ETS PRAXIS

The *PRAXIS*® Study Companion

Physical Science (5485)

ETS Professional Educator PROGRAMS

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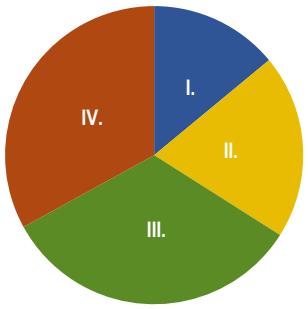
Physical Science (5485)

Test at a Glance

The *Praxis*® Physical Science test is designed to measure knowledge and competencies important for safe and effective beginning practice as a secondary school teacher of a physical science course. Test takers have typically completed a bachelor's degree program with appropriate coursework in the physical sciences—including physics and chemistry—and in education.

Test Name	Physical Science
Test Code	5485
Time	150 minutes
Number of Questions	125
Format	Selected-response questions
Test Delivery	Computer delivered



	Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
I.	Nature and Impact of Science and Engineering	18	14%
II.	Principles and Models of Matter and Energy	25	20%
III.	Chemistry	41	33%
IV.	Physics	41	33%

All questions assess content from the above science domains. Half or more of the questions integrate a Science and Engineering Practice, and approximately one-quarter to one-third of the questions assess content applied to a Task of Teaching of Science.

About the Test

The Physical Science content topics span the physical science curriculum, including content related to (I) Nature and Impact of Science and Engineering, (II) Principles and Models of Matter and Energy, (III) Chemistry, and (IV) Physics.

The assessment is designed and developed through work with practicing physical science teachers, teacher educators, and higher education content specialists to reflect the science knowledge teachers need to teach the physical science curriculum and to reflect state and national standards, including the National Science Teaching Association Preparation Standards for the physical sciences (chemistry and physics). Content and practices measured reflect the Disciplinary Core Ideas (DCIs) and Science and Engineering Practices (SEPs) established by the National Research Council in A Framework for K-12 Science Education and included in the Next Generation Science Standards.

The 125 selected-response questions measure concepts, terms, phenomena, methods, applications, data analysis, and problem solving in science. A full list of the science topics covered is provided in **Content Topics**.

Test takers will not need to use calculators in taking this test. The periodic table of the elements is available as a Help screen, along with a table of information that presents various physical constants and a few conversion factors among SI units. Whenever necessary, additional values of physical constants are included with the text of a question.

Test takers can expect half or more of the questions on the test to integrate science content knowledge with one or more of the SEPs, listed under **Science and Engineering Practices**.

Test takers will also find that approximately one-quarter to one-third of the questions call for application of physical science content and processes within a teaching scenario or an instructional task. Such questions—designed to measure applications of science knowledge to the kinds of decisions and evaluations a teacher must make during work with students, curriculum, and instruction—situate science content questions in tasks critical for teaching. **Tasks of Teaching Science** contains a list of tasks that are a routine part of science instruction. These tasks, identified based on research on science instruction, have been confirmed by a national committee of teachers and teacher educators as important for effective teaching of secondary science.

Note: This test may contain some questions that will not count toward your score.

Content Topics

This list details the topics that may be included on the test. All test questions will cover one or more of these topics.

Discussion Questions

In this section, discussion questions are open-ended questions or statements intended to help test your knowledge of fundamental concepts and your ability to apply those concepts to classroom or real-world situations. **We do not provide answers for the discussion questions** but thinking about the answers will help improve your understanding of fundamental concepts and may help you answer a broad range of questions on the test. Most of the questions require you to combine several pieces of knowledge to formulate an integrated understanding and response. They are written to help you gain increased understanding and facility with the test's subject matter. You may want to discuss these questions and possible areas with a teacher or mentor.

I. Nature and Impact of Science and Engineering

A. Nature of Science

1. Nature of scientific knowledge
   a. Involves a variety of investigation methods
   b. Based on experimental evidence that is reproducible
   c. How major concepts develop and change over time in light of new evidence
   d. Constructing and testing hypotheses
   e. Use of particulate representations, models, laws, and theories to explain natural phenomena
   f. Development and application of models to explain natural phenomena
   g. Involves process skills, including observing, categorizing, comparing, generalizing, inferring, concluding, and communicating
2. Experimental design, data collection, and analysis
   a. Standard units of measurement, dimensional analysis, and unit conversion
   b. Scientific notation and use of significant figures
   c. Experimental design, including identifying variables, planning data collection, and how it supports testing of the hypothesis
   d. Processing, organizing, graphing, and reporting of data
   e. Error analysis, including accuracy and precision, mean, and percent error
   f. Identifying the sources and effects of error
   g. Interpreting and drawing conclusions from data

3. Laboratory procedures
    a. Appropriate preparation, use, storage, and disposal of materials
    b. Preparing solutions of varying concentration
    c. Appropriate use of laboratory equipment (including selection, calibration, and maintenance)
    d. Safety procedures and precautions for the laboratory

B. Science, Engineering, Technology, Society, and the Environment

1. Interdependence of science, engineering, and technology
    a. How engineering advances lead to important discoveries in science
    b. Science and technology that drive each other forward
2. Engineering Design
    a. Defining problems in terms of criteria for success and constraints or limits
    b. Designing solutions, including proposing and evaluating in terms of criteria, constraints, and limitations
    c. Optimizing the design, including systematic modification and refinement
3. Using science and engineering to identify and address negative impacts on the environment and society
    a. Acid rain
    b. Pollution
    c. Greenhouse gases
    d. Ozone layer depletion
    e. Plastics
    f. Waste disposal and recycling
4. Advantages and disadvantages associated with various types of energy production
    a. Energy conservation
    b. Recycling of materials
    c. Renewable and nonrenewable energy sources
    d. Pros and cons of power generation based on various sources (e.g., fossil, nuclear, hydro, wind, solar, and geothermal)
5. Applications of chemistry and physics and technology in daily life
    a. Water purification
    b. Plastics, soap, batteries, and other commercial products
    c. Mining and industrial processes
    d. Communications, telescopes, and medical imaging
    e. Biological applications

Discussion Questions: Nature of Science

- What are the characteristics of a valid scientific hypothesis?
- Name a scientific law and explain why it is a law rather than a theory.
- What is the difference between an observation and an inference?
- Compare information obtained from the television, a newspaper article, a Web site, and a scientific journal for accuracy, for understandability, and for use in the classroom setting.
- 1,000 kilometers is equivalent to how many millimeters?
- Express the number 0.002270 using scientific notation. How many significant figures does the number have in decimal notation and in scientific notation?
- What is the density of a brass cube, expressed to the correct number of significant figures, if a side and the mass are measured and recorded as $2.5\,\text{cm}$ and $64.92\,\text{g}$?
- Considering the scale on a buret, what is the uncertainty in volume measurements made and how many significant figures should be included in the recorded volume?
- Design an experiment and identify the independent and the dependent variable. Does the experimental design include a control?
- What is the difference between the accuracy and the precision of a data set?
- Describe how to prepare $500\,\text{mL}$ of $1\,M\,\text{HCl}(aq)$ using $12\,M\,\text{HCl}(aq)$ and distilled water.
- What safety precautions should be taken when preparing a dilute solution of HCl from concentrated HCl?
- What is the proper way to clean up a small spill of concentrated HCl?
- What are the following pieces of equipment used for in the laboratory: buret, pipet, Erlenmeyer flask, and volumetric flask?

