VIRGINIA BOARD OF EDUCATION
AGENDA ITEM

Agenda Item: **B**

Date: **November 17, 2022**

Title: **Final Review of the Advisory Board on Teacher Education and Licensure's Recommendation for a Passing Score for the Praxis® Chemistry (5246) Test for the Science – Chemistry Endorsement**

Presenter: **Joan B. Johnson, Assistant Superintendent for Teacher Education and Licensure**

Email: **Joan.Johnson@doe.virginia.gov** **Phone: 804-371-2522**

Purpose of Presentation:
Action required by state or federal law or regulation.

Executive Summary:

The proposed recommendation from the Advisory Board on Teacher Education and Licensure (ABTEL) is to set a passing score for the **Praxis® Chemistry (5246) Test** for the Chemistry endorsement. The Praxis® Chemistry (5246) test will replace the Praxis® Chemistry: Content Knowledge (5245) test. This **new** assessment was designed and developed through work with practicing chemistry teachers, teacher educators, and higher education chemistry specialists to reflect the science knowledge teachers need to teach the chemistry curriculum and to reflect state and national standards, including the National Science Teacher Association Preparation Standards for chemistry. This test will be required for individuals seeking initial licensure unless exempted by holding a full, clear out-of-state license with no deficiencies and can be taken and passed to add an endorsement in Chemistry by individuals holding a valid renewable teaching license.

Educational Testing Service (ETS) provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the Praxis Chemistry test, the recommended passing score is 56 out of a possible 100 raw-score points. The scale score associated with a raw score of 56 is **146** on a 100–200 scale.

The current Praxis® Chemistry: Content Knowledge (5245) Test has a Board prescribed passing score of 153 on a 100-200 scale. The Praxis® Chemistry (5246) test is a **new** assessment and the previous passing score was not a consideration of ETS or ABTEL when establishing this test's passing score. Because this is a **new** assessment, ABTEL is also recommending that a data review be conducted after one year to determine if the passing score is providing for the greatest opportunity of teachers entering the profession while maintaining rigor.

On September 19, 2022 information regarding the multistate standard-setting process was presented to ABTEL members by Malik K. McKinley, Sr., Director of Client Relations, Professional Educator Programs, Office for Teacher Licensure and Certification, Student and Teacher Assessment Division, Educational Testing Service. ABTEL members reviewed the standard-setting report and recommended that the Board approve the passing score of 146 (the standard setting panel's recommendation).

Attached are the Multistate Standard-Setting Technical Report - Praxis® Chemistry (5246) Test and the Praxis® Study Companion. Also attached is a literature review and analysis of licensure assessment and student outcomes that was provided to the Virginia Board of Education (Board) in January 2022 that might provide useful information regarding the predictive value of teacher licensure assessments on student outcomes.

This item supports Priority 2 of the Board's Comprehensive Plan: 2018-2023.

No changes have been made to this item since first review.

Action Requested:
Final review: Action requested at this meeting

Superintendent's Recommendation
The Superintendent of Public Instruction recommends that the Board approve the recommendation of the Advisory Board on Teacher Education and Licensure to establish a passing score of 146 for the Praxis® Chemistry (5246) Test. Individuals may take either the currently prescribed assessment for the Chemistry endorsement, Praxis® Chemistry: Content Knowledge (5245) or the new Praxis® Chemistry (5246) test through June 30, 2023. Beginning July 1, 2023, the Praxis® Chemistry: Content Knowledge (5245) test will be accepted only for those individuals who took and passed the test during the period it was prescribed by the Board of Education.

Rationale for Action:
The *Code of Virginia* and *Licensure Regulations for School Personnel* require the Board to prescribe assessments for licensure. The current prescribed assessment for the Chemistry endorsement, Praxis® Chemistry: Content Knowledge (5245) test, has been updated, and the

regenerated Praxis® Chemistry (5246) Test for the Science – Chemistry will be offered by the Educational Testing Service (ETS). A passing score needs to be established for the revised test.

Previous Review or Action:
Date: October 20, 2022
Action: First Review

Background Information and Statutory Authority:
Currently, the Board requires the following assessments for initial licensure:

- Virginia Communication and Literacy Assessment (VCLA);
- Praxis Subject Assessments; and
- Praxis® Teaching Reading: Elementary (5205) for specified endorsements.

The Board prescribes the Praxis Subject Assessments as a professional teacher's assessment requirement for initial licensure in Virginia. The current Board of Education's prescribed assessment for chemistry is the Praxis® Chemistry: Content Knowledge (5245).

The Praxis® Chemistry (5246) test will replace the Praxis® Chemistry: Content Knowledge (5245) test. This **new** assessment is designed and developed through work with practicing chemistry teachers, teacher educators, and higher education chemistry specialists to reflect the science knowledge teachers need to teach the chemistry curriculum and to reflect state and national standards, including the National Science Teacher Association Preparation Standards for chemistry. 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 K1-12 Science Education and included in the Next Generation Science Standards.

In May 2021, a multistate standard-setting study was designed and conducted by the Educational Testing Service (ETS) to support the decision-making process of education agencies establishing a passing score (cut score) for the Praxis® Chemistry (5246) test. Panelists from 15 states and Washington, D.C., participated on the panel. The education agencies recommended panelists with (a) experience as either chemistry teachers or college faculty who prepare chemistry teachers and (b) familiarity with the knowledge and skills required of beginning chemistry teachers.

A detailed summary of the study, Multistate Standard-Setting Technical Report - Praxis® Chemistry (5246) is attached. The technical report contains three sections. The first section describes the content and format of the test. The second section describes the standard-setting processes and methods. The third section presents the results of the standard-setting study.

