ILLINOIS LICENSURE TESTING SYSTEM

FIELD 106 SCIENCE: CHEMISTRY

TEST FRAMEWORK

November 2003

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Science and Technology
Life Science
Physical Science
Earth Systems and the Universe
Matter, Structure, and Practical Knowledge
Stoichiometry and Chemical Reactions

SUBAREA I—SCIENCE AND TECHNOLOGY

0001 Understand and apply knowledge of science as inquiry.

- Recognize the assumptions, processes, purposes, requirements, and tools of scientific inquiry.
- Use evidence and logic in developing proposed explanations that address scientific questions and hypotheses.
- Identify various approaches to conducting scientific investigations and their applications.
- Use tools and mathematical and statistical methods for collecting, managing, analyzing (e.g., average, curve fit, error determination), and communicating results of investigations.
- Demonstrate knowledge of ways to report, display, and defend the results of an investigation.

0002 Understand and apply knowledge of the concepts, principles, and processes of technological design.

- Recognize the capabilities, limitations, and implications of technology and technological design and redesign.
- Identify real-world problems or needs to be solved through technological design.
- Apply a technological design process to a given problem situation.
- Identify a design problem and propose possible solutions, considering such constraints as tools, materials, time, costs, and laws of nature.
- Evaluate various solutions to a design problem.

0003 Understand and apply knowledge of accepted practices of science.

- Demonstrate an understanding of the nature of science (e.g., tentative, replicable, historical, empirical) and recognize how scientific knowledge and explanations change over time.
- Compare scientific hypotheses, predictions, laws, theories, and principles and recognize how they are developed and tested.
- Recognize examples of valid and biased thinking in reporting of scientific research.
- Recognize the basis for and application of safety practices and regulations in the study of science.

0004 Understand and apply knowledge of the interactions among science, technology, and society.

- Recognize the historical and contemporary development of major scientific ideas and technological innovations.
- Demonstrate an understanding of the ways that science and technology affect people's everyday lives, societal values and systems, the environment, and new knowledge.
- Analyze the processes of scientific and technological breakthroughs and their effects on other fields of study, careers, and job markets.
- Analyze issues related to science and technology at the local, state, national, and global levels (e.g., environmental policies, genetic research).
- Evaluate the credibility of scientific claims made in various forums (e.g., the media, public debates, advertising).

0005 Understand and apply knowledge of the major unifying concepts of all sciences and how these concepts relate to other disciplines.

- Identify the major unifying concepts of the sciences (e.g., systems, order, and organization; constancy, change, and measurement) and their applications in real-life situations.
- Recognize connections within and among the traditional scientific disciplines.
- Apply fundamental mathematical language, knowledge, and skills at the level of algebra and statistics in scientific contexts.
- Recognize the fundamental relationships among the natural sciences and the social sciences.

SUBAREA II—LIFE SCIENCE

0006 Understand and apply knowledge of cell structure and function.

- Compare and contrast the structures of viruses and prokaryotic and eukaryotic cells.
- Identify the structures and functions of cellular organelles.
- Describe the processes of the cell cycle.
- Explain the functions and applications of the instruments and technologies used to study the life sciences at the molecular and cellular levels.

0007 Understand and apply knowledge of the principles of heredity and biological evolution.

- Recognize the nature and function of the gene, with emphasis on the molecular basis of inheritance and gene expression.
- Analyze the transmission of genetic information (e.g., Punnett squares, sex-linked traits, pedigree analysis).
- Analyze the processes of change at the microscopic and macroscopic levels.
- Identify scientific evidence from various sources, such as the fossil record, comparative anatomy, and biochemical similarities, to demonstrate knowledge of theories about processes of biological evolution.

0008 Understand and apply knowledge of the characteristics and life functions of organisms.

- Identify the levels of organization of various types of organisms and the structures and functions of cells, tissues, organs, and organ systems.
- Analyze the strategies and adaptations used by organisms to obtain the basic requirements of life.
- Analyze factors (e.g., physiological, behavioral) that influence homeostasis within an organism.
- Demonstrate an understanding of the human as a living organism with life functions comparable to those of other life forms.