Discussion Questions: Science, Engineering, Technology, Society, and the Environment

- What are the major contributors to acid rain?
- Give some reasons why electronic waste such as computers should be recycled.
- What are some examples of nonrenewable energy resources?
- Compare the availability and limitations of the following sources of power: geothermal, nuclear, hydroelectric, solar, and fossil fuel.
- In what settings is solar power most effective?
- Describe the reverse osmosis process that is sometimes used for water purification.
- What are the acid-base properties of commonly used consumer products such as ammonia cleaner, vinegar, and orange juice?
- Why do polarized sunglasses reduce glare, while nonpolarized sunglasses simply reduce the total amount of light reaching the eyes?
- List some applications of lasers in daily life.

II. Principles and Models of Matter and Energy

A. Atomic and Nuclear Structure and Processes

1. Current model of atomic structure
   a. Description of basic model, including number and location of protons, neutrons, and electrons
   b. Atomic number, atomic mass, and isotopes
   c. Correlation between the electron configuration of elements and their position on the periodic table
   d. Development and experimental basis of current model
2. Radioactivity
   a. Basic characteristics of alpha particles, beta particles, and gamma radiation
   b. Radioactive decay (e.g., half-life)
   c. Identifying fission and fusion reactions
   d. Identifying products of nuclear reactions

B. Relationships Between Energy and Matter

1. Organization of matter
   a. Pure substances (elements and compounds)
   b. Mixtures (homogeneous, heterogeneous, solutions, suspensions)
   c. States of matter (solid, liquid, gas, and plasma)
   d. Atoms, ions, and molecules
2. Difference between chemical and physical properties and changes
   a. Chemical versus physical properties or changes
   b. Conservation of matter in chemical and physical processes
3. Conservation of energy in chemical and physical processes
   a. Kinetic and potential energy concepts and particulate models
   b. Forms of energy, including chemical, electrical, thermal, electromagnetic, and nuclear
   c. Conversion between different forms of energy
   d. Energy required to break bonds and energy released when bonds form
   e. Exothermic and endothermic processes
4. Temperature, thermal energy, and specific heat capacity, including computational thinking
   a. Temperature scales (Kelvin, Celsius, and Fahrenheit)
   b. Heat transfer (conduction, convection, and radiation)
   c. Specific heat capacity

5. Energy concepts involving phase transitions, including particulate models
   a. Phase diagrams
   b. Heats of vaporization, fusion, and sublimation
   c. Heating curves
6. Kinetic molecular theory, including particulate and mathematical models
   a. Assumptions and applications of the kinetic molecular theory
   b. Ideal gas behavior (e.g., relationships between temperature, pressure, and volume)

Discussion Questions: Atomic and Nuclear Structure and Processes

- An element has three isotopes, each with a different mass. Explain why the mass number for the element that is listed on the periodic table is not equal to the mass of any of the isotopes.
- What is the relationship between the position of an element on the periodic table and its electron configuration?
- Compare the mass and charge of alpha particles and beta particles. How is gamma radiation different from alpha and beta radiation?
- If a sample that initially contains $100\ g$ of a radioactive isotope contains $25\ g$ of the isotope after 4 days, what is the half-life of the radioactive isotope?
- Why is there lead mixed in with all deposits of uranium ores? How are isotopes of the same element alike? How are they different?
- How is fission different from fusion or radioactive decay?
- What was the role of earlier atomic models, such as the Bohr's model of the atom, in the development of modern atomic theory?

Discussion Questions: Relationships Between Energy and Matter

- Compare and contrast liquids and gases in terms of shape, volume, fluidity, and compressibility.
- In their standard state, which of the following elements are diatomic: bromine, chlorine, argon, and helium?
- What are some examples of the different types of mixtures?
- What is a cation?
- Test tubes contain three colorless liquids: alcohol, water, and a weak solution of ammonia. What properties could be used to identify the liquids?
- What are some examples of chemical properties?
- Describe a process that involves both a chemical change and a physical change?
- Is balancing a chemical equation an application of the law of conservation of energy or the law of conservation of matter?
- What is an example of the conversion of chemical energy to electrical energy?
- Is the combustion of CH_4 an exothermic or an endothermic process?
- How does the internal energy of a closed system change when a gas expands?
- Convert $350\ K$ to degrees Celsius.

- If 100 g of water at 20°C absorbs 5 kJ of heat, by what amount will the temperature of the water increase?
- Explain why metal feels cooler to the touch than wood at the same temperature.
- Compare and contrast the arrangement and motions of molecules of a substance in the solid, liquid, and gaseous states.
- What phase changes involve an increase in entropy?
- How much heat is absorbed as 10 g of ice melts at the freezing point?
- How does the boiling point of water at high altitudes differ from that at sea level? Why is it different?
- What are the major differences between an ideal gas and a real gas?
- When a gas expands from 5 L to 10 L as its temperature increases from 300 K to 500 K, what is the change in the pressure of the gas?

III. Chemistry

A. Chemical Composition, Bonding, and Structure

1. Mole concept and application to chemical systems
   a. Avogadro's number, molar mass, and mole conversions
   b. Percent composition
2. Names and chemical formulas for simple inorganic compounds
   a. Interpreting chemical formulas
   b. Naming compounds based on formula
   c. Writing formulas based on name of compound
3. Properties and models of bonding
   a. Ionic bonding
   b. Covalent bonding (polar and nonpolar)
   c. Metallic bonding
   d. Relative bond strengths and bond lengths of single, double, and triple bonds
   e. Electron dot and Lewis structures
   f. Molecular structure models (shape, bond angles, and polarity)
   g. Intermolecular forces (e.g., hydrogen bonding, dipole-dipole)
4. How bonding, structure, and intermolecular interactions are related to physical properties of pure substances
   a. Boiling points and melting points
   b. Solubility

B. Chemical Reactions and Periodicity

1. The periodic table as a model
   a. Arranged in groups and periods
   b. Symbols of the element, atomic number, and atomic mass
   c. Location of metals, nonmetals, metalloids, and transition elements

2. Trends in physical and chemical properties of the elements based on their position on the periodic table
    a. Atomic and ionic radius
    b. Ionization energy
    c. Electronegativity
    d. Physical properties
    e. Chemical properties and reactivity
3. Chemical reaction equations
    a. Identifying single-replacement, double-replacement, neutralization, precipitation, combustion, synthesis, decomposition, and oxidation-reduction reactions
    b. Predicting products of simple reaction types
    c. Balancing equations
    d. Stoichiometric relationships based on balanced equations
4. Chemical reaction kinetics
    a. Catalysts
    b. Factors affecting reaction rate, including concentration, surface area, temperature, and pressure

C. Solutions and Acid-Base Chemistry

1. Analysis of types of solutions
    a. Dilute, concentrated, unsaturated, saturated, and supersaturated
    b. Concentration terms (molarity and percent by mass or volume)
2. Solutions and solubility
    a. Factors affecting rate of dissolving (temperature, pressure, surface area, and stirring)
    b. Interpreting solubility curves (temperature dependence)
    c. Electrolytes, nonelectrolytes, and electrical conductivity of solutions
3. Models of acids and bases and their properties
    a. Identifying common acids and bases
    b. Strong and weak acids and bases (degree of dissociation in aqueous solution)
    c. Relationship between acidity and pH or $[H^+]$
    d. Applications of buffers
4. Concepts involving acid-base neutralization
    a. Neutralization
    b. Use of acid-base indicators
    c. Titrations

Discussion Questions: Chemical Composition, Bonding, and Structure

- How many carbon atoms are in one mole of propane?
- What is the molecular formula of a compound that has the empirical formula C_2H_4O and a molar mass of 88 g?

