This test is now delivered as a computer-based test.
See www.nystce.nesinc.com for current program information.
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INTRODUCTION

Purpose of This Preparation Guide

This preparation guide is designed to help familiarize candidates with the content and format of a test for the New York State Teacher Certification Examinations (NYSTCE®) program. Education faculty and administrators at teacher preparation institutions may also find the information in this guide useful as they discuss the test with candidates.

The knowledge and skills assessed by the test are acquired throughout the academic career of a candidate. A primary means of preparing for the test is the collegiate preparation of the candidate.

This preparation guide illustrates some of the types of questions that appear on a test; however, the set of sample questions provided in this preparation guide does not necessarily define the content or difficulty of an entire actual test. All test components (e.g., directions, question content and formats) may differ from those presented here. The NYSTCE program is subject to change at the sole discretion of the New York State Education Department.

Organization of This Preparation Guide

Contained in the beginning sections of this preparation guide are general information about the NYSTCE program and how the tests were developed, a description of the organization of test content, and strategies for taking the test.

Following these general information sections, specific information about the test described in this guide is presented. The test objectives appear on the pages following the test-specific overview. The objectives define the content of the test.

Next, information about the multiple-choice section of the test is presented, including sample test directions. Sample multiple-choice questions are also presented, with the correct responses indicated and explanations of why the responses are correct.

Following the sample multiple-choice questions, a description of the written assignment section of the test is provided, including sample directions. A sample written assignment is presented next, followed by a sample strong response to the assignment and an evaluation of that response.

For Further Information

If you have questions after reading this preparation guide, you may wish to consult the NYSTCE Registration Bulletin. You can view or print the registration bulletin online at www.nystce.nesinc.com.
How Were the NYSTCE Tests Developed?

The New York State Teacher Certification Examinations are criterion referenced and objective based. A criterion-referenced test is designed to measure a candidate’s knowledge and skills in relation to an established standard rather than in relation to the performance of other candidates. The explicit purpose of these tests is to help identify for certification those candidates who have demonstrated the appropriate level of knowledge and skills that are important for performing the responsibilities of a teacher in New York State public schools.

Each test is designed to measure areas of knowledge called subareas. Within each subarea, statements of important knowledge and skills, called objectives, define the content of the test. The test objectives were developed for the New York State Teacher Certification Examinations in conjunction with committees of New York State educators.

Test questions matched to the objectives were developed using, in part, textbooks; New York State learning standards and curriculum guides; teacher education curricula; and certification standards. The test questions were developed in consultation with committees of New York State teachers, teacher educators, and other content and assessment specialists.

An individual’s performance on a test is evaluated against an established standard. The passing score for each test is established by the New York State Commissioner of Education based on the professional judgments and recommendations of New York State teachers. Examinees who do not pass a test may retake it at any of the subsequently scheduled test administrations.
Organization of Content

The content covered by each test is organized into **subareas**. These subareas define the major content domains of the test.

Subareas typically consist of several **objectives**. Objectives provide specific information about the knowledge and skills that are assessed by the test.

Each objective is elaborated on by **focus statements**. The focus statements provide examples of the range, type, and level of content that may appear on the tests.

**Test questions** are designed to measure specific test objectives. The number of objectives within a given subarea generally determines the number of questions that will address the content of that subarea on the test. In other words, the subareas that consist of more objectives will receive more emphasis on the test and contribute more to a candidate's test score than the subareas that consist of fewer objectives.

The following example, taken from the field of Social Studies, illustrates the relationship of test questions to subareas, objectives, and focus statements.

---

**SOCIAL STUDIES (05)**

**SUBAREA I—HISTORY**

0003 Understand the major political, social, economic, scientific, and cultural developments and turning points that shaped the course of world history from 1500 through 1850.

- analyzing the roles, contributions, and diverse perspectives of individuals and groups involved in independence struggles in Latin America

Which of the following was an important goal of nineteenth-century Latin American liberals?

- A. establishing governments based on the separation of church and state
- B. reducing the influence of competitive individualism in social and economic life
- C. creating strong centralized governments
- D. making plantation agriculture the foundation of economic development

Each multiple-choice question is designed to measure one of the test objectives.

The focus statements provide examples of the range, type, and level of content that may appear on the test for questions measuring the objective.

The objectives define the knowledge and skills that New York State teachers and teacher educators have determined to be important for teachers to possess.

The field is divided into major content subareas. The number of objectives in each subarea may vary, depending on the breadth of content contained within it.

This is the name and field number of the test.
TEST-TAKING STRATEGIES

Be On Time.

Arrive at the test center on time so that you are rested and ready to begin the test when instructed to do so.

Follow Directions.

At the beginning of the test session and throughout the test, follow all directions carefully. This includes the oral directions that will be read by the test administrators and any written directions in the test booklet. The test booklet will contain general directions for the test as a whole and specific directions for individual test questions or groups of test questions. If you do not understand something about the directions, do not hesitate to raise your hand and ask your test administrator.

Pace Yourself.

The test schedule is designed to allow sufficient time for completion of the test. Each test session is four hours in length. The tests are designed to allow you to allocate your time within the session as you need. You can spend as much time on any section of the test as you need, and you can complete the sections of the test in any order you desire; however, you will be required to return your materials at the end of the four-hour session.

Since the allocation of your time during the test session is largely yours to determine, planning your own pace for taking the test is very important. Do not spend a lot of time with a test question that you cannot answer promptly; skip that question and move on. If you skip a question, be sure to skip the corresponding row of answer choices on your answer document. Mark the question in your test booklet so that you can return to it later, but be careful to appropriately record on the answer document the answers to the remaining questions.

You may find that you need less time than the four hours allotted in a test session, but you should be prepared to stay for the entire time period. Do not make any other commitments for this time period that may cause you to rush through the test.

Read Carefully.

Read the directions and the questions carefully. Read all response options. Remember that multiple-choice test questions call for the “best answer”; do not choose the first answer that seems reasonable. Read and evaluate all choices to find the best answer. Read the questions closely so that you understand what they ask. For example, it would be a waste of time to perform a long computation when the question calls for an approximation.

Read the test questions, but don’t read into them. The questions are designed to be straightforward, not tricky.
Mark Answers Carefully.

Your answers for all multiple-choice questions will be scored electronically; therefore, the answer you select must be clearly marked and the only answer marked. If you change your mind about an answer, erase the old answer completely. Do not make any stray marks on the answer document; these may be misinterpreted by the scoring machine.

**IF YOU SKIP A MULTIPLE-CHOICE QUESTION, BE SURE TO SKIP THE CORRESPONDING ROW OF ANSWER CHOICES ON YOUR ANSWER DOCUMENT.**

You may use any available space in the test booklet for notes, but your answers and your written response must be clearly marked on your answer document. ONLY ANSWERS AND WRITTEN RESPONSES THAT APPEAR ON YOUR ANSWER DOCUMENT WILL BE SCORED. Answers and written responses in your test booklet will not be scored.

**Guessing**

As you read through the response options, try to find the best answer. If you cannot quickly find the best answer, try to eliminate as many of the other options as possible. Then guess among the remaining answer choices. Your score on the test is based on the number of test questions that you have answered correctly. There is no penalty for incorrect answers; therefore, it is better to guess than not to respond at all.

**Passages or Other Presented Materials**

Some test questions are based on passages or other presented materials (e.g., graphs, charts). You may wish to employ some of the following strategies while you are completing these test questions.

