UTAH 9–12 SCIENCE WITH ENGINEERING EDUCATION (SEEd) STANDARDS

(BIOLOGY, CHEMISTRY, EARTH AND SPACE SCIENCE, AND PHYSICS)

Adopted June 2019
by the
Utah State Board of Education
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

Sydnee Dickson, Ed.D.
State Superintendent of Public Instruction

https://www.schools.utah.gov

Articulation of SEPs, CCCs, and DCIs

Science and Engineering Practices	Crosscutting Concepts	Disciplinary Core Ideas
Asking questions or defining problems: Students engage in asking testable questions and defining problems to pursue understandings of phenomena. **Developing and using models:** Students develop physical, conceptual, and other models to represent relationships, explain mechanisms, and predict outcomes. **Planning and carrying out investigations:** Students plan and conduct scientific investigations in order to test, revise, or develop explanations. **Analyzing and interpreting data:** Students analyze various types of data in order to create valid interpretations or to assess claims/conclusions. **Using mathematics and computational thinking:** Students use fundamental tools in science to compute relationships and interpret results. **Constructing explanations and designing solutions:** Students construct explanations about the world and design solutions to problems using observations that are consistent with current evidence and scientific principles. **Engaging in argument from evidence:** Students support their best explanations with lines of reasoning using evidence to defend their claims. **Obtaining, evaluating, and communicating information:** Students obtain, evaluate, and derive meaning from scientific information or presented evidence using appropriate scientific language. They communicate their findings clearly and persuasively in a variety of ways including written text, graphs, diagrams, charts, tables, or orally.	Patterns: Students observe patterns to organize and classify factors that influence relationships Cause and effect: Students investigate and explain causal relationships in order to make tests and predictions. Scale, proportion, and quantity: Students compare the scale, proportions, and quantities of measurements within and between various systems. Systems and system models: Students use models to explain the parameters and relationships that describe complex systems. Energy and matter: Students describe cycling of matter and flow of energy through systems, including transfer, transformation, and conservation of energy and matter. Structure and function: Students relate the shape and structure of an object or living thing to its properties and functions. Stability and change: Students evaluate how and why a natural or constructed system can change or remain stable over time.	Physical Sciences: (PS1) Matter and Its Interactions (PS2) Motion and Stability: Forces and Interactions (PS3) Energy (PS4) Waves Life Sciences: (LS1) Molecules to Organisms (LS2) Ecosystems (LS3) Heredity (LS4) Biological Evolution Earth and Space Sciences: (ESS1) Earth's Place in the Universe (ESS2) Earth's Systems (ESS3) Earth and Human Activity Engineering Design: (ETS1.A) Defining and Delimiting an Engineering Problem (ETS1.B) Developing Possible Solutions (ETS1.C) Optimizing the Design Solution

CHEMISTRY

INTRODUCTION

The chemistry SEEd standards explore the foundational principles of chemistry that allow students to investigate the ways in which chemistry impacts everyday life. Students investigate the properties and structure of matter at atomic and subatomic scales to explain how they influence a system's larger scale, structures, properties, and functions. Students explain how macroscopic observations are translated into molecular-level representations and then develop and use these models to describe molecules with chemical equations or mathematical expressions. Students analyze data on the relationships between atomic and molecular structures and the properties of materials that are observed macroscopically using the human senses and scientific instruments. Students explain that matter is conserved in chemical reactions and nutrient cycles, the ability of humans to design and control chemical systems for the benefit of society, and the ways that energy interacts with matter. Additionally, students design and evaluate solutions to problems that exist in these areas.

Strand CHEM.1: THE STRUCTURE AND PROPERTIES OF ATOMS

Atoms have substructures of their own including a small central nucleus containing protons and neutrons surrounded by a larger region containing electrons. The strong nuclear interaction provides the primary force that holds nuclei together. Without it, the electromagnetic forces between protons would make all nuclei other than hydrogen unstable. Processes of fusion, fission, and radioactive decay of unstable nuclei involve changes in nuclear binding energies. Elements are placed in columns and rows on the periodic table to reflect their common and repeating properties.