The Praxis® Chemistry Study Companion is also attached. This document describes the purpose and structure of the test. In brief, the test measures knowledge and competencies that are important for safe and effective beginning practice as a chemistry teacher. The two-hour and 30 minute assessment contains 125 selected-response items covering five content areas: *Nature and Impact of Science and Engineering* (approximately 17 items), *Principles and Models of Matter and Energy* (approximately 31 items), *Chemical Composition, Bonding, and Structure* (approximately 25 items), *Chemical Reactions and Periodicity* (approximately 29 items), and *Solutions and Acid-Base Chemistry* (approximately 23 items). As described in the test description, more than 40 percent of questions integrate a *Science and Engineering Practice*, and approximately 25 percent of questions assess content applied to a *Task of Teaching of Science*. The reporting scale for the Praxis Chemistry test ranges from 100 to 200 scale-score points.

Multistate Standard-Setting Study

The Multistate standard-setting study for the Praxis® Chemistry (5246) test is detailed in the attached report.

The following table presents the estimated conditional standard error of measurement (CSEM) around the recommended passing score. A standard error represents the uncertainty associated with a test score. The scale scores associated with one and two CSEM above and below the recommended passing score are provided. The conditional standard error of measurement provided is an estimate.

Conditional Standard Error of Measurement Summaries
PRAXIS® CHEMISTRY (5246)

	Raw Score	Scale Score Equivalent
Recommended passing score (CSEM)	***56 (4.99)***	***146***
- 2 CSEM	47	133
- 1 CSEM	52	140
+1 CSEM	61	153
+2 CSEM	66	160

ETS provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the Praxis Chemistry test, the recommended passing score is 56 out of a possible 100 raw-score points. The scale score associated with a raw score of 56 is **146** on a 100–200 scale.

The current Praxis® Chemistry: Content Knowledge (5245) Test has a Board prescribed passing score of 153 on a 100-200 scale. The Praxis® Chemistry (5246) test is a **new** assessment and the previous passing score was not a consideration of ETS or ABTEL when establishing this test's passing score. Because this is a **new** assessment, ABTEL is also recommending that a data review be conducted after one year to determine if the passing score is providing for the greatest opportunity of teachers entering the profession while maintaining rigor.

On September 19, 2022 information regarding the multistate standard-setting process was presented to ABTEL members by Malik K. McKinley, Sr., Director of Client Relations, Professional Educator Programs, Office for Teacher Licensure and Certification, Student and Teacher Assessment Division, Educational Testing Service. ABTEL members reviewed the standard-setting report and recommended that the Board approve the passing score of 146 (the standard setting panel's recommendation).

The *Code of Virginia* provides the authority for the Board of Education to promulgate *Licensure Regulations for School Personnel*.

Section **22.1-298.1** of the *Code of Virginia* states, in part, the following:

> § **22.1-298.1** **Regulations governing licensure.**
> *C. The Board of Education's regulations shall include requirements that a person seeking initial licensure:*
> *1. Demonstrate proficiency in the relevant content area, communication, literacy, and other core skills for educators by achieving a qualifying score on professional assessments or meeting alternative evaluation standards as prescribed by the Board;*
> *2. Complete study in attention deficit disorder;*
> *3. Complete study in gifted education, including the use of multiple criteria to identify gifted students; and*
> *4. Complete study in methods of improving communication between schools and families and ways of increasing family involvement in student learning at home and at school.*

Code of Virginia, Section 22.1-16. Bylaws and regulations generally.
Code of Virginia, Section 22.1-299. License required of teachers.
Code of Virginia, Section 22.1-305.2. Advisory Board on Teacher Education and Licensure.

The *Licensure Regulations for School Personnel* state, in part, the following:

> 8VAC20-22-40. Conditions for Licensure.

... B. All candidates who hold at least a baccalaureate degree from a regionally accredited college or university and who seek an initial Virginia teaching license shall obtain passing scores on professional teacher's assessments prescribed by the Virginia Board of Education. With the exception of the career switcher program that requires assessments as prerequisites, individuals shall complete the professional teacher's assessment requirements within the three-year validity of the initial provisional license….

8VAC20-22-70. Additional Endorsements.

A. An individual who holds a teaching license may add an additional teaching endorsement to the license by passing a rigorous academic subject test for endorsements in which a test is prescribed by the Virginia Board of Education. This testing option does not apply to individuals (i) who are seeking an early/primary education preK-3 or elementary education preK-6 endorsement, special education endorsements, or a reading specialist endorsement or (ii) who hold a Technical Professional License, Vocational Evaluator License, Pupil Personnel Services License, School Manager License, or Division Superintendent License.

Timetable for Further Review/Action:
Upon Board approval, information regarding the Praxis® Chemistry (5246) Test for the Science – Chemistry Endorsement will be disseminated to Virginia educational agencies and posted on the VDOE website.

Impact on Fiscal and Human Resources:
The individuals taking the Praxis® Chemistry (5246) Test will incur the costs for the test.

Attachment A

Multistate Standard-Setting Technical Report for the

Praxis® Chemistry (5246)

Student and Teacher Assessments: Validity and Test Use

ETS

Princeton, New Jersey

May 2021

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Executive Summary

To support the decision-making process of education agencies establishing a passing score (cut score) for the *Praxis*® Chemistry (5246) test, research staff from Educational Testing Service (ETS) designed and conducted a multistate standard-setting study (Tannenbaum, 2011, 2012).