One strategy is to read the passage or other presented material thoroughly and carefully and then answer each question, referring to the passage or presented material only as needed. Another strategy is to read the questions first, gaining an idea of what is sought in them, and then read the passage or presented material with the questions in mind. Yet another strategy is to review the passage or presented material to gain an overview of its content, and then answer each question by referring back to the passage or presented material for the specific answer. Any of these strategies may be appropriate for you. You should not answer the questions on the basis of your own opinions but rather on the basis of the information in the passage or presented material.

**Check Accuracy.**

Use any remaining time at the end of the test session to check the accuracy of your work. Go back to the test questions that gave you difficulty and verify your work on them. Check the answer document, too. Be sure that you have marked your answers accurately and have completely erased changed answers.
ABOUT THE CHEMISTRY TEST

The purpose of the Chemistry Content Specialty Test (CST) is to assess knowledge and skills in the following seven subareas:

Subarea I.  Foundations of Scientific Inquiry
Subarea II.  Matter and Atomic Structure
Subarea III.  Energy, Chemical Bonds, and Molecular Structure
Subarea IV.  Chemical Reactions
Subarea V.  Stoichiometry and Solutions
Subarea VI.  Interactions of Chemistry and the Environment
Subarea VII.  Foundations of Scientific Inquiry: Constructed-Response Assignment

The test objectives presented on the following pages define the content that may be assessed by the Chemistry CST. Each test objective is followed by focus statements that provide examples of the range, type, and level of content that may appear on the test for questions measuring that objective.

The test contains approximately 90 multiple-choice test questions and one constructed-response (written) assignment. The figure below illustrates the approximate percentage of the test corresponding to each subarea.

The section that follows the test objectives presents sample test questions for you to review as part of your preparation for the test. To demonstrate how each objective may be assessed, a sample question is presented for each objective. The correct response and an explanation of why the response is correct follow each question. A sample written assignment is also presented, along with an example of a strong response to the assignment and an evaluation of that response.

The sample questions are designed to illustrate the nature of the test questions; they should not be used as a diagnostic tool to determine your individual strengths and weaknesses.

A section containing the Periodic Table of the Elements will be provided in the Chemistry test booklet. A sample Periodic Table of the Elements can be found before the sample Chemistry test questions in this guide.
CHEMISTRY TEST OBJECTIVES

Foundations of Scientific Inquiry
Matter and Atomic Structure
Energy, Chemical Bonds, and Molecular Structure
Chemical Reactions
Stoichiometry and Solutions
Interactions of Chemistry and the Environment

Foundations of Scientific Inquiry: Constructed-Response Assignment

The New York State chemistry educator has the knowledge and skills necessary to teach effectively in New York State public schools. The chemistry teacher is a skilled problem solver who understands the historical development of ideas in science and the connections among science, mathematics, and technology. The chemistry teacher knows how to access, generate, process, and transfer information using appropriate technologies and can apply knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions. Most importantly, the chemistry teacher understands the process of scientific inquiry and applies chemistry concepts, principles, and theories to pose questions, seek answers, and communicate explanations of natural phenomena.

SUBAREA I—FOUNDATIONS OF SCIENTIFIC INQUIRY

0001 Understand the relationships and common themes that connect mathematics, science, and technology.

For example:

• applying chemical theory to various systems (e.g., geological, biological, astronomical)
• analyzing the use of chemistry, mathematics, and other sciences in the design of a technological solution to a given problem
• analyzing the role of technology in the advancement of scientific knowledge
• using a variety of software (e.g., spreadsheets, graphing utilities, molecular modeling and visualization software, statistical packages, simulations) and information technologies to model and solve problems in mathematics, science, and technology
0002 Understand the historical and contemporary contexts of the study of chemistry.

For example:

• analyzing the significance of key events, theories, experiments, and individuals in the history of chemistry
• recognizing the impact of society on the study of chemistry (e.g., growing demands for nonpolluting fuels, detergents, and refrigerants; biomedical advances; expanding markets for drugs and recyclable products)
• assessing the implications for society of recent developments in chemistry (e.g., synthetic materials, pharmaceuticals, alternative fuels)

0003 Understand the process of scientific inquiry and the role of observation and experimentation in explaining natural phenomena.

For example:

• analyzing processes by which new scientific knowledge and hypotheses are generated
• analyzing ethical issues related to the process of scientific inquiry
• assessing the appropriateness of a specified experimental design to test a given chemical hypothesis
• assessing the role of communication among scientists in promoting scientific progress

0004 Understand the processes of gathering, organizing, reporting, and interpreting scientific data, and apply this understanding in the context of chemistry investigations.

For example:

• assessing the appropriateness, validity, and reliability of a given method or procedure for collecting data for a specified purpose
• selecting an appropriate and effective graphic representation (e.g., chart, table, graph) for organizing, reporting, and analyzing given experimental data
• applying procedures and criteria for sharing and formally reporting experimental procedures and data, including percent error
• analyzing relationships between factors (e.g., inverse, direct, linear) as indicated by experimental data

0005 Understand principles and procedures of measurement used in chemistry.

For example:

• evaluating the appropriateness of units of measurement, measuring devices, or methods of measurement for given situations
• analyzing likely sources of error in given measurements in chemistry experiments and their consequences in subsequent calculations
• using significant figures and scientific notation in expressing measurements, making calculations, and reporting data
• distinguishing between accuracy and precision in scientific measurements
Understand equipment, materials, and chemicals used in chemistry investigations; and apply procedures for their proper, safe, and legal use.

For example:

- identifying laboratory glassware and equipment and making appropriate selections for specific experiments
- analyzing the principles upon which given laboratory instruments are based (e.g., pH meters, gas chromatographs)
- applying proper methods for storing, identifying, and dispensing given chemicals and the legal guidelines for disposing of chemicals
- applying proper procedures for safety in the laboratory (e.g., use of goggles, fume hoods)
- applying proper procedures for dealing with accidents and injuries in the chemistry laboratory (e.g., use of fire blankets, fire extinguishers)
- applying information from material safety data sheets (MSDS) and chemical hygiene plans (CHP)

SUBAREA II—MATTER AND ATOMIC STRUCTURE

Understand the concept of matter, and analyze chemical and physical properties of and changes in matter.

For example:

- differentiating among elements, compounds, and mixtures
- using the physical and chemical properties of an unknown substance to identify it
- identifying the methods by which chemical properties of matter are determined
- distinguishing between physical and chemical changes in matter

Understand the various models of atomic structure, the principles of quantum theory, and the properties and interactions of subatomic particles.

For example:

- identifying major features of models of atomic structure (e.g., Bohr, Rutherford, Heisenberg, Schrödinger) and the supporting evidence for these models (e.g., gold foil experiment, emission spectra)
- relating interactions among electrons, protons, and neutrons to their properties
- analyzing the relationships among electron energy levels, photons, and atomic spectra
- analyzing the electron configurations of atoms and ions
- predicting and interpreting Lewis dot symbols of atoms and ions
0009 **Understand the organization of the periodic table.**

For example:

- analyzing the organization of the periodic table in terms of atomic number and properties of the elements
- analyzing trends (e.g., ionization energies, covalent atomic radii) within periods and groups in the periodic table
- predicting physical and chemical properties of given elements based on their positions in the periodic table
- using the periodic table to gain information (e.g., relative reactivity) about given elements

0010 **Understand the kinetic molecular theory, the nature of phase changes, and the gas laws.**

For example:

- comparing arrangements and movements of particles in solids, liquids, and gases
- analyzing basic principles of the kinetic molecular theory (e.g., particles of matter are in continual motion, real versus ideal gas behavior)
- analyzing heating and cooling curves qualitatively and quantitatively
- analyzing phase diagrams
- setting up and solving problems involving relationships among temperature, pressure, and volume of a gas

