleus and its vertical arrangement by the placement of elements with similar chemical properties in columns. Students should also be able to translate information about patterns in the periodic table into words that describe the importance of the outermost electrons in atoms.

- Students will use the ideas of attraction and repulsion (i.e., charges—cations/anions) at the atomic scale to explain the structure of matter, such as in ion formation, and to explain the properties of matter such as density, luster, melting point, boiling point, etc.

- Students will also use the ideas of attraction and repulsion (charges—cations/anions) at the atomic scale to explain transformations of matter—for example, reaction with oxygen, reactivity of metals, types of bonds formed, and number of bonds formed. Students will explain bonding through the patterns in outermost electrons, periodic trends, and chemical properties.

To explain the outcomes of chemical reactions using the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties, students should use investigations, simulations, and models of chemical reactions to prove that atoms are conserved. For example, students might observe simple reactions in a closed system and measure the mass before and after the reaction as well as count atoms in reactants and products in chemical formulas. Students should also construct chemical formulas involving main group elements in order to model that atoms are conserved in chemical reactions (the Law of Conservation of Mass). Students will need to describe and predict simple chemical reactions, including combustion, involving main group elements. Students should use units when modeling the outcome of chemical reactions. When reporting quantities, students should choose a level of accuracy appropriate to limitations on measurement.

Students should also be able to write a rigorous explanation of the outcome of simple chemical reactions, using data from their own investigations, models, theories, and simulations. They should strengthen their explanations by drawing and citing evidence from informational text.

In order to address how the substructure of substances at the bulk scale infers the strength of electrical forces between particles, emphasis should be on the importance of outermost electrons in bulk physical properties, bonding, and stability. *Students need to realize that valence electrons are important.*

Students should plan and conduct investigations to show that structure and interactions of matter at the bulk amount, and accuracy of data required producing reliable information and considering limitations on the precision of the data.

Students should also plan and conduct investigations using attraction and repulsion (charges—cations/anions) at the atomic scale to explain the structure of matter at the bulk scale. For example, students could investigate how the strength of forces between particles is dependent on particle type (ions, atoms, molecules, networked materials [allotropes]). Students should examine crystal structures and amorphous structures.

Students should also plan and conduct investigations using attraction and repulsion (charges—cations/anions) at the atomic scale to explain the properties of matter at the bulk scale—for example, investigating melting point, boiling point, vapor pressure, and surface tension. Students might also plan and conduct an investigation using attraction and repulsion (charges—cations/anions) at the atomic scale to explain transformations of matter at the bulk scale—for example, collecting data to create cooling and heating curves.

Students might also conduct short or more sustained research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles. Information should be gathered from multiple reliable sources and used to support claims. Any data reported should include appropriate units and limitations on measurements should be considered.

As students consider communicating scientific and technical information about why the molecular-level structure is important in the functioning of designed materials, focus should be on attractive and repulsive forces. Students might research information about Life Cycle Analysis (LCA), which examines every part of the production, use, and final disposal of a product. LCA requires that students examine the inputs (raw materials and energy) required to manufacture products, as well as the outputs (atmospheric emissions, waterborne wastes, solid wastes, coproducts, and other resources). This will allow them to make connections between molecular-level structure and product functionality. Students should evaluate the LCA process and communicate a solution to a real-world problem, such as the environmental impact of different types of grocery bags (paper or plastic/reusable vs. disposable), cold drink containers (plastic, glass, or aluminum), or hot drink containers (paper, Styrofoam, or ceramic). They will base their solution to their chosen real-world problem on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Students should then use technology to present a life-cycle-stage model that considers the LCA and typical inputs and outputs measured for their real-world problem. Students will need to consider the properties of various materials (e.g. Molar mass, solubility, bonding) to decide what materials to use for what purposes, inputs and outputs measured for their real-world problem. Students will need to consider the properties of various materials (e.g. Molar mass, solubility, bonding) to decide what materials to use for what purposes. When students have properties appropriate for the final use, they will be able to consider material uses in LCAs to determine if they are environmentally appropriate. For further reference see ChemMatters, February 2014, “It’s Not Easy Being Green, Or Is It?” at www.acs.org/content/acs/en/education/resources/highschool/chemmatters.html.

Integration of Engineering-

In this unit, students consider communicating scientific and technical information about why the molecular level structure is important in the functioning of designed materials. Students evaluate a solution to a complex real-world problem, such as electrically conductive materials made of metal, plastics made of organic polymers, or pharmaceuticals designed for specific biological targets, and then use a computer simulation to model the impact of that solution.

Connecting with English Language Arts Literacy and Mathematics

Connections to English Language Arts/Literacy-

- Translate information from the periodic table about the patterns of electrons in the outermost energy level of atoms into words that describe the relative properties of elements.
- Write an explanation for the outcome of a simple chemical reaction based on the outermost electron

states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties of elements using well-chosen, relevant, and sufficient facts; extended definitions; and concrete details from students' own investigations, models, theories, simulations, and peer review.

- Develop and strengthen explanations for the outcome of a simple chemical reaction by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties of elements.
- Draw evidence from informational texts about the outermost electron states of atoms, trends in the periodic table, and patterns of chemical properties of elements to construct a rigorous explanation of the outcome of a simple chemical reaction.
- Cite specific textual evidence comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
    - Conduct short as well as more sustained research projects to compare the structure of substances at the bulk scale and use this research to infer the strength of electrical forces between particles.
    - Gather applicable information from multiple reliable sources to support the claim that electrical forces between particles can be used to explain the structure of substances at the bulk scale.
    - Develop evidence comparing the structure of substances at the bulk scale and the strength of electrical forces between particles.

Connections to Mathematics-

- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities representing periodic trends for main group elements based on patterns of electrons in the outermost energy level of atoms.
- Considering the outermost energy level of atoms, define appropriate quantities for descriptive modeling of periodic trends for main group elements based on patterns of electrons in outermost energy levels.
- Use units as a way to understand the outcome of a simple chemical reaction involving main group elements based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Choose and interpret units consistently in chemical reactions.
- Determine and interpret the scale and origin in graphs and data displays representing patterns of chemical properties, outer electron states of atoms, trends in the periodic table, and patterns of chemical properties.
- Determine a level of accuracy appropriate to limitations on measurement when reporting quantities of simple chemical reactions.
- Use units as a simple way to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret units comparing the structure of substances at the bulk scale to infer the strength of electrical forces between particles. Choose and interpret the scale and origin in graphs and data displays comparing the structure of substances and the bulk scale and electrical forces between particles.
- Determine a level of accuracy appropriate to limitations on measurements of the strength of electrical forces between particles.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

- 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

Students of all ages show a wide range of beliefs about the nature and behavior or particles. They lack an appreciation of the very small size of particles; believe there must be something in the space between particles; have difficulty in appreciating the intrinsic motion of particles in solids, liquids and gases; and have problems in conceptualizing forces between particles (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.

Biology-

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used, for example, to form new cells.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another.
- Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.
- Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

Earth and space sciences-

- 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 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 points of rocks.

Connections to Other Courses

Biology-

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
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