Texas
Educator Certification
Examination Program

Preparation Manual
Physical Science 6–12 (237)

Overview and Exam Framework

Reference Materials

Sample Selected-Response Questions

Sample Selected-Response Answers and Rationales

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Section 3: Overview and Exam Framework Physical Science 6–12 (237)

Exam Overview

Exam Name	**Physical Science 6–12**
Exam Code	237
Time	5 hours
Number of Questions	100 selected-response questions
Format	Computer-administered test (CAT)

The TExES Physical Science 6–12 (237) exam is designed to assess whether an examinee has the requisite knowledge and skills that an entry-level educator in this field in Texas public schools must possess. The 100 selected-response questions are based on the Physical Science 6–12 exam framework. Questions on this exam range from grades 6–12. Your final scaled score will be based only on scored questions.

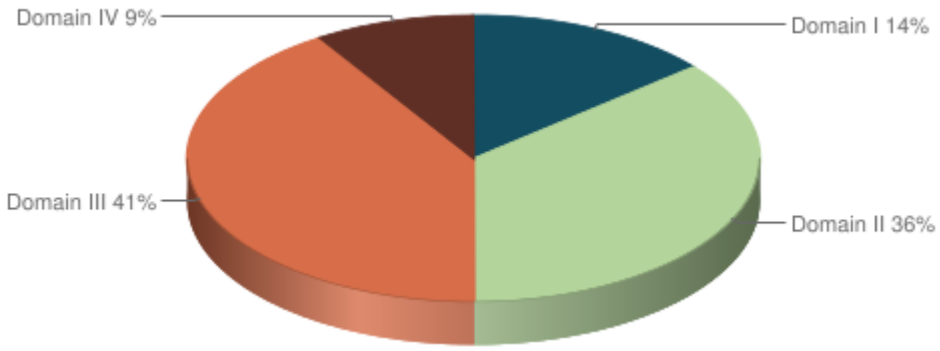
The Standards

Standard I	The science teacher manages classroom, field and laboratory activities to ensure the safety of all students and the ethical care and treatment of organisms and specimens.
Standard II	The science teacher understands the correct use of tools, materials, equipment and technologies.
Standard III	The science teacher understands the process of scientific inquiry and its role in science instruction.
Standard IV	The science teacher has theoretical and practical knowledge about teaching science and about how students learn science.
Standard V	The science teacher knows the varied and appropriate assessments and assessment practices to monitor science learning.
Standard VI	The science teacher understands the history and nature of science.
Standard VII	The science teacher understands how science affects the daily lives of students and how science interacts with and influences personal and societal decisions.

Standard VIII	The science teacher knows and understands the science content appropriate to teach the statewide curriculum (Texas Essential Knowledge and Skills [TEKS]) in physical science.
Standard XI	The science teacher knows unifying concepts and processes that are common to all sciences.

Domains and Competencies

Domain	Domain Title	Approx. Percentage of Exam	Standards Assessed
I	Scientific Inquiry and Processes	14%	Physical Science 6–12 I–III, VI–VII, XI
II	Physics	36%	Physical Science 6–12 VIII
III	Chemistry	41%	Physical Science 6–12 VIII
IV	Science Learning, Instruction and Assessment	9%	Physical Science 6–12 IV–V



The content covered by this exam is organized into broad areas of content called **domains**. Each domain covers one or more of the educator standards for this field. Within each domain, the content is further defined by a set of **competencies**. Each competency is composed of two major parts:

- The **competency statement**, which broadly defines what an entry-level educator in this field in Texas public schools should know and be able to do.
- The **descriptive statements**, which describe in greater detail the knowledge and skills eligible for testing.

Domain I—Scientific Inquiry and Processes

Competency 001—The teacher understands how to select and manage learning activities to ensure the safety of all students and the correct use and care of organisms, natural resources, materials, equipment and technologies.

The beginning teacher:

A. Uses current sources of information about laboratory safety, including safety regulations and guidelines for the use of science facilities.

B. Recognizes potential safety hazards in the laboratory and in the field and knows how to apply procedures, including basic first aid, for responding to accidents.

C. Employs safe practices in planning, implementing and managing all instructional activities and designs and implements rules and procedures to maintain a safe learning environment.

D. Understands procedures for selecting, maintaining and safely using chemicals, tools, technologies, materials, specimens and equipment, including procedures for the recycling, reuse and conservation of laboratory resources and for the safe handling and ethical treatment of organisms.

E. Knows how to use appropriate equipment and technology (e.g., Internet, spreadsheet, calculator) for gathering, organizing, displaying and communicating data in a variety of ways (e.g., charts, tables, graphs, diagrams, maps, satellite images, written reports, oral presentations).

F. Understands how to use a variety of tools, techniques and technology to gather, organize and analyze data; how to perform calculations; and how to apply appropriate methods of statistical measures and analyses.

G. Knows how to apply techniques to calibrate measuring devices and understands concepts of precision, accuracy and error with regard to reading and recording numerical data from scientific instruments (e.g., significant figures).

H. Uses the International System of Units (i.e., metric system) and performs unit conversions within and across measurement systems.

Competency 002—The teacher understands the nature of science, the process of scientific inquiry and the unifying concepts that are common to all sciences.

The beginning teacher:

A. Understands the nature of science, the relationship between science and technology, the predictive power of science and limitations to the scope of science (i.e., the types of questions that science can and cannot answer).

B. Knows the characteristics of various types of scientific investigations (e.g., descriptive studies, controlled experiments, comparative data analysis) and how and why scientists use different types of scientific investigations.

C. Understands principles and procedures for designing and conducting a variety of scientific investigations — with emphasis on inquiry-based investigations — and how to communicate and defend scientific results.

D. Understands how logical reasoning, verifiable observational and experimental evidence and peer review are used in the process of generating and evaluating scientific knowledge.

E. Understands how to identify potential sources of error in an investigation, evaluate the validity of scientific data and develop and analyze different explanations for a given scientific result.

F. Knows the characteristics and general features of systems; how properties and patterns of systems can be described in terms of space, time, energy and matter; and how system components and different systems interact.

G. Knows how to apply and analyze the systems model (e.g., interacting parts, boundaries, input, output, feedback, subsystems) across the science disciplines.

H. Understands how shared themes and concepts (e.g., systems, order and organization; evidence, models and explanation; change, constancy and measurements; evolution and equilibrium; and form and function) provide a unifying framework in science.

I. Understands the difference between a theory and a hypothesis, how models are used to represent the natural world and how to evaluate the strengths and limitations of a variety of scientific models (e.g., physical, conceptual, mathematical).

Competency 003—The teacher understands the history of science, how science impacts the daily lives of students and how science interacts with and influences personal and societal decisions.

The beginning teacher:

A. Understands the historical development of science, key events in the history of science and the contributions that diverse cultures and individuals of both genders have made to scientific knowledge.

B. Knows how to use examples from the history of science to demonstrate the changing nature of scientific theories and knowledge (i.e., that scientific theories and knowledge are always subject to revision in light of new evidence).

C. Knows that science is a human endeavor influenced by societal, cultural and personal views of the world, and knows that decisions about the use and direction of science are based on factors such as ethical standards, economics and personal and societal biases and needs.

D. Understands the application of scientific ethics to the conducting, analyzing and publishing of scientific investigations.

E. Applies scientific principles to analyze factors (e.g., diet, exercise, personal behavior) that influence personal and societal choices concerning fitness and health (e.g., physiological and psychological effects and risks associated with the use of substances and substance abuse).

F. Applies scientific principles, the theory of probability and risk/benefit analysis to analyze the advantages of, disadvantages of or alternatives to a given decision or course of action.

G. Understands the role science can play in helping resolve personal, societal and global issues (e.g., recycling, population growth, disease prevention, resource use, evaluating product claims).

Domain II—Physics

Competency 004—The teacher understands the description of motion in one and two dimensions.

The beginning teacher:

A. Generates, analyzes and interprets graphs describing the motion of a particle.

B. Applies vector concepts to displacement, velocity and acceleration in order to analyze and describe the motion of a particle.

C. Solves problems involving uniform and accelerated motion using scalar (e.g., speed) and vector (e.g., velocity) quantities.

D. Analyzes and solves problems involving projectile motion.

E. Analyzes and solves problems involving uniform circular and rotary motion.

F. Understands motion of fluids.

G. Understands motion in terms of frames of reference and relativity concepts.

Competency 005—The teacher understands the laws of motion.

The beginning teacher:

A. Identifies and analyzes the forces acting in a given situation and constructs a free-body diagram.

B. Solves problems involving the vector nature of force (e.g., resolving forces into components, analyzing static or dynamic equilibrium of a particle).

C. Identifies and applies Newton's laws to analyze and solve a variety of practical problems (e.g., properties of frictional forces, acceleration of a particle on an inclined plane, displacement of a mass on a spring, forces on a pendulum).

Competency 006—The teacher understands the concepts of gravitational and electromagnetic forces in nature.

