

# Massachusetts Tests for Educator Licensure® (MTEL®)

## FIELD 12: CHEMISTRY TEST OBJECTIVES

Subarea	Multiple-Choice	Range of Objectives	Approximate Test Weighting
I.	Nature of Science and Properties of Matter	01–05	20%
II.	Atomic Structure and Chemical Bonding	06–12	20%
III.	Chemical Reactions and Solutions	13–15	20%
IV.	Thermodynamics	16–20	<u>20%</u>
			<b>80%</b>
	<b>Open-Response</b>		
V.	Integration of Knowledge and Understanding	21	<b>20%</b>

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**Effective September 1, 2009**

**Massachusetts Tests for Educator Licensure® (MTEL®)  
Test Objectives  
Field 12: Chemistry**

**SUBAREAS:**

NATURE OF SCIENCE AND PROPERTIES OF MATTER  
ATOMIC STRUCTURE AND CHEMICAL BONDING  
CHEMICAL REACTIONS AND SOLUTIONS  
THERMODYNAMICS  
INTEGRATION OF KNOWLEDGE AND UNDERSTANDING

**NATURE OF SCIENCE AND PROPERTIES OF MATTER [20%]**

**0001 Understand the processes of gathering, organizing, analyzing, and reporting scientific data.**

For example:

- Demonstrate knowledge of the formulation of scientific questions and the testing of hypotheses using appropriate methods for collecting data in chemistry investigations.
- Demonstrate knowledge of various methods of representing, organizing, and reporting experimental results.
- Apply mathematical concepts to measurement (accuracy vs. precision, significant figures, scientific notation, unit conversion) and the analysis and interpretation of data (statistical analysis, modeling).
- Demonstrate the ability to draw conclusions and make predictions from empirical data.

**0002 Understand scientific tools, instruments, materials, and safety practices.**

For example:

- Demonstrate knowledge of the safe and proper use of laboratory equipment and materials used in chemistry investigations.
- Select appropriate scientific tools, instruments, and techniques for specified chemistry investigations.
- Recognize proper methods for storing, identifying, dispensing, and disposing of chemicals.
- Demonstrate knowledge of the appropriate protocols for maintaining safety and responding to emergencies in laboratory situations.

## Field 12: Chemistry Test Objectives

### 0003 Understand the relationships among science, technology, and society.

For example:

- Identify the benefits, risks, and ethical concerns associated with research in chemistry and related technologies.
- Recognize how societal conditions support or inhibit scientific research and technological advances.
- Demonstrate knowledge of the integration and interdependence among scientific disciplines and between chemistry, engineering, and technology.

### 0004 Understand chemical and physical properties and changes in matter.

For example:

- Demonstrate knowledge of the atomic nature of matter and the characteristics of elements, compounds, and mixtures.
- Demonstrate knowledge of different types of mixtures (e.g., solutions, colloidal dispersions, non-colloidal suspensions).
- Demonstrate knowledge of appropriate techniques to achieve a desired separation of a mixture.
- Distinguish between physical and chemical properties and between physical and chemical changes in matter.
- Apply knowledge of physical and chemical properties to identify unknown substances.
- Analyze the role of intermolecular forces in surface tension, capillary action, viscosity, and physical changes.

### 0005 Understand the kinetic molecular theory, the nature of phase changes, and the gas laws.

For example:

- Describe the arrangements and movements of particles in solids, liquids, and gases.
- Recognize the basic principles of the kinetic molecular theory.
- Analyze heating and cooling curves qualitatively and quantitatively.
- Analyze phase diagrams.
- Solve problems involving gas law relationships.

**Field 12: Chemistry  
Test Objectives**

**ATOMIC STRUCTURE AND CHEMICAL BONDING [20%]**

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

For example:

- Recognize the major features of historical models of atomic structure and the supporting evidence for these models.
- Demonstrate knowledge of the properties of electrons, protons, and neutrons and their interactions.
- Demonstrate knowledge of the principles of quantum mechanics.
- Analyze the relationships among electron energy levels, photons, and atomic spectra.
- Analyze the electron configurations of atoms and ions.

**0007 Understand the process of nuclear transformation.**

For example:

- Recognize the characteristics (e.g., composition, charge, mass, penetrating power) of the different types of emanations from the decay of radioactive elements.
- Analyze the processes of natural radioactivity and artificial transmutation.
- Solve problems involving nuclear decay.

**0008 Understand the organization of the periodic table.**

For example:

- Analyze the organization of the periodic table in terms of atomic number and properties of the elements.
- Predict trends within periods and groups in the periodic table.
- Predict physical and chemical properties of given elements based on their positions in the periodic table.
- Compare the relative reactivity of elements based on electron configurations deduced from their positions in the periodic table.
- Predict oxidation numbers of elements using the periodic table.

## Field 12: Chemistry Test Objectives

### **0009 Understand the nomenclature and structure of inorganic and organic compounds.**

For example:

- Identify the symbolic notation for given elements.
- Apply the IUPAC rules of nomenclature to name given inorganic and organic compounds from their formulas.
- Analyze the chemical composition and basic structure of organic compounds (e.g., alkanes, alkenes, alkynes, common functional groups).
- Identify the chemical structures of biomolecules (e.g., nucleic acids, proteins, carbohydrates, lipids).
- Distinguish among structural, geometric, and optical isomers.

