National Evaluation Series

Test Framework

Chemistry (321)

May 2023

Content Domain	Range of Competencies	Approximate Percentage of Test Score
I. Structure and Properties of Matter	0001–0003	50%
II. Chemical Reactions	0004–0006	30%
III. Energy Changes	0007–0008	20%

STRUCTURE AND PROPERTIES OF MATTER

0001: Understand the structure of the atom, using crosscutting concepts and science and engineering practices to show that understanding.

- Analyze atomic systems using experimental evidence, the quantum mechanical model, and the development of historical models (e.g., Dalton's, Thomson's, Rutherford's).
- Demonstrate knowledge of the comparative characteristics of subatomic particles (i.e., mass, charge, and location within an atom).
- Demonstrate knowledge of the relationship between atomic number, neutron-to-proton ratio, and nuclear stability within an atom.
- Demonstrate knowledge of the relationship between an atom's mass number and the element's atomic mass and isotopic masses.
- Apply knowledge of the formation of new elements through nuclear processes (e.g., fission, fusion, alpha or beta decay).
- Demonstrate knowledge of electron configurations under various models and representations (e.g., Bohr diagram, subshell list, Lewis dot diagram, orbital diagram).
- Apply knowledge of the electromagnetic spectrum and wave-particle duality to explain the electronic characteristics of atomic systems.

0002: Understand the properties of elements and the patterns in those properties, using crosscutting concepts and science and engineering practices to show that understanding.

- Demonstrate knowledge of physical and chemical properties and their role in the identification and categorization of elements.
- Apply knowledge of the structure of the periodic table and its dependence on atomic structure (e.g., periods, groups, lanthanides, metals, nonmetals).
- Analyze data on the periodic trends in the properties of elements (e.g., atomic radius, electron affinity, electronegativity, ionization energy).
- Apply knowledge of atomic structure, Coulomb's law, and quantum mechanics to explain trends in the properties of elements.

0003: Understand the formation and characteristics of chemical compounds, using crosscutting concepts and science and engineering practices to show that understanding.

- Demonstrate knowledge of various types of chemical bonds (e.g., ionic, covalent, metallic) and their characteristics.
- Apply knowledge of atomic structure and bonding characteristics to explain trends in the properties of compounds.
- Apply knowledge of atomic structure and electrostatics to the formation of chemical bonds, including predictions of an element's bonding behavior (e.g., constituent atoms, bond energies, covalent bond length, ionic internuclear distance).
- Apply knowledge of simple bonding models (e.g., Lewis structures, electron density diagrams, structural formulas) to explain the formation of compounds.
- Apply knowledge of the valence-shell-electron-pair repulsion (VSEPR) theory connected to predictions of molecular geometry (i.e., shape, angle, and structure name) and polarity.
- Analyze the structures and characteristics of large organic molecules using knowledge of bonding characteristics, polarity, and intermolecular forces.
- Demonstrate knowledge of chemical formulas and names for inorganic and simple organic compounds according to the International Union of Pure and Applied Chemistry (IUPAC) nomenclature guidelines.

0004: Understand the compositions and characteristics of mixtures, using crosscutting concepts and science and engineering practices to show that understanding.

- Demonstrate knowledge of the physical properties, chemical properties, and characteristics of mixtures (e.g., solutions, homogeneous, heterogeneous).
- Demonstrate knowledge of how a mixture's particle size and composition affect its properties (e.g., colligative properties of a solution, density of an alloy, Tyndall effect in colloids).
- Apply knowledge of the separation of mixtures based on their physical and chemical properties.
- Apply knowledge of concentration units and calculations using concentration (e.g., molarity, parts per million, pH).
- Demonstrate knowledge of factors affecting solubility (e.g., temperature, pressure, strength of particle interactions).
- Demonstrate knowledge of the structures and characteristics of acids and bases.

0005: Understand the formation and properties of various states of matter, using crosscutting concepts and science and engineering practices to show that understanding.

- Demonstrate knowledge of various types of intermolecular forces.
- Apply knowledge of atomic structure, electrostatic forces, and chemical bonding to compare the strengths of intermolecular forces in various substances.
- Demonstrate knowledge of the relative spacing, motion, and energy of particles in various states of matter (e.g., solids, liquids, gases).
- Apply knowledge of how intermolecular forces affect properties (e.g., vapor pressure, melting point, boiling point) and phase changes of pure substances.
- Demonstrate knowledge of the characteristics of various types of solids (i.e., ionic, molecular, network, and metallic).
- Apply knowledge of the kinetic molecular theory of gases to predict qualitative changes in gas systems.
- Analyze the behavior of gases using mathematical relationships between bulk properties (e.g., the ideal gas law, Dalton's law of partial pressures, van der Waals equation for real gases).