0011 **Understand the process of nuclear transformation.**

For example:

- comparing characteristics (e.g., mass, penetrating power) of the different types of emanations from the decay of radioactive elements
- analyzing the processes of natural radioactivity and artificial transmutation
- solving problems involving half-life of radioactive particles
- calculating nuclear mass defect and nuclear binding energy

**SUBAREA III—ENERGY, CHEMICAL BONDS, AND MOLECULAR STRUCTURE**

0012 **Understand the principles of calorimetry.**

For example:

- differentiating among forms of energy (e.g., heat, chemical, nuclear)
- analyzing the results of calorimetry experiments
- distinguishing between heat and temperature
0013 **Understand thermodynamics and energy relationships in chemical bonding and chemical reactions.**

For example:

- analyzing the three laws of thermodynamics and their applications to chemical systems
- predicting the spontaneity of given reactions based on enthalpy changes, entropy changes, and temperatures of the systems
- analyzing energy changes due to the formation or breaking of chemical bonds
- solving problems involving energy changes during chemical reactions (e.g., heat of combustion, heat of formation)
- interpreting potential-energy diagrams of chemical reactions

0014 **Understand the types of bonds between atoms (ionic, covalent, and metallic bonds), the formation of these bonds, and properties of substances containing the different bonds.**

For example:

- comparing the characteristics of various types of bonds between atoms (e.g., bond strength, polarity)
- analyzing chemical bonding in terms of electron behavior (e.g., interpreting Lewis structures, predicting molecular geometry)
- analyzing factors that affect bond strength (e.g., electronegativity, electron affinity)
- predicting properties of a substance based on the type of bonds holding the atoms together

0015 **Understand the types of intermolecular forces and properties of substances containing the different forces between molecules.**

For example:

- comparing the characteristics of various types of intermolecular forces
- predicting the kind of force between molecules of a given structure
- relating the physical properties of substances to their intermolecular forces
- relating the unique properties of water to its molecular structure and intermolecular forces
0016 Understand the nomenclature and structure of inorganic and organic compounds.

For example:
- applying the IUPAC rules of nomenclature
- distinguishing among inorganic structures (e.g., ionic solids, network solids, metallic solids)
- analyzing the chemical composition and basic structure of organic compounds (e.g., saturated, unsaturated, and aromatic hydrocarbons; halogen, oxygen, and nitrogen derivatives)
- distinguishing among functional groups of organic compounds
- distinguishing among structural, geometric, and optical isomers

SUBAREA IV—CHEMICAL REACTIONS

0017 Understand factors that affect reaction rates and methods of measuring reaction rates.

For example:
- applying collision theory to situations involving factors that influence reaction rates
- relating experimental measurements to reaction rates and rate laws
- relating reaction mechanisms to rate laws
- determining order of reactions and rate constants and solving first-order rate problems

0018 Understand the principles of chemical equilibrium.

For example:
- analyzing the effects of concentration, pressure, temperature, and catalysts on chemical equilibrium
- applying Le Chatelier's principle to chemical systems
- solving problems involving equilibrium constants (e.g., $K_a$, $K_b$, $K_{eq}$, $K_p$, $K_{sp}$, $K_w$)

0019 Understand the theories, principles, and applications of acid-base chemistry.

For example:
- analyzing acids and bases according to operational and conceptual definitions (i.e., Arrhenius, Brønsted-Lowry, Lewis)
- analyzing the principles and applications of acid-base titration
- determining the hydronium ion concentration and the pH for various acid, base, and salt solutions
- comparing the relative strengths of given acids based on periodic relationships
- analyzing buffer solutions qualitatively and quantitatively
0020 Understand redox reactions and electrochemistry.

For example:

• analyzing processes that occur during redox reactions
• determining oxidation numbers and balancing redox equations
• determining standard and nonstandard electrode potentials
• predicting whether given redox reactions will occur
• analyzing the components (e.g., anode, cathode) and operating principles of electrochemical cells

0021 Understand the nature of organic reactions.

For example:

• recognizing the relationship between the rates of reactions involving organic compounds and bond types
• analyzing common types of reactions (i.e., combustion, addition, substitution, polymerization, oxidation, esterification)
• recognizing applications of organic reactions

SUBAREA V—STOICHIOMETRY AND SOLUTIONS

0022 Understand the mole concept.

For example:

• relating the mole to Avogadro's number
• relating the gram-atomic mass of an element to the mass of one mole of the element
• calculating the number of moles in a given mass or volume of a substance
• demonstrating knowledge of how the mass of a single atom or molecule can be calculated

0023 Understand the relationship between the mole concept and chemical formulas.

For example:

• solving problems involving molecular and formula masses
• solving percent-composition problems
• determining empirical and molecular formulas
0024 **Understand the relationships expressed in chemical equations.**

For example:
- interpreting chemical notation
- recognizing various types of reactions and predicting their products
- balancing equations
- recognizing net ionic equations
- solving stoichiometric problems involving moles, mass, and volume (including limiting reactant and percent yield)

0025 **Understand the properties of solutions and colloidal suspensions, and analyze factors that affect solubility.**

For example:
- analyzing the colligative properties of solutions (i.e., freezing point depression, boiling point elevation, osmotic pressure, vapor pressure lowering)
- solving problems involving concentrations of solutions (e.g., molarity, molality, percent by mass)
- analyzing factors (e.g., temperature, pressure, molecular structure, surface area) that affect solubility
- interpreting solubility curves

**SUBAREA VI—INTERACTIONS OF CHEMISTRY AND THE ENVIRONMENT**

0026 **Understand industrial and household chemistry.**

For example:
- analyzing industrial processes (e.g., processes by which petroleum is separated into fractions)
- analyzing chemical processes in the home (e.g., organic reactions involving leavening agents and fermentation)
- recognizing safety issues related to industrial and household chemistry (e.g., mixing household chemicals, acceptable disposal methods)
0027 Understand the applications of nuclear reactions.
    For example:
    • analyzing the use of radioisotopes (e.g., in the life sciences, in geological and 
      archaeological dating)
    • analyzing the role of the components of a nuclear reactor and the issue of waste 
      disposal
    • assessing the risks and benefits of nuclear technology
    • identifying sources of radioactive emissions in the environment and analyzing 
      the risks and benefits they pose for humans

0028 Understand factors and processes related to the release of chemicals into the 
    environment.
    For example:
    • analyzing the chemical processes related to the release of chemicals into the 
      atmosphere (e.g., acid rain, greenhouse effect, ozone depletion, photochemical 
      smog, photosynthesis, nitrogen cycle)
    • analyzing the chemical processes related to the release of chemicals into 
      aquatic and terrestrial environments (e.g., eutrophication, groundwater 
      contamination, water purification, fluoridation)
    • analyzing methods for preventing and reversing environmental damage resulting 
      from the release of chemicals into the environment (e.g., recycling, sewage 
      treatment plants, pollution control devices, biomediation)

SUBAREA VII—FOUNDATIONS OF SCIENTIFIC INQUIRY: CONSTRUCTED-
RESPONSE ASSIGNMENT

The content to be addressed by the constructed-response assignment is described 
in Subarea I, Objectives 01–06.
MULTIPLE-CHOICE SECTION

This preparation guide provides sample multiple-choice questions and a sample written assignment for the test. The multiple-choice questions illustrate the objectives of the test—one sample question for each objective.

Three pieces of information are presented for each test question:

1. the number of the test objective that the sample question illustrates,
2. a sample test question,
3. an indication of the correct response and an explanation of why it is the best available response.

Keep in mind when reviewing the questions and response options that there is one best answer to each question. Remember, too, that each explanation offers one of perhaps many perspectives on why a given response is correct or incorrect in the context of the question; there may be other explanations as well.

