

Chemistry

State Standard Number	State Standard Area/Description	Unit Name	Course Topic Description
C	Chemistry		
C1	<p>Students will understand the nature of science and demonstrate an ability to practice scientific reasoning by applying it to the design, execution, and evaluation of scientific investigations. Students will demonstrate their understanding that scientific knowledge is gathered through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. They will be able to distinguish between types of scientific knowledge (e.g., hypotheses, laws, theories) and become aware of areas of active research in contrast to conclusions that are part of established scientific consensus. They will use their scientific knowledge to assess the costs, risks, and benefits of technological systems as they make personal choices and participate in public policy decisions. These insights will help them analyze the role science plays in society, technology, and potential career opportunities.</p>		
C1.1	<p>Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct</p>		

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	observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.		
C1.1A	Generate new questions that can be investigated in the laboratory or field.	Unit 1 Introduction to Chemistry and Matter	The Science of Chemistry
C1.1B	Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.	Unit 1 Introduction to Chemistry and Matter	Measurements on Chemistry
C1.1C	Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity-length, volume, weight, time interval, temperature-with the appropriate level of precision).		
C1.1D	Identify patterns in data and relate them to theoretical models.	Unit 1 Introduction to Chemistry and Matter	Measurements on Chemistry
C1.1E	Describe a reason for a given conclusion using evidence from an investigation.	Unit 1 Introduction to Chemistry and Matter	The Science of Chemistry
C1.1f	Predict what would happen if the variables, methods, or timing of an investigation were changed.	Unit 1 Introduction to Chemistry and Matter	The Science of Chemistry
C1.1g	Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation	Unit 1 Introduction to Chemistry and Matter	The Science of Chemistry

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C1.1h	Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.		
C1.1i	Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.		
C1.2	The integrity of the scientific process depends on scientists and citizens understanding and respecting the "Nature of Science." Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.		
C1.2A	Critique whether or not specific questions can be answered through scientific investigations.		

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C1.2B	Identify and critique arguments about personal or societal issues based on scientific evidence.		
C1.2C	Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.	Unit 1 Introduction to Chemistry and Matter	Heat, Energy and Understanding Numbers
C1.2D	Evaluate scientific explanations in a peer review process or discussion format.		
C1.2E	Evaluate the future career and occupational prospects of science fields.		
C1.2f	Critique solutions to problems, given criteria and scientific constraints.		
C1.2g	Identify scientific tradeoffs in design decisions and choose among alternative solutions.		
C1.2h	Describe the distinctions between scientific theories, laws, hypotheses, and observations.	Unit 1 Introduction to Chemistry and Matter	The Science of Chemistry
C1.2i	Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core	Unit 2 Atoms and Atomic Electrons	The Atomic Theory

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	knowledge.		
C1.2j	Apply science principles or scientific data to anticipate effects of technological design decisions.		
C1.2k	Analyze how science and society interact from a historical, political, economic, or social perspective.		
C2	Students recognize the many forms of energy and understand that energy is central to predicting and explaining how and why chemical reactions occur. The chemical topics of bonding, gas behavior, kinetics, enthalpy, entropy, free energy, and nuclear stability are addressed in this standard. Chemistry students relate temperature to the average kinetic energy of the molecules and use the kinetic molecular theory to describe and explain the behavior of gases and the rates of chemical reactions. They understand nuclear stability in terms of reaching a state of minimum potential energy.		
P2.p1	Three forms of potential energy are gravitational, elastic, and chemical. Objects can have elastic potential energy due to their compression or chemical potential energy due to the arrangement of the atoms. (prerequisite)		
P2.p1A	Describe energy changes associated with changes of state in terms of the arrangement and order of the atoms (molecules) in each state. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Properties of Matter