0009 Understand and apply knowledge of how organisms interact with each other and with their environment.

- Identify living and nonliving components of the environment and how they interact with one another.
- Recognize the concepts of populations, communities, ecosystems, and ecoregions and the role of biodiversity in living systems.
- Analyze factors (e.g., ecological, behavioral) that influence interrelationships among organisms.
- Develop a model or explanation that shows the relationships among organisms in the environment (e.g., food web, food chain, ecological pyramid).
- Recognize the dynamic nature of the environment, including how communities, ecosystems, and ecoregions change over time.
- Analyze interactions of humans with their environment.
- Explain the functions and applications of the instruments and technologies used to study the life sciences at the organism and ecosystem levels.

SUBAREA III—PHYSICAL SCIENCE

0010 Understand and apply knowledge of the nature and properties of energy in its various forms.

- Describe the characteristics of and relationships among thermal, acoustical, radiant, electrical, chemical, mechanical, and nuclear energies through conceptual questions.
- Analyze the processes by which energy is exchanged or transformed through conceptual questions.
- Apply the three laws of thermodynamics to explain energy transformations, including basic algebraic problem solving.
- Apply the principle of conservation as it applies to energy through conceptual questions and solving basic algebraic problems.

0011 Understand and apply knowledge of the structure and properties of matter.

- Describe the nuclear and atomic structure of matter, including the three basic parts of the atom.
- Analyze the properties of materials in relation to their chemical or physical structures (e.g., periodic table trends, relationships, and properties) and evaluate uses of the materials based on their properties.
- Apply the principle of conservation as it applies to mass and charge through conceptual questions.
- Analyze bonding and chemical, atomic, and nuclear reactions (including endothermic and exothermic reactions) in natural and man-made systems and apply basic stoichiometric principles.
- Apply kinetic theory to explain interactions of energy with matter, including conceptual questions on changes in state.
- Explain the functions and applications of the instruments and technologies used to study matter and energy.

0012 Understand and apply knowledge of forces and motion.

- Demonstrate an understanding of the concepts and interrelationships of position, time, velocity, and acceleration through conceptual questions, algebra-based kinematics, and graphical analysis.
- Demonstrate an understanding of the concepts and interrelationships of force (including gravity and friction), inertia, work, power, energy, and momentum.
- Describe and predict the motions of bodies in one and two dimensions in inertial and accelerated frames of reference in a physical system, including projectile motion but excluding circular motion.
- Analyze and predict motions and interactions of bodies involving forces within the context of conservation of energy and/or momentum through conceptual questions and algebra-based problem solving.
- Describe the effects of gravitational and nuclear forces in real-life situations through conceptual questions.
- Explain the functions and applications of the instruments and technologies used to study force and motion in everyday life.

0013 Understand and apply knowledge of electricity, magnetism, and waves.

- Recognize the nature and properties of electricity and magnetism, including static charge, moving charge, basic RC circuits, fields, conductors, and insulators.
- Recognize the nature and properties of mechanical and electromagnetic waves (e.g., frequency, source, medium, spectrum, wave-particle duality).
- Describe the effects and applications of electromagnetic forces in real-life situations, including electric power generation, circuit breakers, and brownouts.
- Analyze and predict the behavior of mechanical and electromagnetic waves under varying physical conditions, including basic optics, color, ray diagrams, and shadows.

SUBAREA IV—EARTH SYSTEMS AND THE UNIVERSE

0014 Understand and apply knowledge of Earth's land, water, and atmospheric systems and the history of Earth.

- Identify the structure and composition of Earth's land, water, and atmospheric systems and how they affect weather, erosion, fresh water, and soil.
- Recognize the scope of geologic time and the continuing physical changes of Earth through time.
- Evaluate scientific theories about Earth's origin and history and how these theories explain contemporary living systems.
- Recognize the interrelationships between living organisms and Earth's resources and evaluate the uses of Earth's resources.