On the following page are sample test directions similar to those that candidates see when they take the test.
SAMPLE TEST DIRECTIONS FOR MULTIPLE-CHOICE QUESTIONS

DIRECTIONS

This test booklet contains a multiple-choice section and a section with a single written assignment. You may complete the sections of the test in the order you choose.

Each question in the first section of this booklet is a multiple-choice question with four answer choices. Read each question CAREFULLY and choose the ONE best answer. Record your answer on the answer document in the space that corresponds to the question number. Completely fill in the space that has the same letter as the answer you have chosen. *Use only a No. 2 lead pencil.*

**Sample Question:**

1. What is the capital of New York?
   
   A. Buffalo  
   B. New York City  
   C. Albany  
   D. Rochester

The correct answer to this question is C. You would indicate that on the answer document as follows:

1. [A] [B] [●] [D]

You should answer all questions. Even if you are unsure of an answer, it is better to guess than not to answer a question at all. You may use the margins of the test booklet for scratch paper, but you will be scored only on the responses on your answer document.

The directions for the written assignment appear later in this test booklet.

**FOR TEST SECURITY REASONS, YOU MAY NOT TAKE NOTES OR REMOVE ANY OF THE TEST MATERIALS FROM THE ROOM.**

The words "End of Test" indicate that you have completed the test. You may go back and review your answers, but be sure that you have answered all questions before raising your hand for dismissal. Your test materials must be returned to a test administrator when you finish the test.

If you have any questions, please ask them now before beginning the test.

**STOP**

DO NOT GO ON UNTIL YOU ARE TOLD TO DO SO.
# Periodic Table of the Elements

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<td>85 Rn</td>
<td>(222)</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Lanthanide Series</th>
<th>Actinide Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>57 La 138.9</td>
<td>89 Ac (227)</td>
</tr>
<tr>
<td>58 Ce 140.1</td>
<td>90 Th 232.0</td>
</tr>
<tr>
<td>59 Pr 140.9</td>
<td>91 Pa 231.0</td>
</tr>
<tr>
<td>60 Nd 144.2</td>
<td>92 U 238.0</td>
</tr>
<tr>
<td>61 Pm (147)</td>
<td>93 Np 237.0</td>
</tr>
<tr>
<td>62 Sm 150.4</td>
<td>94 Pu (244)</td>
</tr>
<tr>
<td>63 Eu 152.0</td>
<td>95 Am (243)</td>
</tr>
<tr>
<td>64 Gd 157.3</td>
<td>96 Cm (247)</td>
</tr>
<tr>
<td>65 Tb 158.9</td>
<td>97 Bk (247)</td>
</tr>
<tr>
<td>66 Dy 162.5</td>
<td>98 Cf (251)</td>
</tr>
<tr>
<td>67 Ho 164.9</td>
<td>99 Es (254)</td>
</tr>
<tr>
<td>68 Er 167.3</td>
<td>100 Fm (257)</td>
</tr>
<tr>
<td>69 Tm 168.9</td>
<td>101 Md (258)</td>
</tr>
<tr>
<td>70 Yb 173.0</td>
<td>102 No (255)</td>
</tr>
<tr>
<td>71 Lu 175.0</td>
<td>103 Lr (257)</td>
</tr>
</tbody>
</table>

§ The International Union for Pure and Applied Chemistry has not adopted official names or symbols for these elements.
Objective 0001
Understand the relationships and common themes that connect mathematics, science, and technology.

1. Use the information below to answer the question that follows.

The chemical composition of a mineral is variable within a narrow range of possibilities. This is because ions of equal charge and similar size can substitute for one another. Coupled substitutions are also possible. In a coupled substitution, ions of different charges substitute for one another. When this happens, a second substitution must also occur to compensate for the unbalanced charge that results from the first substitution. For instance, the ion pair Na\(^{+1}\)Al\(^{+3}\) can substitute for the ion pair Ca\(^{+2}\)Mg\(^{+2}\).

A common formula of the mineral plagioclase is NaAlSi\(_3\)O\(_8\). Which of the following chemical formulas represents plagioclase in which the ion pair Ca\(^{+2}\)Al\(^{+3}\) substitutes for the ion pair Na\(^{+1}\)Si\(^{+4}\)?

A. Ca\(_2\)AlO\(_8\)  
B. Ca\(_2\)Al\(_2\)SiO\(_8\)  
C. CaAlO\(_8\)  
D. CaAl\(_2\)Si\(_2\)O\(_8\)

Correct Response: D. The ion pair to be replaced has a +5 charge, as does the ion pair that is to be added. Since the overall charge on the formula for an ionic compound must be zero, these ion pairs can be substituted for each other in a 1:1 ratio. If one Na\(^{+1}\)Si\(^{+4}\) ion pair is removed from the original plagioclase formula and replaced with one Ca\(^{+2}\)Al\(^{+3}\) ion pair, the formula CaAl\(_2\)Si\(_2\)O\(_8\) results.
Objective 0002
Understand the historical and contemporary contexts of the study of chemistry.

2. In the 1970s, environmentalists and the public became increasingly concerned about the consequences of depletion of Earth's ozone layer. This concern helped prompt an increase in research related to:

A. battery technology.
B. biodegradable plastics.
C. aerosol propellants.
D. lead-free gasoline.

Correct Response: C. In the mid-1970s, scientists first theorized that a group of atmospheric pollutants known as chlorofluorocarbons (CFCs) may be responsible for the observed depletion of Earth's ozone layer. These compounds were manufactured for many uses, including as propellants in aerosol spray cans. This connection prompted research into the impact of the CFCs from spray cans on the ozone layer, which ultimately led to bans on the use of CFCs by many countries.
Objective 0003
Understand the process of scientific inquiry and the role of observation and experimentation in explaining natural phenomena.

3. A scientist has recently discovered the mechanism by which an important biological reaction takes place. Which of the following subsequent steps is most likely to lead to broad acceptance of this discovery by the scientific community?

A. The hypothesis that led to the discovery is announced and reported in a scientific journal.

B. The experiment on which the new discovery is based is independently replicated in another laboratory.

C. Previous hypotheses concerning the mechanism are tested and shown to be incapable of explaining existing data and observations.

D. A majority of researchers working on this reaction or on similar reactions think that the conclusions of the scientist are reasonable.

Correct Response: B. All of the steps listed would aid, to some degree, in the broad acceptance of the discovery by the scientific community. The replication of experimental data by unbiased investigators, however, represents an important milestone in the discovery process. Of the choices listed, therefore, the independent replication of the experiment by another laboratory is the most important step towards broad acceptance by the scientific community.
Objective 0004
Understand the processes of gathering, organizing, reporting, and interpreting scientific data, and apply this understanding in the context of chemistry investigations.

4. **Use the formula below to answer the question that follows.**

\[
\log P = \frac{-\Delta H_v}{2.3RT} + C
\]

The relationship between vapor pressure and temperature is described by this formula, where \( P \) represents vapor pressure, \( \Delta H_v \) represents enthalpy of vaporization, \( T \) represents temperature, and \( R, C, \) and \( \Delta H_v \) are constants. In order to represent this relationship as a straight line, the axes of the graph should represent:

A. \( \log P \) and \( T \).
B. \( \log P \) and \( 1/T \).
C. \( P \) and \( T \).
D. \( P \) and \( 1/T \).

Correct Response: B. If the given equation is written in the following form:

\[
\log P = \frac{-\Delta H_v}{2.3R} \cdot \frac{1}{T} + C
\]

it follows the mathematical representation for a straight line as \( y = mx + b \). The slope (m) and the \( y \)-intercept (b) should be constants, and the values \(-\Delta H_v, R, \) and \( C \) are identified as constants in the question. The \( y \)-axis and \( x \)-axis of the graph should therefore represent \( \log P \) and \( \frac{1}{T} \), respectively.
Objective 0005
Understand principles and procedures of measurement used in chemistry.