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P2.p1B	Use the positions and arrangements of atoms and molecules in solid, liquid, and gas state to explain the need for an input of energy for melting and boiling and a release of energy in condensation and freezing. (prerequisite)	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Change of State
C2.1x	Potential energy is stored whenever work must be done to change the distance between two objects. The attraction between the two objects may be gravitational, electrostatic, magnetic, or strong force. Chemical potential energy is the result of electrostatic attractions between atoms.		
C2.1a	Explain the changes in potential energy (due to electrostatic interactions) as a chemical bond forms and use this to explain why bond breaking always requires energy.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent
C2.1b	Describe energy changes associated with chemical reactions in terms of bonds broken and formed (including intermolecular forces).	Unit 6 Chemical Reactions and Nuclear Chemistry	Energy in Reactions
C2.1c	Compare qualitatively the energy changes associated with melting various types of solids in terms of the types of forces between the particles in the solid.		
C2.2	Molecules that compose matter are in constant motion (translational, rotational, vibrational). Energy may be transferred from one object to another during collisions between molecules.		
C2.2A	Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.	Unit 6 Chemical Reactions and Nuclear Chemistry	Order in the Universe

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C2.2B	Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
C2.2x	As temperature increases, the average kinetic energy and the entropy of the molecules in a sample increases.	Unit 6 Chemical Reactions and Nuclear Chemistry	Energy in Reactions
C2.2c	Explain changes in pressure, volume, and temperature for gases using the kinetic molecular model.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Properties of Gases
C2.2d	Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Change of State
C2.2e	Compare the entropy of solids, liquids, and gases.	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
C2.2f	Compare the average kinetic energy of the molecules in a metal object and a wood object at room temperature.		
C2.3x	For molecules to react, they must collide with enough energy (activation energy) to break old chemical bonds before their atoms can be rearranged to form new substances.	Unit 6 Chemical Reactions and Nuclear Chemistry	Reaction Energy and Reaction Kinetics
C2.3a	Explain how the rate of a given chemical reaction is dependent on the temperature and the activation energy.	Unit 6 Chemical Reactions and Nuclear Chemistry	Reaction Energy and Reaction Kinetics

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C2.3b	Draw and analyze a diagram to show the activation energy for an exothermic reaction that is very slow at room temperature.	Unit 6 Chemical Reactions and Nuclear Chemistry	Reaction Energy and Reaction Kinetics
C2.4x	For each element, the arrangement of electrons surrounding the nucleus is unique. These electrons are found in different energy levels and can only move from a lower energy level (closer to nucleus) to a higher energy level (farther from nucleus) by absorbing energy in discrete packets. The energy content of the packets is directly proportional to the frequency of the radiation. These electron transitions will produce unique absorption spectra for each element. When the electron returns from an excited (high energy state) to a lower energy state, energy is emitted in only certain wavelengths of light, producing an emission spectra.		
C2.4a	Describe energy changes in flame tests of common elements in terms of the (characteristic) electron transitions.	Unit 2 Atoms and Atomic Electrons	Refinement of the Atomic Model
C2.4b	Contrast the mechanism of energy changes and the appearance of absorption and emission spectra.	Unit 2 Atoms and Atomic Electrons	Refinement of the Atomic Model
C2.4c	Explain why an atom can absorb only certain wavelengths of light.	Unit 2 Atoms and Atomic Electrons	Refinement of the Atomic Model
C2.4d	Compare various wavelengths of light (visible and nonvisible) in terms of frequency and relative energy.	Unit 2 Atoms and Atomic Electrons	Refinement of the Atomic Model