- **Standard CHEM.1.1** **Obtain, evaluate, and communicate information** regarding the structure of the atom on the basis of experimental evidence. Emphasize the relationship between proton number and element identity, isotopes, and electrons in atoms. Examples of experimental evidence could include the gold foil experiment, cathode ray tube, or atomic spectrum data. (PS1.A)

- **Standard CHEM.1.2** **Analyze and interpret data** to identify patterns in the stability of isotopes and predict likely modes of radioactive decay. Emphasize that different isotopes of the same element decay by different modes and at different rates depending on their nuclear stability. Examples of data could include band of stability charts, mass or nuclear binding energy per nucleon, or the inverse relationship between half-life and nuclear stability. (PS1.C)

- **Standard CHEM.1.3** **Use mathematics and computational thinking** to relate the rates of change in quantities of radioactive isotopes through radioactive decay (alpha, beta, and positron) to ages of materials or persistence in the environment. Emphasize a conceptual understanding of half-life. Examples could include radiocarbon dating, nuclear waste management, or nuclear medicine. (PS1.C)

- **Standard CHEM.1.4** **Construct an explanation** about how fusion can form new elements with greater or lesser nuclear stability. Emphasize the nuclear binding energy, with the conceptual understanding that when fusion of elements results in a more stable nucleus, large quantities of energy are released, and when fusion results in a less stable nucleus, large quantities of energy are required. Examples could include the building up of elements in the universe starting with hydrogen to form heavier elements, the composition of stars, or supernovae producing heavy elements. (PS1.C, ESS1.A)

- **Standard CHEM.1.5** **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. Emphasize conceptual understanding of trends and patterns. Examples could include trends in ionization energy, atomic radius, or electronegativity. Examples of properties for main group elements could include general reactivity, bonding type, or ion formation. (PS1.A)

Strand CHEM.2: THE STRUCTURE AND PROPERTIES OF MOLECULES

Electrical attractions and repulsions between charged particles (atomic nuclei and electrons) in matter explain the structure of atoms and the forces between atoms that cause them to form molecules via chemical bonds. Molecules can range in size from two atoms to thousands of atoms. The same forces cause atoms to combine to form extended structures, such as crystals or metals. The varied properties of the materials, both natural and manufactured, can be understood in terms of the atomic and molecular particles present and the forces within and between them. Materials are engineered to fulfill a desired function or role with desired properties.

- **Standard CHEM.2.1** **Analyze data** to predict the type of bonding most likely to occur between two elements using the patterns of reactivity on the periodic table. Emphasize the types and strengths of attractions between charged particles in ionic, covalent, and metallic bonds. Examples could include the attraction between electrons on one atom and the nucleus of another atom in a covalent bond or between ions in an ionic compound. (PS1.A, PS2.B)

- **Standard CHEM.2.2** **Plan and carry out an investigation** to compare the properties of substances at the bulk scale and relate them to molecular structures. Emphasize using models to explain or describe the strength of electrical forces between particles. Examples of models could include Lewis dot structures or ball and stick models. Examples of particles could include ions, atoms, molecules, or networked materials (such as graphite). Examples of properties could include melting point and boiling point, vapor pressure, solubility, or surface tension. (PS1.A)

- **Standard CHEM.2.3** **Engage in argument supported by evidence** that the functions of natural and designed macromolecules are related to their chemical structures. Emphasize the roles of attractive forces between and within molecules. Examples could include non-covalent interactions between base pairs in DNA allowing it to be unzipped for replication, the network of atoms in a diamond conferring hardness, or the nonpolar nature of polyester (PET) making it quick-drying. (PS1.A)

- **Standard CHEM.2.4** Evaluate **design solutions** where synthetic chemistry was used to solve a problem (cause and effect). *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution*. Emphasize the design of materials to control their properties through chemistry. Examples could include pharmaceuticals that target active sites, teflon to reduce friction on surfaces, or nanoparticles of zinc oxide to create transparent sunscreen. (PS1.A, ETS1.A, ETS1.B, ETS1.C)

Strand CHEM.3: STABILITY AND CHANGE IN CHEMICAL SYSTEMS

Conservation of matter describes the cycling of matter and the use of resources. In both chemical and physical changes, the total number of each type of atom is conserved. When substances are combined, they may interact with each other to form a solution. The proportion of substances in a solution can be represented with concentration. In a chemical change, the atoms are rearranged by breaking and forming bonds to create different molecules, which may have different properties. Chemical processes can be understood in terms of the collisions of molecules and the rearrangements of atoms. The rate at which chemical processes occur can be modified. 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. Chemists can control and design chemical systems to create desirable results, although sometimes there are also unintended consequences.

- **Standard CHEM.3.1** **Use mathematics and computational thinking** to analyze the distribution and proportion of particles in solution. Emphasize proportional reasoning and the impact of concentration on solution properties, rather than algorithmic calculations. Examples of concentrations affecting solutions could include the Beer-Lambert Law, colligative properties, or pH. (PS1.A)

- **Standard CHEM.3.2** **Analyze data** to identify patterns that assist in making predictions of the outcomes of simple chemical reactions. Emphasize patterns based on the outermost electrons of atoms, trends in the periodic table, and knowledge of chemical properties. Examples could include reactions between main group elements, combustion reactions, or reactions between Arrhenius acids and bases. (PS1.B)

