California Subject Examinations for Teachers®

TEST GUIDE

SCIENCE SUBTEST III: CHEMISTRY

Subtest Description

This document contains the Chemistry subject matter requirements arranged according to the domains covered by Subtest III: Chemistry of CSET: Science. In parentheses after each named domain is the CCTC-assigned domain code from the Chemistry subject matter requirements.

CS-TG-SD121X-01

California Subject Examinations for Teachers (CSET®)

Science
Subtest III: Chemistry

Part I: Content Domains for Subject Matter Understanding and Skill in Chemistry

ATOMIC AND MOLECULAR STRUCTURE (SMR Domain 1)

Candidates demonstrate an understanding of atomic and molecular structure as contained in the Science Content Standards for California Public Schools (1998) and outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of atomic and molecular structure, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate understanding of how periodicity of physical and chemical properties of the elements relates to atomic structure. They base this on a demonstrated understanding of current models of atomic, molecular, and subatomic structure.

0001 Periodic Table and Periodicity (SMR 1.1)

a. Differentiate periodic groups and families of elements and their properties
b. Relate valence electrons and the electron shell structure (s, p, d, f orbitals) to an element's position in the periodic table
c. Predict periodic trends including electronegativity, ionization energy, and the relative sizes of ions and atoms

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 1c-d, 1f-g)

0002 Atomic Structure (SMR 1.2)

a. Analyze the evolution of the atomic model (including, but not limited to, the historical importance of the Bohr model and the development of the quantum structure of the atom)
b. Relate atomic spectroscopy and the photoelectric effect to the quantum structure of the atom
c. Illustrate the position and describe the properties of quarks, protons, neutrons, and electrons within atoms

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: h-j, 11g)

0003 Molecular Structure and Chemical Bonds (SMR 1.3)

a. Compare types of molecular bonds including ionic, covalent and hydrogen bonds
b. Draw Lewis dot structures for compounds and ions
c. Predict molecular geometries using Lewis dot structures and hybridized atomic orbitals, e.g., valence shell electron pair repulsion model (VSEPR)
d. Relate intermolecular electrostatic forces, including Van der Waals, polar and induced polar, and ionic, to their expected states of matter and their characteristic physical properties

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 2a-h)

CHEMICAL REACTIONS (SMR Domain 2)

Candidates demonstrate an understanding of the foundations of chemical reactions as contained in the Science Content Standards for California Public Schools (1998) and outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of chemical reactions and their underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate an understanding of the principles that underlie the conditions governing chemical reactions. They apply the principle of conservation of matter and are able to quantify the mass of products and reactants. Candidates understand that chemical reaction rates depend on factors that affect the frequency of collisions and reactivities of reactant molecules. They explain and predict the behavior of chemical systems by applying the principle of chemical equilibrium as a dynamic process at the molecular level.

0004 Conservation of Matter and Stoichiometry (SMR 2.1)

a. Calculate molar mass, mass, number of particles, and volume, at standard temperature and pressure (STP) for elements and compounds
b. Calculate the masses of reactants and products, and percent yield using balanced chemical equations, including problems with a limiting reagent
c. Distinguish reaction types, including single replacement, double replacement, synthesis, decomposition, and combustion
d. Utilize the rules of oxidation states to balance oxidation-reduction reactions

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 3a-g)

0005 Reaction Rates and Chemical Equilibrium (SMR 2.2)

a. Predict the effect of temperature, pressure, and concentration on chemical equilibrium (LeChatelier's principle) and the reaction rate
b. Interpret a diagram showing activation energy along the reaction pathway
c. Identify and predict the role of catalysts on the reaction rate

d. Write and calculate an equilibrium constant expression for a given reaction
e. Know that equilibrium is established when the reaction rates of the forward and reverse reactions are equal

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 8a-d, 9a-c)

KINETIC MOLECULAR THEORY (SMR Domain 3)

Candidates demonstrate an understanding of the foundations of the kinetic molecular theory contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of kinetic molecular theory and its underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates understand kinetic molecular theory and use it to generate a description of the motion of atoms and molecules. They use kinetic molecular theory to explain and predict the properties and behaviors of gases.