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C2.5x	Nuclear stability is related to a decrease in potential energy when the nucleus forms from protons and neutrons. If the neutron/proton ratio is unstable, the element will undergo radioactive decay. The rate of decay is characteristic of each isotope; the time for half the parent nuclei to decay is called the half-life. Comparison of the parent/daughter nuclei can be used to determine the age of a sample. Heavier elements are formed from the fusion of lighter elements in the stars.		
C2.5a	Determine the age of materials using the ratio of stable and unstable isotopes of a particular type.		
C2.r5b	Illustrate how elements can change in nuclear reactions using balanced equations. (recommended)	Unit 6 Chemical Reactions and Nuclear Chemistry	Introduction to Nuclear Chemistry
C2.r5c	Describe the potential energy changes as two protons approach each other. (recommended)		
C2.r5d	Describe how and where all the elements on earth were formed. (recommended)		
C3	Students apply the First and Second Laws of Thermodynamics to explain and predict most chemical phenomena. Chemistry students use the term enthalpy to describe the transfer of energy between reactants and products in simple calorimetry experiments performed in class and will recognize Hess's Law as an application of the conservation of energy. Students understand the		

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	tremendous energy released in nuclear reactions is a result of small amounts of matter being converted to energy.		
P3.p1	When energy is transferred from one system to another, the quantity of energy before transfer equals the quantity of energy after transfer. (prerequisite)	Unit 6 Chemical Reactions and Nuclear Chemistry	Order in the Universe
P3.p1A	Explain that the amount of energy necessary to heat a substance will be the same as the amount of energy released when the substance is cooled to the original temperature. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Heat, Energy and Understanding Numbers
C3.1x	For chemical reactions where the state and amounts of reactants and products are known, the amount of energy transferred will be the same regardless of the chemical pathway. This relationship is called Hess's law.		
C3.1a	Calculate the delta H for a given reaction using Hess's Law.		
C3.1b	Draw enthalpy diagrams for exothermic and endothermic reactions.		
C3.1c	Calculate the delta H for a chemical reaction using simple coffee cup calorimetry.		
C3.1d	Calculate the amount of heat produced for a given mass of reactant from a balanced chemical equation.		

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P3.p2	Nuclear reactions take place in the sun. In plants, light from the sun is transferred to oxygen and carbon compounds, which, in combination, have chemical potential energy (photosynthesis). (prerequisite)		
P3.p2A	Trace (or diagram) energy transfers involving various types of energy including nuclear, chemical, electrical, sound, and light. (prerequisite)		
C3.2x	Chemical reactions involve breaking bonds in reactants (endothermic) and forming new bonds in the products (exothermic). The enthalpy change for a chemical reaction will depend on the relative strengths of the bonds in the reactants and products.	Unit 6 Chemical Reactions and Nuclear Chemistry	Order in the Universe
C3.2a	Describe the energy changes in photosynthesis and in the combustion of sugar in terms of bond breaking and bond making.		
C3.2b	Describe the relative strength of single, double, and triple covalent bonds between nitrogen atoms.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent
C3.3	Heating increases the kinetic (translational, rotational, and vibrational) energy of the atoms composing elements and the molecules or ions composing compounds. As the kinetic (translational) energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a sample of a crystalline solid increases the kinetic (vibrational) energy of the atoms, molecules, or ions. When the kinetic (vibrational) energy becomes great enough, the crystalline structure breaks down, and the solid melts.		

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C3.3A	Describe how heat is conducted in a solid.		
C3.3B	Describe melting on a molecular level.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Change of State
C3.3x	Chemical bonds possess potential (vibrational and rotational) energy.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent
C3.3c	Explain why it is necessary for a molecule to absorb energy in order to break a chemical bond.		
C3.4	Chemical interactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic).	Unit 6 Chemical Reactions and Nuclear Chemistry	Energy in Reactions
C3.4A	Use the terms endothermic and exothermic correctly to describe chemical reactions in the laboratory.	Unit 6 Chemical Reactions and Nuclear Chemistry	Energy in Reactions
C3.4B	Explain why chemical reactions will either release or absorb energy.		
C3.4x	All chemical reactions involve rearrangement of the atoms. In an exothermic reaction, the products have less energy than the reactants. There are two natural driving forces: (1) toward minimum energy (enthalpy) and (2) toward maximum disorder (entropy).		