5. A student who is performing an experiment must measure out 0.02 mL of 0.50 M HCl. The most accurate piece of equipment to measure this quantity would be a:

A. 50 mL buret.
B. 25 mL graduated cylinder.
C. 10 mL beaker.
D. 1 mL pipet.

Correct Response: D. All of the pieces of equipment listed can be used to measure the volume of an aqueous solution. The laboratory equipment used for this task, however, would need gradations sufficiently small to measure accurately the relatively small volume of 0.02 mL. The 1 mL pipet would likely have a gradation every 0.01 mL and would, therefore, be the best choice for accurately measuring a volume of 0.02 mL.
Objective 0006

Understand equipment, materials, and chemicals used in chemistry investigations; and apply procedures for their proper, safe, and legal use.

6. Use the information below to answer the question that follows.

<table>
<thead>
<tr>
<th>REACTIVITY DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stability:</strong></td>
</tr>
<tr>
<td><strong>Hazardous Polymerization:</strong></td>
</tr>
<tr>
<td><strong>Conditions to Avoid:</strong></td>
</tr>
<tr>
<td><strong>Incompatibles:</strong></td>
</tr>
<tr>
<td><strong>Decomposition Products:</strong></td>
</tr>
</tbody>
</table>

The information above is excerpted from a material safety data sheet (MSDS) for methylene chloride. According to this data sheet, a hazard could be caused by allowing methylene chloride to come in contact with:

A. sodium.
B. calcium.
C. hydrogen chloride.
D. acetic acid.

Correct Response: A. A hazardous condition can occur when a substance comes in contact with another substance with which it is incompatible. The information from the MSDS identifies methylene chloride as incompatible with alkali metals, which are the elements in the first column of the periodic table. Therefore, a hazardous condition could arise if methylene chloride came in contact with sodium, an alkali metal.
Objective 0007
Understand the concept of matter, and analyze chemical and physical properties of and changes in matter.

7. Which of the following methods provides information about a substance's chemical properties?

A. acid-base titration
B. X-ray diffraction
C. fractional distillation
D. mass spectrometry

Correct Response: A. A chemical property is a characteristic of a substance that is displayed as it undergoes a change in chemical composition. Only the acid-base titration involves the substance in a chemical reaction, and therefore a change in its chemical composition. The other methods mentioned provide information about a substance's physical properties.
Objective 0008
Understand the various models of atomic structure, the principles of quantum theory, and the properties and interactions of subatomic particles.

8. Which of the following shows the correct Lewis electron dot representation for a sulfur ion with a negative two charge?

A. \( \text{S}^{2-} \)
B. \( \text{S}^{2-} \)
C. \( \text{S}^{2-} \)
D. \( \text{S}^{2-} \)

Correct Response: C. The Lewis electron dot representation for an atom or ion should show the particle with the correct number of valance electrons and charge. Based on its position in the periodic table (group 16), the neutral sulfur atom has six valence electrons. An ion with a \(-2\) charge has two more electrons than the neutral atom. The sulfur ion with a \(-2\) charge has eight valence electrons, and therefore should have eight dots in its Lewis structure.
Objective 0009
Understand the organization of the periodic table.

9. Use the diagram below to answer the question that follows.

The graph of first ionization energy plotted against atomic number shows that ionization energy is a periodic function. First ionization energy generally increases from alkali metals to noble gases. Exceptions to this general trend can be seen in going from beryllium to boron and from magnesium to aluminum. These two deviations from the line can best be explained by considering each element's:

A. atomic radius.
B. electron configuration.
C. nuclear binding energy.
D. atomic mass.

Correct Response: B. The first ionization energy is the energy required to remove the first electron from an atom in its ground state. In the Group 2 (IIA) elements, which include beryllium and magnesium, the electrons are configured such that there are paired valence electrons in an s orbital. Group 13 (IIIA) elements, which include boron and aluminum, have a single electron in the outermost p orbital. Less energy is needed to remove a single electron from a p orbital than to remove an electron from an s orbital in the same energy level; therefore Group 13 (IIIA) elements have lower first ionization energies than Group 2 (IIA) elements.
Objective 0010
Understand the kinetic molecular theory, the nature of phase changes, and the gas laws.

10. Use the information below to answer the question that follows.

The two graphs below show the hypothetical heating curves for equal molar amounts of two substances, X and Y.

Based on the heating curves, which of the following conclusions comparing the two substances is correct?

A. The specific heat of substance Y in its liquid state is greater than the specific heat of substance X in its liquid state.

B. The molar heat of fusion of substance Y is greater than the molar heat of fusion of substance X.

C. The molar heat of vaporization of substance X is greater than the molar heat of vaporization of substance Y.

D. The boiling point of substance X is greater than the boiling point of substance Y.

Correct Response: B. A heating curve represents the change in temperature of a substance as heat is added. Of the choices listed, only B is consistent with the data provided in the graphs. The molar heat of fusion is the amount of heat required to melt one mole of a substance, represented on the graphs by the lower horizontal segment. A longer horizontal segment indicates that more heat is required to melt all of the substance. In the graphs, the horizontal segment indicating the melting point is longer for substance Y than for substance X, so it can be concluded that its molar heat of fusion is greater.
Objective 0011
Understand the process of nuclear transformation.

11. **Use the information below to answer the question that follows.**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$^1$H</td>
<td>mass = 1.007825 amu</td>
</tr>
<tr>
<td>neutron</td>
<td>mass = 1.008665 amu</td>
</tr>
</tbody>
</table>

The experimentally determined nuclear mass of $^{35}_{17}$Cl is 34.95952 amu. Based on this information, what is the nuclear mass defect of the chlorine-35 nucleus?

A. 0.31436 amu
B. 0.32864 amu
C. 0.32948 amu
D. 0.34376 amu

Correct Response: C. The nuclear mass defect is the difference between the mass of the nucleus and the sum of the masses of the individual protons and neutrons from which it is composed. The chlorine-35 nucleus has 17 protons and 18 neutrons. Seventeen times the mass of a proton (1.007825 amu) plus 18 times the mass of a neutron (1.008665 amu) is 35.28900 amu. This sum differs from the experimentally determined nuclear mass of 34.95952 amu by 0.32948 amu.
Objective 0013
Understand thermodynamics and energy relationships in chemical bonding and chemical reactions.

12. Use the information below to answer the question that follows.

Shown above is the potential energy diagram for the chemical reaction \( \text{N}_2(g) + \text{O}_2(g) \rightarrow 2\text{NO}(g) \). Based on the diagram, which of the following statements is true for this reaction?

A. The reaction absorbs energy.
B. The reactants have more potential energy than the products.
C. The reaction is exothermic.
D. The change in potential energy is negative.

Correct Response: A. The potential energy diagram for this chemical reactions shows that the reactants have less energy than the products. Therefore, the reactants need to absorb energy in order to be converted into products. Reactions that absorb energy are endothermic.
Objective 0014
Understand the types of bonds between atoms (ionic, covalent, and metallic bonds), the formation of these bonds, and properties of substances containing the different bonds.

13. Use the information below to answer the question that follows.

The Lewis dot structures for atoms of two hypothetical elements, A and B, are shown below.