0006 Gases and Their Properties (SMR 3.1)

a. Solve problems using the ideal gas law and use the ideal gas law to predict pressure-volume, pressure-temperature, and volume-temperature relationships
b. Relate pressure, volume, and temperature to the kinetic theory of atoms and molecules in gases
c. Know and use STP to solve gas law problems
d. Convert between Kelvin and Celsius temperature scales
e. Recognize the significance of absolute zero
f. Solve problems using Dalton's law of partial pressures and Graham's Laws of diffusion

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 4a-i)

SOLUTION CHEMISTRY (SMR Domain 4)

Candidates demonstrate an understanding of the foundations of the solution chemistry contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of solution chemistry and its underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates predict and explain the properties and behaviors of acids, bases, and salts in solution. They explain the properties of various solutions.

0007 Solutions (SMR 4.1)

a. Recognize and identify solutes and solvents
b. Calculate concentration in terms of molarity, parts per million, and percent composition

c. Describe the dissolving process at the molecular level
d. Explain how factors such as temperature, pressure, and surface area affect the dissolving process
e. Describe various methods for separation of solutions (e.g., chromatography, distillation)

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 6a-d, 6f)

0008 Acids and Bases (SMR 4.2)

a. Distinguish between strong and weak acids and bases based on degree of dissociation and their chemical properties
b. Calculate pH and hydrogen ion concentration in solutions including buffer solutions
c. Use Arrhenius, Brønsted-Lowry, and Lewis acid-base definitions appropriately to characterize acids and bases and in acid-base reactions

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 5a-g)

CHEMICAL THERMODYNAMICS (SMR Domain 5)

Candidates demonstrate an understanding of the foundations of the chemical thermodynamics contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of chemical thermodynamics and its underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate by solving problems an understanding that energy is exchanged or transformed in all chemical reactions and physical changes of matter. They apply the concepts of thermodynamic properties of materials such as specific heat, heats of fusion, heats of vaporization, and heat of reaction (enthalpy).

0009 Chemical Thermodynamics (SMR 5.1)

a. Perform calculations using specific heat, heats of fusion, heats of vaporization, and heat of reaction (enthalpy)
b. Interpret phase diagrams

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 7b, 7e)

ORGANIC CHEMISTRY AND BIOCHEMISTRY (SMR Domain 6)

Candidates demonstrate an understanding of the foundations of the organic chemistry and biochemistry contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of organic chemistry and biochemistry and their underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates demonstrate understanding that the bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties, and provide the biochemical basis of life.

0010 Organic Chemistry and Biochemistry (SMR 6.1)

a. Explain the bonding characteristics of carbon
b. Recognize the chemical structure of various organic functional groups (i.e., alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids) and provide examples of reactions involving these groups
c. Inventory the ten simplest hydrocarbons that contain single bonds, multiple bonds, and benzene rings
d. Understand the differences in structures and properties between amino acids and their polymers and between sugars and their polymers

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 10b-f)

NUCLEAR PROCESSES (SMR Domain 7)

Candidates demonstrate an understanding of the foundations of the nuclear processes contained in the Science Content Standards for California Public Schools (1998) as outlined in the Science Framework for California Public Schools: Kindergarten Through Grade Twelve (2002) from an advanced standpoint. To ensure a rigorous view of nuclear processes and their underlying structures, candidates have a deep conceptual knowledge of the subject matter. Candidates explain nuclear processes including the radioactive decay of naturally occurring and human-made isotopes, nuclear fission, and nuclear fusion (e.g., stellar nucleosynthesis and synthesis of transuranium elements). They apply understanding of these processes to discuss the benefits and hazards of the use of radiation and radioactivity.

0011 Nuclear Processes (SMR 7.1)

a. Understand how mass-energy relationships in nuclear reactions and radioactive decay requires the relationship $E=mc^2$
b. Compare and contrast alpha, beta, and gamma decay, and the relative kinds of damage to matter caused by α-, β-, and γ- rays

c. Perform calculations involving half-life
d. Contrast the benefits and hazards of the use of radiation and radioactivity

(Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 11b, 11d-f; Investigation and Experimentation: 1m)

Part II: Subject Matter Skills and Abilities Applicable to the Content Domains in Science

Domain 1. Investigation and Experimentation

Candidates for Single Subject Teaching Credentials in Science formulate and conduct scientific investigations. They select appropriate scientific tools, make relevant measurements of changes in natural phenomena, and present unbiased findings in logical and meaningful formats using charts, maps, tables, models, graphs, and labeled diagrams. Candidates apply mathematics to scientific investigations and experimentation(s) for the purpose of quantifying results and drawing conclusions. Candidates interpret experimental results and determine whether further information is necessary to formulate accurate conclusions. They communicate results through various methods, and use technology where appropriate.