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C3.4c	Write chemical equations including the heat term as a part of equation or using delta H notation.		
C3.4d	Draw enthalpy diagrams for reactants and products in endothermic and exothermic reactions.		
C3.4e	Predict if a chemical reaction is spontaneous given the enthalpy (delta H) and entropy (delta S) changes for the reaction using Gibb's Free Energy, $\Delta G = \Delta H - T \Delta S$ (Note: mathematical computation of delta G is not required.)	Unit 6 Chemical Reactions and Nuclear Chemistry	Order in the Universe
C3.4f	Explain why some endothermic reactions are spontaneous at room temperature.	Unit 6 Chemical Reactions and Nuclear Chemistry	Order in the Universe
C3.4g	Explain why gases are less soluble in warm water than cold water.	Unit 5 Solutions, Acids and Bases	Properties of Solutions
C3.5x	Nuclear reactions involve energy changes many times the magnitude of chemical changes. In chemical reactions matter is conserved, but in nuclear reactions a small loss in mass (mass defect) will account for the tremendous release of energy. The energy released in nuclear reactions can be calculated from the mass defect using $E = mc^2$.	Unit 6 Chemical Reactions and Nuclear Chemistry	Harnessing Nuclear Chemistry
C3.5a	Explain why matter is not conserved in nuclear reactions.	Unit 6 Chemical Reactions and Nuclear Chemistry	Harnessing Nuclear Chemistry

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C4	Compounds, elements, and mixtures are categories used to organize matter. Students organize materials into these categories based on their chemical and physical behavior. Students understand the structure of the atom to make predictions about the physical and chemical properties of various elements and the types of compounds those elements will form. An understanding of the organization the Periodic Table in terms of the outer electron configuration is one of the most important tools for the chemist and student to use in prediction and explanation of the structure and behavior of atoms.		
P4.p1	Properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion. (prerequisite)	Unit 4 Equations	Properties of Gases
P4.p1A	For a substance that can exist in all three phases, describe the relative motion of the particles in each of the phases. (prerequisite)	Unit 4 Equations	Change of State
P4.p1B	For a substance that can exist in all three phases, make a drawing that shows the arrangement and relative spacing of the particles in each of the phases. (prerequisite)	Unit 4 Equations	Change of State
P4.p1C	For a simple compound, present a drawing that shows the number of particles in the system does not change as a result of a phase change. (prerequisite)		
P4.p2	Elements are a class of substances composed of a single kind of atom. Compounds are composed of two or more different elements chemically combined. Mixtures are composed of two or more different elements and/or compounds physically combined. Each element		

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	and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample. (prerequisite)		
P4.p2A	Distinguish between an element, compound, or mixture based on drawings or formulae. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
P4.p2B	Identify a pure substance (element or compound) based on unique chemical and physical properties. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
P4.p2C	Separate mixtures based on the differences in physical properties of the individual components. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
P4.p2D	Recognize that the properties of a compound differ from those of its individual elements. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
C4.1x	Compounds have a fixed percent elemental composition. For a compound, the empirical formula can be calculated from the percent composition or the mass of each element. To determine the molecular formula from the empirical formula, the molar mass of the substance must also be known.	Unit 3 The Periodic Law and The Language of Chemistry	Using Chemical Formulas and Oxidation Numbers
C4.1a	Calculate the percent by weight of each element in a compound based on the compound formula.	Unit 3 The Periodic Law and The Language of Chemistry	Using Chemical Formulas and Oxidation Numbers
C4.1b	Calculate the empirical formula of a compound based on the percent by weight of each element in the compound.	Unit 3 The Periodic Law and The Language of Chemistry	Using Chemical Formulas and Oxidation Numbers