The beginning teacher:

A. Applies the law of universal gravitation to solve a variety of problems (e.g., determining the gravitational fields of the planets, analyzing properties of satellite orbits).

B. Calculates electrostatic forces, fields and potentials.

C. Understands the properties of magnetic materials and the molecular theory of magnetism.

D. Identifies the source of the magnetic field and calculates the magnetic field for various simple current distributions.

E. Analyzes the magnetic force on charged particles and current-carrying conductors.

F. Understands induced electric and magnetic fields and analyzes the relationship between electricity and magnetism.

G. Understands the electromagnetic spectrum and the production of electromagnetic waves.

Competency 007—The teacher understands applications of electricity and magnetism.

The beginning teacher:

A. Analyzes common examples of electrostatics (e.g., a charged balloon attached to a wall, behavior of an electroscope, charging by induction).

B. Understands electric current, resistance and resistivity, potential difference, capacitance and electromotive force in conductors and circuits.

C. Analyzes series and parallel DC circuits in terms of current, resistance, voltage and power.

D. Identifies basic components and characteristics of AC circuits.

E. Understands the operation of an electromagnet.

F. Understands the operation of electric meters, motors, generators and transformers.

Competency 008—The teacher understands the conservation of energy and momentum.

The beginning teacher:

A. Understands the concept of work.

B. Understands the relationships among work, energy and power.

C. Solves problems using the conservation of mechanical energy in a physical system (e.g., determining potential energy for conservative forces, conversion of potential to kinetic energy, analyzing the motion of a pendulum).

D. Applies the work-energy theorem to analyze and solve a variety of practical problems (e.g., finding the speed of an object given its potential energy, determining the work done by frictional forces on a decelerating car).

E. Understands linear and angular momentum.

F. Solves a variety of problems (e.g., collisions) using the conservation of linear and angular momentum.

Competency 009—The teacher understands the laws of thermodynamics.

The beginning teacher:

A. Understands methods of heat transfer (i.e., convection, conduction, radiation).

B. Understands the molecular interpretation of temperature and heat.

C. Solves problems involving thermal expansion, heat capacity and the relationship between heat and other forms of energy.

D. Applies the first law of thermodynamics to analyze energy transformations in a variety of everyday situations (e.g., electric light bulb, power-generating plant).

E. Understands the concept of entropy and its relationship to the second law of thermodynamics.

Competency 010—The teacher understands the characteristics and behavior of waves.

The beginning teacher:

A. Understands interrelationships among wave characteristics such as velocity, frequency, wavelength and amplitude and relates them to properties of sound and light (e.g., pitch, color).

B. Compares and contrasts transverse and longitudinal waves.

C. Describes how various waves are propagated through different media.

D. Applies properties of reflection and refraction to analyze optical phenomena (e.g., mirrors, lenses, fiber-optic cable).

E. Applies principles of wave interference to analyze wave phenomena, including acoustical (e.g., harmonics) and optical phenomena (e.g., patterns created by thin films and diffraction gratings).

F. Identifies and interprets how wave characteristics and behaviors are used in medical, industrial and other real-world applications.

Competency 011—The teacher understands the fundamental concepts of quantum physics.

The beginning teacher:

A. Interprets wave-particle duality.

B. Identifies examples and consequences of the uncertainty principle.

C. Understands the photoelectric effect.

D. Uses the quantum model of the atom to describe and analyze absorption and emission spectra (e.g., line spectra, blackbody radiation).

E. Explores real-world applications of quantum phenomena (e.g., lasers, photoelectric sensors, semiconductors, superconductivity).

Domain III—Chemistry

Competency 012—The teacher understands the characteristics of matter and atomic structure.

The beginning teacher:

A. Differentiates between physical and chemical properties and changes of matter.

B. Explains the structure and properties of solids, liquids and gases.

C. Identifies and analyzes properties of substances (i.e., elements and compounds) and mixtures.

D. Models the atom in terms of protons, neutrons and electron clouds.

E. Identifies elements and isotopes by atomic number and mass number and calculates average atomic mass of an element.

F. Understands atomic orbitals and electron configurations and describes the relationship between electron energy levels and atomic structure.

G. Understands the nature and historical significance of the periodic table.

H. Applies the concept of periodicity to predict the physical properties (e.g., atomic and ionic radii) and chemical properties (e.g., electronegativity, ionization energy) of an element.

Competency 013—The teacher understands the properties of gases.

The beginning teacher:

A. Understands interrelationships among temperature, number of moles, pressure and volume of gases contained within a closed system.

B. Analyzes data obtained from investigations with gases in a closed system and determines whether the data are consistent with the ideal gas law.

C. Applies the gas laws (e.g., Charles's law, Boyle's law, combined gas law) to describe and calculate gas properties in a variety of situations.

D. Applies Dalton's law of partial pressure in various situations (e.g., collecting a gas over water).

E. Understands the relationship between kinetic molecular theory and the ideal gas law.

F. Knows how to apply the ideal gas law to analyze mass relationships between reactants and products in chemical reactions involving gases.

Competency 014—The teacher understands properties and characteristics of ionic and covalent bonds.

The beginning teacher:

A. Relates the electron configuration of an atom to its chemical reactivity.

B. Compares and contrasts characteristics of ionic and covalent bonds.

C. Applies the octet rule to construct Lewis structures.

D. Identifies and describes the arrangement of atoms in molecules, ionic crystals, polymers and metallic substances.

E. Understands the influence of bonding forces on the physical and chemical properties of ionic and covalent substances.

F. Identifies and describes intermolecular and intramolecular forces.

G. Uses intermolecular forces to explain the physical properties of a given substance (e.g., melting point, crystal structure).

H. Applies the concepts of electronegativity, electron affinity and oxidation state to analyze chemical bonds.

I. Evaluates energy changes in the formation and dissociation of chemical bonds.

J. Understands the relationship between chemical bonding and molecular geometry.

Competency 015—The teacher understands and interprets chemical equations and chemical reactions.

The beginning teacher:

A. Identifies elements, common ions and compounds using scientific nomenclature.

B. Uses and interprets symbols, formulas and equations in describing interactions of matter and energy in chemical reactions.

C. Understands mass relationships involving percent composition, empirical formulas and molecular formulas.

D. Interprets and balances chemical equations using conservation of mass and charge.

E. Understands mass relationships in chemical equations and solves problems using calculations involving moles, limiting reagents and reaction yield.

F. Identifies factors (e.g., temperature, pressure, concentration, catalysts) that influence the rate of a chemical reaction and describes their effects.

G. Understands principles of chemical equilibrium and solves problems involving equilibrium constants.

H. Identifies the chemical properties of a variety of common household chemicals (e.g., baking soda, bleach, ammonia) in order to predict the potential for chemical reactivity.

Competency 016—The teacher understands types and properties of solutions.

The beginning teacher:

A. Analyzes factors that affect solubility (e.g., temperature, pressure, polarity of solvents and solutes) and rate of dissolution (e.g., surface area, agitation).

B. Identifies characteristics of saturated, unsaturated and supersaturated solutions.

C. Determines the molarity, molality, normality and percent composition of aqueous solutions.

D. Analyzes precipitation reactions and derives net ionic equations.

E. Understands the colligative properties of solutions (e.g., vapor pressure lowering, osmotic pressure changes, boiling-point elevation, freezing-point depression).

F. Understands the properties of electrolytes and explains the relationship between concentration and electrical conductivity.

G. Understands methods for measuring and comparing the rates of reaction in solutions of varying concentration.

H. Analyzes models to explain the structural properties of water and evaluates the significance of water as a solvent in living organisms and the environment.

Competency 017—The teacher understands energy transformations that occur in physical and chemical processes.

The beginning teacher:

A. Analyzes the energy transformations that occur in phase transitions.

B. Solves problems in calorimetry (e.g., determining the specific heat of a substance, finding the standard enthalpy of formation and reaction of substances).

C. Applies the law of conservation of energy to analyze and evaluate energy exchanges that occur in exothermic and endothermic reactions.

D. Understands thermodynamic relationships among spontaneous reactions, entropy, enthalpy, temperature and Gibbs free energy.

Competency 018—The teacher understands nuclear fission, nuclear fusion and nuclear reactions.

The beginning teacher:

A. Uses models to explain radioactivity and radioactive decay (i.e., alpha, beta, gamma).

B. Interprets and balances equations for nuclear reactions.

C. Compares and contrasts fission and fusion reactions (e.g., relative energy released in the reactions, mass distribution of products).

D. Knows how to use the half-life of radioactive elements to solve real-world problems (e.g., carbon dating, radioactive tracers).

E. Understands stable and unstable isotopes.

F. Knows various issues associated with using nuclear energy (e.g., medical, commercial, environmental).

Competency 019—The teacher understands oxidation and reduction reactions.

