AFK12SE/NGSS Strand Disciplinary Core Idea	Conceptual Understanding for Teachers at 9-12
Matter and Its Interactions ***How can one explain the structure, properties, and interactions of matter?***	***How can one explain the structure, properties, and interactions of matter?***
PS1.A: STRUCTURE AND PROPERTIES OF MATTER *How do particles combine to form the variety of matter one observes?* ● Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. ● The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. ● The repeating patterns of this table reflect patterns of outer electron states. ● The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. ● Stable forms of matter are those in which the electric and magnetic field energy is minimized. ● A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.	● What is matter? ● What are the properties of the various states of matter? ● What are chemical and physical properties and how are they used to identify substances? ● What are the relationships among number of moles, volume, temperature, and pressure of gases? ● What is the structure of an atom? ● What models are commonly used and how were they developed over time? ● What are the limitations of the Bohr model of the atom? ● How are atomic spectra related to our understanding of atomic structure? ● How was the Periodic Table developed? ● What trends exist in the Periodic Table and how do those trends reflect atomic structure? ● In what ways do atoms combine to form novel substances? ● How is the stability of a molecule related to its energy? ● What are the characteristics of different types of bonding and how can these be predicted using the Periodic Table? ● How can bonding characteristics be used to determine the shape of a molecule? ● How can bonding characteristics and molecular shape be used to determine the polarity of a molecule? ● What conventions do chemists use for naming chemical compounds and writing chemical formulas?
PS1.B: CHEMICAL REACTIONS *How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?* ● Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy.	● How does kinetic molecular theory explain chemical processes? ● How is energy involved a chemical reaction? ● How does a balanced chemical reaction represent conservation of mass in a given chemical reaction? ● How can the products and amount of a chemical reaction be predicted given the reactants? ● How does an activity series help to predict the nature of a chemical reaction? ● How can chemical half reactions be combined to create electrochemical cells?

● 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, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. ● Chemical processes and properties of materials underlie many important biological and geophysical phenomena.	● How does the strength of an acid and base impact the resulting reaction? ● How does pH change over the course of a titration? ● In what ways can the rate of a chemical reaction be changed? ● In what ways can the chemical equilibrium shift in a reaction? ● In what ways are chemical processes used in the mining of metals, minerals, ores, and elements? ● In what ways are chemical processes used in biological phenomena?
	● In what ways can the concentration of solutions be expressed? ● How do polar and non-polar materials behave differently in water and non-polar solvents? ● What is the relationships between the concentration and strength of an acid or base? ● How do different types if intermolecular forces explain the properties of liquids, gases and solids?
PS1.C: NUCLEAR PROCESSES *What forces hold nuclei together and mediate nuclear processes?* ● The total number of neutrons plus protons does not change in any nuclear process. ● Spontaneous radioactive decays follow a characteristic exponential decay law. ● Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present.	● How do the number of protons, electrons, and neutrons change during nuclear decay? ● How does the amount of radioactive materials change over the course of a nuclear decay reaction? ● How is half-life used to determine the age of rocks and other natural materials?
PS3: Energy	***How is energy transferred and conserved?***
PS3.A: DEFINITIONS OF ENERGY *What is energy?* ● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. ● "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine. ● "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. ● These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as	● How does energy change during phase changes for a material? ● How does enthalpy change during chemical reactions? ● What are the relationships among enthalpy, entropy, and free energy, and how do they predict the spontaneity of a reaction? ● How is electrical energy produced in a voltaic cell? ● How are cell reactions and standard cell potential calculated for a voltaic cell? ● How does electrolysis occur? ● What evidence is there for the wave particle duality of electrons?

either motions of particles or energy stored in fields (which mediate interactions between particles). ● This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	
PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER *What is meant by conservation of energy?* *How is energy transferred between objects or systems?* ● 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.	● What is the relationship between energy of a system and its surroundings? ● How can the relationship between the energy of a system and its surroundings be used to determine the heat of a reaction?
PS4.B: ELECTROMAGNETIC RADIATION *What is light?* *How can one explain the varied effects that involve light?* *What other forms of electromagnetic radiation are there?* ● 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. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) ● Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities.	● How do quantum mechanical models and molecular orbital theory improve our ability to explain chemical behavior?
	● How do organisms use simple elements to form complex organic molecules? ● How does cellular respiration result in a net transfer of energy? ● How do carbon, hydrogen, and oxygen from glucose molecules combine with other elements to form more complex carbon based molecules? ● What is the role of enzymes in the breaking down and synthesis of molecules? ● What is the structure of DNA? ● What is the relationship among DNA, genes, and protein synthesis?
	● What are the different ways in which carbon atoms combine to make different classes of organic compounds? ● How do different functional groups predict the properties and reactivity of organic compounds?

	● How does the structure of reactants in an organic reaction predict the products?
	● What is the greenhouse effect? ● What are common greenhouse gases and how do they contribute to climate change? ● How can chemistry help to mitigate global climate change? ● How can chemistry help to mitigate other air quality concerns?
Supporting Competencies	
Math	● How can mathematical and statistical models evaluate the strength of a conclusion? ● How are mathematical models used in chemistry? ● What are the applications of calculus in chemistry?
Earth Science	● How do Earth's major systems interact to impact Earth processes? ● How do humans depend on Earth's resources? ● What human activities have positively and negatively impacted Earth's climate? ● How do the chemical and physical properties of water and its movement create changes in the surface and subsurface of the Earth?
Biology	● What are major organelles, and how do these impact cell function? ● How do organisms obtain and use the matter and energy they need to live and grow? ● What are the structural relationships among DNA, proteins, and genes? ● How do matter and energy move through an ecosystem? ● How does the environment influence populations of organisms over multiple generations? ● How do organisms grow and develop?
Physics	● What is energy and how is it measured? ● How is energy transferred between objects? ● How do we model energy and energy changes at the particulate level? ● What is the relationship between thermal energy and temperature?