1.1 Question Formulation

a. Formulate and evaluate a viable hypothesis
b. Recognize the value and role of observation prior to question formulation
c. Recognize the iterative nature of questioning
d. Given an experimental design, identify possible hypotheses that it may test

(Science Content Standards for California Public Schools, Grade 6: 7a)

1.2 Planning a Scientific Investigation (including Experimental Design)

a. Given a hypothesis, formulate an investigation or experimental design to test that hypothesis
b. Evaluate an experimental design for its suitability to test a given hypothesis
c. Distinguish between variable and controlled parameters

(Science Content Standards for California Public Schools, Grade 5: 6c-d; Grade 8: 9a, 9c)

1.3 Observation and Data Collection

a. Identify changes in natural phenomena over time without manipulating the phenomena (e.g., a tree limb, a grove of trees, a stream, a hill slope)
b. Analyze the locations, sequences, and time intervals that are characteristic of natural phenomena (e.g., locations of planets over time, succession of species in an ecosystem)

c. Select and use appropriate tools and technology (e.g., computer-linked probes, spreadsheets, graphing calculators) to perform tests, collect data, analyze relationships, and display data
d. Evaluate the precision, accuracy, and reproducibility of data
e. Identify and analyze possible reasons for inconsistent results, such as sources of error or uncontrolled conditions
f. Identify and communicate sources of unavoidable experimental error
g. Recognize the issues of statistical variability and explain the need for controlled tests
h. Know and evaluate the safety issues when designing an experiment and implement appropriate solutions to safety problems
i. Appropriately employ a variety of print and electronic resources (e.g., the World Wide Web) to collect information and evidence as part of a research project
j. Assess the accuracy validity and reliability of information gathered from a variety of sources

(Science Content Standards for California Public Schools, Grade 3: 5a; Grade 6: 7a-b, 7g-h; Grade 7: 7a-b; Grade 8: 9b; Grades 9-12, Investigation and Experimentation: 1a-c, 1i-j, 1m)

1.4 Data Analysis/Graphing

a. Construct appropriate graphs from data and develop qualitative and quantitative statements about relationships between variables
b. Recognize the slope of the linear graph as the constant in the relationship y=kx and apply this principle in interpreting graphs constructed from data
c. Apply simple mathematical relationships to determine a missing quantity in an algebraic expression, given the two remaining terms (e.g., speed = distance/time, density = mass/volume, force = pressure x area, volume = area x height)
d. Determine whether a relationship on a given graph is linear or non-linear and determine the appropriateness of extrapolating the data
e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions

(Science Content Standards for California Public Schools, Grade 6: 7c; Grade 8: 9d-g; Grades 9-12, Investigation and Experimentation: 1e)

1.5 Drawing Conclusions and Communicating Explanations

a. Draw appropriate and logical conclusions from data
b. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence
c. Communicate the steps and results of an investigation in written reports and oral presentations
d. Recognize whether evidence is consistent with a proposed explanation
e. Construct appropriate visual representations of scientific phenomenon and processes (e.g., motion of Earth's plates, cell structure)

f. Read topographic and geologic maps for evidence provided on the maps and construct and interpret a simple scale map

(Science Content Standards for California Public Schools, Grade 5: 6g; Grade 6: 7e-f; Grade 7: 7c-e; Grade 8: 9a; Grades 9-12, Investigation and Experimentation: 1d, 1h)

Domain 2. Nature of Science

Candidates recognize that science is an active endeavor in which acquisition of knowledge is based upon the collection and examination of data. Candidates understand that scientists have a responsibility to report fully and openly the methods and results of their observations and experiments, even if those results disagree with their favored hypotheses or are controversial in public opinion. They understand that to hide data, arbitrarily eliminate data, or conceal how an experiment was conducted is to invite errors, make those errors difficult to discover, and risk harm to colleagues and communities. They understand that scientists carefully consider questions and challenges raised by fellow scientists about the assumptions, procedures, and accuracy of their experiments. They understand that a fundamental aspect of scientific inquiry is that it is dynamic and self-correcting by design. Conclusions, hypotheses, and theories are tested in every experiment and revised or rejected when they no longer correctly or accurately predict experimental results. Candidates understand that scientists must consider the safety, ethical concerns, risks, and costs and benefits of experiments to society.