The beginning teacher:

A. Determines the oxidation state of ions and atoms in compounds.

B. Identifies and balances oxidation and reduction reactions.

C. Uses reduction potentials to determine whether a redox reaction will occur spontaneously.

D. Explains the operation and applications of electrochemical cells.

E. Analyzes applications of oxidation and reduction reactions from everyday life (e.g., combustion, rusting, electroplating, batteries).

Competency 020—The teacher understands acids, bases and their reactions.

The beginning teacher:

A. Identifies the general properties of, and relationships among, acids, bases and salts.

B. Identifies acids and bases by using models of Arrhenius, Brønsted-Lowry and Lewis.

C. Differentiates between strong and weak acids and bases.

D. Applies the relationship between hydronium ion concentration and pH for acids and bases.

E. Understands and analyzes acid-base equilibria and buffers.

F. Analyzes and applies the principles of acid-base titration.

G. Analyzes neutralization reactions based on the principles of solution concentration and stoichiometry.

H. Describes the effects of acids and bases in the real world (e.g., acid precipitation, physiological buffering).

Domain IV—Science Learning, Instruction and Assessment

Competency 021—The teacher understands research-based theoretical and practical knowledge about teaching science, how students learn science and the role of scientific inquiry in science instruction.

The beginning teacher:

A. Knows research-based theories about how students develop scientific understanding and how developmental characteristics, prior knowledge, experience and attitudes of students influence science learning.

B. Understands the importance of respecting student diversity by planning activities that are inclusive and selecting and adapting science curricula, content, instructional materials and activities to meet the interests, knowledge, understanding, abilities, possible career paths and experiences of all students, including English-language learners.

C. Knows how to plan and implement strategies to encourage student self-motivation and engagement in their own learning (e.g., linking inquiry-based investigations to students' prior knowledge, focusing inquiry-based instruction on issues relevant to students, developing instructional materials using situations from students' daily lives, fostering collaboration among students).

D. Knows how to use a variety of instructional strategies to ensure all students comprehend content-related texts, including how to locate, retrieve and retain information from a range of texts and technologies.

E. Understands the science teacher's role in developing the total school program by planning and implementing science instruction that incorporates school-wide objectives and the statewide curriculum as defined in the Texas Essential Knowledge and Skills (TEKS).

F. Knows how to design and manage the learning environment (e.g., individual, small-group, whole-class settings) to focus and support student inquiries and to provide the time, space and resources for all students to participate in field, laboratory, experimental and nonexperimental scientific investigation.

G. Understands the rationale for using active learning and inquiry methods in science instruction and how to model scientific attitudes such as curiosity, openness to new ideas and skepticism.

H. Knows principles and procedures for designing and conducting an inquiry-based scientific investigation (e.g., making observations; generating questions; researching and reviewing current knowledge in light of existing evidence; choosing tools to gather and analyze evidence; proposing answers, explanations and predictions; communicating and defending results).

I. Knows how to assist students with generating, refining, focusing and testing scientific questions and hypotheses.

J. Knows strategies for assisting students in learning to identify, refine and focus scientific ideas and questions guiding an inquiry-based scientific investigation; to develop, analyze and evaluate different explanations for a given scientific result; and to identify potential sources of error in an inquiry-based scientific investigation.

K. Understands how to implement inquiry strategies designed to promote the use of higher-level thinking skills, logical reasoning and scientific problem solving in order to move students from concrete to more abstract understanding.

L. Knows how to guide students in making systematic observations and measurements.

M. Knows how to sequence learning activities in a way that uncovers common misconceptions, allows students to build upon their prior knowledge and challenges them to expand their understanding of science.

Competency 022—The teacher knows how to monitor and assess science learning in laboratory, field and classroom settings.

The beginning teacher:

A. Knows how to use formal and informal assessments of student performance and products (e.g., projects, laboratory and field journals, rubrics, portfolios, student profiles, checklists) to evaluate student participation in and understanding of inquiry-based scientific investigations.

B. Understands the relationship between assessment and instruction in the science curriculum (e.g., designing assessments to match learning objectives, using assessment results to inform instructional practice).

C. Knows the importance of monitoring and assessing students' understanding of science concepts and skills on an ongoing basis by using a variety of appropriate assessment methods (e.g., performance assessment, self-assessment, peer assessment, formal/informal assessment).

D. Understands the purposes, characteristics and uses of various types of assessment in science, including formative and summative assessments, and the importance of limiting the use of an assessment to its intended purpose.

E. Understands strategies for assessing students' prior knowledge and misconceptions about science and how to use those assessments to develop effective ways to address the misconceptions.

F. Understands characteristics of assessments, such as reliability, validity and the absence of bias, in order to evaluate assessment instruments and their results.

G. Understands the role of assessment as a learning experience for students and strategies for engaging students in meaningful self-assessment.

H. Recognizes the importance of selecting assessment instruments and methods that provide all students with adequate opportunities to demonstrate their achievements.

I. Recognizes the importance of clarifying teacher expectations by sharing evaluation criteria and assessment results with students.

This reference material will also be available to you during the exam. To access it, click on the

icon located in the lower-left corner of the screen.

Definitions and Physical Constants

The value of 9.8 m/s^2 is used for the acceleration of gravity near Earth's surface.

The universal gas constant is 8.314 J/K-mol or 0.08206 L-atm/K-mol.

Planck's constant is 6.6256×10^{-34} J-s.

Avogadro's number is 6.022×10^{23}.

The right-hand rule is used with conventional current (the flow of positive charge from the positive terminal to the negative terminal).

End of Definitions and Physical Constants

This reference material will also be available to you during the exam. To access it, click on the Reference Materials icon located in the lower-left corner of the screen.

PERIODIC TABLE OF THE ELEMENTS

1 **1A**																	18 **8A**
1 **H** 1.01	2 **2A**											13 **3A**	14 **4A**	15 **5A**	16 **6A**	17 **7A**	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 23.0	12 **Mg** 24.3	3 **3B**	4 **4B**	5 **5B**	6 **6B**	7 **7B**	8	9 **8B**	10	11 **1B**	12 **2B**	13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 39.9
19 **K** 39.1	20 **Ca** 40.1	21 **Sc** 45.0	22 **Ti** 47.9	23 **V** 50.9	24 **Cr** 52.0	25 **Mn** 54.9	26 **Fe** 55.8	27 **Co** 58.9	28 **Ni** 58.7	29 **Cu** 63.5	30 **Zn** 65.4	31 **Ga** 69.7	32 **Ge** 72.6	33 **As** 74.9	34 **Se** 79.0	35 **Br** 79.9	36 **Kr** 83.8
37 **Rb** 85.5	38 **Sr** 87.6	39 **Y** 88.9	40 **Zr** 91.2	41 **Nb** 92.9	42 **Mo** 95.9	43 **Tc** (98.9)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57–71	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89–103	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (282)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

Lanthanide Series	57 **La** 138.9	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinide Series	89 **Ac** (227)	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Section 4: Sample Selected-Response Questions Physical Science 6–12 (237)

This section presents some sample exam questions for you to review as part of your preparation for the exam. To demonstrate how each competency may be assessed, sample questions are accompanied by the competency that they measure. While studying, you may wish to read the competency before and after you consider each sample question. Please note that the competency statements do not appear on the actual exam.

For each sample exam question, there is a correct answer and a rationale for each answer option. The sample questions are included to illustrate the formats and types of questions you will see on the exam; however, your performance on the sample questions should not be viewed as a predictor of your performance on the actual exam.

The following reference materials will be available to you during the exam:

- Definitions and Physical Constants (see page 14)
- Periodic Table (see page 15)

Domain I—Scientific Inquiry and Processes

Competency 001—The teacher understands how to select and manage learning activities to ensure the safety of all students and the correct use and care of organisms, natural resources, materials, equipment and technologies.

1. Which of the following is safety equipment that can be found in a high school chemistry lab?

   A. Bunsen burner

   B. Eyewash station

   C. Barometer

   D. Glass mercury thermometer

   Answer _____

2. Which THREE of the following are units in the International System of Units (SI)?

   A. Kelvin

   B. Pound

   C. Kilogram

   D. Mole

   Answer _____

Competency 002—The teacher understands the nature of science, the process of scientific inquiry and the unifying concepts that are common to all sciences.

3. Which of the following is a scientific inference?

   A. Data suggests that Mars once had liquid water

   B. Repeated measurements of a quantity will reduce random error

   C. Electrical equipment should be grounded

   D. A measurement has three significant figures

Answer _____

Competency 003—The teacher understands the history of science, how science impacts the daily lives of students and how science interacts with and influences personal and societal decisions.

4. Of the following, which contributes the most to water pollution in streams near mountains?

   A. Nuclear power plants

   B. Mine drainage

   C. Carbon dioxide emissions from gas-powered automobiles

   D. Oil-well drilling

Answer _____

5. Historically, the Bohr model was successful in explaining which of the following?

   A. The emission spectrum of the hydrogen atom

   B. The red shift in the spectrum of light from distant stars

   C. The black-body radiation spectrum

   D. The photoelectric effect

Answer _____

Domain II—Physics

Competency 004—The teacher understands the description of motion in one and two dimensions.