Participating States

Panelists from 15 states, and Washington, D.C., were recommended to serve on one of two panels by their respective education agencies. The education agencies recommended panelists with (a) experience as either chemistry teachers or college faculty who prepare chemistry teachers and (b) familiarity with the knowledge and skills required of beginning chemistry teachers.

Recommended Passing Score

ETS provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the *Praxis* Chemistry test, the recommended passing score[1] is 56 out of a possible 100 raw-score points. The scale score associated with a raw score of 56 is 146 on a 100–200 scale.

[1] Results from the two panels participating in the study were averaged to produce the recommended passing score.

Introduction

To support the decision-making process for education agencies establishing a passing score (cut score) for the *Praxis*® Chemistry (5246) test, research staff from ETS designed and conducted a multistate standard-setting study (Tannenbaum, 2011, 2012) in May 2021. Education agencies[2] recommended panelists with (a) experience as either chemistry teachers or college faculty who prepare chemistry teachers and (b) familiarity with the knowledge and skills required of beginning chemistry teachers. Fifteen states, and Washington, D.C., (Table 1) were represented by 25 panelists. (See Appendix A for the names and affiliations of the panelists.)

Table 1
Participating States , and Washington, D.C., and the Number of Panelists

Arkansas (1 panelist)	Nevada (1 panelist)
Delaware (1 panelist)	New Jersey (1 panelist)
Indiana (5 panelists)	North Carolina (1 panelist)
Kansas (2 panelists)	South Dakota (2 panelists)
Kentucky (1 panelist)	Utah (1 panelist)
Louisiana (1 panelist)	Virginia (2 panelists)
Maryland (2 panelists)	Washington, D.C. (1 panelist)
Montana (1 panelist)	West Virginia (2 panelists)

The following technical report contains three sections. The first section describes the content and format of the test. The second section describes the standard-setting processes and methods. The third section presents the results of the standard-setting study.

ETS provides a recommended passing score from the multistate standard-setting study to education agencies. In each state, and D.C., the department of education, the board of education, or a designated educator licensure board is responsible for establishing the operational passing score in accordance with applicable regulations. This study provides a recommended passing score, which represents the combined judgments of a group of experienced educators. Each state, and D.C. may want to consider the recommended passing score but also other sources of information when setting the final

[2] States and jurisdictions that currently use *Praxis* tests were invited to participate in the multistate standard-setting study.

Praxis Chemistry passing score (see Geisinger & McCormick, 2010). A state, and D.C. may accept the recommended passing score, adjust the score upward to reflect more stringent expectations, or adjust the score downward to reflect more lenient expectations. There is no *correct* decision; the appropriateness of any adjustment may only be evaluated in terms of its meeting the state, and D.C.'s needs.

Two sources of information to consider when setting the passing score are the standard error of measurement (SEM) and the standard error of judgment (SEJ). The former addresses the reliability of the *Praxis* Chemistry test score and the latter, the reliability of panelists' passing-score recommendation. The SEM allows states, and D.C. to recognize that any test score on any standardized test—including a *Praxis* Chemistry test score—is not perfectly reliable. A test score only *approximates* what a candidate truly knows or truly can do on the test. The SEM, therefore, addresses the question: How close of an approximation is the test score to the *true* score? The SEJ allows states, and D.C. to gauge the likelihood that the recommended passing score from the current panel would be similar to the passing scores recommended by other panels of experts similar in composition and experience. The smaller the SEJ, the more likely that another panel would recommend a passing score consistent with the recommended passing score. The larger the SEJ, the less likely the recommended passing score would be reproduced by another panel.

In addition to measurement error metrics (e.g., SEM, SEJ), each state, and D.C. should consider the likelihood of classification errors. That is, when adjusting a passing score, policymakers should consider whether it is more important to minimize a false-positive decision or to minimize a false-negative decision. A false-positive decision occurs when a candidate's test score suggests that they should receive a license/certificate, but their actual level of knowledge/skills indicates otherwise (i.e., the candidate does not possess the required knowledge/skills). A false-negative decision occurs when a candidate's test score suggests that they should not receive a license/certificate, but they actually do possess the required knowledge/skills. States, and D.C. needs to consider which decision error is more important to minimize.

Overview of the *Praxis*® Chemistry Test

The *Praxis*® Chemistry *Study Companion* document (ETS, in press) describes the purpose and structure of the test. In brief, the test measures whether entry-level chemistry teachers have the knowledge/skills believed necessary for competent professional practice.

The two-hour and 30 minute assessment contains 125 selected-response items[3] covering five content areas: *Nature and Impact of Science and Engineering* (approximately 17 items), *Principles and Models of Matter and Energy* (approximately 31 items), *Chemical Composition, Bonding, and Structure* (approximately 25 items), *Chemical Reactions and Periodicity* (approximately 29 items), and *Solutions and Acid-Base Chemistry* (approximately 23 items).[4] As described in the test description (ETS, in press), more than 40 percent of questions integrate a *Science and Engineering Practice*, and approximately 25 percent of questions assess content applied to a *Task of Teaching of Science*. The reporting scale for the *Praxis* Chemistry test ranges from 100 to 200 scale-score points.

Processes and Methods

The design of the standard-setting study included two, independent expert panels. Before the study, panelists received an email explaining the purpose of the standard-setting study and requesting that they review the content specifications for the test. This review helped familiarize the panelists with the general structure and content of the test.

For each panel, the standard-setting study began with a welcome and introduction by the meeting facilitator. The facilitator described the test, provided an overview of standard setting, and presented the agenda for the study. Appendix B shows the standard-setting study agenda.