A:\[ \text{Lewis dot structure for A} \]

B:\[ \text{Lewis dot structure for B} \]

The two elements react, forming an ionic compound. Which of the following correctly shows the resulting product using Lewis dot symbols?

A. \[ \text{Lewis dot structure for product} \]

B. \[ 5[\text{Lewis dot structure for A} ]^6^- \text{, } 6\text{B}^{5+} \]

C. \[ 3\text{A}^{2+} \text{, } 2[\text{Lewis dot structure for B} ]^3^- \]

D. \[ \text{A}^{2+} [\text{Lewis dot structure for B} ]^3^- \]

Correct Response: C. The Lewis dot structure of element A indicates that it is an alkaline earth metal (group 2), which means that it will form +2 cations by losing electrons. The Lewis dot structure of element B indicates that it is from group 15 and will attract electrons to form –3 anions. When ionic bonds form between atoms of these elements, the two outer valence electrons of A are transferred to the B atoms. Since each atom of A has only two outer valence electrons to offer and each atom of B needs three electrons to fill its outer valence shell, the ratio of A to B atoms needs to be 3:2 to result in an electrically neutral compound. Thus, C correctly represents the ionic compound using Lewis dot symbols.
Objective 0015
Understand the types of intermolecular forces and properties of substances containing the different forces between molecules.

14. Hydrogen bonds are found between molecules containing hydrogen and:

   A. bromine.
   B. carbon.
   C. fluorine.
   D. selenium.

Correct Response: C. A hydrogen bond is a strong intermolecular force that occurs when a hydrogen atom that is covalently bonded in one molecule is simultaneously attracted to an atom in another molecule. For this to occur, the atoms to which the hydrogen is both bonded and attracted must be small and highly electronegative. The only atoms that are both small and electronegative enough to be involved in hydrogen bonding are nitrogen, oxygen, and fluorine. Therefore, of the choices listed, only molecules containing hydrogen and fluorine are capable of hydrogen bonding.
Objective 0016
Understand the nomenclature and structure of inorganic and organic compounds.

15. Which of the following types of substances are very hard, melt at very high temperatures, and are nonconductors of electricity?

   A. amorphous solids
   B. ionic solids
   C. metallic solids
   D. network solids

Correct Response: D. Network solids are held together by an extensive network of covalent bonds in three dimensions. To break these bonds requires a large amount of energy. Moreover, because the network of covalent bonds is extensive, the melting point for these substances is quite high. The three-dimensional nature of the covalent bonding makes the network stiff, inflexible, and very hard. Furthermore, there are no free ions in the structure available to conduct electricity. Therefore, of the choices listed, network solids best match the listed properties.
16. **Use the information below to answer the question that follows.**

![Graph showing the decomposition of H₂O₂.](image)

The graph above shows data for the decomposition of H₂O₂. The graph indicates that this reaction is:

A. zero order.
B. first order.
C. second order.
D. third order.

Correct Response: B. The rate of the reaction for the first order decomposition of hydrogen peroxide can be expressed as:

$$\text{rate} = \frac{-\Delta[H₂O₂]}{\Delta t} \text{ or as rate } = k[H₂O₂].$$

Setting these two equations equal to each other yields $$\frac{-\Delta[H₂O₂]}{\Delta t} = k[H₂O₂]$$. Integrating this equation using calculus yields

$$\ln \left[ \frac{[H₂O₂]}{[H₂O₂]₀} \right] = -kt,$$

which can be rewritten as

$$\ln [H₂O₂] = -kt + \ln [H₂O₂]₀.$$ This latter equation follows the format for a linear equation,

$$y = mx + b,$$

where the y-axis is $$\ln [H₂O₂]$$ and the x-axis is time.
17. Use the diagram below to answer the two questions that follow.

In the beverage industry, carbon dioxide is introduced into a pressure vessel containing flavored sugar water to give the characteristic fizz associated with soda. After the system has reached equilibrium, the carbonated water is sent through tubing to be bottled.

During the manufacturing process, which of the following conditions would shift the equilibrium to favor a reduced carbon dioxide concentration in the beverage?

A. a leak in the pressure vessel
B. a decrease in the temperature of the cooling coil
C. an increase in the length of time the carbon dioxide is left in contact with the sugar water
D. an increase in the level to which the vessel is filled with sugar water

Correct Response:  A. Several factors can affect chemical equilibrium, but in the situation described, temperature and pressure are likely to be of the greatest concern. Either an increased temperature or a decreased pressure would be unfavorable to carbon dioxide going into solution. Therefore, of the choices listed, only a leak in the pressure vessel, which would lower the system's pressure, is likely to cause the beverage to have a reduced carbon dioxide concentration.
Objective 0012
Understand the principles of calorimetry.

18. To calculate the amount of energy required for the cooling coil to bring the contents of the vessel to the desired temperature, which of the following information is needed?

   I. desired temperature decrease
   II. specific heat of the sugar water
   III. volume and density of the sugar water
   IV. molecular weight of the sugar water

A. I and IV only
B. II and III only
C. I, II, and III only
D. I, III, and IV only

Correct Response: C. Several pieces of information are required to determine the amount of energy needed to cool the vessel contents. First, one must know how many degrees Celsius the contents are to be cooled. Another important piece of information is this particular solution's specific heat, the amount of energy necessary to change the temperature of one gram of the solution by one degree Celsius. Finally, the volume and density of the sugar water can be used to calculate the mass of sugar water in the vessel. So the information identified in options I, II, and III is required to make the calculation.
Objective 0019
Understand the theories, principles, and applications of acid-base chemistry.

19. What is the pH of a 0.115 M solution of NH₃? \(K_b\text{ NH}_3 = 1.8 \times 10^{-5}\)
   
   A. 2.84  
   B. 8.32  
   C. 10.2  
   D. 11.2  
   
   Correct Response: D. The equilibrium for the weak base ammonia is represented by the following reaction: \(\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)\). The equilibrium expression for this reaction is \(K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}\), where \([\text{NH}_4^+] = [\text{OH}^-]\). Using the given values for \(K_b\) and \([\text{NH}_3]\) (assuming that the small amount of dissociation does not change initial \([\text{NH}_3]\)), the expression can be solved, yielding a hydroxide ion concentration of 0.00144 M. This value is used to calculate the pH of the solution by the following steps:

   \[
   \text{pOH} = -\log 0.00144 = 2.84 \\
   \text{pH} = 14.00 - 2.84 = 11.2
   \]
Objective 0020
Understand redox reactions and electrochemistry.

20. Use the information below to answer the question that follows.

<table>
<thead>
<tr>
<th>Half-Reaction</th>
<th>Standard Reduction Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag⁺(aq) + e⁻ → Ag(s)</td>
<td>0.80 V</td>
</tr>
<tr>
<td>Mg²⁺(aq) + 2e⁻ → Mg(s)</td>
<td>−2.37 V</td>
</tr>
</tbody>
</table>

Which of the following diagrams correctly illustrates the electrochemical cell for the cell reactions above?

A.  

B.  

C.  

D.  

Correct Response: B. The standard reduction potentials for the silver and magnesium ions are +0.80 V and −2.37 V, respectively. Spontaneous electrochemical cells must have positive voltages, so the magnesium half reaction will run as an oxidation at +2.37 V. The anode is the electrode where oxidation takes place. Solid magnesium will be oxidized into the magnesium ion in this cell. The reduction of the silver ion to solid silver will occur at the cathode.
Objective 0021
Understand the nature of organic reactions.