- What information is provided in the formula for calcium hydroxide, $Ca(OH)_2$?
- What is the number of moles of oxygen atoms in 5 moles of the hydrate $CaSO_4 \cdot 2H_2O$?
- Name each of the following compounds: Na_2O, Cu_2O, and P_2O_5.
- Write the electron dot and structural formulas for formaldehyde, CH_2O.
- Which of the following molecules has the shortest bond length: HF, HCl, N_2, or O_2?
- Which type of bonding is found in each of the following solids: KCl, $NaSO_4$, and Cu?
- Compare the molecular shapes of CH_4, NH_3, and H_2O.
- Does CO_2 have any polar bonds? Is it a polar molecule? Why?
- What is the predominate intermolecular force involved between two PCl_3 molecules?
- Correlate the relative boiling points of the following compounds with their molecular structure and intermolecular interactions: H_2O, Cl_2, Br_2, HCl, and H_2.
- Why is ammonia gas very soluble in water while oxygen is only slightly soluble?

Discussion Questions: Chemical Reactions and Periodicity

- In what location of the periodic table are nonmetals generally found?
- List some examples of transition elements.
- How do atomic radii, ionization energies, and melting points change across period and down columns in the periodic table?
- List the elements H, He, Li, and Be in order of increasing atomic radius.
- How do the chemical properties of the elements in a period change as you move from left to right across the periodic table?
- What are the electron configurations for atoms of sodium and sulfur? Based on their electron configurations, what is the formula of the compound that forms in the reaction of sodium and sulfur?
- How is a decomposition reaction different from a synthesis reaction?
- Balance the following equation: $Al + CuCl_2 \rightarrow AlCl_3 + Cu$. What type(s) of reaction is it?
- Is the following process an oxidation or reduction? $Ni^{2+} + 2e^- \rightarrow Ni$
- What is the oxidation state of Mn in $KMnO_2$?
- What is the limiting reagent in the reaction to form water when $10\ g$ of hydrogen is mixed with $32\ g$ of oxygen?
- At standard temperature and pressure, what is the ratio of the volumes of hydrogen gas and oxygen gas that react to form water?
- What is the effect of temperature and catalysts on reaction rates?

Discussion Questions: Solutions and Acid-Base Chemistry

- Is a very concentrated solution saturated, supersaturated, or unsaturated? What else do you need to know to answer the question?

- How many grams of solute are present in $1.5\,\text{L}$ of $0.30\,M\,KNO_3$?
- What is the relationship between surface area and dissolution rate?
- Will increasing temperature increase the solubility of any substance?
- Which of the following 1 *M* solutions will have the lowest freezing point: C_2H_5OH, KI, or $MgCl_2$?
- Classify the following molecules as electrolytes or nonelectrolytes: H_2S, HCl, and CCl_4.
- What is $[H^+]$ in an aqueous solution with $pH = 5$?
- If the pH of a solution decreases from 5 to 4, by how much does the concentration of hydrogen ions increase?
- What is the $[OH^-]$ of a solution with $[H^+] = 1 \times 10^{-8}\,M$?
- What is an example of a buffer solution? How will the pH change as acid is added to the buffer solution?
- Determine the endpoint in an acid-base titration using a plot of pH versus the volume of base added to an acid.
- What indicator would be used in a titration involving a strong acid and a weak base and why?
- If Na_2CO_3 is dissolved in water, will the solution be acidic, basic, or neutral?

IV. Physics

A. Mechanics

1. Description of motion in one and two dimensions
   a. Scalar quantities (distance, mass, speed, time, and energy)
   b. Vector quantities (displacement, velocity, acceleration, force, and momentum)
   c. Linear motion
   d. Two-dimensional motion, including circular motion and projectile motion
2. Newton's laws of motion
   a. First law (mass and inertia)
   b. Second law (net force, mass, and acceleration)
   c. Third law (action-reaction pairs)
3. Weight, mass, density, and buoyancy
   a. Distinguish between weight and mass
   b. Newton's law of universal gravitation
   c. Acceleration due to gravity
   d. Fluid properties (Archimedes' principle and density)
4. Analysis of motion and forces and applications
   a. Friction
   b. Center of mass
   c. Impulse and linear momentum

   d. Conservation of momentum and collisions (elastic and inelastic)
   e. Uniform circular motion
   f. Projectile motion
   g. Periodic motion (Hooke's law, pendulums, and springs)
5. Energy and work
   a. Mechanical energy (kinetic and potential)
   b. Conservation of energy
   c. Concept of work and power
   d. Force and distance relationships in simple machines

B. Electricity, Magnetism, and Waves

1. Electrostatics
   a. Static electric charge (attractive and repulsive forces)
   b. Methods of charge separation (friction, conduction, induction, and polarization)
   c. Coulomb's law and electric fields
   d. Electric potential and potential difference (voltage)
   e. Conductors and insulators
2. Properties and relationships involving electric current
   a. Current, resistance, potential difference (voltage)
   b. Ohm's law
   c. Relationship between power, electric current, and potential difference
   d. Electrical energy in daily life (kilowatt-hour)
   e. Difference between direct current and alternating current
   f. Sources of potential difference (batteries, generators, photocells)
   g. Analysis of simple series and parallel circuits
3. Magnetic fields, forces, and materials
   a. Magnetic forces (attractive and repulsive) and fields
   b. Magnets (bar magnets and poles, permanent magnets, and electromagnets)
   c. Relationships between electricity and magnetism and applications (motors and generators)
4. Types of waves and their characteristics
   a. Transverse and longitudinal
   b. Relationships between amplitude, wavelength, frequency, period, and speed of propagation, and energy (mechanical and electromagnetic)
   c. Superposition, standing waves, and resonance
5. Electromagnetic waves and the electromagnetic spectrum
   a. Model and properties of light (electric and magnetic fields, speed of light, energy, and photons)

   b. Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, x-rays, and gamma rays)
   c. The visible spectrum
6. Light wave phenomena
   a. Reflection, refraction, and total internal reflection
   b. Diffraction, interference, and polarization
   c. Scattering, absorption, dispersion, and transmission
7. Sound
   a. Compression waves
   b. Echoes
   c. Speed of sound (sonic boom and sound barrier)
   d. Pitch (frequency) and loudness (intensity)
   e. Applications of resonance (e.g., musical instruments, harmonics)
   f. Applications of Doppler effect involving sound
8. Geometric optics
   a. Mirrors (plane, convex, and concave)
   b. Lenses (converging and diverging)
   c. Using diagrams to characterize image formation (e.g., distance, size, orientation, and real versus virtual)
   d. Simple instruments (e.g., magnifying glass, prisms)

Discussion questions: Mechanics

- What is the difference between speed and velocity?
- Describe in graphical form the position, velocity, and acceleration of an object that is thrown vertically upward and returns to its starting point.
- Illustrate the magnitude and direction of the resultant of two perpendicular vectors.
- Explain how Newton's third law applies to the flight of a bird.
- What is the relationship between the distance that separates two objects and the force of gravitational attraction?
- What is meant by the term "terminal velocity"?
- Compare the buoyant force acting on an object floating on water to its weight.
- What forces are acting on a crate at rest on an inclined ramp?
- Explain why gymnasts performing on a balance beam raise their arms to regain their balance.
- How does the conservation of momentum apply to collisions?
- What is the direction of the centripetal force acting on an object moving in uniform circular motion?
- A ball is dropped, and another ball of smaller mass is fired horizontally from the same height. Which ball hits the ground first?
- What variables affect the period of a pendulum?
- Describe the relationship between the period and the frequency of a harmonic oscillator.

- Describe in graphical form the potential energy, kinetic energy, and total mechanical energy of a linear harmonic oscillator as a function of position.
- Which requires more work: lifting a 100-kilogram sack a vertical distance of 2 meters or lifting a 50-kilogram sack a vertical distance of 4 meters?
- Explain mechanical advantage using a lever as an example.