Reviewing the Test

The standard-setting panelists first took the test and then discussed the content measured. This discussion helped bring the panelists to a shared understanding of what the test does and does not cover, which serves to reduce potential judgment errors later in the standard-setting process.

[3] Twenty-five of the 125 selected-response items are pretest items and do not contribute to a candidate's score.
[4] The number of items for each content area may vary slightly from form to form of the test.

The test discussion covered the major content areas being addressed by the test. Panelists were asked to remark on any content areas that would be particularly challenging for entry-level teachers or areas that address content particularly important for entry-level teachers.

Defining the Just-Qualified Candidate

Following the review of the test, panelists described the just-qualified candidate. The *just-qualified candidate description* plays a central role in standard setting (Perie, 2008); the goal of the standard-setting process is to identify the test score that aligns with this description.

Panel 1 created a description of the just-qualified candidate—the knowledge/skills that differentiate a *just-qualified* from a *not quite-qualified* candidate. To create this description, the panel first split into smaller groups to consider the just-qualified candidate. Then they reconvened and, through whole-group discussion, determined the description of the just-qualified candidate to use for the remainder of the study.

The written description of the just-qualified candidate summarized the panel discussion in a list format. The description was not intended to describe all the knowledge and skills of the just-qualified candidate but only highlight those that differentiate a *just-qualified candidate* from a *not-quite-qualified* candidate. The written description was distributed to panelists to use during later phases of the study (see Appendix C for the just-qualified candidate description).

For Panel 2, the panelists began with the description of the just-qualified candidate developed by Panel 1. Given that the multistate standard-setting study was designed to provide two recommendations for the same performance standard, it was important that panels use a consistent just-qualified candidate description to frame their judgments. The panelists reviewed the just-qualified candidate description, and any ambiguities were discussed and clarified.

Panelists' Judgments

The standard-setting process for the *Praxis* Chemistry test was a probability-based Modified Angoff method (Brandon, 2004; Hambleton & Pitoniak, 2006). Using this method, each panelist judged each item on the likelihood (probability or chance) that the just-qualified candidate would answer the item correctly. Panelists made their judgments using the following rating scale: 0, .05, .10, .20, .30, .40, .50, .60, .70, .80, .90, .95, 1. The lower the value, the less likely it is that the just-qualified candidate would answer the item correctly because the item is difficult for the just-qualified candidate. The higher the value, the more likely it is that the just-qualified candidate would answer the item correctly.

Panelists were asked to approach the judgment process in two stages. First, they reviewed both the description of the just-qualified candidate and the item and determined the probability that the just-qualified candidate would answer the question correctly. The facilitator encouraged the panelists to consider the following rules of thumb to guide their decision:

- Items in the 0 to .30 range were those the just-qualified candidate would have a *low chance* of answering correctly.
- Items in the .40 to .60 range were those the just-qualified candidate would have a *moderate chance* of answering correctly.
- Items in the .70 to 1 range were those that the just-qualified candidate would have a *high chance* of answering correctly.

Next, panelists decided how to refine their judgment within the range. For example, if a panelist thought that there was a *high chance* that the just-qualified candidate would answer the question correctly, the initial decision would be in the .70 to 1 range. The second decision for the panelist was to judge if the likelihood of answering it correctly is .70, .80, .90, .95 or 1.

After the training, panelists made practice judgments and discussed those judgments and their rationales. All panelists completed a post-training evaluation to confirm that they had received adequate training in the Modified Angoff method and felt prepared to continue; the standard-setting process continued only if all panelists confirmed their readiness.

Following this first round of judgments (*Round 1*), item-level feedback was provided to the panel. The panelists' judgments were displayed for each item and summarized across panelists. Item-level data were highlighted to show when panelists converged in their judgments or diverged in their judgments (i.e., when at least two-thirds of the panelists' judgments were in the same difficulty range).

The panelists discussed their item-level judgments. These discussions helped panelists maintain a shared understanding of the knowledge/skills of the just-qualified candidate and helped to clarify aspects of items that might not have been clear to all panelists during the Round 1 judgments. The purpose of the discussion was not to encourage panelists to conform to another's judgment, but to understand the different relevant perspectives among the panelists.

In Round 2, panelists discussed their Round 1 judgments and were encouraged by the facilitator (a) to share the rationales for their judgments and (b) to consider their judgments in light of the rationales provided by the other panelists. Panelists recorded their Round 2 judgments only for items when they wished to change a Round 1 judgment. Panelists' final judgments for the study, therefore, consist of their Round 1 judgments and any adjusted judgments made during Round 2.

Other than the description of the just qualified candidate, results from Panel 1 were not shared with Panel 2. The item-level judgments from Panel 2 were independent of judgments from Panel 1.

Results

Expert Panels

Table 2 presents a summary of the panelists' demographic information. The panel included 25 educators representing 15 states, and D.C. (See Appendix A for a listing of panelists.) Seventeen panelists were teachers, five were college faculty, one was an administrator or department head, one was a director of field experiences, and one was a chemistry teacher/chair of department. Four of the five faculty members' job responsibilities included the training of chemistry teachers. The number of experts by panel and their demographic information are presented in Appendix D (Table D1).

