

Chemistry Subject Matter Requirements

Content Domains for Subject Matter Understanding and Skill in Chemistry

Domain 1. Structure and Properties of Matter

1.1 Understand the structure of matter.

- Analyze the evidence used in the development of the quantum model of the atom (e.g., the Bohr model, atomic spectroscopy, and the photoelectric effect).
- Demonstrate knowledge of the positions of protons, neutrons, and electrons within atoms and their properties.
- Differentiate periodic groups and families of elements and their properties.
- Relate valence electrons and the electron shell structure (*s*, *p*, *d*, *f* orbitals) to an element's chemical properties and position in the periodic table.
- Predict periodic trends, including electronegativity, ionization energy, reactivity, and the relative sizes of ions and atoms.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.A)

1.2 Understand the properties of matter.

- Use the kinetic molecular theory to compare and contrast solids, liquids, and gases and to interpret phase diagrams.
- Relate the electrostatic interactions between particles in a substance, such as types of intramolecular and intermolecular forces, to the substance's physical and chemical properties (e.g., melting point, solubility, vapor pressure, flammability).
- Solve problems involving the ideal gas law under standard temperature and pressure (STP) and non-STP conditions and predict the relationships between pressure and volume, pressure and temperature, and volume and temperature for ideal gases (e.g., Boyle's law, Charles's law).
- Demonstrate the ability to convert between the Kelvin and Celsius temperature scales and knowledge of the significance of absolute zero.
- Solve problems using Dalton's law of partial pressures and Graham's law of effusion.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.A)

1.3 Understand the behavior and properties of solutions.

- Demonstrate knowledge of the behavior of solutions, including identifying solutes and solvents and methods of calculating concentration (e.g., molarity, parts per million, percent composition).
- Demonstrate knowledge of the process of dissolution at the molecular level, including factors that affect solubility (e.g., temperature, pressure, surface area).
- Apply knowledge of simple methods for the separation of mixtures (e.g., chromatography, distillation).
- Distinguish between strong and weak acids and bases on the basis of degree of dissociation and their chemical properties.

- e. Calculate pH and hydrogen ion concentration in strong and weak acid or base solutions.
- f. Use Arrhenius, Brønsted-Lowry, and Lewis acid-base definitions appropriately to characterize acids and bases and in acid-base reactions.
- g. Apply knowledge of buffer solutions, including solving problems related to buffer solutions.

1.4 Understand nuclear processes.

- a. Demonstrate knowledge of mass-energy relationships in nuclear reactions and radioactive decay ($E = mc^2$).
- b. Compare and contrast alpha, beta, and gamma decay, including changes in the nucleus, balancing nuclear reactions, and the relative kinds of damage to matter caused by alpha, beta, and gamma rays.
- c. Compare and contrast fission and fusion.
- d. Perform calculations involving half-life.
- e. Apply knowledge of the radiometric dating of rocks and other materials.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.C)

Domain 2. Chemical Reactions and Chemical Bonding

2.1 Understand chemical reactions.

- a. Demonstrate knowledge of different types of chemical reactions, including predicting the products of chemical reactions.
- b. Interpret potential energy diagrams of reactions (e.g., determining activation energies with and without catalysts, identifying reactions as endothermic or exothermic).
- c. Demonstrate knowledge of collision theory and factors that influence reaction rate, including catalysts.
- d. Predict the effect of temperature, pressure, and concentration on chemical equilibrium (Le Chatelier's principle).
- e. Demonstrate knowledge of chemical equilibrium, including determining equilibrium constant expressions and/or values for given reactions.
- f. Apply knowledge of Gibbs energy to analyze the spontaneity of chemical reactions and predict the relative amounts of products and reactants.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.B)

2.2 Understand chemical bonding.

- a. Compare and contrast ionic, covalent, and metallic bonding.
- b. Demonstrate knowledge of models representing the structure of molecules and compounds and the bonding between atoms (e.g., Lewis electron dot structures for compounds and ions).
- c. Predict molecular geometries using Lewis electron dot structures and hybridized atomic orbitals (e.g., valence shell electron pair repulsion [VSEPR] model).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.B)

2.3 Understand conservation of matter and stoichiometry.

- Calculate molar mass, mass, moles, number of particles, and volume at standard temperature and pressure (STP) for elements and compounds.
- Calculate quantities of reactants and products and percent yield using balanced chemical equations, including problems with a limiting reagent.
- Use the law of conservation of matter to balance chemical equations, including oxidation-reduction reactions.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.B)

2.4 Understand organic chemistry and biochemistry.

- Demonstrate knowledge of the bonding characteristics of carbon.
- Recognize the chemical structure of various organic functional groups (e.g., alcohols, ketones, ethers, amines, esters, aldehydes, organic acids).
- Demonstrate knowledge of basic chemical reactions involving organic functional groups (e.g., substitution, addition, esterification).
- Recognize the ten simplest hydrocarbons that contain single bonds, multiple bonds, and benzene rings.
- Analyze the differences in structures and properties between biologically significant monomers and their polymers (e.g., sugars forming carbohydrates, amino acids forming proteins, glycerol/fatty acids forming lipids, nucleotides forming nucleic acids).
- Demonstrate knowledge of materials (e.g., medicine, synthetics) produced from natural resources.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: MS-PS1.A)

Domain 3. Energy

3.1 Understand the definitions of energy, conservation of energy, and energy transfer.

- Analyze the energy in a system, including describing energy in terms of the motion and interactions of matter and radiation and recognizing that energy in systems is continually transferred from one object to another and between its possible forms (e.g., kinetic, potential).
- Demonstrate knowledge of how different manifestations of energy (e.g., sound, light, thermal energy) can be modeled as a combination of energy associated with the motion of particles and energy associated with the relative position of these particles.
- Apply knowledge of heat, specific heat, enthalpy of fusion, enthalpy of vaporization, and enthalpy of reaction to perform calculations (e.g., calorimetry) and explain phenomena.
- Interpret heating and cooling curves.
- Apply knowledge of the energy changes associated with the breaking or forming of chemical bonds during a chemical process.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS3.A, PS3.B)

3.2 Understand energy in chemical processes and everyday life.

- a. Analyze the benefits and hazards of the use of radiation, radioactivity, and nuclear energy, in comparison to nonnuclear processes.
- b. Demonstrate knowledge of electric power generation from fossil fuels and alternative fuels (e.g., solar, tidal, nuclear).
- c. Apply knowledge of the source of the energy produced by the sun and how this energy is captured on Earth.
- d. Demonstrate knowledge of energy production and use associated with photosynthesis and cellular respiration.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS3.D)

Selected text in these subject matter requirements reprinted with permission from A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas, 2016 by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.