# Massachusetts Tests for Educator Licensure™
# Test Objectives
# Field 12: Chemistry

**SUBAREAS:**

THE NATURE OF CHEMICAL INQUIRY
MATTER AND ATOMIC STRUCTURE
ENERGY, CHEMICAL BONDS, AND MOLECULAR STRUCTURE
CHEMICAL REACTIONS
QUANTITATIVE RELATIONSHIPS
INTERACTIONS OF CHEMISTRY, SOCIETY, AND THE ENVIRONMENT

## THE NATURE OF CHEMICAL INQUIRY

**0001 Understand the nature of scientific inquiry, scientific processes, and the role of observation and experimentation in science.**

For example: processes by which new scientific knowledge and hypotheses are generated; experimental design and hypothesis testing; and the role of communication among scientists in promoting scientific progress.

**0002 Understand the processes of gathering, organizing, reporting, and interpreting scientific data in the context of chemistry investigations.**

For example: methods and procedures for collecting data for various purposes; appropriate and effective graphic representations (e.g., graph, table, diagram) for organizing and reporting experimental data; procedures and criteria for formally reporting experimental results and data to the scientific community; and relationships between factors (e.g., inverse, direct, linear) as indicated by experimental data.

**0003 Understand principles and procedures of measurement used in chemistry.**

For example: units of measurement, measuring devices, and methods of measurement for given situations; likely sources of error in given measurements in chemistry experiments; significant figures, scientific notation, and reporting data.

**0004 Understand proper, safe, and legal use of equipment, materials, and chemicals used in chemistry investigations.**

For example: the principles upon which given laboratory instruments are based (e.g., pH meters, gas chromatographs); proper methods for storing, identifying, and dispensing given chemicals and the legal guidelines for disposing chemicals; proper procedures for dealing with accidents and injuries in the chemistry laboratory; and proper procedures for safety in the laboratory (e.g., use of goggles, fire blankets, types of fire extinguishers).

## MATTER AND ATOMIC STRUCTURE

**0005 Understand the concept of matter, and analyze chemical and physical properties of and changes in matter.**

For example: differentiating among elements, compounds, and mixtures; using the physical and chemical properties of an unknown substance in order to identify it; analyzing the methods by which chemical properties of matter are determined; and distinguishing between physical and chemical changes in matter.

**0006 Understand the various models of atomic structure, the principles of quantum theory, and the properties and interactions of subatomic particles.**

For example: major features of models of atomic structure (e.g., Bohr, Rutherford, Schrödinger); interactions among electrons, protons, and neutrons and their properties (e.g., mass, charge); relationships among electron energy levels, photons, and atomic spectra; and analyzing the electron configurations of atoms and ions.

**0007 Understand the organization of the periodic table.**

For example: the organization of the periodic table in terms of atomic number and properties of the elements; trends (e.g., ionization energies, covalent atomic radii) within periods and groups in the periodic table; predicting physical and chemical properties of given elements based on their positions in the periodic table; and using the periodic table to gain information (e.g., relative reactivity) about given elements.

**0008 Understand the kinetic theory, the nature of phase changes, and the gas laws.**

For example: arrangements and movements of particles in solids, liquids, and gases; basic principles of the kinetic theory (e.g., particles of matter are in continual motion, real versus ideal gas behavior); analyzing heating and cooling curves qualitatively and quantitatively; and setting up and solving problems involving gas law relationships.

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**0009 Apply the conventions of chemical notation and representations.**

For example: the symbolic notation for given elements; applying the IUPAC rules of nomenclature to name given inorganic compounds from their formulas; recognizing and interpreting Lewis structures; and determining molecular geometry from Lewis structures.

**0010 Understand the process of nuclear transformation.**

For example: characteristics (e.g., mass, penetrating power) of the different types of emanations from the decay of radioactive elements; the processes of natural radioactivity and artificial transmutation; solving problems involving half-life of radioactive particles; and calculating nuclear mass defect and nuclear binding energy.

**ENERGY, CHEMICAL BONDS, AND MOLECULAR STRUCTURE**

**0011 Understand the principles of thermodynamics and calorimetry.**

For example: the three laws of thermodynamics and their applications to chemical systems; predicting the spontaneity of given reactions based on enthalpy changes, entropy changes, and temperatures of the systems; analyzing the results of calorimetry experiments; and distinguishing between heat and temperature.

**0012 Understand energy relationships in chemical bonding and chemical reactions.**

For example: energy changes due to the formation or breaking of chemical bonds; solving problems involving energy changes during chemical reactions (e.g., heat of combustion, heat of formation); and interpreting potential energy diagrams of chemical reactions.

**0013 Understand the types of bonds between atoms (including ionic, covalent, and metallic bonds), the formation of these bonds, and properties of substances containing the different bonds.**

For example: the characteristics of various types of bonds between atoms (e.g., bond strength, polarity); electron behavior in the formation of bonds between atoms; factors that affect bond strength (e.g., electronegativity, electron affinity); and predicting properties of a substance based on type of atomic bond.