Table 2
Panel Member Demographics (Across Panels)

Background Survey Question	Number	Percent
What is your current position?	**N**	**%**
Teacher	17	68
Administrator/Department head	1	4
College faculty	5	20
Director of Field Experiences (supervises student teachers)	1	4
Chemistry Instructor and Chair of Department	1	4
How do you describe yourself (i.e., race/ethnicity)?	**N**	**%**
Asian or Asian American	2	8
Black or African American	2	8
Hispanic or Latino	1	4
White	20	80
What is your gender?	**N**	**%**
Female	18	72
Male	7	25

Table 2 (continued from the previous page)
Panel Member Demographics (Across Panels)

Background Survey Question	Number	Percent
Are you currently certified to teach chemistry in your state?	N	%
Yes	21	84
No	4	16
Are you currently teaching chemistry in your state?	**N**	**%**
Yes	19	76
No	6	24
Are you currently supervising or mentoring other chemistry teachers?	**N**	**%**
Yes	9	36
No	16	64
At what P–12 grade level are you currently teaching chemistry?	**N**	**%**
Middle school (6–8 or 7–9)	2	8
Middle and High school	1	4
High school (9–12 or 10–12)	14	56
Not currently teaching at the P–12 level	8	32
Including this year, how many years of experience do you have teaching chemistry?	**N**	**%**
3 years or less	1	4
4–7 years	6	24
8–11 years	3	12
12–15 years	5	20
16 years or more	10	40
Which best describes the location of your P–12 school?	**N**	**%**
Urban	5	20
Suburban	7	28
Rural	6	24
Not currently working at the P–12 level	7	28
If you are college faculty, are you currently involved in the training/ preparation of chemistry teacher candidates?	**N**	**%**
Yes	4	16
No	1	4
Not college faculty	20	80

Standard-Setting Judgments

Table 3 summarizes the mean passing score recommendations after Round 2 from each panel. Table 3 also includes the standard deviation and the standard error of judgment (SEJ) (Brennon, 2002, Tannenbaum & Katz, 2013). The SEJ is one way of estimating the reliability or consistency of a panel's standard-setting judgments. It indicates how likely it would be for several other panels of educators similar in makeup, experience, and standard-setting training to the current panel to recommend the same passing score on the same form of the test. (For each panel, the panelists' judgments during Rounds 1 and 2, are presented in Appendix D, Tables D2-D4.)

Table 3
Summary of Round 2 Standard-setting Judgments by Panel

Statistic	Panel 1	Panel 2
Mean	51.54	59.44
Minimum	39.20	50.00
Maximum	59.30	69.90
SD	4.82	6.90
SEJ	1.29	2.08

With multistate standard-setting studies with two panels, the confidence intervals created by adding/subtracting two SEJs to each panel's recommended passing score typically overlap. For this study, the confidence intervals do not overlap, indicating that their recommendations may not be as comparable.

The Round 2 mean score is each panel's final recommended passing score. The panel's passing score recommendation for the *Praxis* Chemistry test are 51.54 for Panel 1 and 59.44 for Panel 2 (out of a possible 100 raw-score points). The values were rounded to the next highest whole number to determine the functional recommended passing score--52 for Panel 1 and 60 for Panel 2. The scale scores associated with 52 and 60 raw points are 140 and 151, respectively.

In addition to the recommended passing score for each panel, the average passing score across the two panels is provided to help education agencies determine an appropriate passing score. The panels' average passing score recommendation for the *Praxis* Chemistry test is 55.49 (out of a possible 100 raw-score points). The value was rounded to 56 (next highest raw score) to determine the functional recommended passing score. The scale score associated with 56 raw points is 146.

The conditional standard error of measurement (CSEM) around the recommended passing score is 4.99 raw points. A standard error represents the uncertainty associated with a test score (See Appendix E for further information about the CSEM.) Table 4 shows the raw scores and the scale scores associated with one and two CSEM below and above the recommended passing score (See Appendix D, Tables D5 and D6 for this data, per panel).

Table 4
Scores 1 and 2 CSEM Around the Recommended Passing Score (RPS)

Scores	Raw Score Points out of 100	Praxis Scale Score Equivalent
RPS - 2 CSEM	47	133
RPS - 1 CSEM	52	140
RPS	**56**	**146**
RPS +1 CSEM	61	153
RPS +2 CSEM	66	160

Notes. CSEM = conditional standard error(s) of measurement. The CSEM of the recommended passing score is 4.99 raw points. The unrounded CSEM value is added to, or subtracted from, the rounded passing-score recommendation. The resulting values are rounded up to the next-highest whole number and then converted to scale scores.

Final Evaluations

The panelists completed an evaluation at the conclusion of the standard-setting study. The evaluation asked the panelists to provide feedback about the quality of the standard-setting implementation and the factors that influenced their decisions. The responses to the evaluation provided evidence of the validity of the standard-setting process, and, as a result, evidence of the reasonableness of the recommended passing score.

Panelists were shown the panel's recommended passing score after Round 2 and asked, in the evaluation, (a) how comfortable they are with the recommended passing score and (b) if they think the score was *too high*, *too low*, or *about right*. A summary of the final evaluation results, per panel, is presented in Appendix D (Tables D7 – D14).

All panelists *strongly agreed* or *agreed* that they understood the purpose of the study and that the facilitator's instructions and explanations were clear. All panelists *strongly agreed* or *agreed* that they were prepared to make their standard-setting judgments. All panelists *strongly agreed* or *agreed* that the standard-setting process was easy to follow.

All panelists reported that the description of the just-qualified candidate was *very influential* or *somewhat influential* in guiding their standard-setting judgments. All of the panelists reported that between-round discussions were at least *somewhat influential* in guiding their judgments. More than three-quarters of the panelists (20 of the 25 panelists) indicated that their own professional experience was *very influential* in guiding their judgments.