Discussion questions: Electricity, Magnetism, and Waves

- Why are metals good conductors of electricity?
- Compare the electrostatic force between two point charges separated by a certain distance with the electrostatic force if the distance is doubled.
- How are series circuits different from parallel circuits?
- Write the mathematical expression for the equivalent resistance of two resistors connected in series or two resistors connected in parallel.
- Describe the orientation of field lines of a bar magnet.
- What color light is transmitted through a piece of blue glass?
- List in order of increasing energy (or decreasing wavelength) the following forms of electromagnetic radiation: gamma rays, microwaves, x-rays, visible light, ultraviolet, and infrared.
- What wave phenomena are involved in the separation of white light into a spectrum of colors by a prism?
- Does the size of the image in a plane mirror change as the object moves away from the mirror?
- What happens to parallel rays of light when they pass through a convex lens?
- When you blow over a bottle, what happens to the frequency as you fill the bottle with water?

Science and Engineering Practices

The SEPs represent eight practices that scientists and engineers—and students and teachers—use to investigate the world and to design and build systems. Many test questions will integrate one or more of these practices.

1. Asking questions (for science) and defining problems (for engineering)
    - Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
    - Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
    - Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
    - Ask questions to clarify and refine a model, an explanation, or an engineering problem.
    - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

- Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

2. Developing and using models
   - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.
   - Design a test of a model to ascertain its reliability.
   - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
   - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
   - Develop a complex model that allows for manipulation and testing of a proposed process or system.
   - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.
3. Planning and carrying out investigations
   - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
   - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
   - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
   - Select appropriate tools to collect, record, analyze, and evaluate data.
   - Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.
   - Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

4. Analyzing and interpreting data
    - Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
    - Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
    - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
    - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
    - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
    - Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
5. Using mathematics and computational thinking
    - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
    - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
    - Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
    - Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
    - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m^3, acre-feet, etc.).
6. Constructing explanations (for science) and designing solutions (for engineering)
    - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
    - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
    - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

7. Engaging in argument from evidence
   - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
   - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
   - Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
   - Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
   - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
   - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).
8. Obtaining, evaluating, and communicating information
   - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
   - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
   - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
   - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

- Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Tasks of Teaching Science

This list includes instructional tasks that teachers engage in that are essential for effective Physical Science teaching. Many test questions will measure content through application to one or more of these tasks.

Scientific Instructional Goals, Big Ideas, and Topics

1. Selecting or sequencing appropriate instructional goals or big ideas for a topic
2. Identifying the big idea or instructional goal of an instructional activity
3. Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
4. Linking science ideas to one another and to particular activities, models, and representations within and across units

Scientific Investigations and Demonstrations

5. Selecting investigations or demonstrations, including virtual, that facilitate understanding of disciplinary core ideas, scientific practices, or crosscutting concepts
6. Evaluating investigation questions for quality (e.g., testable, empirical)
7. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question
8. Critiquing scientific procedures, data, observations, or results for their quality, accuracy, or appropriateness
9. Supporting students in generating questions for investigation or identifying patterns in data and observations

Scientific Resources (texts, curriculum materials, journals, and other print and media-based resources)

10. Evaluating instructional materials and other resources for their ability to address scientific concepts; engage students with relevant phenomena; develop and use scientific ideas; promote students' thinking about phenomena, experiences, and knowledge; take account of students' ideas and background; and assess student progress
11. Choosing resources that support the selection of accurate, valid, and appropriate goals for science learning

Student Ideas (including common misconceptions, alternate conceptions, and partial conceptions)

12. Analyzing student ideas for common misconceptions regarding intended scientific learning
13. Selecting diagnostic items and eliciting student thinking about scientific ideas and practices to identify common student misconceptions and the basis for those misconceptions

14. Developing or selecting instructional moves, approaches, or representations that provide evidence about common student misconceptions and help students move toward a better understanding of the idea, concept, or practice

Scientific Language, Discourse, Vocabulary, and Definitions

15. Selecting scientific language that is precise, accurate, grade-appropriate, and illustrates key scientific concepts
16. Anticipating scientific language and vocabulary that may be difficult for students
17. Modeling the use of appropriate verbal and written scientific language in critiquing arguments or explanations, in describing observations, or in using evidence to support a claim, etc.
18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation

Scientific Explanations (includes claim, evidence, and reasoning)

19. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence
20. Selecting explanations of natural phenomena that are accurate and accessible to students

Scientific Models and Representations (analogies, similes, metaphors, simulations, illustrations, diagrams, data tables, performances, videos, animations, graphs, and examples)

21. Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals
22. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal
23. Evaluating student models or representations for evidence of scientific understanding
24. Generating or selecting diagnostic questions to evaluate student understanding of specific models or representations
25. Evaluating student ideas about what makes for good scientific models and representations

Physical Science (5485) Sample Test Questions

The sample questions that follow are examples of the kinds of questions that are on the test. They are not, however, representative of the entire scope of the test in either content or difficulty. Answers with explanations follow the questions.

Directions: Select the best answer or answers for each question below.

1. Which of the following statements is a hypothesis that is testable in a high school chemistry laboratory?

   (A) The total mass remains constant during a chemical reaction.

   (B) The rust that formed on a nail is iron oxide.

   (C) A larger mass of an unknown salt will dissolve in warm water than will dissolve in cold water.

   (D) The temperature of a reaction mixture increased by $20°C$.

$$^{242}_{96}\text{Cm} + {}^{4}_{2}\alpha \rightarrow {}^{243}_{97}\text{Bk} + {}^{1}_{1}\text{p} + \ldots {}^{1}_{0}\text{n}$$

2. According to the preceding unbalanced nuclear equation, how many neutrons are released per atom of $^{242}_{96}\text{Cm}$?

   (A) Two

   (B) Three

   (C) Four

   (D) Five

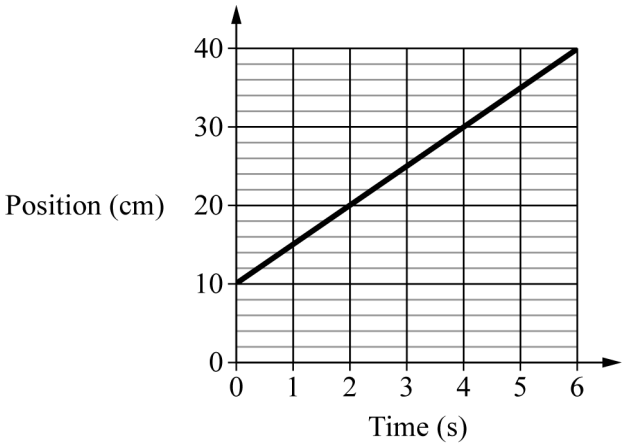
3. What is the approximate percent by mass of oxygen in C_2H_6O? (The molar mass of C_2H_6O is $46\,g/mol$.)

   (A) 10%

   (B) 35%

   (C) 60%

   (D) 75%



4. The preceding graph gives the position versus time for an object moving in a straight line. Based on the graph, which **TWO** of the following statements about the slope of the plotted line are correct?

   (A) It is equal to $5.0\ \text{cm/s}$.

   (B) It is equal to $6.7\ \text{cm/s}$.

   (C) It represents the acceleration of the object.

   (D) It represents the speed of the object.

5. Which of the following student claims illustrates a correct use of terminology related to the periodic table?

   (A) Argon and chromium are noble gases.

   (B) Lithium and rubidium are alkaline-earth metals.

   (C) Calcium and krypton are in the same period.

   (D) Silicon and phosphorus are in the same group.

6. A simple circuit made of a 12-volt battery and a 2-ohm resistor has a measured current of 6 amps. If a 4-ohm resistor is added in series with the 2-ohm resistor, what is the current through the 2-ohm resistor?