### **0010 Understand the mass relationships in chemical compounds.**

For example:

- Solve problems involving molecular and formula masses.
- Solve percent-composition problems.
- Determine empirical and molecular formulas.

### **0011 Understand chemical bonding and the effect of bond type on the properties of substances.**

For example:

- Demonstrate knowledge of the characteristics of various types of chemical bonding.
- Analyze electron behavior in the formation of bonds between atoms.
- Analyze factors that affect bond strength (e.g., electronegativity, electron affinity).
- Predict and interpret Lewis structures.
- Use the VSEPR and valence-bond theory to predict molecular geometry and molecular polarity.
- Predict properties of a substance based on type of atomic bond.

## Field 12: Chemistry Test Objectives

### 0012 Understand the connection between intramolecular bonding and intermolecular forces.

For example:

- Recognize the characteristics of different types of intermolecular forces (e.g., dispersion, dipole-dipole, hydrogen bonding, ion-dipole).
- Predict the kind of intermolecular force present between molecules of a given structure.
- Analyze factors that affect solubility.

## CHEMICAL REACTIONS AND SOLUTIONS [20%]

### 0013 Understand the types and characteristics of chemical reactions.

For example:

- Identify common types of inorganic and organic chemical reactions.
- Recognize chemical reactions in the home, in industrial processes, and in the environment (e.g., fermentation, leavening, acid rain, eutrophication).
- Predict the products of common types of inorganic and organic reactions (e.g., acid-base, precipitation, redox, substitution, elimination).
- Demonstrate knowledge of the principles and applications of acid-base titration and buffer systems.

### 0014 Understand the quantitative relationships expressed in chemical equations.

For example:

- Balance chemical reactions, including redox equations.
- Solve stoichiometric problems involving moles, mass, and volume, including problems with limiting reagents.
- Calculate the percent yield for given chemical reactions.
- Solve problems involving concentrations of solutions.
- Demonstrate knowledge of the mole concept and its use in chemical calculations.
- Determine the hydronium ion concentration and the pH and pOH for various acid, base, and salt solutions.

## Field 12: Chemistry Test Objectives

### **0015 Understand the factors that affect reaction rates and methods of measuring reaction rates.**

For example:

- Identify factors that influence reaction rates for inorganic, organic, and biochemical reactions.
- Relate experimental measurements to reaction rates and rate laws.
- Demonstrate knowledge of reaction mechanisms for simple reactions.
- Determine order of reactions and rate constants.

### **THERMODYNAMICS [20%]**

### **0016 Understand the principles of thermodynamics and calorimetry.**

For example:

- Demonstrate knowledge of the three laws of thermodynamics and their applications to chemical and biochemical systems.
- Differentiate among different forms of energy and between heat and temperature.
- Solve problems involving specific heat.
- Analyze the results of calorimetry experiments.

### **0017 Understand the energy relationships in chemical bonding and chemical reactions.**

For example:

- Analyze energy changes due to the formation of or breaking of chemical bonds.
- Solve problems involving energy changes during chemical reactions.
- Predict the spontaneity of a given reaction based on the free energy change and analyze the effect of enthalpy changes, entropy changes, or temperature changes on spontaneity.
- Interpret potential energy diagrams of chemical reactions.

## Field 12: Chemistry Test Objectives

### 0018 Understand the principles of chemical equilibrium.

For example:

- Recognize the dynamic nature of equilibrium and how it relates to concentration, pressure, temperature, and catalysts.
- Apply Le Chatelier's principle to chemical systems.
- Solve problems involving equilibrium constants.
- Compare equilibrium constant values with reaction quotient values to predict the direction a reaction will proceed to reach equilibrium.
- Recognize how the extent of a reaction relates to the equilibrium constant.
- Analyze buffer problems qualitatively and quantitatively.

### 0019 Understand the properties of solutions as they relate to equilibrium.

For example:

- Analyze the colligative properties of solutions.
- Analyze how temperature and pressure affect solubility.
- Interpret solubility curves.

### 0020 Understand electrochemistry.

For example:

- Predict whether a given redox reaction will occur based on standard reduction potentials.
- Calculate voltage under nonstandard conditions.
- Analyze the components (e.g., anode, cathode) and operating principles of voltaic and electrolytic cells.
- Demonstrate qualitative and quantitative understanding of the relationships between the equilibrium constant, Gibbs free energy, and voltage.

**Field 12: Chemistry  
Test Objectives**

**INTEGRATION OF KNOWLEDGE AND UNDERSTANDING [20%]**

*In addition to answering multiple-choice items, candidates will prepare written responses to questions addressing content summarized in the objective below.*

**0021 Prepare an organized, developed analysis on a topic related to one or more of the following subareas: Nature of Science and Properties of Matter, Atomic Structure and Chemical Bonding, Chemical Reactions and Solutions, and Thermodynamics.**

(Refer to objectives 0001 through 0020 and associated descriptive statements.)