All of the panelists indicated they were at least *somewhat comfortable* with the passing score recommended by their panel; 17 of the 25 panelists were very comfortable. Twenty-three of the 25 panelists indicated their panel's recommended passing score was *about right*. Two panelists from Panel

1 indicated that the passing score was too low; the Panel 1 recommendation was lower than that from Panel 2.

Summary

To support the decision-making process for education agencies establishing a passing score (cut score) for the *Praxis* Chemistry test, research staff from ETS designed and conducted a multistate standard-setting study.

ETS provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the *Praxis* Chemistry test, the recommended passing score[5] is 56 out of a possible 100 raw-score points. The scale score associated with a raw score of 56 is 146 on a 100–200 scale.

[5] Results from the two panels participating in the study were averaged to produce the recommended passing score.

References

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Appendix A: Panelists' Names & Affiliations

Participating Panelists With Affiliation and State

Panelist Name	Panelists' Affiliation and State Abbreviation
Lori Beasley	Seaford School District (DE)
Jennifer Bland	Greenbrier West High School (WV)
Spencer Cody	Edmunds Central School District (SD)
Amy Connor	Frederick High School (MD)
Kyong Damron	Lawrence Central High School (IN)
Susanne Dana	Montgomery County Public Schools (VA)
Aaron Dehne	Ed W Clark High School Clark County School District (NV)
Diane DeVivo	Warren Hills Regional HS (NJ)
Lauren Doran	Athens Drive High School (NC)
Sharla Dowding	Black Hills State University (SD)
Rosie Easterday	Fort Wayne Community Schools (IN)
Ivy Fortmeyer	Rocky Mountain College (MT)
Maree Funk	Zachary High School (LA)
Patricia Hodison	Washington High School (KS)
Patricia Kramolisch	Beville Middle School (VA)
Sheena Lawson	University of the Cumberlands (KY)
James Lipchock	Washington College (MD)
Meredith Moore	Washington International School (DC)
Adam Robb	Moundridge High School (KS)
Rebecca Sansom	Brigham Young University (UT)
Michele Shultz	Lebanon Community School Corporation (IN)
Michael Tilley	West Virginia University (WV)
Grant Wangila	University of Arkansas at Pine Bluff (AR)
Lori White	Cascade High School (IN)

Participating Panelists With Affiliation and State (continued from previous page)

Panelist Name	Panelists' Affiliation and State Abbreviation
Lionel Zhao	Northwest Allen County Schools (IN)

Appendix B: Agenda

Praxis® Chemistry (5246)

Standard-Setting Study

Day 1 Agenda

Welcome and Introduction

Overview of Standard Setting and the *Praxis* Chemistry Test

Review the *Praxis* Chemistry Test

Discuss the *Praxis* Chemistry Test

Lunch

Panel 1: Define the Knowledge/Skills of a Just-Qualified Candidate (small-group drafts)

Panel 1: Define the Knowledge/Skills of a Just-Qualified Candidate (whole-group consensus)

Panel 2: Understand the Knowledge/Skills of the Just-Qualified Candidate (whole-group discussion)

Collect Materials; End of Day 1

Praxis® Chemistry (5246)

Standard-Setting Study

Day 2 Agenda

Overview of Day 2

Standard Setting Training in the Modified Angoff Method

Round 1 Standard Setting Judgments

Round 1 Feedback and Round 2 Judgments

Lunch

Feedback on Round 2 Recommended Passing Score

Complete Final Evaluation

Collect Materials; End of Study

Appendix C: Just-Qualified Candidate Description

Description of the Just-Qualified Candidate[6]

A just-qualified candidate…

Nature and Impact of Science and Engineering

1. Knows the basic principles of experimental designs (e.g., systematic vs. random error).
2. Is familiar with the most common environmental impact of chemical processes
3. Knows how to interpret models to explain scientific phenomenon
4. Knows how to interpret and analyze graphical representations of data

Principles and Models of Matter and Energy

5. Understands the fundamental classifications and properties of matter
6. Is familiar with the fundamental relationship between matter and energy.
7. Knows how to apply gas laws to predict the properties and behavior of ideal gases.
8. Knows the basic principles of thermodynamics (e.g., heat and enthalpy).
9. Knows atomic structure of the quantum mechanical model as it relates to chemical, physical, and nuclear properties of the atom

Chemical Composition, Bonding, and Structure

10. Is familiar with the basic principles of chemical nomenclature
11. Knows how to write formulas of common compounds and polyatomic ions
12. Knows relationships between percent composition and empirical formulas
13. Is familiar with the relationship between a 2-dimensional representation and its 3-dimensional molecular geometry
14. Knows covalent, ionic, and metallic bonding and its relationship to structure and properties.
15. Knows how to identify the predominant intermolecular forces for a substance.
16. Is familiar with how IMFs affect physical properties.

Chemical Reactions and Periodicity

17. Knows the organization of the elements on the periodic table and how it relates to physical and chemical properties of different elements.
18. Understands simple stoichiometric calculations
19. Knows how to predict the products of basic chemical reactions (e.g., single- and double-displacement reactions)
20. Is familiar with basic principles of kinetics, oxidation-reduction, and electrochemistry

[6] Description of the just-qualified candidate focuses on the knowledge/skills that differentiate a *just* from a *not quite* qualified candidate.