6. A ball of mass m is thrown horizontally with an initial speed v_0 from the top of a building that is height h above level ground. In the absence of air resistance, how much time will elapse before the ball strikes the ground?

   A. $\frac{v_0}{g}$

   B. $\frac{h}{v_0}$

   C. $\sqrt{2gh}$

D. $\sqrt{\frac{2h}{g}}$

Answer _____

7. Two satellites are each in a circular orbit around Earth at a distance *R* and 2*R*, respectively, from Earth's center. If the satellite at distance *R* has an orbital speed of υ, the satellite at distance 2*R* must have an orbital speed equal to

A. 2υ

B. $\sqrt{2}\,\upsilon$

C. υ

D. $\frac{\upsilon}{\sqrt{2}}$

Answer _____

Competency 005—The teacher understands the laws of motion.

8. A 50 N force is applied to a 10 kg block that is initially at rest on a rough horizontal surface. If the block accelerates uniformly at 2 m/s^2, what is the magnitude of the frictional force acting on the object?

A. 98 N

B. 50 N

C. 30 N

D. 20 N

Answer _____

Competency 006—The teacher understands the concepts of gravitational and electromagnetic forces in nature.

9. A simple pendulum with period *T* on Earth is transported to the Moon where the gravitational force is about one-sixth the gravitational force on Earth. The period of the pendulum on the Moon is approximately equal to which of the following?

A. 6*T*

B. $\sqrt{6}\,T$

C. *T*

D. $\frac{T}{6}$

Answer _____

10. On the basis of Coulomb's law, which of the following is true about the electrostatic force between two charges?

A. It increases in magnitude as the distance between the charges increases

B. It is dependent on the masses of the charges

C. It can be attractive or repulsive

D. It is equal to the magnetic force between the charges

Answer _____

Competency 007—The teacher understands applications of electricity and magnetism.

11. A 5 Ω resistor connected in series with a voltage source dissipates 20 W of power. If the source voltage is doubled, the power dissipated by the resistor will be equal to which of the following?

A. 80 W

B. 40 W

C. 20 W

D. 5 W

Answer _____

12. A circuit consists of a 1.0 ohm resistor and a 4 ohm resistor connected in parallel to a 20.0 volt source. What is the total current in the circuit?

A. 4.0 amps

B. 5.0 amps

C. 15 amps

D. 25 amps

Answer _____

Competency 008—The teacher understands the conservation of energy and momentum.

13. A railroad boxcar of mass M is moving along a straight horizontal track with speed u. It collides and couples with a second boxcar of mass $4M$ that is at rest. What is the kinetic energy of the coupled boxcars immediately after the collision?

A. 0

B. $\frac{1}{10}Mu^2$

C. $\frac{1}{2}Mu^2$

D. $\frac{5}{2}Mu^2$

Answer _____

14. An object with a mass of 2 kg is accelerated by a force on a frictionless flat surface and is moving in a straight line. The net work done on the object is 20 J. What is the resulting change in the kinetic energy of the object?

A. 10 J

B. 20 J

C. 40 J

D. 200 J

Answer _____

Competency 009—The teacher understands the laws of thermodynamics.

15. The first law of thermodynamics is a statement of which of the following?

A. The ideal gas law

B. The uncertainty principle

C. The law of conservation of energy

D. The behavior of the entropy of a system

Answer _____

16. On a cold night, frost forms on the top of a car but does not form on the underside. The pattern of frost formation indicates that the car is losing heat through what process?

A. Radiation

B. Convection

C. Conduction

D. Inertia

Answer _____

Competency 010—The teacher understands the characteristics and behavior of waves.

17. A light ray passes from air (n = 1) into glass (n = 1.55). Which of the following is true about the angle of refraction?

A. It is equal to the angle of incidence

B. It is less than the angle of incidence

C. It is equal to the angle of reflection

D. It is greater than the angle of reflection

Answer _____

18. Of the following phenomena, which is characteristic of light but not of sound?

A. Diffraction

B. Interference

C. Polarization

D. Dispersion

Answer _____

Competency 011—The teacher understands the fundamental concepts of quantum physics.

19. According to the Bohr model of the hydrogen atom, the energy E_n of an electron in the nth energy level of the atom is equal to $E_n = \frac{13.6}{n^2}$eV. What is the energy of the photon emitted when an electron makes a transition from the $n = 2$ level to the $n = 1$ level?

A. 6.8 eV

B. 10.2 eV

C. 13.6 eV

D. 17.0 eV

Answer _____

20. In the photoelectric effect, light is incident on a metallic surface and photoelectrons are emitted. If f and λ represent the frequency and wavelength, respectively, of the incident light, and W represents the work function of the metal, which of the following equations correctly gives the maximum kinetic energy E of the emitted photoelectrons?

A. $E = h\lambda$

B. $E = hf$

C. $E = W$

D. $E = hf - W$

Answer _____

Domain III—Chemistry

Competency 012—The teacher understands the characteristics of matter and atomic structure.

21. Of the following, which is an example of a physical change only?

A. Snow sublimating in the Arctic

B. An iron nail rusting

C. A candle burning

D. A lead storage battery recharging

Answer _____

22. Based on its position on the periodic table, which of the following elements has the most metallic chemical properties?

A. Cs

B. Au

C. Sb

D. Br

Answer _____

Competency 013—The teacher understands the properties of gases.

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

23. If 44.8 L of O_2, measured at 273 K and 1 atm, reacts completely with 2.00 mol of CH_4 according to the equation above, what volume of CO_2, measured at 273 K and 1 atm, is produced?

A. 11.2 L

B. 22.4 L

C. 44.8 L

D. 89.6 L

Answer _____

24. A mixture of gases, 200 L O_2, 300 L He, and 500 L N_2, each at standard temperature and pressure, are compressed into a 10 L tank. If the total pressure of the compressed gases is 200 atm, which of the following is the partial pressure of O_2 in the tank?

A. 10 atm

B. 20 atm

C. 40 atm

D. 200 atm

Answer _____

Competency 014—The teacher understands properties and characteristics of ionic and covalent bonds.

25. In which of the following compounds is there both covalent and ionic bonding in the solid state?

A. $MgCl_2$

B. H_2S

C. CCl_2H_2

D. $CaSO_4$

Answer _____

26. Of the following, which has the highest normal boiling point?

A. Ar

B. CH_4

C. NH_3

D. O_2

Answer _____

Competency 015—The teacher understands and interprets chemical equations and chemical reactions.

27. Which of the following is the balanced equation for the displacement reaction of potassium with aluminum nitrate?

A. $3\ K + Al(NO_3)_3 \rightarrow 3\ KNO_3 + Al$

B. $K + AlNO_3 \rightarrow KNO_3 + Al$

C. $3\ K + AlNO_3 \rightarrow K_3N + AlO_3$

D. $K + AlN \rightarrow KN + Al$

Answer _____

$$C(s) + O_2(g) \rightleftharpoons CO_2(g)$$

28. Which of the following is the equilibrium constant, K_C, for the reaction represented above?

A. $K_C = \frac{[CO_2]}{[C][O_2]}$

B. $K_C = \frac{[C][O_2]}{[CO_2]}$

C. $K_C = \frac{[CO_2]}{[O_2]}$

D. $K_C = \frac{[O_2]}{[CO_2]}$

Answer _____

Competency 016—The teacher understands types and properties of solutions.

29. Which of the following is the molar concentration of KNO_3 in a 4.00 L solution that contains 50.5 g of KNO_3?

A. 2.00 M

B. 0.500 M

C. 0.250 M

D. 0.125 M

Answer _____

30. Sugar was dissolved in water at 50°C. When the temperature of the solution was reduced to 30°C, some of the sugar precipitated. Of the following, which best describes the solution after some of the sugar precipitated?

A. Saturated

B. Supersaturated

C. Unsaturated

D. Dilute

Answer _____

Competency 017—The teacher understands energy transformations that occur in physical and chemical processes.

31. If 5.0 mL of 80.0°C water is mixed with 15.0 mL of 20.0°C water in a thermally insulated container, which of the following will be the temperature of the water once thermal equilibrium is reached?

A. 75°C

B. 50°C

C. 35°C

D. 25°C

Answer _____

Competency 018—The teacher understands nuclear fission, nuclear fusion and nuclear reactions.

32. The half-life of a radioactive isotope X is 12 hours. Starting with a pure 80.0 g sample of the isotope, how much of the isotope will remain in the sample after 48 hours have elapsed?

A. 40 g

B. 20 g

C. 10 g

D. 5 g

Answer _____

Competency 019—The teacher understands oxidation and reduction reactions.