   (A) 2 amps

   (B) 3 amps

   (C) 4 amps

   (D) 6 amps

7. Students are working on a research project to identify the best material to use to make drinking straws. Initially, the students consider two criteria: minimizing carbon dioxide emissions and reducing energy consumption. Of the following, which is the most relevant question the students should also address to best meet the criteria of the project?

   (A) Which countries provide the raw materials to make the straws?

   (B) Can the straws be reused multiple times?

   (C) What are the average length and width of each straw?

   (D) Will the straws degrade when exposed to sunlight?

Solution	Moles of Solute	Volume of Solution
1	0.20 mol	1.0 L
2	0.10 mol	2.0 L
3	0.010 mol	0.010 L
4	0.0010 mol	0.200 L

8. The preceding table gives information about the composition of four solutions. Students use the table to identify and explain which solution is the most concentrated. Of the following student responses, which shows the best understanding of the concept of solution concentration?

   (A) Solution 1, because it has the largest number of moles of solute.

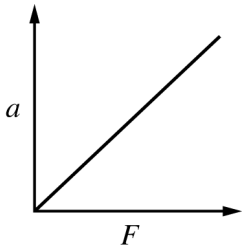
   (B) Solution 2, because it has the largest volume of solution.

   (C) Solution 3, because it has the largest ratio of number of moles of solute per volume of solution.

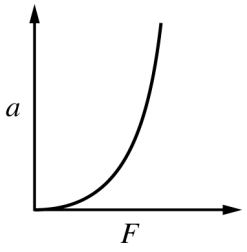
   (D) Solution 4, because it has the largest ratio of volume of solution per number of moles of solute.

9. Which of the following graphs correctly illustrates the relationship between the magnitude of the net force F acting on an object and the magnitude of the acceleration a of the object?

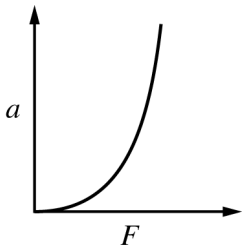
(A)



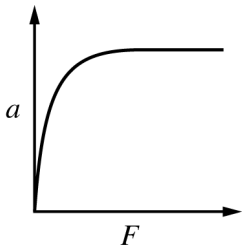
(C)



(B)



(D)



Source 1	A hydrogen bond is an attractive force between an H atom with a partial positive charge and an atom with a partial negative charge.
Source 2	Hydrogen bonding is a special type of dipole-dipole force that occurs between an H atom that is covalently bonded to a very electronegative atom and another very electronegative atom.

10. A teacher gathers the information provided in the preceding table. What source provides the most complete and accurate information?

(A) Source 1, because a hydrogen bond can exist between an H atom with a partial positive charge and any atom with a partial negative charge.

(B) Source 1, because attractive forces can develop between atoms with opposite charges in a hydrogen bond.

(C) Source 2, because H atoms can form covalent bonds with another H atom or with atoms of most other elements.

(D) Source 2, because when an H atom is covalently bonded to an N, O, or F atom in a molecule, it can form hydrogen bonds with N, O, or F atoms in a nearby molecule.

11. A student makes an electromagnet by wrapping an insulated copper wire around an iron nail and connecting the ends of the wire to a 1.5-volt battery. Which **TWO** of the following could the student do to increase the strength of the electromagnet?

    (A) Replace the 1.5-volt battery with a 9.0-volt battery.

    (B) Double the number of loops of the wire around the nail.

    (C) Add a resistor to the closed circuit.

    (D) Remove the nail from the center of the coil of wire.

12. A sample containing 2.0 moles of an ideal gas at $480\,\text{K}$ is placed inside a rigid container at an initial pressure P_1. Which equation represents the final pressure P_2 when the temperature of the sample reaches $240\,\text{K}$?

    (A) $P_2 = \frac{P_1}{4}$

    (B) $P_2 = \frac{P_1}{2}$

    (C) $P_2 = 2P_1$

    (D) $P_2 = P_1$

13. Students plan an experiment to determine the percent composition of a mixture of insoluble $CaCO_3$ crystals and soluble Na_2CO_3 crystals. The students will add water to a sample of the mixture to dissolve the Na_2CO_3. Of the following, which step must be done before the water is added?

    (A) Pass the sample through a sieve.

    (B) Boil the water to kill any bacteria.

    (C) Measure the mass of the sample.

    (D) Measure the pH of the water.

14. Br is more electronegative than which **TWO** of the following elements?

    (A) O

    (B) F

    (C) Se

    (D) As

15. An apple is observed to be floating in a bucket of water. A person then pushes the apple downward so that the apple is completely below the surface of the water. Which of the following best describes the buoyant force acting on the apple while it is being held under the surface of the water?

    (A) There is no buoyant force.

    (B) The buoyant force is less than the weight of the apple.

    (C) The buoyant force is equal to the weight of the apple.

    (D) The buoyant force is greater than the weight of the apple.

16. Students are asked to give an example of a common base and explain their choice. Which of the following student responses shows the best understanding of a property of basic substances?

    (A) Black coffee is basic, because the pH is less than 7.

    (B) Crushed tomatoes are basic, because the $[H^+]$ is higher than $1 \times 10^{-7} M$.

    (C) Yogurt is basic, because one drop of it on blue litmus paper turns the paper red.

    (D) Aqueous ammonia is basic, because one drop of it on red litmus paper turns the paper blue.

Material	Index of Refraction
Crown glass	1.50
Polycarbonate	1.60
Cubic zirconia	2.15
Diamond	2.42

17. The preceding table gives the index of refraction for several materials. In a refraction investigation, a ray of light travels from air into each of the media listed in the table with the same angle of incidence. In which medium will the ray of light have the largest angle of refraction? (Note that the index of refraction for air is 1.00.)

    (A) Crown glass

    (B) Polycarbonate

    (C) Cubic zirconia

    (D) Diamond

18. A substance has a very high melting point, is a hard, crystalline solid at room temperature, and readily conducts electricity only when dissolved in water. Based on the information, which of the following types of bonding is most likely present in the substance?

    (A) Nonpolar covalent

    (B) Polar covalent

    (C) Ionic

    (D) Metallic

19. Which of the following is the outer electron configuration of an atom in its ground state of an element that has chemical properties similar to those of Ga?

    (A) $3s^2 3p^1$

    (B) $4s^2 3d^{10}$

    (C) $4s^2 3d^{10} 4p^2$

    (D) $5s^2 4d^{10} 5p^5$

20. A ball is launched with an initial velocity of $5\,\text{m/s}$ at the following angles with respect to ground level: $30°$, $45°$, $60°$, and $90°$. Assuming negligible air resistance, which of the following statements is true regarding the vertical (height) and horizontal distances that the ball travels?

    (A) The vertical distance will be greatest at $90°$, and the horizontal distance will be greatest at $30°$.

    (B) The vertical distance will be greatest at $90°$, and the horizontal distance will be greatest at $45°$.

    (C) The vertical distance will be greatest at $45°$, and the horizontal distance will be greatest at $60°$.

    (D) The vertical distance will be greatest at $45°$, and the horizontal distance will be greatest at $90°$.

$$C_2H_6(g) + O_2(g) \rightarrow ?$$

21. Students use the preceding incomplete representation of a chemical reaction to predict the products formed. Which of the following student predictions is the most accurate?

    (A) $CO_2(g)$ is produced if the reaction is complete.

    (B) $H_2O_2(l)$ is produced if the reaction is complete.

    (C) $C(s)$ is produced if $O_2(g)$ is the limiting reactant.

    (D) $H_2(g)$ is produced if $C_2H_6(g)$ is the limiting reactant.