0015 Understand and apply knowledge of the dynamic nature of Earth.

- Analyze and explain large-scale dynamic forces, events, and processes that affect Earth's land, water, and atmospheric systems, including conceptual questions about plate tectonics, El Niño, drought, and climatic shifts.
- Identify and explain Earth processes and cycles and cite examples in real-life situations, including conceptual questions on rock cycles, volcanism, and plate tectonics.
- Analyze the transfer of energy within and among Earth's land, water, and atmospheric systems, including the identification of energy sources of volcanoes, hurricanes, thunderstorms, and tornadoes.
- Explain the functions and applications of the instruments and technologies used to study the earth sciences, including seismographs, barometers, and satellite systems.

0016 Understand and apply knowledge of objects in the universe and their dynamic interactions.

- Describe and explain the relative and apparent motions of the sun, the moon, stars, and planets in the sky.
- Recognize properties of objects (e.g., comets, asteroids) within the solar system and their dynamic interactions.
- Recognize the types, properties, and dynamics of objects external to the solar system (e.g., black holes, supernovas, galaxies).

0017 Understand and apply knowledge of the origins of and changes in the universe.

- Identify scientific theories dealing with the origin of the universe (e.g., big bang).
- Analyze evidence relating to the origin and physical evolution of the universe (e.g., microwave background radiation, expansion).
- Compare the physical and chemical processes involved in the life cycles of objects within galaxies.
- Explain the functions and applications of the instruments, technologies, and tools used in the study of the space sciences, including the relative advantages and disadvantages of Earth-based versus space-based instruments and optical versus nonoptical instruments.

SUBAREA V—MATTER, STRUCTURE, AND PRACTICAL KNOWLEDGE

0018 Understand and apply knowledge of basic scientific and mathematical skills, safe laboratory practices, and issues of public concern related to the field of chemistry.

- Apply appropriate mathematical skills (e.g., algebraic operations, graphing, statistics, scientific notation) and technology to collect, analyze, and report data and to solve problems in chemistry.
- Select appropriate experimental procedures and equipment for the measurement and determination of chemical reactions and properties.
- Recognize safety practices in the chemistry laboratory, including the characteristics and purposes of chemical hygiene plans.
- Evaluate the role of chemistry in daily life, including ways in which basic research and the development of new technology affect society.

0019 Understand and apply knowledge of periodic relationships and the nature of matter.

- Demonstrate knowledge of the chemical constitution of matter as elements, compounds, and mixtures.
- Distinguish between physical and chemical changes.
- Demonstrate knowledge of basic techniques used to separate substances based on differences in properties.
- Analyze the periodic nature of the elements and the relationship between their electron configuration and the periodic table.
- Connect the chemical and physical properties of elements to electron configuration.
- Demonstrate proficiency at naming compounds and writing formulas.

0020 Understand and apply knowledge of the development and central concepts of atomic theory and structure, including the quantum mechanical model.

- Recognize the central concepts of atomic theory and atomic structure.
- Demonstrate knowledge of the historical progression in the development of the theory of the atom, including the contributions of Dalton, Thomson, Rutherford, and Bohr.
- Describe the energy of an electron in an atom or ion in terms of the four quantum numbers.
- Demonstrate a qualitative knowledge of the role of probability in the description of an orbital's size and shape.
- Analyze the properties of an atomic nucleus that affect its stability.
- Apply strategies for writing and balancing equations for nuclear reactions (e.g., fission, fusion, radioactivity and bombardment).

0021 Understand and apply knowledge of the formation of bonds and the geometry and properties of the resulting compounds.

- Analyze electron behavior in the formation of various types of bonds (e.g., ionic, covalent) and the polarity of compounds in terms of shape and electronegativity differences.
- Apply the concepts of Lewis structures, valence-shell electron-pair repulsion, and hybridization to describe molecular geometry and bonding.
- Demonstrate knowledge of the general features and properties of compounds of metals, nonmetals, and transition elements and the materials derived from them.
- Describe the hybridization of the central atom based on the geometry of coordination compounds.

0022 Understand and apply knowledge of the kinetic molecular theory and the nature and properties of molecules in the gaseous, liquid, and solid states.