**0014 Understand types and characteristics of molecular interaction and properties of substances containing different types of interactive forces between molecules.**

For example: predicting the kind of interaction between molecules of a given structure; the unique properties of water and its molecular structure and intermolecular forces; and relating the physical properties of substances to their intermolecular forces.

**0015 Understand the nomenclature and structure of organic compounds.**

For example: the IUPAC rules of nomenclature; the chemical composition and basic structure of organic compounds (e.g., saturated, unsaturated, and aromatic hydrocarbons; halogen, oxygen, and nitrogen derivatives); and distinguishing among structural, geometric, and optical isomers.

## CHEMICAL REACTIONS

**0016 Understand factors that affect reaction rates and methods of measuring reaction rates.**

For example: collision theory and factors that influence reaction rates; relating experimental measurements to reaction rates and rate laws; relating reaction mechanisms to rate laws; determining order of reactions and rate constants; and solving first-order rate problems.

**0017 Understand the principles of chemical equilibrium.**

For example: the effects of concentration, pressure, temperature, and catalysts on chemical equilibrium; applying Le Chatelier's principle to chemical systems; solving problems involving equilibrium constants; and solving problems involving solubility product constants of slightly soluble salts.

**0018 Understand the theories, principles, and applications of acid-base chemistry.**

For example: analyzing acids and bases according to operational and conceptual definitions (Arrhenius, Brönsted-Lowry, Lewis); the principles and applications of acid-base titration; determining the hydronium ion concentration and the pH for various acid, base, and salt solutions; and the relative strengths of given acids based on periodic relationships.

**0019 Understand redox reactions and electrochemistry.**

For example: processes that occur during redox reactions; determining oxidation numbers and balancing redox equations; predicting whether given redox reactions will occur based on standard electrode potentials; and analyzing the components (e.g., anode, cathode) and operating principles of electrochemical and electrolytic cells.

**0020 Understand the nature of organic reactions.**

For example: analyzing the rates of reactions involving organic compounds based on bond types and strengths; and analyzing common types of reactions (i.e., combustion, addition, substitution, polymerization, oxidation, esterification).

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## QUANTITATIVE RELATIONSHIPS

**0021 Understand the mole concept.**

For example: relating the mole to Avogadro's number; relating the gram-atomic mass of an element to the mass of one mole of the element; and calculating the number of moles in a given mass or volume of a substance.

**0022 Understand the relationship between the mole concept and chemical formulas.**

For example: solving problems involving molecular and formula masses; solving percentage composition problems; and determining empirical and molecular formulas.

**0023 Understand the quantitative relationships expressed in chemical equations.**

For example: interpreting chemical notation; balancing equations; recognizing net ionic equations; and solving stoichiometric problems involving moles, mass, and volume (including limiting reactant and percent yield).

**0024 Understand the properties of solutions and colloidal suspensions, and analyze factors that affect solubility.**

For example: the colligative properties of solutions (i.e., freezing point depression, boiling point elevation, osmotic pressure, vapor pressure lowering); solving problems involving concentrations of solutions (e.g., molarity, molality, percent concentration); and factors (e.g., temperature, pressure, molecular structure) that affect solubility.

## INTERACTIONS OF CHEMISTRY, SOCIETY, AND THE ENVIRONMENT

**0025 Understand the historical and contemporary contexts of the study of chemistry.**

For example: significant events, theories, experiments, and individuals in the history of chemistry; and the societal implications of developments in chemistry.

**0026 Understand the chemistry of practical processes and applications of chemical theory to other scientific disciplines.**

For example: industrial processes (e.g., processes by which petroleum is separated into fractions); chemical processes in the home (e.g., organic reactions involving leavening agents and fermentation); and the application of chemical theory to other disciplines (e.g., procedures by which nucleic acids are cleaved for genetic analysis).

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**0027 Understand the applications of nuclear reactions.**

For example: the use of radioisotopes in the life sciences and in geological and archaeological dating; the role of the components of a nuclear reactor and the issue of waste disposal; and the risks and benefits of nuclear technology.

**0028 Understand factors and processes related to the release of chemicals into the environment.**

For example: the chemical processes that result from the release of chemicals into the atmosphere (e.g., acid rain, greenhouse effect, ozone depletion, photochemical smog); the chemical processes that result from the release of chemicals into aquatic and terrestrial environments (e.g., eutrophication, dissolved oxygen, groundwater contamination, toxic chemicals); and methods for preventing environmental damage resulting from the release of chemicals into the environment (e.g., recycling, sewage treatment plants, pollution control devices).

**0029 Understand the interrelationships among chemistry, society, technology, and other disciplines.**

For example: the impact of chemistry and technology on society; similarities and differences between science and technology (e.g., science as investigating the natural world, technology as solving human adaptation problems); the technological design process; ethical considerations related to science and technology; and the application of scientific and technological decision making at the community, state, national, and international level.