22. Of the following, which is true for all chemical and physical processes that do not include nuclear changes?

    (A) The processes will eventually reach completion.

    (B) The processes are exothermic.

    (C) During the processes, kinetic energy is always converted to chemical energy.

    (D) During the processes, the total mass will most likely remain constant.

23. For a classroom experiment, students prepare an aqueous solution of known concentration by dissolving $MgCl_2(s)$. Of the following, which **TWO** procedures should the students follow so that the solid dissolves at a faster rate?

    (A) Using a very large volumetric flask to prepare the solution.

    (B) Using a glass rod to stir the solution continuously.

    (C) Using high-purity $MgCl_2(s)$.

    (D) Using a mortar and pestle to grind the solid before adding it to water.

24. Two carts are on the same track. Cart 1 has a mass of $2\,\text{kg}$ and travels to the right at $3\,\text{m/s}$. Cart 2 has a mass of 1kg and travels to the left at $3\,\text{m/s}$. If the two carts have a perfectly inelastic collision, which of the following is most likely to occur as a result of the collision?

    (A) Cart 1 and cart 2 will stick together and travel to the right at 1m/s.

    (B) Cart 1 and cart 2 will stick together and travel to the left at 1m/s.

    (C) Cart 1 will travel to the left at 1m/s, and cart 2 will travel to the right at 1m/s.

    (D) Cart 1 will travel to the left at 1m/s, and cart 2 will travel to the right at a speed greater than 1m/s.

25. Which **TWO** of the following aspects of natural gas extraction and use are environmental benefits of using natural gas instead of coal as a fuel to produce electricity?

    (A) Sulfur-containing compounds are removed during the purification of natural gas.

    (B) Natural gas produces less carbon dioxide per unit of energy than do other fossil fuels.

    (C) Methane is released into the atmosphere during extraction and transportation of natural gas.

    (D) Water is used during the hydraulic fracturing process to extract natural gas.

26. As a demonstration, a teacher partially submerges a vertical tube that is open at both ends in a container filled with water. The teacher holds a tuning fork over the end of the tube that is open to air and raises and lowers the tube until the observed sound is at a maximum. This demonstration illustrates which of the following phenomena?

    (A) Diffraction

    (B) Resonance

    (C) The Doppler effect

    (D) Total internal reflection

$$\text{A}(g) + \text{B}(g) \rightarrow \text{AB}(g)$$

27. The preceding chemical equation represents an exothermic gas-phase reaction. Which of the following is most likely to increase the initial rate of formation of $\text{AB}(g)$?

    (A) Decreasing the temperature

    (B) Decreasing the pressure of both A and B

    (C) Adding a substance that reacts with A and B

    (D) Adding a catalyst

Type of Electromagnetic Radiation	Range of Frequencies
Ultraviolet	3.0×10^{16} Hz to 7.5×10^{14} Hz
Infrared	4.3×10^{14} Hz to 3.0×10^{11} Hz

28. Based on the information in the preceding table, which **TWO** of the following comparisons about ultraviolet and infrared light are true?

    (A) Ultraviolet light has shorter wavelengths than infrared light does.

    (B) Ultraviolet light has longer wavelengths than infrared light does.

    (C) Photons of ultraviolet light have less energy than photons of infrared light do.

    (D) Photons of ultraviolet light have more energy than photons of infrared light do.

Experiment	Charge 1	Charge 2	Distance of Separation
1	$1\mu C$	$1\mu C$	2 cm
2	$1\mu C$	$1\mu C$	4 cm
3	$2\mu C$	$2\mu C$	2 cm
4	$2\mu C$	$2\mu C$	4 cm

29. The preceding table lists magnitudes of charge for two point charges and the distance between them in four experiments. In which experiment is the electrostatic force between the point charges greatest?

    (A) Experiment 1

    (B) Experiment 2

    (C) Experiment 3

    (D) Experiment 4

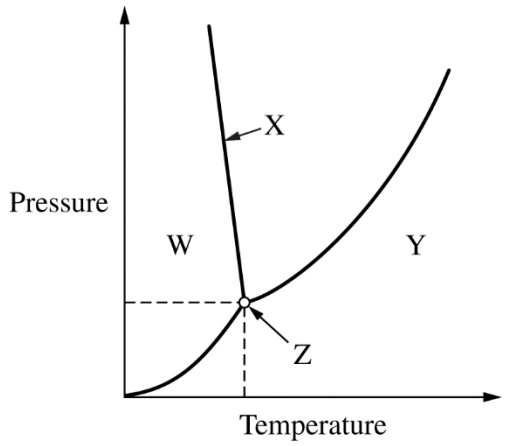
30. Which of the following uses dimensional analysis to correctly calculate the distance, in cm, traveled by a car moving at a speed of 90 km/hour for 30 minutes?

(A) $\frac{30\,\text{min}}{1} \times \frac{1\,\text{hour}}{60\,\text{min}} \times \frac{1\,\text{m}}{1\times10^{3}\,\text{km}} \times \frac{1\,\text{cm}}{1\times10^{2}\,\text{m}}$

(B) $\frac{30\,\text{min}}{1} \times \frac{60\,\text{min}}{1\,\text{hour}} \times \frac{90\,\text{km}}{1\,\text{hour}} \times \frac{100\,\text{cm}}{1\,\text{km}}$

(C) $\frac{30\,\text{min}}{1} \times \frac{90\,\text{km}}{1\,\text{hour}} \times \frac{1\times10^{3}\,\text{m}}{1\,\text{km}} \times \frac{100\,\text{cm}}{1\,\text{m}}$

(D) $\frac{30\,\text{min}}{1} \times \frac{1\,\text{hour}}{60\,\text{min}} \times \frac{90\,\text{km}}{1\,\text{hour}} \times \frac{1\times10^{3}\,\text{m}}{1\,\text{km}} \times \frac{100\,\text{cm}}{1\,\text{m}}$



31. Students are asked to add labels to different parts of the preceding incomplete phase diagram for a substance. Of the following student responses, which is most accurate?

	Label for W	Label for X	Label for Y	Label for Z
(A)	Solid	Condensation and evaporation	Liquid	Boiling point
(B)	Solid	Freezing and melting	Gas	Triple point
(C)	Liquid	Freezing and melting	Solid	Melting point
(D)	Gas	Condensation and evaporation	Liquid	Triple point

32. Of the following, which topic sequence would best help students learn how energy is transferred between two metal objects initially at different temperatures when placed in contact with each other?

	First Topic	Second Topic	Third Topic	Fourth Topic
(A)	Temperature scales	Heat versus temperature	Convection	States of matter
(B)	Heat versus temperature	Temperature scales	Conduction	States of matter
(C)	States of matter	Temperature scales	Heat versus temperature	Conduction
(D)	States of matter	Convection	Temperature scales	Heat versus temperature

Physical Science (5485) Answers

1. The correct answer is (C). The statement that an unknown salt will be more soluble at higher solvent temperatures is a testable hypothesis that can be supported or refuted through investigation. The equipment needed for such an investigation is commonly available in high school chemistry labs.

Content	I A
Science and Engineering Practice	3
Task of Teaching Science	6

2. The correct answer is (A). In a balanced nuclear equation, the sums of the mass numbers and atomic numbers of the reactant side of the equation are equal to the respective sums on the product side. In this case, the sum of the mass numbers of the reactants is equal to $242+4=246$. To balance the product side, the coefficient of the ${}_{0}^{1}n$ must be 2, so that the sum of the mass numbers is equal to $243+1+2=246$. Thus, two neutrons are released per atom of ${}_{96}^{242}Cm$.