Solutions and Acid-Base Chemistry

21. Knows basic calculations of solutions such as concentration, dilution, molarity
22. Is familiar with how colligative properties affect the properties of solutions
23. Is familiar with common applications of chemical equilibrium (Le Chatelier's principle) and basic calculations of equilibrium constants (e.g., Law of Mass Action).
24. Knows characteristics of acid and bases (e.g., strong and weak, electrical conductivity, pH scale)
25. Is familiar with simple acid-base titrations

Appendix D: Panel-Specific Results

Table D1
Panel Member Demographics per Panel

Background Survey Question	Panel 1 Number	Panel 1 Percent	Panel 2 Number	Panel 2 Percent
What is your current position?	N	%	N	%
Teacher	9	64	8	73
Administrator/Department head	0	0	1	9
College faculty	3	21	2	18
Director of Field Experiences (supervises student teachers)	1	7	0	0
Chemistry Instructor and Chair of Department	1	7	0	0
How do you describe yourself (i.e., race/ethnicity)?	N	%	N	%
Asian or Asian American	1	7	1	9
Black or African American	2	14	0	0
Hispanic or Latino	1	7	0	0
White	10	71	10	91
What is your gender?	N	%	N	%
Female	8	57	10	91
Male	6	43	1	9
Are you currently certified to teach chemistry in your state?	N	%	N	%
Yes	12	86	9	82
No	2	14	2	18
Are you currently teaching chemistry in your state?	N	%	N	%
Yes	12	86	7	64
No	2	14	4	36
Are you currently supervising or mentoring other chemistry teachers?	N	%	N	%
Yes	6	49	3	27
No	8	57	8	73

Table D1 (continued from previous page)
Panel Member Demographics per Panel

Background Survey Question	Panel 1 Number	Panel 1 Percent	Panel 2 Number	Panel 2 Percent
At what P–12 grade level are you currently teaching chemistry?	N	%	N	%
Middle school (6–8 or 7–9)	1	7	1	9
Middle and High school	0	0	1	9
High school (9–12 or 10–12)	8	57	6	55
Not currently teaching at the P–12 level	5	36	3	27
Including this year, how many years of experience do you have teaching chemistry?	N	%	N	%
3 years or less	0	0	1	9
4–7 years	2	14	4	36
8–11 years	3	21	0	0
12–15 years	2	14	3	27
16 years or more	7	50	3	27
Which best describes the location of your P–12 school?	N	%	N	%
Urban	3	21	2	18
Suburban	4	29	3	27
Rural	2	14	4	36
Not currently working at the P–12 level	5	36	2	18
If you are college faculty, are you currently involved in the training/ preparation of chemistry teacher candidates?	N	%	N	%
Yes	3	21	1	9
No	0	0	1	9
Not college faculty	11	79	9	82

Table D2

Panel 1 Passing Score Summary by Round of Judgments

Panelist	Round 1	Round 2
1	40.00	39.20
2	41.70	44.35
3	50.80	51.50
4	51.50	51.40
5	51.50	51.70
6	52.20	51.85
7	53.30	53.30
8	53.80	52.90
9	54.50	54.40
10	55.40	50.70
11	55.90	53.70
12	56.40	55.90
13	57.10	51.35
14	64.85	59.30

Note: Data from panelists 1, 2, and 14 were detected as outliers (High, 2000; see Appendix E for technical notes). Their scores are not recommended for removal, however, because they were observed to be following the standard-setting process faithfully.

Table D3

Panel 2 Passing Score Summary by Round of Judgments

Panelist	Round 1	Round 2
1	44.95	50.00
2	45.95	51.40
3	46.65	52.05
4	54.40	54.20
5	57.65	59.85
6	59.60	59.60
7	61.10	60.60
8	62.45	62.55
9	64.35	64.65
10	69.40	69.90
11	72.35	69.05

Table D4 summarizes each panel's judgments, per round. The Round 1 judgments are made without discussion among the panelists. Therefore, the most variability in judgments is typically present in the first round. Round 2 judgments, however, are informed by panel discussion; thus, it is common to see a decrease both in the standard deviation and SEJ. This decrease—indicating convergence among the panelists' judgments—was observed for both panels.

Table D4

Summary of Standard-setting Judgments by Panel and by Round

Statistic	Panel 1, Round 1	Panel 1, Round 2	Panel 2, Round 1	Panel 2, Round 2
Mean	52.78	51.54	58.08	59.44
Minimum	40.00	39.20	44.95	50.00
Maximum	64.85	59.30	72.32	69.90
SD	6.15	4.82	9.30	6.90
SEJ	1.64	1.29	2.81	2.08

Tables D5 and D6 show, for Panel 1 and 2, respectively, the raw scores and the scale scores associated with one and two CSEM below and above each panel's recommended passing scores. The unrounded CSEM value is added to, or subtracted from, the rounded passing-score recommendation. The resulting values are rounded up to the next-highest whole number and then converted to scale scores.

Table D5

Scores 1 and 2 CSEM Around the RPS from Panel 1

Panel 1 Scores	Raw Score Points out of 100	Praxis Scale Score Equivalent
RPS - 2 CSEM	42	126
RPS - 1 CSEM	47	133
Panel 1 RPS	**52**	**140**
RPS +1 CSEM	58	148
RPS +2 CSEM	63	155

Notes. CSEM = conditional standard error(s) of measurement. The CSEM of the recommended passing score is 5.02 raw points.

Table D6

Scores 1 and 2 CSEM Around the RPS from Panel 2

Panel 2 Scores	Raw Score Points out of 100	Praxis Scale Score Equivalent
RPS - 2 CSEM	51	139
RPS - 1 CSEM	56	146
Panel 2 RPS	**60**	**151**
RPS +1 CSEM	65	158
RPS +2 CSEM	70	165

Notes. CSEM = conditional standard error(s) of measurement. The CSEM of the recommended passing score is 4.92 raw points.