21. **Use the information below to answer the question that follows.**

A small molecule joins with other identical molecules in an addition reaction catalyzed by a free radical, as shown in the diagram below. As the reaction continues, long chains are formed, each with an unpaired electron at one end. The process terminates when two of these chains combine.

\[ \text{X} + \text{C} \rightarrow \text{X} - \text{C} - \text{C} \]

Compounds formed by the process described above are most likely to be associated with:

A. plastic products.
B. nuclear waste products.
C. DNA synthesis.
D. cancer cell proliferation.

**Correct Response:** A. The reaction describes an addition polymerization process. Depending on what atoms or functional groups are attached to the carbon atoms, the long chain molecules form products such as polyethylene, polypropylene, and polyvinyl chloride. These materials are used to make various plastic products such as bottles, packaging films, and piping.
22. An oxide of element X can be made to decompose according to the following unbalanced reaction.

\[ \text{X}_2\text{O}_3 \rightarrow \text{X} + \text{O}_2 \]

When 306 grams of \( \text{X}_2\text{O}_3 \) are dissociated, 4.50 moles of \( \text{O}_2 \) are produced. What is the approximate gram atomic mass of X?

A. 6.90 amu  
B. 10.8 amu  
C. 13.5 amu  
D. 27.0 amu

Correct Response: D. First the equation must be balanced, giving \( 2\text{X}_2\text{O}_3 \rightarrow 4\text{X} + 3\text{O}_2 \). Since 4.5 moles of \( \text{O}_2 \) are produced in the reaction, the initial molar amount of \( \text{X}_2\text{O}_3 \) can be calculated using the relationship \( \frac{4.5}{3} = \frac{X}{2} \). Thus, 306 grams of \( \text{X}_2\text{O}_3 \) is 3 moles. The mass of the oxygen in 3 moles of \( \text{X}_2\text{O}_3 \) is calculated by multiplying the atomic mass of oxygen (16.0 amu) by the total number of oxygen atoms (9), which is 144 g of oxygen. The remaining 162 g is the element X, and to calculate its gram atomic mass, 162 is divided by 6, the total number of atoms of element X in 3 moles of \( \text{X}_2\text{O}_3 \). Therefore, the answer is 27.0 amu.
Objective 0023
Understand the relationship between the mole concept and chemical formulas.

23. What is the percent of hydrogen by mass in (CH₃)₂CHCOOH?
   A. 3.48%
   B. 4.26%
   C. 6.91%
   D. 9.17%

Correct Response: D. According to the formula, there are 4 moles of carbon, 8 moles of hydrogen, and 2 moles of oxygen in 1 mole of the compound. Using molar masses for these elements from the periodic table, the molar mass of the compound is 88.12 g/mol. Of this total, 8.08 grams is contributed by hydrogen. Thus, the percent of hydrogen by mass is given by the expression, \( \frac{8.08 \text{ g}}{88.12 \text{ g}} \times 100\% \), which is 9.17%.
Objective 0024
Understand the relationships expressed in chemical equations.

24. Which of the following equations represents an oxidation-reduction reaction?

A. \( \text{TiCl}_4(g) + 2\text{Mg}(l) \rightarrow \text{Ti}(s) + 2\text{MgCl}_2(l) \)

B. \( \text{LiOH}(aq) + \text{HCl}(aq) \rightarrow \text{LiCl}(aq) + \text{H}_2\text{O}(l) \)

C. \( \text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g) \)

D. \( \text{SO}_3(g) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{SO}_4(aq) \)

Correct Response: A. Oxidation-reduction reactions are characterized by changes in the oxidation numbers of the atoms involved. The oxidation number of one atom is increased (the oxidation), while the oxidation number of another atom is decreased (the reduction). In the reaction between titanium(IV) chloride and magnesium, the titanium atom is reduced from a +4 oxidation number as a reactant to zero when elemental as a product. Paired with this reduction is the oxidation of magnesium from neutral as the element to +2 when in a compound with the chloride ion.
A 90 g sample of KNO₃ is contaminated with 10 g of NaCl. In order to obtain pure KNO₃, the mixture is dissolved in 100 mL of H₂O at 80°C. At what temperature will approximately 75 g of pure KNO₃ crystallize from the prepared solution?

A. 0°C  
B. 22°C  
C. 45°C  
D. 55°C

Correct Response: A. As the solution is cooled, the solubility of the solutes decreases. At about 50°C, KNO₃ will start to crystallize out of solution, as 90 g KNO₃/100 g H₂O is the saturation amount at this temperature. If the solution is cooled down to 0°C, only about 15 grams of KNO₃ can remain dissolved, so approximately 75 grams of KNO₃ (90 g – 15 g) will have crystallized at this temperature. The solubility of NaCl is above 10 g/100 g H₂O at all temperatures shown, so no NaCl will crystallize.
Objective 0026
Understand industrial and household chemistry.

26. A well-maintained, properly running nuclear power plant uses water from a nearby river to help cool the reactor. People living downstream from the power plant have noticed many dead fish in the area. Based on this information, the dead fish are most likely the result of:

A. dissolved oxygen in the water being limited due to the increased temperature of the cooling water.

B. radioactive isotopes with a very long half-life being released into the water.

C. heavy water meant to be pumped into the moderator being accidentally released into the river.

D. dissolved metals from the containment vessel being released into the water.

Correct Response: A. Since the nuclear power plant uses river water for cooling, the water is discharged back to the river at a higher temperature. The solubility of gases, such as oxygen, decreases as the temperature of the water increases. Therefore, if the temperature of the downstream river water is increased significantly by the power plant, the amount of dissolved oxygen may decrease below levels required by certain aquatic species.
27. \(^{32}\text{P}\) and \(^{131}\text{I}\) are radioactive isotopes used to treat bone marrow and thyroid cancer. Their usefulness is in part due to their tendency to concentrate in specific organs. Which of the following characteristics is also necessary to make an isotope a good candidate for this form of radiotherapy?

A. The isotope emits only alpha radiation.

B. The isotope has a short half-life.

C. The isotope produces primarily heat energy rather than particle emissions.

D. The isotope's decay rate is constant.

Correct Response: B. While radioactive isotopes do play beneficial roles in treating certain human diseases, they pose a threat to healthy tissue because they are radioactive. Isotopes that have a short half-life are desirable for treating cancers in targeted areas of the body because they do not remain long enough in high concentrations in the body to cause damage to normal, healthy tissue.
Objective 0028
Understand factors and processes related to the release of chemicals into the environment.

28. When wastewater containing phosphates is released into lakes and ponds, eutrophication often occurs. Which of the following best describes the role of the phosphates in this process?

A. They act as chelating agents, depriving fish of nutrients.

B. They precipitate calcium ions, which increases the turbidity of the water.

C. They act as acids, lowering the pH of the water.

D. They cause algae to grow rapidly, which depletes dissolved oxygen.

Correct Response: D. Phosphates act as a source of phosphorus, an important plant nutrient. Waters rich in plant nutrients can support a bloom of algae, a microscopic photosynthetic plant. While daylight will lead to oxygen production, nighttime-dissolved oxygen levels are greatly reduced due to respiration of the excessive biomass. An increased level of organic materials in the lake will also support a larger population of decomposers, which respire and consume dissolved oxygen as well.
WRITTEN ASSIGNMENT SECTION

On the following pages are:

- Sample test directions for the written assignment section
- A sample written assignment
- An example of a strong response to the assignment
- The performance characteristics and scoring scale
- An evaluation of the strong response

On the actual test, candidates will be given a different written assignment from the one provided as a sample in this preparation guide.
DIRECTIONS FOR THE WRITTEN ASSIGNMENT

This section of the test consists of a written assignment. You are to prepare a written response of about 150–300 words on the assigned topic. The assignment can be found on the next page. You should use your time to plan, write, review, and edit your response to the assignment.