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C4.1c	Use the empirical formula and molecular weight of a compound to determine the molecular formula.	Unit 3 The Periodic Law and The Language of Chemistry	Using Chemical Formulas and Oxidation Numbers
C4.2	All compounds have unique names that are determined systematically.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Ionic Compounds and Writing and Naming Covalent and Polyatomic Compounds
C4.2A	Name simple binary compounds using their formulae.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Ionic Compounds and Writing and Naming Covalent and Polyatomic Compounds
C4.2B	Given the name, write the formula of simple binary compounds.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Ionic Compounds and Writing and Naming Covalent and Polyatomic Compounds
C4.2x	All molecular and ionic compounds have unique names that are determined systematically.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Ionic Compounds and Writing and Naming Covalent and Polyatomic Compounds
C4.2c	Given a formula, name the compound.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Ionic Compounds and Writing and Naming Covalent and Polyatomic Compounds
C4.2d	Given the name, write the formula of ionic and molecular compounds.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Ionic Compounds and Writing and Naming Covalent and Polyatomic Compounds
C4.2e	Given the formula for a simple hydrocarbon, draw and name the isomers.		

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C4.3	Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.		
C4.3A	Recognize that substances that are solid at room temperature have stronger attractive forces than liquids at room temperature, which have stronger attractive forces than gases at room temperature.	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
C4.3B	Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
C4.3x	Solids can be classified as metallic, ionic, covalent, or network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent Chemical Bonding 2: Ionic and Metallic
C4.3c	Compare the relative strengths of forces between molecules based on the melting point and boiling point of the substances.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent Chemical Bonding 2: Ionic and Metallic
C4.3d	Compare the strength of the forces of attraction between molecules of different elements. (For example, at room temperature, chlorine is a gas and iodine is a solid.)		
C4.3e	Predict whether the forces of attraction in a solid are primarily metallic, covalent, network covalent, or ionic based upon the elements' location on the periodic table.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent Chemical Bonding 2: Ionic and Metallic
C4.3f	Identify the elements necessary for hydrogen bonding (N, O, F).		

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C4.3g	Given the structural formula of a compound, indicate all the intermolecular forces present (dispersion, dipolar, hydrogen bonding).	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Liquids and Solids
C4.3h	Explain properties of various solids such as malleability, conductivity, and melting point in terms of the solid's structure and bonding.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent Chemical Bonding 2: Ionic and Metallic
C4.3i	Explain why ionic solids have higher melting points than covalent solids. (For example, NaF has a melting point of 995°C, while water has a melting point of 0° C.)	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent Chemical Bonding 2: Ionic and Metallic
C4.4x	The forces between molecules depend on the net polarity of the molecule as determined by shape of the molecule and the polarity of the bonds.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Liquids and Solids
C4.4a	Explain why at room temperature different compounds can exist in different phases.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Change of State
C4.4b	Identify if a molecule is polar or nonpolar given a structural formula for the compound.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Liquids and Solids
C4.5x	The forces in gases are explained by the ideal gas law.		
C4.5a	Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume relationship in gases.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Gas Laws

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C4.5b	Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-temperature relationship in gases.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Gas Laws
C4.5c	Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the temperature-volume relationship in gases.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Gas Laws
C4.6x	The mole is the standard unit for counting atomic and molecular particles in terms of common mass units.	Unit 2 Atoms and Atomic Electrons	Weigh and Counting Atoms
C4.6a	Calculate the number of moles of any compound or element given the mass of the substance.	Unit 2 Atoms and Atomic Electrons/ Unit 3 The Periodic Law and The Language of Chemistry	Weigh and Counting Atoms/ Using Chemical Formulas and Oxidation Numbers
C4.6b	Calculate the number of particles of any compound or element given the mass of the substance.	Unit 2 Atoms and Atomic Electrons/ Unit 3 The Periodic Law and The Language of Chemistry	Weigh and Counting Atoms/ Using Chemical Formulas and Oxidation Numbers
C4.7x	The physical properties of a solution are determined by the concentration of solute.	Unit 5 Solutions, Acids and Bases	Properties of Solutions
C4.7a	Investigate the difference in the boiling point or freezing point of pure water and a salt solution.	Unit 5 Solutions, Acids and Bases	Properties of Solutions
C4.7b	Compare the density of pure water to that of a sugar solution.	Unit 5 Solutions, Acids and Bases	Properties of Solutions