CHEMICAL REACTIONS

0006: Understand the characteristics of chemical reactions, using crosscutting concepts and science and engineering practices to show that understanding.

- Apply knowledge of chemical notation (e.g., chemical formulas, chemical equations, net ionic equations).
- Demonstrate knowledge of common types of chemical reactions (i.e., synthesis, decomposition, single replacement, double replacement, and combustion).
- Analyze chemical reactions using data to predict products (e.g., the solubility rules, the common oxidation states of elements, the activity series of metals and nonmetals, the properties of acids and bases).
- Demonstrate knowledge of common acid-base reactions, including neutralization.
- Demonstrate knowledge of oxidation-reduction reactions, including electrochemical cells.

0007: Understand mass and particle number relationships in chemical reactions, using crosscutting concepts and science and engineering practices to show that understanding.

- Apply knowledge of the use of balanced chemical equations to represent chemical reactions.
- Apply knowledge of the mole, Avogadro's number, and their relationships to mass and particle number.
- Apply knowledge of mass percent data and the description of compounds through empirical or molecular formulas.
- Apply knowledge of stoichiometry to predict relationships between reactant(s) and/or product(s) (e.g., mole to mole, gram to gram, mole to particle, mole to liter).
- Apply stoichiometric reasoning to situations involving a limiting reagent.
- Demonstrate knowledge of common experimental techniques (e.g., titration, gravimetric analysis) for determining amounts of reactants and products.
- Analyze the results of investigations using mathematical tools (e.g., theoretical yield, actual yield, percent error) to evaluate their success.

0008: Understand the kinetics of chemical reactions and the description of equilibrium systems, using crosscutting concepts and science and engineering practices to show that understanding.

- Apply knowledge of collision theory and its connections to qualitative factors affecting reaction rates (i.e., concentration, temperature, surface area, and catalyst).
- Analyze graphical and numerical representations (i.e., concentration, time, and rate) of reaction rates.
- Demonstrate knowledge of rate-determining steps in a reaction mechanism.
- Demonstrate knowledge of dynamic equilibrium in physical and chemical systems, including the equilibrium constant.
- Apply knowledge of Le Châtelier's principle and factors that can change equilibrium concentrations (e.g., temperature, pressure, amounts of reactants or products, presence of a common ion).
- Demonstrate knowledge of common applications of equilibrium systems (e.g., weak acid and base solutions, buffer solutions, electrochemical cells, solubility products).

ENERGY CHANGES

0009: Understand energy changes in physical, chemical, and nuclear processes, using crosscutting concepts and science and engineering practices to show that understanding.

- Apply knowledge of the connection between phase change and energy transfer, including with heating curves and phase diagrams.
- Apply knowledge of energy flows of physical and chemical processes (i.e., endothermic and exothermic) and what they imply about the process.
- Apply knowledge of calorimetry as an experimental technique, including concepts of specific heat capacity, temperature change, and thermal equilibrium.
- Apply knowledge of temperature as a measure of average kinetic energy, including with Maxwell-Boltzmann distributions.
- Demonstrate knowledge of the varying energies of chemical bonds formed and broken during a chemical reaction using models (e.g., potential energy diagrams, enthalpy diagrams, Born-Haber cycle).
- Demonstrate knowledge of the energy released during nuclear fission, nuclear fusion, and radioactive decay.

0010: Understand the thermodynamics of physical and chemical processes, using crosscutting concepts and science and engineering practices to show that understanding.

- Demonstrate knowledge of the laws of thermodynamics.
- Apply knowledge of enthalpy to the calculation of enthalpy change values (e.g., Hess's law, standard enthalpies of formation).
- Demonstrate knowledge of entropy changes in physical and chemical processes.
- Analyze chemical systems using the relationship between entropy, enthalpy, temperature, and Gibbs free energy, including predictions of spontaneity.
- Apply knowledge of the interconnections between Gibbs free energy and other measures of chemical systems (e.g., equilibrium constants, electrochemical cell potential).