Content	II A
Science and Engineering Practice	5

3. The correct answer is (B). Based on the chemical formula, there is one mole of oxygen atoms in one mole of C_2H_6O. One mole of oxygen atoms has a mass of $16\,g$. The percent by mass of oxygen is equal to $\frac{16\,g}{46\,g}\times 100\%$, which is approximately 35%.

Content	III A
Science and Engineering Practice	5

4. The correct answers are (A) and (D). The slope is equal to the change in position of the object over time and represents the speed of the object. The speed of this object can be calculated from any two points on the plotted line. For example,

$$v=\frac{40\text{ cm}-10\text{ cm}}{6\text{ s}-0\text{ s}}=\frac{30\text{ cm}}{6\text{ s}}=5.0\text{ cm/s}.$$

Content	IV A
Science and Engineering Practice	5

5. The correct answer is (C). A row in the periodic table is known as a period. Calcium (Ca) and krypton (Kr) are both in the fourth period.

Content	III B
Task of Teaching Science	18

6. The correct answer is (A). The equivalent resistance of the series circuit is
$R_{eq}=R_1+R_2=2\text{ ohms}+4\text{ ohms}=6\text{ ohms}$

The current for the circuit is $I = \frac{V}{R} = \frac{12 \text{ volts}}{6 \text{ ohms}} = 2 \text{ amps}$. In a series circuit, the current through the resistors is the same and equal to the current for the circuit (2 amps).

Content	IV B
Science and Engineering Practice	5

7. The correct answer is (B). The processing of the raw materials and the manufacturing of the straws are likely to be major contributors to carbon dioxide emissions and energy consumption during the life cycle of the straws. Therefore, whether the material allows the straws to be reusable is a relevant question to address to meet criteria of the project.

Content	I B
Science and Engineering Practice	1
Task of Teaching Science	3

8. The correct answer is (C). Concentration is generally expressed as a ratio of the amount of solute per the amount of solvent or solution. For solution 3, the ratio

$$\frac{0.010 \text{ mol solute}}{0.010 \text{ L solution}} = 1.0 \text{ mol solute} / 1.0 \text{ L of solution}$$

When comparing solutions with the same unit of concentration, the larger the ratio, the higher the concentration of the solution. In this example, the concentration is expressed as molar concentration.

Content	III C
Science and Engineering	5
Task of Teaching Science	12

9. The correct answer is (A). According to Newton's second law, $F = ma$, which can be rearranged to give $a = \frac{F}{m}$. The graph in option A correctly represents that the magnitude of acceleration a is directly proportional to the applied force F for an object with mass m.

Content	IV A
Science and Engineering Practice	5

10. The correct answer is (D). Source 2 provides the most complete and accurate information about hydrogen bonding. Hydrogen bonding occurs between a hydrogen covalently bonded to a very electronegative atom, such as N, O, or F, and an electronegative atom in a nearby molecule. The information is important in predicting the properties of molecular compounds based on the relative strengths of intermolecular forces, particularly when comparing compounds with similar molecular masses.

Content	III A
Science and Engineering Practice	8
Task of Teaching Science	11

11. The correct answers are (A) and (B). Increasing the voltage of the battery and doubling the number of loops of wire around the nail will increase the strength of the magnetic field.

Content	IV B

12. The correct answer is (B). Based on the ideal gas laws, specifically Gay-Lussac's law $\frac{P_1}{T_1}=\frac{P_2}{T_2}$, if the Kelvin temperature of a sample of gas held at constant volume is reduced by half, its pressure is also reduced by half.

Content	II B
Science and Engineering Practice	5

13. The correct answer is (C). This type of experiment typically involves dissolving a sample in water and collecting the insoluble component by filtration. The percent composition of $CaCO_3$ is determined using the following calculation: $\frac{\text{mass of dried } CaCO_3}{\text{mass of sample of the mixture}}\times 100\%$; therefore, the mass of the sample of the mixture should be measured before adding water and the collected $CaCO_3$ should be dried to constant mass.

Content	I A
Science and Engineering Practice	3
Task of Teaching Science	8

14. The correct answers are (C) and (D). Electronegativity generally increases across a row and decreases down a column on the periodic table. Therefore, based on its position on the periodic table, Br is more electronegative than As and Se but less electronegative than O and F.

Content	III B

15. The correct answer is (D). The buoyant force acting on the apple is equal to the weight of water displaced by the apple. When the apple is floating, the buoyant force, which is directed upward, is equal to the weight of the apple, which is directed downward. When the apple is completely submerged, the volume of water displaced by the apple is larger than it is when the apple is floating; therefore, the buoyant force is greater than the weight of the apple.

Content	IV A

16. The correct answer is (D). Aqueous ammonia is basic. Properties of bases include turning red litmus paper blue, pH greater than 7, $[H^+]$ less than $1\times10^{-7}M$, slippery feel, and bitter taste.

Content	III C
Science and Engineering Practice	6
Task of Teaching Science	19

17. The correct answer is (A). When a light ray travels from a medium with an index of refraction n_i into another medium with a higher index of refraction n_r, the ray is bent toward the normal, which is a line perpendicular to the boundary at the point of incidence. The angle of refraction is the angle between the normal and the bent light ray. According to Snell's law, for a given angle of incidence, the larger the ratio $\frac{n_i}{n_r}$ the larger the angle of refraction.

Therefore, the light ray is bent the least and the angle of refraction is largest when the light ray passes from air into crown glass.

Content	IV B
Science and Engineering Practice	5

18. The correct answer is (C). The electrostatic attraction between ions in a lattice structure generally results in hard, crystalline solids with high melting points. Ionic compounds dissolved in water dissociate to form solutions that conduct electricity.

Content	III A
Science and Engineering Practice	4

19. The correct answer is (A). Elements with the same number of valence electrons tend to have similar chemical properties. Based on its outer electron configuration, $4s^2 3d^{10} 4p^1$, an atom of Ga has three valence electrons, $4s^2 4p^1$. The outer electron configuration, $3s^2 3p^1$, represents an atom in its ground state of an element with three valence electrons and corresponds to Al, which is in the same column of the periodic table as Ga.

Content	II A
Science and Engineering Practice	2

20. The correct answer is (B). It assumed the only force acting on a projectile during its motion is gravity. Consider that the initial velocity is the resulting vector of vertical velocity and the horizontal velocity. The vertical component of velocity and vertical distance traveled are at their greatest when the ball is launched directly upward at a $90°$ angle. As the launch angle decreases, the vertical component of velocity and vertical distance traveled decrease, and the horizontal component of velocity increases. However, the horizontal distance traveled only increases to its maximum at a $45°$ launch angle. At launch angles less than $45°$, decreasing flight times result in decreasing horizontal distances traveled.

Content	IV A
Science and Engineering Practice	5

21. The correct answer is (A). $C_2H_6(g)$ is a hydrocarbon fuel that will undergo complete combustion with the oxidant $O_2(g)$ to produce $CO_2(g)$ and $H_2O(l)$.

Content	III B
Science and Engineering Practice	2
Task of Teaching Science	21

22. The correct answer is (D). According to the law of conservation of mass, during all chemical and physical processes in a closed system, the total mass will remain constant.

Content	II B

23. The correct answers are (B) and (D). Constant stirring or agitation of the mixture of $MgCl_2(s)$ in water and grinding the sample of $MgCl_2(s)$ to increase its surface area will increase the rate of dissolution by increasing the amount of $MgCl_2(s)$ exposed to the water.