- **Standard CHEM.3.3** **Plan and carry out an investigation** to observe the change in properties of substances in a chemical reaction to relate the macroscopically observed properties to the molecular level changes in bonds and the symbolic notation used in chemistry. Emphasize that the visible macroscopic changes in chemical reactions are a result of changes on the molecular level. Examples of observable properties could include changes in color or the production of a solid or gaseous product. (PS1.B)

- **Standard CHEM.3.4** **Use mathematics and computational thinking** to support the observation that matter is conserved during chemical reactions and matter cycles. Emphasize that chemical reactions occur on both small and global scales, and that matter is always conserved. Examples of small scale reactions could include ratios of reactants and products in a single chemical reaction or simple stoichiometric calculation. Examples of global scale matter cycles could include tracing carbon through the chemical reactions of photosynthesis, combustion, or respiration. (PS1.B)

■ **Standard CHEM.3.5** **Develop solutions** related to the management, conservation, and utilization of mineral resources (matter). *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize the conservation of matter and minerals as a limited resource. Examples of Utah mineral resources could include copper, uranium, potash, coal, oil, or natural gas. Examples of constraints could include cost, safety, reliability, or possible social, cultural, and environmental impacts. (PS1.B, ESS3.A, ETS1.A, ETS1.B, ETS1.C)

■ **Standard CHEM.3.6** **Construct an explanation** using experimental evidence for how reaction conditions affect the rate of change of a reaction. Emphasize collision theory as an explanatory principle. Examples of reaction conditions could include temperature, concentration, particle size, or presence of a catalyst. (PS1.B)

■ **Standard CHEM.3.7** **Design a solution** that would refine a chemical system by specifying a change in conditions that would produce increased or decreased amounts of a product at equilibrium. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize a qualitative understanding of Le Châtelier's Principle and connections between macroscopic and molecular level changes. (PS1.B, ETS1.A, ETS1.B, ETS1.C)

■ **Standard CHEM.3.8** **Obtain, evaluate, and communicate information** regarding the effects of designed chemicals in a complex real-world system. Emphasize the role of chemistry in solving problems, while acknowledging unintended consequences. Examples could include ozone depletion and restoration, DDT, development of medicines, the preservation of historical artifacts, or use of bisphenol-A in plastic manufacturing. (PS1.A)

Strand CHEM.4: ENERGY IN CHEMICAL SYSTEMS

A system's total energy is conserved as energy is continually transferred from one particle to another and between its various possible forms. The energy of a system depends on the motion and interactions of matter and radiation within that system. When bonds are formed between atoms, energy is released. Energy must be provided when bonds are broken. When electromagnetic radiation with longer wavelengths is absorbed by matter, it is generally converted into thermal energy or heat. When visible light is absorbed by matter, it results in phenomena related to color. When shorter wavelength electromagnetic radiation is absorbed by matter, it can ionize atoms and cause damage to living cells. Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve the release or absorption of large amounts of energy. Society's demand for energy requires thinking creatively about ways to provide energy that don't deplete limited resources or produce harmful emissions.

- **Standard CHEM.4.1** **Construct an argument from evidence** about whether a simple chemical reaction absorbs or releases energy. Emphasize that the overall change in energy is related to the energy absorbed when bonds are broken and the energy released when bonds are formed. Examples could include chemical reactions releasing or absorbing energy to or from the surrounding solution or the metabolism of glucose. (PS1.B, PS3.B)

- **Standard CHEM.4.2** **Construct an explanation** of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. Emphasize a qualitative understanding. Examples could include that low energy electromagnetic radiation can increase molecular rotation and bond vibration, visible light can cause electronic transitions, and high energy electromagnetic radiation can result in ionization and bond breaking. (PS4.B)

- **Standard CHEM.4.3** **Design** a device that converts energy from one form into another to solve a problem. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize chemical potential energy as a type of stored energy. Examples of sources of chemical potential energy could include oxidation-reduction or combustion reactions. (PS3.B, ETS1.A, ETS1.B, ETS1.C)

- **Standard CHEM.4.4** **Use models** to describe the changes in the composition of the nucleus of the atom during nuclear processes, and compare the energy released during nuclear processes to the energy released during chemical processes. Emphasize a qualitative understanding of nuclear changes. Examples of nuclear processes could include the formation of elements through fusion in stars, generation of electricity in a nuclear power plant, radioactive decay, or the use of radioisotopes in nuclear medicine. (PS1.C, PS3.D)

■ **Standard CHEM.4.5** **Develop an argument from evidence** *to evaluate a proposed solution* to societal energy demands *based on prioritized criteria and trade-offs that account for a range of constraints that could include cost, safety, reliability, as well as possible social, cultural, and environmental impacts*. (PS3.D, ETS1.A, ETS1.B, ETS1.C)