33. Which of the following is the oxidation number for Cr in K_2CrO_4?

A. +1

B. +4

C. +6

D. +8

Answer _____

34. Which TWO of the following represent reduction processes?

A. $Cu \rightarrow Cu^{+} + e^{-}$

B. $Na^{+} + e^{-} \rightarrow Na$

C. $Cu^{2+} + e^{-} \rightarrow Cu^{+}$

D. $Cu^{+} \rightarrow Cu^{2+} + e^{-}$

Answer _____

Competency 020—The teacher understands acids, bases and their reactions.

35. Which of the following is a weak acid?

A. HF

B. HCl

C. HNO_3

D. RbOH

Answer _____

36. What is the pH of 0.00006 M $HNO_3(aq)$?

A. 4.0

B. 4.2

C. 5.0

D. 6.0

Answer _____

Domain IV—Science Learning, Instruction and Assessment

Competency 021—The teacher understands research-based theoretical and practical knowledge about teaching science, how students learn science and the role of scientific inquiry in science instruction.

37. Which of the following is an element of inquiry-based science instruction?

A. A teacher-led question-and-answer session

B. A video presentation of science principles to be included in a unit of study

C. A student forming a hypothesis prior to a lab activity

D. A student writing a report after researching information on the Internet

Answer _____

38. Which of the following student responses is an example of correct conceptual understanding?

A. Air has no mass

B. The Sun is a star

C. Heavy objects cannot float

D. The Moon and the Sun are the same size

Answer _____

Competency 022—The teacher knows how to monitor and assess science learning in laboratory, field and classroom settings.

39. Which of the following is a type of summative assessment?

A. A final examination

B. A homework exercise

C. An interview

D. A question-and-answer session

Answer _____

40. Giving a short quiz before starting a new unit is most appropriate to help with which of the following?

A. Planning the major content outcomes for the unit

B. Discovering what prior knowledge or misconceptions the students may have

C. Assessing which students will probably learn the most from the upcoming unit

D. Assessing which students will require more of the teacher's time outside of class

Answer _____

Section 4: Sample Selected-Response Answers and Rationales
Physical Science 6–12 (237)

This section presents some sample exam questions for you to review as part of your preparation for the exam. To demonstrate how each competency may be assessed, sample questions are accompanied by the competency that they measure. While studying, you may wish to read the competency before and after you consider each sample question. Please note that the competency statements do not appear on the actual exam.

For each sample exam question, there is a correct answer and a rationale for each answer option. The sample questions are included to illustrate the formats and types of questions you will see on the exam; however, your performance on the sample questions should not be viewed as a predictor of your performance on the actual exam.

The following reference materials will be available to you during the exam:

- Definitions and Physical Constants (see page 14)
- Periodic Table (see page 15)

Domain I—Scientific Inquiry and Processes

Competency 001—The teacher understands how to select and manage learning activities to ensure the safety of all students and the correct use and care of organisms, natural resources, materials, equipment and technologies.

1. Which of the following is safety equipment that can be found in a high school chemistry lab?

   A. Bunsen burner

   B. Eyewash station

   C. Barometer

   D. Glass mercury thermometer

Answer

Option B is correct because an eyewash station is used to flush the eyes when liquids have been splashed or sprayed into a person's eyes. **Option A is incorrect** because a Bunsen burner is used to heat some materials in the lab and must be used with care. **Option C is incorrect** because a barometer is used to measure atmospheric pressure. **Option D is incorrect** because a glass mercury thermometer can pose a significant hazard due to possible broken glass and mercury exposure.

2. Which THREE of the following are units in the International System of Units (SI)?

   A. Kelvin

   B. Pound

   C. Kilogram

D. Mole

Answer

Options A, C, and D are correct because they are each units in the International System of Units (SI). The kelvin is the SI unit of absolute temperature. The kilogram is an SI unit of mass. The mole is an SI unit that is equal to 6.02×10^{23} representative particles. For example, one mole of Na contains 6.02×10^{23} atoms and one mole of O_2 contains 6.02×10^{23} molecules. **Option B is incorrect** because a pound is not an SI unit but is a unit of measurement in a number of other systems of measurement.

Competency 002—The teacher understands the nature of science, the process of scientific inquiry and the unifying concepts that are common to all sciences.

3. Which of the following is a scientific inference?

A. Data suggests that Mars once had liquid water

B. Repeated measurements of a quantity will reduce random error

C. Electrical equipment should be grounded

D. A measurement has three significant figures

Answer

Option A is correct because it is a reasonable conclusion drawn from data, which defines a scientific inference. **Option B is incorrect** because it is a mathematical statement of fact. **Option C is incorrect** because it describes a safety practice. **Option D is incorrect** because it is an observation.

Competency 003—The teacher understands the history of science, how science impacts the daily lives of students and how science interacts with and influences personal and societal decisions.

4. Of the following, which contributes the most to water pollution in streams near mountains?

A. Nuclear power plants

B. Mine drainage

C. Carbon dioxide emissions from gas-powered automobiles

D. Oil-well drilling

Answer

Option B is correct because acid and metal ion mine drainage from abandoned coal mines has a significant impact on many streams in mountainous coal-mining regions. **Option A is incorrect** because although nuclear power plants can contribute to thermal pollution, plants are typically located near rivers or oceans, not in mountain regions near streams. Radioactive emissions are not common and are not the major source of water pollution in mountain streams. **Option C is incorrect** because carbon dioxide emissions can lead to a minor amount

of dissolved carbon dioxide (carbonic acid), but the level is not considered significant. **Option D is incorrect** because oil well drilling is not typically done in areas that could affect streams in mountainous regions.

5. Historically, the Bohr model was successful in explaining which of the following?

A. The emission spectrum of the hydrogen atom

B. The red shift in the spectrum of light from distant stars

C. The black-body radiation spectrum

D. The photoelectric effect

Answer

Option A is correct because the primary success of the Bohr model was its derivation of the Rydberg formula for the spectral emission lines of hydrogen. **Option B is incorrect** because the Bohr model is not germane to the red shift of light coming from distant stars, which is explained by the Doppler effect. **Option C is incorrect** because the Bohr model is not germane to the spectrum of black-body radiation, which is explained by Planck's radiation formula. **Option D is incorrect** because the Bohr model is not germane to the photoelectric effect, which is explained by Einstein's photoelectric equation.

Domain II—Physics

Competency 004—The teacher understands the description of motion in one and two dimensions.

6. A ball of mass m is thrown horizontally with an initial speed v_0 from the top of a building that is height h above level ground. In the absence of air resistance, how much time will elapse before the ball strikes the ground?

A. $\frac{v_0}{g}$

B. $\frac{h}{v_0}$

C. $\sqrt{2gh}$

D. $\sqrt{\frac{2h}{g}}$

Answer

Option D is correct because it properly recognizes that the horizontal and vertical motions of the ball are independent of each other and then uses the equations of straight-line motion applied to the vertical motion of the ball to calculate the time that elapses before the ball strikes the ground. The kinematical equations of motion give $h = \frac{1}{2}gt^2$. Thus, solving for the time t gives $t^2 = \frac{2h}{g}$, or $t = \sqrt{\frac{2h}{g}}$. **Option A is incorrect** because it assumes that

$v_0 = gt$, which is not true. **Option B is incorrect** because it ignores gravity and assumes that the vertical component of the speed is constant and equal in value to v_0, which is not true. **Option C is incorrect** because it is equal to the vertical component of the speed of the ball just before it strikes the ground and not the time it takes to fall.

7. Two satellites are each in a circular orbit around Earth at a distance R and $2R$, respectively, from Earth's center. If the satellite at distance R has an orbital speed of v, the satellite at distance $2R$ must have an orbital speed equal to

A. $2v$

B. $\sqrt{2}\,v$

C. v

D. $\frac{v}{\sqrt{2}}$

Answer

Option D is correct because it properly applies the equation for an object in circular motion in Earth's gravitational field to compute the orbital speed. The equation for the orbital speed is $v^2 = \frac{GM}{R}$, where G is the universal gravitational constant, M is the mass of the Earth, and R is the distance from Earth's center. When the orbital radius is doubled, the orbital speed decreases by a factor of $\frac{1}{\sqrt{2}}$. **Option A is incorrect** because it assumes that the orbital speed is proportional to R, which is not true. **Option B is incorrect** because it assumes that the orbital speed is proportional to $\sqrt{R}$, which is not true. **Option C is incorrect** because it assumes that the orbital speed does not depend on the radius of the orbit, which is not true.

Competency 005—The teacher understands the laws of motion.

8. A 50 N force is applied to a 10 kg block that is initially at rest on a rough horizontal surface. If the block accelerates uniformly at 2 m/s^2, what is the magnitude of the frictional force acting on the object?