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C4.8	Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons.		
C4.8A	Identify the location, relative mass, and charge for electrons, protons, and neutrons.	Unit 2 Atoms and Atomic Electrons	The Atomic Theory
C4.8B	Describe the atom as mostly empty space with an extremely small, dense nucleus consisting of the protons and neutrons and an electron cloud surrounding the nucleus.	Unit 2 Atoms and Atomic Electrons	The Atomic Theory
C4.8C	Recognize that protons repel each other and that a strong force needs to be present to keep the nucleus intact.		
C4.8D	Give the number of electrons and protons present if the fluoride ion has a -1 charge.	Unit 2 Atoms and Atomic Electrons	The Atomic Theory
C4.8x	Electrons are arranged in main energy levels with sublevels that specify particular shapes and geometry. Orbitals represent a region of space in which an electron may be found with a high level of probability. Each defined orbital can hold two electrons, each with a specific spin orientation. The specific assignment of an electron to an orbital is determined by a set of 4 quantum numbers. Each element and, therefore, each position in the periodic table is defined by a unique set of quantum numbers.		

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C4.8e	Write the complete electron configuration of elements in the first four rows of the periodic table.	Unit 2 Atoms and Atomic Electrons	Electron Configuration
C4.8f	Write kernel structures for main group elements.		
C4.8g	Predict oxidation states and bonding capacity for main group elements using their electron structure.	Unit 3 The Periodic Law and The Language of Chemistry	Using Chemical Formulas and Oxidation Numbers
C4.8h	Describe the shape and orientation of s and p orbitals.	Unit 2 Atoms and Atomic Electrons	Refinement of the Atomic Model
C4.8i	Describe the fact that the electron location cannot be exactly determined at any given time.	Unit 2 Atoms and Atomic Electrons	Refinement of the Atomic Model
C4.9	In the periodic table, elements are arranged in order of increasing number of protons (called the atomic number). Vertical groups in the periodic table (families) have similar physical and chemical properties due to the same outer electron structures.	Unit 3 The Periodic Law and The Language of Chemistry	Development of the Periodic Table
C4.9A	Identify elements with similar chemical and physical properties using the periodic table.	Unit 3 The Periodic Law and The Language of Chemistry	Tour of the Periodic Table
C4.9x	The rows in the periodic table represent the main electron energy levels of the atom. Within each main energy level are sublevels that represent an orbital shape and orientation.	Unit 3 The Periodic Law and The Language of Chemistry	Tour of the Periodic Table

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C4.9b	Identify metals, non-metals, and metalloids using the periodic table.	Unit 3 The Periodic Law and The Language of Chemistry	Tour of the Periodic Table
C4.9c	Predict general trends in atomic radius, first ionization energy, and electronegativity of the elements using the periodic table.		
C4.10	A neutral atom of any element will contain the same number of protons and electrons. Ions are charged particles with an unequal number of protons and electrons. Isotopes are atoms of the same element with different numbers of neutrons and essentially the same chemical and physical properties.		
C4.10A	List the number of protons, neutrons, and electrons for any given ion or isotope.	Unit 2 Atoms and Atomic Electrons	The Atomic Theory
C4.10B	Recognize that an element always contains the same number of protons.	Unit 2 Atoms and Atomic Electrons	The Atomic Theory
C4.10x	The atomic mass listed on the periodic table is an average mass for all the different isotopes that exist, taking into account the percent and mass of each different isotope.	Unit 2 Atoms and Atomic Electrons	Weigh and Counting Atoms
C4.10c	Calculate the average atomic mass of an element given the percent abundance and mass of the individual isotopes.	Unit 2 Atoms and Atomic Electrons	Weigh and Counting Atoms
C4.10d	Predict which isotope will have the greatest abundance given the possible isotopes for an element and the average atomic mass in the periodic table.	Unit 2 Atoms and Atomic Electrons	Weigh and Counting Atoms