Content	III C
Science and Engineering Practice	3
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24. The correct answer is (A). In a perfectly inelastic collision, the two carts will stick together, and momentum, but not kinetic energy, is conserved. This is expressed as $m_1v_1 + m_2v_2 = (m_1 + m_2)v_f$, where v_f is the velocity of the joined carts. Rearranging to solve for v_f and substituting the known quantities with velocity directed rightward as positive gives

$$v_f = \frac{(2\,\text{kg})(3\,\text{m/s}) + (1\,\text{kg})(-3\,\text{m/s})}{(2\,\text{kg} + 1\,\text{kg})} = 1\,\text{m/s}$$

to the right. The correct answer can be deduced by recognizing that cart 1, which is traveling to the right, has more momentum than cart 2 does, so the joined carts will also travel to the right at a slower speed.

Content	IV A
Science and Engineering Practice	5

25. The correct answers are (A) and (B). Because sulfur-containing compounds are removed during purification, the burning of natural gas is not a major contributor to acid rain. Natural gas produces less carbon dioxide, a greenhouse gas, per unit of energy than other fossil fuels do when combusted. Methane is also a greenhouse gas, so its inadvertent release into the atmosphere is an environmental drawback. The use of water during hydraulic fracturing can potentially deplete or contaminate local freshwater supplies.

Content	I B

26. The correct answer is (B). The demonstration illustrates the phenomenon of resonance. The sound waves generated by the tuning fork travel down the tube and are reflected off the surface of the water. At certain lengths from the top of the tube to the surface of the water, the resulting interference creates a standing wave, and the sound is observably louder.

Content	IV B
Task of Teaching Science	5

27. The correct answer is (D). In the presence of a catalyst, the activation energy of a reaction is reduced. This means that there will be a larger number of successful collisions between the reactions to form the product, which will consequently increase the initial rate of formation of the product.

Content	III B

28. The correct answers are (A) and (D). The relationship between frequency and wavelength is expressed as $\text{frequency} = \frac{\text{speed of light}}{\text{wavelength}}$. Since the frequencies of ultraviolet light are higher than those of infrared light, the wavelengths of ultraviolet light are shorter than those of infrared light. The relationship between energy of a photon and frequency is expressed as $\text{energy} \propto \text{frequency}$. Since the frequencies of ultraviolet light are higher than those of infrared light, the photon energies of ultraviolet light are shorter than those of infrared light.

Content	IV B
Science and Engineering Practice	5

29. The correct answer is (C). Based on Coulomb's law, $F = \frac{kq_1q_2}{r^2}$, the electrostatic force F is greatest in experiment 1, where $q_1 = 2\,\mu\text{C}$, $q_2 = 2\,\mu\text{C}$, and $r = 2\,\text{cm}$.

Content	IV B
Science and Engineering Practice	5

30. The correct answer is (D). The expression correctly applies the conversion factors for time and distance so that the units cancel out to give an answer in cm.

Content	I A
Science and Engineering Practice	5

31. The correct answer is (B). W is the region on the graph that corresponds to pressures and temperatures at which the substance is a solid. X corresponds to pressures and temperatures at which the solid and liquid phases are in equilibrium and freezing and melting are occurring. Z corresponds to the triple point at which the solid, liquid, and gaseous substances coexist in equilibrium. Y is the region on the graph that corresponds to pressures and temperatures at which the substance is a gas.

Content	II B
Science and Engineering Practice	2
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32. The correct answer is (C). The topic sequence that would best help students learn how energy is transferred between two metal objects initially at different temperatures when placed in contact with each other is as follows: states of matter, temperature scales, heat versus temperature, and conduction. Students learn that the metal objects are composed of atoms that are tightly packed in a rigid arrangement and vibrate in place; that the temperatures of the objects are a measure of the average kinetic energy of the atoms; that heat, or thermal energy, is the sum of the of the kinetic energy of the atoms of each object; and that conduction is the process by which the thermal energy is transferred through collisions between the atoms of the objects in contact.

Content	II B
Task of Teaching Science	1

Understanding Question Types

The *Praxis*® assessments include a variety of question types: constructed response (for which you write a response of your own); selected response, for which you select one or more answers from a list of choices or make another kind of selection (e.g., by selecting a sentence in a text or by selecting part of a graphic); and numeric entry, for which you enter a numeric value in an answer field. You may be familiar with these question formats from taking other standardized tests. If not, familiarize yourself with them so you don't spend time during the test figuring out how to answer them.

Understanding Selected-Response and Numeric-Entry Questions

For most questions, you respond by clicking an oval to select a single answer from a list of answer choices.

However, interactive question types may also ask you to respond by:

- Selecting more than one choice from a list of choices.
- Typing in a numeric-entry box. When the answer is a number, you may be asked to enter a numerical answer. Some questions may have more than one entry box to enter a response.
- Selecting parts of a graphic. In some questions, you will select your answers by selecting a location (or locations) on a graphic such as a map or chart, as opposed to choosing your answer from a list.
- Selecting sentences. In questions with reading passages, you may be asked to choose your answers by selecting a sentence (or sentences) within the reading passage.
- Dragging and dropping answer choices into targets on the screen. You may be asked to select answers from a list of choices and to drag your answers to the appropriate location in a table, paragraph of text or graphic.
- Selecting answer choices from a drop-down menu. You may be asked to choose answers by selecting choices from a drop-down menu (e.g., to complete a sentence).

Remember that with every question you will get clear instructions.

Understanding Constructed-Response Questions

Constructed-response questions require you to demonstrate your knowledge in a subject area by writing your own response to topics. Essays and short-answer questions are types of constructed-response questions.

For example, an essay question might present you with a topic and ask you to discuss the extent to which you agree or disagree with the opinion stated. You must support your position with specific reasons and examples from your own experience, observations, or reading.

Review a few sample essay topics:

- *Brown v. Board of Education of Topeka*

  "We come then to the question presented: Does segregation of children in public schools solely on the basis of race, even though the physical facilities and other 'tangible' factors may be equal, deprive the children of the minority group of equal educational opportunities? We believe that it does."

  A. What legal doctrine or principle, established in *Plessy v. Ferguson* (1896), did the Supreme Court reverse when it issued the 1954 ruling quoted above?
  B. What was the rationale given by the justices for their 1954 ruling?

- *In his self-analysis, Mr. Payton says that the better-performing students say small-group work is boring and that they learn more working alone or only with students like themselves. Assume that Mr. Payton wants to continue using cooperative learning groups because he believes they have value for all students.*

  - Describe **TWO** strategies he could use to address the concerns of the students who have complained.
  - Explain how each strategy suggested could provide an opportunity to improve the functioning of cooperative learning groups. Base your response on principles of effective instructional strategies.

- *"Minimum-wage jobs are a ticket to nowhere. They are boring and repetitive and teach employees little or nothing of value. Minimum-wage employers take advantage of people because they need a job."*

  - Discuss the extent to which you agree or disagree with this opinion. Support your views with specific reasons and examples from your own experience, observations, or reading.

Keep these things in mind when you respond to a constructed-response question:

1. **Answer the question accurately.** Analyze what each part of the question is asking you to do. If the question asks you to describe or discuss, you should provide more than just a list.
2. **Answer the question completely.** If a question asks you to do three distinct things in your response, you should cover all three things for the best score. Otherwise, no matter how well you write, you will not be awarded full credit.
3. **Answer the question that is asked.** Do not change the question or challenge the basis of the question. You will receive no credit or a low score if you answer another question or if you state, for example, that there is no possible answer.
4. **Give a thorough and detailed response.** You must demonstrate that you have a thorough understanding of the subject matter. However, your response should be straightforward and not filled with unnecessary information.
5. **Take notes on scratch paper** so that you don't miss any details. Then you'll be sure to have all the information you need to answer the question.
6. **Reread your response.** Check that you have written what you thought you wrote. Be sure not to leave sentences unfinished or omit clarifying information.

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