A. 98 N

B. 50 N

C. 30 N

D. 20 N

Answer

Option C is correct because it properly assumes that the net force acting on the block is equal to the applied force minus the frictional force, and then it applies Newton's second law of motion to obtain the equation 50 N − f = 10 kg × 2 m/s^2, which, solving for the frictional force f, gives f = 30 N. **Option A is incorrect** because it assumes that the frictional force is equal to the weight of the object, or 10 kg × 9.8 m/s^2, which is not true. **Option B is incorrect** because it incorrectly assumes that the frictional force is equal to the applied force of 50 N. **Option**

D is incorrect because it assumes that the frictional force is equal to the mass of the block times its acceleration, or 10 kg × 2 m/s^2, which is not true.

Competency 006—The teacher understands the concepts of gravitational and electromagnetic forces in nature.

9. A simple pendulum with period *T* on Earth is transported to the Moon where the gravitational force is about one-sixth the gravitational force on Earth. The period of the pendulum on the Moon is approximately equal to which of the following?

A. $6T$

B. $\sqrt{6}\ T$

C. T

D. $\frac{T}{6}$

Answer

Option B is correct because the period of a simple pendulum is equal to $2\pi\sqrt{\frac{L}{g}}$, where *L* is the length of the pendulum and *g* is the acceleration due to gravity, and because $g_{Moon} = \frac{1}{6}g_{Earth}$, the period on the Moon is equal to $\sqrt{6}\ T$, as the following calculation shows:

$$T_{Moon} = 2\pi\sqrt{\frac{L}{g_{Moon}}} = 2\pi\sqrt{\frac{L}{\frac{1}{6}g_{Earth}}}.$$

$$T_{Moon} = 2\pi\sqrt{\frac{L}{\frac{1}{6}g_{Earth}}} = 2\pi\sqrt{\frac{6L}{g_{Earth}}}.$$

$$T_{Moon} = 2\pi\sqrt{\frac{6L}{g_{Earth}}} = \sqrt{6}\times 2\pi\sqrt{\frac{L}{g_{Earth}}} = \sqrt{6}\,T.$$

Option A is incorrect because it assumes that the period of a simple pendulum is proportional to $\frac{1}{g}$ instead of $\frac{1}{\sqrt{g}}$, where *g* is the acceleration due to gravity. **Option C is incorrect** because it assumes that the period of the pendulum is independent of the acceleration due to gravity *g*. **Option D is incorrect** because it assumes that the period of a simple pendulum is proportional to *g* instead of $\frac{1}{\sqrt{g}}$, where *g* is the acceleration due to gravity.

10. On the basis of Coulomb's law, which of the following is true about the electrostatic force between two charges?

A. It increases in magnitude as the distance between the charges increases

B. It is dependent on the masses of the charges

C. It can be attractive or repulsive

D. It is equal to the magnetic force between the charges

Answer

Option C is correct because according to Coulomb's law, the electrostatic force between two charges depends on the relative signs of the charges and will be attractive when the two charges are oppositely charged and will be repulsive when the two charges are either both positively charged or both negatively charged. **Option A is incorrect** because according to Coulomb's law, the electrostatic force between two charges is inversely proportional to the square of the distance between the charges and, therefore, decreases in magnitude as the distance between the charges increases. **Option B is incorrect** because according to Coulomb's law, the electrostatic force between two charges is not dependent on the masses of the charges. **Option D is incorrect** because Coulomb's law is not concerned with magnetic forces.

Competency 007—The teacher understands applications of electricity and magnetism.

11. A 5 Ω resistor connected in series with a voltage source dissipates 20 W of power. If the source voltage is doubled, the power dissipated by the resistor will be equal to which of the following?

A. 80 W

B. 40 W

C. 20 W

D. 5 W

Answer

Option A is correct because Ohm's law gives the equation $P = \frac{V^2}{R}$ for the power P dissipated by a resistor, where R is the resistance of the resistor and V is the voltage across the resistor. Thus, doubling the source voltage quadruples the power dissipated, giving a value of 80 W. **Option B is incorrect** because it assumes that doubling the source voltage doubles the power dissipated, which is not true. **Option C is incorrect** because it assumes that doubling the source voltage has no effect on the power dissipated, which is not true. **Option D is incorrect** because it assumes that doubling the source voltage reduces the power dissipated by a factor of four, which is not true.

12. A circuit consists of a 1.0 ohm resistor and a 4 ohm resistor connected in parallel to a 20.0 volt source. What is the total current in the circuit?

A. 4.0 amps

B. 5.0 amps

C. 15 amps

D. 25 amps

Answer

Option D is correct because it is based on the fact that the voltage across each resistor in this parallel circuit is 20.0 volts. Based on Ohm's law ($V = IR$) the current through the 1.0 ohm resistor is 20 amps and the current through the 4.0 ohm resistor is 5.0 amps. The total current in the circuit is equal to 20 amps + 5.0 amps = 25 amps. **Option A is incorrect** because it gives the result for a circuit in which the resistors are connected in series. **Options B and C are incorrect** because they each give a result that is not the current for this circuit.

Competency 008—The teacher understands the conservation of energy and momentum.

13. A railroad boxcar of mass M is moving along a straight horizontal track with speed u. It collides and couples with a second boxcar of mass $4M$ that is at rest. What is the kinetic energy of the coupled boxcars immediately after the collision?

A. 0

B. $\frac{1}{10}Mu^2$

C. $\frac{1}{2}Mu^2$

D. $\frac{5}{2}Mu^2$

Answer

Option B is correct because it properly applies the law of conservation of linear momentum to determine that the correct speed of the coupled boxcars just after the collision is given by the equation $Mu = (M + 4M)u_{coupled}$, which can be solved to give $u_{coupled} = \frac{u}{5}$. It then uses this speed to calculate that the kinetic energy of the coupled boxcars just after the collision is equal to $\frac{1}{2}(M + 4M)(\frac{u}{5})^2 = \frac{1}{10}Mu^2$. **Option A is incorrect** because, based on the law of conservation of linear momentum, the coupled boxcars must be moving. **Option C is incorrect** because it assumes that the kinetic energy is conserved, which is only true of an elastic collision. The coupling indicates that the collision is inelastic. **Option D is incorrect** because it assumes that the speed of the coupled boxcars is u, which is not true.

14. An object with a mass of 2 kg is accelerated by a force on a frictionless flat surface and is moving in a straight line. The net work done on the object is 20 J. What is the resulting change in the kinetic energy of the object?

A. 10 J

B. 20 J

C. 40 J

D. 200 J

Answer

Option B is correct because based on the work-energy principle derived from conservation of energy, the change in kinetic energy is equal to the net work done. The change in kinetic energy is 20 J. **Options A, C, and D are incorrect** because they are not based on the work-energy principle.

Competency 009—The teacher understands the laws of thermodynamics.

15. The first law of thermodynamics is a statement of which of the following?

A. The ideal gas law

B. The uncertainty principle

C. The law of conservation of energy

D. The behavior of the entropy of a system

Answer

Option C is correct because the first law of thermodynamics is simply a statement of the law of conservation of energy. **Option A is incorrect** because the ideal gas law is a consequence of the kinetic theory of gases, not of the first law of thermodynamics. **Option B is incorrect** because the uncertainty principle is a consequence of quantum mechanics, not of the first law of thermodynamics. **Option D is incorrect** because the second law of thermodynamics, not the first law, is a statement about the behavior of the entropy of a system.

16. On a cold night, frost forms on the top of a car but does not form on the underside. The pattern of frost formation indicates that the car is losing heat through what process?

A. Radiation

B. Convection

C. Conduction

D. Inertia

Answer

Option A is correct because the frost formed on top of the car is the result of the radiative transfer of thermal energy from the car into the air, which cools off the car and allows the formation of frost. **Options B and C are incorrect** because they are not heat transfer mechanisms relevant to the situation described. **Option D is incorrect** because inertia is not a heat transfer method.

Competency 010—The teacher understands the characteristics and behavior of waves.

17. A light ray passes from air (n = 1) into glass (n = 1.55). Which of the following is true about the angle of refraction?

A. It is equal to the angle of incidence

B. It is less than the angle of incidence

C. It is equal to the angle of reflection

D. It is greater than the angle of reflection

Answer

Option B is correct because by Snell's law, the light ray will be bent toward the normal to the surface when it passes from air into glass, which means that the angle of refraction is less than the angle of incidence. **Option A is incorrect** because by Snell's law, the light ray will be bent toward the normal to the surface when it passes from air into glass, which means that the angle of refraction is less than, and not equal to, the angle of incidence. **Option C is incorrect** because by Snell's law, the light ray will be bent toward the normal to the surface when it passes from air into glass, which means that the angle of refraction is less than the angle of incidence. Because the angle of incidence is equal to the angle of reflection, the angle of refraction is less than, and not equal to, the angle of reflection. **Option D is incorrect** because by Snell's law, the light ray will be bent toward the normal to the surface when it passes from air into glass, which means that the angle of refraction is less than the angle of incidence. Because the angle of incidence is equal to the angle of reflection, the angle of refraction is less than, and not greater than, the angle of reflection.