- Demonstrate knowledge of the basic principles of the kinetic molecular theory.
- Explain the properties of solids, liquids, and gases and changes of state in terms of the kinetic molecular theory and intermolecular forces.
- Apply various laws related to the properties and behavior of ideal gases (e.g., combined gas laws, ideal gas law, Dalton's law of partial pressures, Graham's law of diffusion) to solve problems.
- Demonstrate an understanding of the differences between real and ideal gases.
- Interpret phase diagrams and use them to explain the transitions between solids, liquids, and gases.
- Classify unknown solids as molecular, metallic, ionic, and covalent network solids according to their physical and chemical properties.

0023 Understand and apply knowledge of the interactions of particles in solution and the properties of solutions.

- Describe the solution process, including the effects of temperature and pressure on the solubility of solids, liquids, and gases.
- Analyze the qualitative colligative properties of solutions, including the practical applications of these properties to technological problems.
- Demonstrate knowledge of how to prepare solutions of specific concentrations, including molality, molarity, normality, mole fraction, and percent by weight.
- Select appropriate solvents for the dissolution or purification of solid compounds.

SUBAREA VI—STOICHIOMETRY AND CHEMICAL REACTIONS

0024 Understand and apply knowledge of the concepts and principles of chemical equations and stoichiometry.

- Classify types of chemical reactions and balance equations to describe chemical reactions.
- Use mass and mole relationships in an equation to solve stoichiometric problems (including percent yield and limiting reactants).
- Use gas laws and solution concentrations to solve stoichiometric problems (including percent yield and limiting reactants).
- Demonstrate proficiency at converting between percent composition and the formulas of compounds (including both empirical and molecular formulas).

0025 Understand and apply knowledge of the concepts and principles of acid-base chemistry.

- Compare the Arrhenius, Brønsted-Lowry, and Lewis concepts of acids and bases.
- Recognize the relationship between acid and base strength, pH, and molecular structure.
- Explain the characteristics of buffered solutions in terms of chemical equilibrium of weak acids.
- Demonstrate an understanding of how to prepare a standardized solution or a buffer of a specified pH, given the Ka of various acids and a standardized NaOH solution.
- Design and analyze the results of an acid-base titration (which may include selecting an appropriate indicator or interpreting a titration curve).

0026 Understand and apply knowledge of thermodynamics and their applications to chemical systems.

- Recognize the relationships among enthalpy, entropy, Gibbs free energy, and the equilibrium constant.
- Evaluate the thermodynamic feasibility of various reactions and calculate energy changes during chemical reactions.
- Analyze the thermodynamics and kinetic dynamics that move a reversible reaction to a position of chemical equilibrium.
- Apply Le Chatelier's principle to analyze reversible reactions.

0027 Understand and apply knowledge of electrochemistry.

- Demonstrate an understanding of oxidation/reduction reactions and their relationship to standard reduction potentials.
- Demonstrate an understanding of electrolysis reactions.
- Balance redox reactions.
- Demonstrate knowledge of devising and building electrochemical cells.

0028 Understand and apply knowledge of the mechanisms of chemical reactions and the theory and practical applications of reaction rates.

- Recognize the basics of collision and transition-state theories and the significance of the Arrhenius equation.
- Explain how various factors (e.g., temperature, catalysts) influence reaction rates.
- Analyze experimental data involving reaction rates, concentration, and/or time to determine kinetic parameters (e.g., reaction order, rate constants, activation energy).
- Demonstrate an understanding of the relationship of rate laws to reaction mechanisms.

0029 Understand and apply knowledge of major aspects of organic chemistry.

- Identify the functional group classification and nomenclature of organic compounds and the general characteristics and reactions of each group.
- Demonstrate an understanding of the concepts and mechanisms of substitution, addition, elimination, and other reactions of organic molecules.
- Demonstrate knowledge of appropriate separation, purification, and identification schemes for organic molecules (e.g., chromatography, spectroscopy).
- Recognize the general structure, properties, and uses of organic polymers, pharmaceuticals, pesticides, and other practical products.
- Demonstrate an understanding of the structure, properties, and function of common biological molecules (carbohydrates, lipids, proteins, and nucleic acids) and how these biomolecules are involved in life processes.
- Recognize the general features of three-dimensional structures, bonding, molecular properties, and reactivity of organic molecules.