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C4.10e	Write the symbol for an isotope, ${}^A_Z X$, where Z is the atomic number, A is the mass number, and X is the symbol for the element.	Unit 2 Atoms and Atomic Electrons	The Atomic Theory
C5	Students will analyze a chemical change phenomenon from the point of view of what is the same and what is not the same.		
P5.p1	Changes of state are explained by a model of matter composed of tiny particles that are in motion. When substances undergo changes of state, neither atoms nor molecules themselves are changed in structure. Mass is conserved when substances undergo changes of state. (prerequisite)		
P5.p1A	Draw a picture of the particles of an element or compound as a solid, liquid, and gas. (prerequisite)	Unit 1 Introduction to Chemistry and Matter	Properties of Matter
C5.r1x	The rate of a chemical reaction will depend upon (1) concentration of reacting species, (2) temperature of reaction, (3) pressure if reactants are gases, and (4) nature of the reactants. A model of matter composed of tiny particles that are in constant motion is used to explain rates of chemical reactions. (recommended)	Unit 6 Chemical Reactions and Nuclear Chemistry	Reaction Energy and Reaction Kinetics
C5.r1a	Predict how the rate of a chemical reaction will be influenced by changes in concentration, and temperature, pressure. (recommended)	Unit 6 Chemical Reactions and Nuclear Chemistry	Reaction Energy and Reaction Kinetics
C5.r1b	Explain how the rate of a reaction will depend on concentration, temperature, pressure, and nature of reactant. (recommended)	Unit 6 Chemical Reactions and Nuclear Chemistry	Reaction Energy and Reaction Kinetics

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C5.2	Chemical changes can occur when two substances, elements, or compounds interact and produce one or more different substances whose physical and chemical properties are different from the interacting substances. When substances undergo chemical change, the number of atoms in the reactants is the same as the number of atoms in the products. This can be shown through simple balancing of chemical equations. Mass is conserved when substances undergo chemical change. The total mass of the interacting substances (reactants) is the same as the total mass of the substances produced (products).		
C5.2A	Balance simple chemical equations applying the conservation of matter.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Writing and Balancing Chemical Reaction
C5.2B	Distinguish between chemical and physical changes in terms of the properties of the reactants and products.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Writing and Balancing Chemical Reaction
C5.2C	Draw pictures to distinguish the relationships between atoms in physical and chemical changes.		
C5.2x	A balanced chemical equation will allow one to predict the amount of product formed.		
C5.2d	Calculate the mass of a particular compound formed from the masses of starting materials.		

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C5.2e	Identify the limiting reagent when given the masses of more than one reactant.		
C5.2f	Predict volumes of product gases using initial volumes of gases at the same temperature and pressure.		
C5.2g	Calculate the number of atoms present in a given mass of element.	Unit 2 Atoms and Atomic Electrons	Weigh and Counting Atoms
C5.3x	Most chemical reactions reach a state of dynamic equilibrium where the rates of the forward and reverse reactions are equal.		
C5.3a	Describe equilibrium shifts in a chemical system caused by changing conditions (Le Chatelier's Principle).		
C5.3b	Predict shifts in a chemical system caused by changing conditions (Le Chatelier's Principle).		
C5.3c	Predict the extent reactants are converted to products using the value of the equilibrium constant.		
C5.4	Changes of state require a transfer of energy. Water has unusually high-energy changes associated with its changes of state.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Change of State
C5.4A	Compare the energy required to raise the temperature of one gram of aluminum and one gram of water the same number of degrees.	Unit 6 Chemical Reactions and Nuclear Chemistry	Energy in Reactions