2.1 Scientific Inquiry

a. Distinguish among the terms hypothesis, theory, and prediction as used in scientific investigations
b. Evaluate the usefulness, limitations, and interdisciplinary and cumulative nature of scientific evidence as it relates to the development of models and theories as representations of reality
c. Recognize that when observations do not agree with an accepted scientific theory, either the observations are mistaken or fraudulent, or the accepted theory is erroneous or incorrect
d. Understand that reproducibility of data is critical to the scientific endeavor
e. Recognize that science is a self-correcting process that eventually identifies misconceptions and experimental biases
h. Recognize that an inquiring mind is at the heart of the scientific method and that doing science involves thinking critically about the evidence presented, the usefulness of models, and the limitations of theories
i. Recognize that theories are judged by how well they explain observations and predict results and that when they represent new ideas that are counter to mainstream ideas they often encounter vigorous criticism
j. Recognize that when observations, data, or experimental results do not agree, the unexpected results are not necessarily mistakes; to discard the unusual in order to reach the expected is to guarantee that nothing but what is expected will ever be seen

k. Know why curiosity, honesty, openness, and skepticism are so highly regarded in science and how they are incorporated into the way science is carried out

(Science Content Standards for California Public Schools, Grade 6: 7e; Grades 9-12, Investigation and Experimentation: 1f-g, 1n)

2.2 Scientific Ethics

a. Understand that honesty is at the core of scientific ethics; first and foremost is the honest and accurate reporting of procedures used and data collected
b. Know that all scientists are obligated to evaluate the safety of an investigation and ensure the safety of those performing the experiment
c. Know the procedures for respectful treatment of all living organisms in experimentation and other investigations

2.3 Historical Perspectives

a. Discuss the cumulative nature of scientific evidence as it relates to the development of models and theories
b. Recognize that as knowledge in science evolves, when observations do not support an accepted scientific theory, the observations are reconsidered to determine if they are mistaken or fraudulent, or if the accepted theory is erroneous or incomplete (e.g., an erroneous theory is the Piltdown Man fossil; an incomplete theory is Newton's laws of gravity)
c. Recognize and provide specific examples that scientific advances sometimes result in profound paradigm shifts in scientific theories
d. Discuss the need for clear and understandable communication of scientific endeavors so that they may be reproduced and why reproduction of these endeavors is important

(Science Content Standards for California Public Schools, Grade 6: 7d; Grade 7: 7c, 7e; Grades 9-12, Investigation and Experimentation: 1k, 1n)

Domain 3. Science and Society

Candidates understand that science relies on basic human qualities such as reasoning, insight, curiosity, skill, and creativity – as well as on scientific habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. Candidates recognize their responsibility to increase scientific literacy so that the general population can understand current issues and appreciate their personal roles and responsibilities. Candidates know about possible hazards and take precautions that are the basis for creating a safe learning environment that benefits all students. They are familiar with established rules and guidelines that intend to ensure the safety of students and to protect the subjects and environments studied. Candidates understand that technology is the application of proven scientific knowledge for practical purposes serving human needs; however, science and technology are interrelated—one often propels the other.

3.1 Science Literacy

a. Recognize that science attempts to make sense of how the natural and the designed world function
b. Demonstrate the ability to apply critical and independent thinking to weigh alternative explanations of events
c. Apply evidence, numbers, patterns, and logical arguments to solve problems
d. Understand that, although much has been learned about the objects, events and phenomena in nature, there are many unanswered questions, i.e., science is a work in progress
e. Know that the ability of science and technology to resolve societal problems depends on the scientific literacy of a society

3.2 Diversity

a. Identify examples of women and men of various social and ethnic backgrounds with diverse interests, talents, qualities and motivations who are, or who have been, engaged in activities of science and related fields

3.3 Science, Technology, and Society

a. Identify and evaluate the impact of scientific advances on society
b. Recognize that scientific advances may challenge individuals to reevaluate their personal beliefs

(Science Content Standards for California Public Schools, Grades 9-12, Investigation and Experimentation: 1m, 1n)

3.4 Safety

a. Choose appropriate safety equipment for a given activity (e.g., goggles, apron, vented hood)
b. Discuss the safe use, storage, and disposal of commonly used chemicals and biological specimens
c. Assess the safety conditions needed to maintain a science laboratory (e.g., eye wash, shower, fire extinguisher)
d. Read and decode MSDS/OSHA (Material Safety Data Sheet/Occupational Safety and Health Administration) labels on laboratory supplies and equipment
e. Discuss key issues in the disposal of hazardous materials in either the laboratory or the local community
f. Be familiar with standard safety procedures such as those outlined in the Science Safety Handbook for California Schools (1999)