18. Of the following phenomena, which is characteristic of light but not of sound?

A. Diffraction

B. Interference

C. Polarization

D. Dispersion

Answer

Option C is correct because polarization is a phenomenon exhibited only by transverse waves, such as light, and not by longitudinal waves, such as sound. **Option A is incorrect** because diffraction is a phenomenon exhibited by all waves, including light and sound. **Option B is incorrect** because interference is a phenomenon exhibited by all waves, including light and sound. **Option D is incorrect** because dispersion is a phenomenon exhibited by all waves, including light and sound.

Competency 011—The teacher understands the fundamental concepts of quantum physics.

19. According to the Bohr model of the hydrogen atom, the energy E_n of an electron in the nth energy level of the atom is equal to $E_n = \frac{13.6}{n^2}$eV. What is the energy of the photon emitted when an electron makes a transition from the $n = 2$ level to the $n = 1$ level?

A. 6.8 eV

B. 10.2 eV

C. 13.6 eV

D. 17.0 eV

Answer

Option B is correct because it properly computes the energy difference as $E_2 - E_1 = -\frac{13.6}{2^2}$ eV + $\frac{13.6}{1^2}$ eV = 10.2 eV. **Option A is incorrect** because it computes the energy difference with $\frac{1}{n}$ instead of $\frac{1}{n^2}$. **Option C is incorrect** because it simply computes the energy of the first level. **Option D is incorrect** because it makes an error with the algebraic signs of the terms.

20. In the photoelectric effect, light is incident on a metallic surface and photoelectrons are emitted. If *f* and λ represent the frequency and wavelength, respectively, of the incident light, and *W* represents the work function of the metal, which of the following equations correctly gives the maximum kinetic energy *E* of the emitted photoelectrons?

A. $E = h\lambda$

B. $E = hf$

C. $E = W$

D. $E = hf - W$

Answer

Option D is correct because it properly accounts for the fact that the maximum kinetic energy of the emitted photoelectrons depends directly on the frequency of the incident light and that the electrons must have a minimum energy *W* before they can be emitted from the metal. **Option A is incorrect** because it assumes that the maximum kinetic energy of the emitted photoelectrons is directly proportional to the wavelength of the incident light, which is not true. **Option B is incorrect** because it fails to account for the fact that the electrons must have a minimum energy *W* before they can be emitted from the metal. **Option C is incorrect** because it assumes that the maximum kinetic energy of the emitted photoelectrons is equal to the work function of the metal, which is not true.

Domain III—Chemistry

Competency 012—The teacher understands the characteristics of matter and atomic structure.

21. Of the following, which is an example of a physical change only?

A. Snow sublimating in the Arctic

B. An iron nail rusting

C. A candle burning

D. A lead storage battery recharging

Answer

Option A is correct because snow (H_2O) changes state from solid to gas, which is a physical change, and no chemical changes occur. **Option B is incorrect** because Fe in the iron nail reacts with O_2 to form FeO_2, which is a chemical change. **Option C is incorrect** because the combustion reaction of a candlewick with oxygen in the flame is a chemical change. **Option D is incorrect** because recharging a lead storage battery involves an electrochemical reaction.

22. Based on its position on the periodic table, which of the following elements has the most metallic chemical properties?

A. Cs

B. Au

C. Sb

D. Br

Answer

Option A is correct because in the periodic table, metallic chemical properties generally increase going down the columns and decrease going across the rows. Cs is in the lower left corner of the periodic table. **Option B is incorrect** because Au is much farther to the right than Cs on the periodic table and is a very unreactive metal. **Option C is incorrect** because Sb is much farther to the right and higher than Cs on the periodic table. Sb is a metalloid. **Option D is incorrect** because Br is much farther to the right and higher than Rb on the periodic table. Br is a nonmetal.

Competency 013—The teacher understands the properties of gases.

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

23. If 44.8 L of O_2, measured at 273 K and 1 atm, reacts completely with 2.00 mol of CH_4 according to the equation above, what volume of CO_2, measured at 273 K and 1 atm, is produced?

A. 11.2 L

B. 22.4 L

C. 44.8 L

D. 89.6 L

Answer

Option B is correct because the volume produced is 22.4 L at 298 K and 1 atm. Because 44.8 L of O_2 contains about 2 mol of O_2, it is the limiting reagent. According to the balanced reaction, 1 mol of CO_2 will be produced if the 2 moles of oxygen are consumed. One mol of gas at this temperature and pressure has a volume of about 22.4 L. **Option A is incorrect** because 11.2 L is half the volume of CO_2 that is produced. **Option C is incorrect** because 44.8 L is twice the volume of CO_2 that is produced. **Option D is incorrect** because 89.6 L is four times the volume of CO_2 that is produced.

24. A mixture of gases, 200 L O_2, 300 L He, and 500 L N_2, each at standard temperature and pressure, are compressed into a 10 L tank. If the total pressure of the compressed gases is 200 atm, which of the following is the partial pressure of O_2 in the tank?

A. 10 atm

B. 20 atm

C. 40 atm

D. 200 atm

Answer

Option B is correct because the partial pressure of O_2 in the tank is the product of the mole fraction of O_2 in the mixture and the total pressure. Based on the volumes of the gases in the uncompressed mixture, the mole fraction of O_2 is 0.1, therefore the partial pressure of compressed O_2 in the tank is 20 atm. **Option A is incorrect** because that assumes that the mole fraction of O_2 in the mixture is 0.05. **Option C is incorrect** because that assumes that the mole fraction of O_2 in the mixture is 0.2. **Option D is incorrect** because that assumes that the pressure of O_2 in the mixture is equivalent to the total pressure of the mixture.

Competency 014—The teacher understands properties and characteristics of ionic and covalent bonds.

25. In which of the following compounds is there both covalent and ionic bonding in the solid state?

A. $MgCl_2$

B. H_2S

C. CCl_2H_2

D. $CaSO_4$

Answer

Option D is correct because there is covalent bonding between the S and O atoms that form the polyatomic anion SO_4–, and there is ionic bonding between the SO_4– anions and the Ca^{2+} cations in the solid crystal. **Option A is incorrect** because in $MgCl_2$ there is ionic bonding between Mg^{2+} cations and Cl^- anions. **Option B is incorrect** because in H_2S there is covalent bonding between the H and S atoms. **Option C is incorrect** because in CCl_2H_2 there is covalent bonding between the Cl and C atoms and between the H and C atoms.

26. Of the following, which has the highest normal boiling point?

A. Ar

B. CH_4

C. NH_3

D. O_2

Answer

Option C is correct because NH_3 forms hydrogen bonds in the liquid state and has a normal boiling point of –33°C. **Option A is incorrect** because Ar has weak intermolecular forces and a normal boiling point of –186°C. **Option B is incorrect** because CH_4 has weak intermolecular forces and a normal boiling point of –164°C. **Option D is incorrect** because O_2 has weak intermolecular forces and a normal boiling point of –183°C.

Competency 015—The teacher understands and interprets chemical equations and chemical reactions.

27. Which of the following is the balanced equation for the displacement reaction of potassium with aluminum nitrate?

A. $3\ K + Al(NO_3)_3 \rightarrow 3\ KNO_3 + Al$

B. $K + AlNO_3 \rightarrow KNO_3 + Al$

C. $3\ K + AlNO_3 \rightarrow K_3N + AlO_3$

D. $K + AlN \rightarrow KN + Al$

Answer

Option A is correct because the reaction of potassium with aluminum nitrate forms KNO_3 and Al, and the formula for aluminum nitrate is $Al(NO_3)_3$, the formula for potassium nitrate is KNO_3 and the equation is balanced with an equal number of each type of atom on the right and left side of the equation (i.e., three K atoms, one Al atom, three N atoms, and nine O atoms). **Option B is incorrect** because the formula for aluminum nitrate is not correctly represented. **Option C is incorrect** because the incorrect products are formed, and the formula for aluminum nitrate is not correctly represented. **Option D is incorrect** because the incorrect products are formed, and the compound formulas are not correctly represented.

$$C(s) + O_2(g) \rightleftharpoons CO_2(g)$$

28. Which of the following is the equilibrium constant, K_C, for the reaction represented above?

A. $K_C = \dfrac{[CO_2]}{[C][O_2]}$

B. $K_C = \dfrac{[C][O_2]}{[CO_2]}$

C. $K_C = \dfrac{[CO_2]}{[O_2]}$

D. $K_C = \dfrac{[O_2]}{[CO_2]}$

Answer

Option C is correct because the equilibrium constant in terms of concentration K_C is equal to the concentration of each aqueous or gaseous product over the concentration of each aqueous or gaseous reactant, with each raised to the power that is equal to the coefficient of that component in the balanced equation. Because C(*s*) is a solid, it does not appear in the expression. And because the coefficient for the gaseous product CO_2 and the gaseous reactant O_2 are both 1, they are each raised to the power of one. **Option A is incorrect** because [C] should not be included. **Option B is incorrect** because [C] should not be included; the reactant is in the numerator, and the product is in the denominator. **Option D is incorrect** because the reactant is in the numerator and the product is in the denominator.