Read the assignment carefully before you begin to write. Think about how you will organize your response. You may use any blank space provided on the following pages to make notes, write an outline, or otherwise prepare your response. However, your score will be based solely on the response you write on the lined pages of your answer document.

Your response will be evaluated on the basis of the following criteria.

• PURPOSE: Fulfill the charge of the assignment.

• APPLICATION OF CONTENT: Accurately and effectively apply the relevant knowledge and skills.

• SUPPORT: Support the response with appropriate examples and/or sound reasoning reflecting an understanding of the relevant knowledge and skills.

Your response will be evaluated on the criteria above, not on writing ability. However, your response must be communicated clearly enough to permit valid judgment of your knowledge and skills. The final version of your response should conform to the conventions of edited American English. This should be your original work, written in your own words, and not copied or paraphrased from some other work.

Be sure to write about the assigned topic. Please write legibly. You may not use any reference materials during the test. Remember to review what you have written and make any changes that you think will improve your response.
SAMPLE WRITTEN ASSIGNMENT

WRITTEN ASSIGNMENT

Read the information below; then complete the exercise that follows.

A student wearing appropriate safety equipment is performing a chemistry laboratory investigation to determine the value of the gas constant, \( R \), as used in the ideal gas equation. To achieve this, the pressure, volume, moles, and temperature of a single gas sample will be determined.

The student uses the procedure below to carry out this investigation.

1. Fill a pan and a 100-mL graduated cylinder with cold tap water. Cover the top of the graduated cylinder with plastic wrap, ensuring that there are no air bubbles trapped under the plastic. Quickly invert the graduated cylinder into the pan of water and hold it in place. Remove the plastic wrap.

2. Measure and record the mass of a disposable butane lighter. Hold the lighter underwater just below the mouth of the inverted graduated cylinder.

3. Open the trigger of the lighter to release butane gas into the graduated cylinder. Collect 100 mL of butane gas in the graduated cylinder.

4. Remove the lighter from the water and measure its mass again. Calculate the mass difference from before and after releasing the gas. The mass difference represents the mass of the 100 mL of butane gas in the graduated cylinder. Calculate the moles of butane \( (C_4H_{10}) \).

5. Record the atmospheric pressure and temperature in the laboratory.

6. Insert the collected data into the ideal gas law equation to solve for the constant, \( R \).

Using your knowledge of laboratory techniques, prepare a response in which you:

- identify two weaknesses of the procedure described above and explain why, from a scientific perspective, they are weaknesses; and
- describe two modifications that should be made to the procedure to address the identified weaknesses and explain how these changes would enhance the scientific validity of the results.
There are several weaknesses in the procedure. In step 1 the student fills the pan and cylinder with cold water. This would entail a significant difference between the temperature of the laboratory later recorded and the temperature of the gas. If the student assumes that the temperature of the collected $C_4H_{10}(g)$ is the same as the temperature of the laboratory, she will be using the wrong value for $T$ in the ideal gas equation $PV = nRT$.

To remedy this weakness, the student should fill the pan and cylinder with water that has been allowed to come to room temperature. Thus the temperature of the butane and that of the room will be the same, and the resulting calculations will be more accurate.

A second weakness is that the pressure of the water vapor in the graduated cylinder is not accounted for. The total pressure of the gases in the cylinder is the sum of the pressure of the butane gas plus the pressure of the water vapor ($P_T = P_{H_2O} + P_{C_4H_{10}}$). If the student does not factor in the water vapor pressure, the value she uses for $P$ will be greater than the actual value of the pressure of the butane gas. This will result in an erroneously high calculation of $R$.

To address this weakness, the student should use a reference table to determine the vapor pressure of water at the experimental temperature. The student should then subtract this value from the atmospheric pressure measured in step 5; the difference will represent the pressure of the butane gas. Her use of this adjusted value will result in a more accurate determination of the value of $R$. 
PERFORMANCE CHARACTERISTICS AND SCORING SCALE

Performance Characteristics

The following characteristics guide the scoring of responses to the written assignment.

<table>
<thead>
<tr>
<th>Purpose:</th>
<th>Fulfill the charge of the assignment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of Content:</td>
<td>Accurately and effectively apply the relevant knowledge and skills.</td>
</tr>
<tr>
<td>Support:</td>
<td>Support the response with appropriate examples and/or sound reasoning reflecting an understanding of the relevant knowledge and skills.</td>
</tr>
</tbody>
</table>

Scoring Scale

Scores will be assigned to each response to the written assignment according to the following scoring scale.

<table>
<thead>
<tr>
<th>Score Point</th>
<th>Score Point Description</th>
</tr>
</thead>
</table>
| 4           | The "4" response reflects a thorough command of the relevant knowledge and skills.  
• The response completely fulfills the purpose of the assignment by responding fully to the given task.  
• The response demonstrates an accurate and highly effective application of the relevant knowledge and skills.  
• The response provides strong support with high-quality, relevant examples and/or sound reasoning. |
| 3           | The "3" response reflects a general command of the relevant knowledge and skills.  
• The response generally fulfills the purpose of the assignment by responding to the given task.  
• The response demonstrates a generally accurate and effective application of the relevant knowledge and skills.  
• The response provides support with some relevant examples and/or generally sound reasoning. |
| 2           | The "2" response reflects a partial command of the relevant knowledge and skills.  
• The response partially fulfills the purpose of the assignment by responding in a limited way to the given task.  
• The response demonstrates a limited, partially accurate and partially effective application of the relevant knowledge and skills.  
• The response provides limited support with few examples and/or some flawed reasoning. |
| 1           | The "1" response reflects little or no command of the relevant knowledge and skills.  
• The response fails to fulfill the purpose of the assignment.  
• The response demonstrates a largely inaccurate and/or ineffective application of the relevant knowledge and skills.  
• The response provides little or no support with few, if any, examples and/or seriously flawed reasoning. |
EVALUATION OF THE STRONG RESPONSE

This response is considered a strong response because it reflects a thorough command of relevant knowledge and skills.

Purpose. The writer identifies two weaknesses (the use of cold water and the omission of reference to water vapor pressure) and fully explains why they are weaknesses. (The use of cold water results in the use of incorrect temperature data in the final calculation. The omission of reference to water vapor pressure leads to the invalid assumption that the pressure in the cylinder is attributable solely to the pressure of the butane gas.) The writer also describes an appropriate modification for each identified weakness and fully explains how the modifications would enhance the scientific validity of the results.

Application of Content. Throughout this response, the writer demonstrates an accurate knowledge, both of relationships among temperature, pressure, and volume of a gas, and of assessing the appropriateness of a given method or procedure of collecting data. The writer effectively uses this knowledge to accurately analyze the weaknesses in the procedure and to propose modifications. Both of the weaknesses this writer chose to identify are significant and the two modifications described are appropriate.

Support. Sound reasoning and strong examples are evident throughout this response. For example, in the explanation of the weakness inherent in using cold water in this procedure, the writer identifies an invalid assumption that may be made by the student and clearly shows how that assumption will lead to a flawed calculation. The writer supports this discussion with the specific equation used for determining R, a detail that is highly relevant to this laboratory investigation. The suggested modification of using water at room temperature follows logically from the writer’s objections to using cold water. In the explanation of the second weakness, the writer again identifies an invalid assumption and clearly shows how that assumption leads to a flawed conclusion (the value . . . for P will be greater . . . will result in an erroneously high calculation of R). The description of the modification proposed to address this weakness is supported with clear directions for finding the pressure of the butane gas, including a specific source to be used by the student (a reference table) and a method for finding the difference between the total pressure and the water vapor pressure.