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C5.4B	Measure, plot, and interpret the graph of the temperature versus time of an ice-water mixture, under slow heating, through melting and boiling.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Change of State
C5.4x	All changes of state require energy. Changes in state that require energy involve breaking forces holding the particles together. The amount of energy will depend on the type of forces.		
C5.4c	Explain why both the melting point and boiling points for water are significantly higher than other small molecules of comparable mass (e.g., ammonia and methane).		
C5.4d	Explain why freezing is an exothermic change of state.		
C5.4e	Compare the melting point of covalent compounds based on the strength of IMFs (intermolecular forces).		
C5.5	An atom's electron configuration, particularly of the outermost electrons, determines how the atom can interact with other atoms. The interactions between atoms that hold them together in molecules or between oppositely charged ions are called chemical bonds.		
C5.5A	Predict if the bonding between two atoms of different elements will be primarily ionic or covalent.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent
C5.5B	Predict the formula for binary compounds of main group elements.	Unit 3 The Periodic Law and The Language of Chemistry	Writing and Naming Covalent and Polyatomic Compounds

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C5.5x	Chemical bonds can be classified as ionic, covalent, and metallic. The properties of a compound depend on the types of bonds holding the atoms together.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent Chemical Bonding 2: Ionic and Metallic
C5.5c	Draw Lewis structures for simple compounds.	Unit 3 The Periodic Law and The Language of Chemistry	Chemical Bonding 1: Covalent
C5.5d	Compare the relative melting point, electrical and thermal conductivity and hardness for ionic, metallic, and covalent compounds.		
C5.5e	Relate the melting point, hardness, and electrical and thermal conductivity of a substance to its structure.		
C5.6x	Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve electron transfer are known as oxidation/reduction (or "redox").		
C5.6a	Balance half-reactions and describe them as oxidations or reductions.		
C5.6b	Predict single replacement reactions.	Unit 4 Equations, Reactions, Gases and Liquids and Solids	Types of Chemical Reaction
C5.6c	Explain oxidation occurring when two different metals are in contact.		

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C5.6d	Calculate the voltage for spontaneous redox reactions from the standard reduction potentials.		
C5.6e	Identify the reactions occurring at the anode and cathode in an electrochemical cell.		
C5.7	Acids and bases are important classes of chemicals that are recognized by easily observed properties in the laboratory. Acids and bases will neutralize each other. Acid formulas usually begin with hydrogen, and base formulas are a metal with a hydroxide ion. As the pH decreases, a solution becomes more acidic. A difference of one pH unit is a factor of 10 in hydrogen ion concentration.		
C5.7A	Recognize formulas for common inorganic acids, carboxylic acids, and bases formed from families I and II.	Unit 5 Solutions, Acids and Bases	Properties of Acids
C5.7B	Predict products of an acid-base neutralization.	Unit 5 Solutions, Acids and Bases	Properties of Bases and Their Reaction with Acids
C5.7C	Describe tests that can be used to distinguish an acid from a base.	Unit 5 Solutions, Acids and Bases	Properties of Bases and Their Reaction with Acids
C5.7D	Classify various solutions as acidic or basic, given their pH.		

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C5.7E	Explain why lakes with limestone or calcium carbonate experience less adverse effects from acid rain than lakes with granite beds.		
C5.7x	Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve proton transfer are known as acid/base reactions.		
C5.7f	Write balanced chemical equations for reactions between acids and bases and perform calculations with balanced equations.		
C5.7g	Calculate the pH from the hydronium ion or hydroxide ion concentration.		
C5.7h	Explain why sulfur oxides and nitrogen oxides contribute to acid rain.		
C5.r7i	Identify the Brønsted-Lowry conjugate acid-base pairs in an equation. (recommended)	Unit 5 Solutions, Acids and Bases	Properties of Acids
C5.8	The chemistry of carbon is important. Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.		
C5.8A	Draw structural formulas for up to ten carbon chains of simple hydrocarbons.		



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C5.8B	Draw isomers for simple hydrocarbons.		
C5.8C	Recognize that proteins, starches, and other large biological molecules are polymers.		