Competency 016—The teacher understands types and properties of solutions.

29. Which of the following is the molar concentration of KNO_3 in a 4.00 L solution that contains 50.5 g of KNO_3?

A. 2.00 M

B. 0.500 M

C. 0.250 M

D. 0.125 M

Answer

Option D is correct because the concentration of KNO_3 is 0.125 M, which is calculated as follows: $[KNO_3] = \frac{50.5\text{ g}}{4.00\text{ L}} \times \frac{1\text{ mol } KNO_3}{101\text{ g } KNO_3} = 0.125\text{ M}$. **Option A is incorrect** because 2.00 M is sixteen times more concentrated than the correct concentration. **Option B is incorrect** because 0.500 M is four times more concentrated than the correct concentration. **Option C is incorrect** because 0.250 M is two times more concentrated than the correct concentration.

30. Sugar was dissolved in water at 50°C. When the temperature of the solution was reduced to 30°C, some of the sugar precipitated. Of the following, which best describes the solution after some of the sugar precipitated?

A. Saturated

B. Supersaturated

C. Unsaturated

D. Dilute

Answer

Option A is correct because the solution is saturated, as evidenced by the precipitation of sugar. **Option B is incorrect** because supersaturated describes a solution in which more than the maximum amount of solute is dissolved at that temperature and there is no precipitate. **Option C is incorrect** because unsaturated means that the maximum amount that could dissolve at that temperature has not yet been reached and there is no

precipitate. **Option D is incorrect** because the term "dilute" would indicate that very little sugar is present in the solution, when in fact there is a significant amount of dissolved sugar.

Competency 017—The teacher understands energy transformations that occur in physical and chemical processes.

31. If 5.0 mL of 80.0°C water is mixed with 15.0 mL of 20.0°C water in a thermally insulated container, which of the following will be the temperature of the water once thermal equilibrium is reached?

A. 75°C

B. 50°C

C. 35°C

D. 25°C

Answer

Option C is correct because the temperature of the mixture is 35°C at thermal equilibrium, and is calculated as follows: the warmer water loses the amount of heat that the cooler water gains and is found from ΔHeat(80°C) = –ΔHeat(20°C). Thus, 5 mL × (80 − *T*) = –15 mL × (20 − *T*). And solving for *T* gives *T* = 35°C. **Option A is incorrect** because 75°C is much too warm, considering that much less of the warmer water was added. **Option B is incorrect** because 50°C is too warm, considering that it is not reasonable that the final temperature would be halfway between the two original temperatures given that the volumes of water mixed were not equal. **Option D is incorrect** because it is too low, based on the correct calculations, although, as a guess, it is more likely than A or B.

Competency 018—The teacher understands nuclear fission, nuclear fusion and nuclear reactions.

32. The half-life of a radioactive isotope X is 12 hours. Starting with a pure 80.0 g sample of the isotope, how much of the isotope will remain in the sample after 48 hours have elapsed?

A. 40 g

B. 20 g

C. 10 g

D. 5 g

Answer

Option D is correct because the amount remaining is 5 g. 48 hours is four half-lives. After 12 hours (one half-life), half of the original X atoms will have decayed into another isotope, leaving 40 g of X atoms. Then after another 12 hours, half of the 40 g of X atoms will have decayed, leaving 20 g of X atoms. Then after another 12 hours, half of the 20 g of X atoms will have decayed, leaving 10 g of X atoms. Then after another 12 hours, half of the 10 g of X atoms will have decayed, leaving 5 g of isotope X atoms. **Option A is incorrect** because 40 g of isotope X atoms would remain after 12 hours. **Option B is incorrect** because 20 g of isotope X atoms would remain after 24 hours. **Option C is incorrect** because 10 g of isotope X atoms would remain after 36 hours.

Competency 019—The teacher understands oxidation and reduction reactions.

33. Which of the following is the oxidation number for Cr in K_2CrO_4?

A. +1

B. +4

C. +6

D. +8

Answer

Option C is correct because in K_2CrO_4, the oxidation number for K is +1 and the oxidation number for O is –2. Because the net charge on the compound is zero, then (oxidation number of Cr) + 2(+1) + 4(–2) = 0. Hence, the oxidation number of Cr is +6. **Option A is incorrect** because if the oxidation number was +1 for Cr, then the compound would have a net charge of –5. But the compound has a net charge of zero. **Option B is incorrect** because if the oxidation number was +4 for Cr, then the compound would have a net charge of –2. But the compound has a net charge of zero. **Option D is incorrect** because if the oxidation number was +8 for Cr, then the compound would have a net charge of +2. But the compound has a net charge of zero.

34. Which TWO of the following represent reduction processes?

A. $Cu \rightarrow Cu^+ + e^-$

B. $Na^+ + e^- \rightarrow Na$

C. $Cu^{2+} + e^- \rightarrow Cu^+$

D. $Cu^+ \rightarrow Cu^{2+} + e^-$

Answer

Options B and C are correct because they both represent a reduction process in which the oxidation number is reduced as an electron is added. In option B the oxidation number changes from +1 to 0. In option C the oxidation number changes from +2 to +1. **Option A is incorrect** because it represents an oxidation process in which the oxidation number increases from 0 to +1 as an electron is lost. **Option D is incorrect** because it represents an oxidation process in which the oxidation number increases from +1 to +2 as an electron is lost.

Competency 020—The teacher understands acids, bases and their reactions.

35. Which of the following is a weak acid?

A. HF

B. HCl

C. HNO_3

D. RbOH

Answer

Option A is correct because HF is a weak acid that partially dissociates in water with $K_a = 6 \times 10^{-4}$. **Options B and C are incorrect** because HCl and HNO_3 are strong acids that dissociate almost completely in water. **Option D is incorrect** because RbOH is a base, not an acid.

36. What is the pH of 0.00006 M $HNO_3(aq)$?

A. 4.0

B. 4.2

C. 5.0

D. 6.0

Answer

Option B is correct because pH = 4.2. The pH = −log[H^+]. The concentration 0.00006 M can be expressed as 6 × 10^{-5} M. Hence, pH = –log(6 × 10^{-5}) = –log(6) − log(10^{-5}); hence pH = –0.8 − (–5) = 4.2. **Option A is incorrect** because pH = 4.0 for 1 × 10^{-4} M $HNO_3(aq)$. **Option C is incorrect** because pH = 5.0 for 1 × 10^{-5} M $HNO_3(aq)$. **Option D is incorrect** because pH = 6.0 for 1 × 10^{-6} M $HNO_3(aq)$.

Domain IV—Science Learning, Instruction and Assessment

Competency 021—The teacher understands research-based theoretical and practical knowledge about teaching science, how students learn science and the role of scientific inquiry in science instruction.

37. Which of the following is an element of inquiry-based science instruction?

A. A teacher-led question-and-answer session

B. A video presentation of science principles to be included in a unit of study

C. A student forming a hypothesis prior to a lab activity

D. A student writing a report after researching information on the Internet

Answer

Option C is correct because inquiry-based learning does involve students proposing a hypothesis prior to designing an experiment to test the hypothesis. **Option A is incorrect** because a teacher asking questions is important, but it is not an element of inquiry-based science instruction. **Option B is incorrect** because videos can be helpful, but they are not elements of inquiry-based learning. **Option D is incorrect** because writing reports can have value, but it is not an element of inquiry-based learning.

38. Which of the following student responses is an example of correct conceptual understanding?

A. Air has no mass

B. The Sun is a star

C. Heavy objects cannot float

D. The Moon and the Sun are the same size

Answer

Option B is correct because the Sun is a star. **Option A is incorrect** because air does have mass. **Option C is incorrect** because heavy objects can float. **Option D is incorrect** because the Sun is much larger than the Moon.

Competency 022—The teacher knows how to monitor and assess science learning in laboratory, field and classroom settings.

39. Which of the following is a type of summative assessment?

A. A final examination

B. A homework exercise

C. An interview

D. A question-and-answer session

Answer

Option A is correct because it occurs after completion of learning and assesses what has been learned and how well it has been learned. **Option B is incorrect** because it is a type of formative assessment. **Option C is incorrect** because it is a type of diagnostic assessment. **Option D is incorrect** because it is a type of formative assessment.

40. Giving a short quiz before starting a new unit is most appropriate to help with which of the following?

A. Planning the major content outcomes for the unit

B. Discovering what prior knowledge or misconceptions the students may have

C. Assessing which students will probably learn the most from the upcoming unit

D. Assessing which students will require more of the teacher's time outside of class

Answer

Option B is correct because a brief quiz can reveal the areas of prior knowledge as well as any misconceptions the students may have that should be addressed during the unit. **Option A is incorrect** because planning the major content outcomes should have already been done. **Option C is incorrect** because a short quiz cannot predict which students will learn the most from the unit. **Option D is incorrect** because a short quiz is not adequate to assess how much help various students will need outside of class.