Table D7: Panel 1 Final Evaluation: Process Questions

Likert Statement	Strongly agree *N*	Strongly agree %	Agree *N*	Agree %	Disagree *N*	Disagree %	Strongly disagree *N*	Strongly disagree %
I understood the purpose of this study.	13	93	1	7	0	0	0	0
The instructions and explanations provided by the facilitators were clear.	11	79	3	21	0	0	0	0
The training in the standard-setting method was adequate to give me the information I needed to complete my assignment.	11	79	3	21	0	0	0	0
The explanation of how the recommended passing score is computed was clear.	11	79	3	21	0	0	0	0
The opportunity for feedback and discussion between rounds was helpful.	10	71	4	29	0	0	0	0
The process of making the standard-setting judgments was easy to follow.	10	71	4	29	0	0	0	0

Table D8: Panel 1 Final Evaluation: Influences in Standard-Setting Judgments

How influential was each of the following factors in guiding your standard-setting judgments?	Very influential *N*	Very influential %	Somewhat influential *N*	Somewhat influential %	Not influential *N*	Not influential %
The description of the just-qualified candidate	13	93	1	7	0	0
The between-round discussions	6	43	8	57	0	0
The knowledge/skills required to answer each test item	13	93	1	7	0	0
The passing scores of other panel members	4	29	10	71	0	0
My own professional experience	12	86	2	14	0	0

Table D9: Panel 1 Final Evaluation: Comfort with the Panel's Recommendation

Question	Very comfort-able *N*	Very comfort-able %	Somewhat comfort-able *N*	Somewhat comfort-able %	Somewhat uncom-fortable *N*	Somewhat uncom-fortable %	Very uncom-fortable *N*	Very uncom-fortable %
Overall, how comfortable are you with the panel's recommended passing score?	10	71	4	29	0	0	0	0

Table D10: Panel 1 Final Evaluation: Opinion of the Final Recommendation

Statement	Too low *N*	Too low %	About right *N*	About right %	Too high *N*	Too high %
Overall, the recommended passing score is:	2	14	12	86	0	0

Table D11: Panel 2 Final Evaluation: Process Questions

Likert Statement	Strongly agree *N*	Strongly agree %	Agree *N*	Agree %	Disagree *N*	Disagree %	Strongly disagree *N*	Strongly disagree %
I understood the purpose of this study.	11	100	0	0	0	0	0	0
The instructions and explanations provided by the facilitators were clear.	11	100	0	0	0	0	0	0
The training in the standard-setting method was adequate to give me the information I needed to complete my assignment.	11	100	0	0	0	0	0	0
The explanation of how the recommended passing score is computed was clear.	11	100	0	0	0	0	0	0
The opportunity for feedback and discussion between rounds was helpful.	11	100	0	0	0	0	0	0
The process of making the standard-setting judgments was easy to follow.	11	100	0	0	0	0	0	0

Table D12: Panel 2 Final Evaluation: Influences in Standard-Setting Judgments

How influential was each of the following factors in guiding your standard-setting judgments?	Very influential *N*	Very influential %	Somewhat influential *N*	Somewhat influential %	Not influential *N*	Not influential %
The description of the just-qualified candidate	11	100	0	0	0	0
The between-round discussions	8	73	3	27	0	0
The knowledge/skills required to answer each test item	10	91	1	9	0	0
The passing scores of other panel members	6	55	4	36	1	9
My own professional experience	8	73	3	27	0	0

Table D13: Panel 2 Final Evaluation: Comfort with the Panel's Recommendation

Question	Very comfort-able *N*	Very comfort-able %	Somewhat comfort-able *N*	Somewhat comfort-able %	Somewhat uncom-fortable *N*	Somewhat uncom-fortable %	Very uncom-fortable *N*	Very uncom-fortable %
Overall, how comfortable are you with the panel's recommended passing score?	7	64	4	36	0	0	0	0

Table D14: Panel 2 Final Evaluation: Opinion of the Final Recommendation

Statement	Too low *N*	Too low %	About right *N*	About right %	Too high *N*	Too high %
Overall, the recommended passing score is:	0	0	11	100	0	0

Appendix E: Technical Notes

Standard Error of Judgment (SEJ)

The standard error of judgment (SEJ) is one way of estimating the reliability or consistency of a panel's standard-setting judgments. It indicates how likely it would be for several other panels of educators similar in makeup, experience, and standard-setting training to the current panel to recommend the same threshold score on the same form of the assessment. The SEJ assumes that panelists are randomly selected and that standard-setting judgments are independent. It is seldom the case that panelists are randomly sampled, and only the first round of judgments may be considered independent. The SEJ, therefore, likely underestimates the uncertainty of threshold scores (Tannenbaum & Katz, 2013).

The SEJ is calculated by dividing the standard deviation of the panelists' judgments (*SD*) by the square root of the number of panelists (*n*). The result serves as an estimate of the standard error of the mean (Brennan, 2002).

$$SEJ = \mathrm{SD} / \sqrt{n}$$

Outlier Analysis

An analysis of the data is conducted per panel. Judgments that are above or below 1.5 times the interquartile range for that panel are identified as outliers (High, 2000). ETS makes recommendations on the removal of *specific* outliers based on the observations of the panel facilitator. The panel facilitator reports whether or not the specified panelist was faithfully participating in the standard-setting process. The decision to accept the panel recommendation with or without the outlier data is solely at the discretion of the state.

Conditional Standard Error of Measurement (CSEM)

The conditional standard error of measurement (*CSEM*) for a test is computed from the study value (*SV*) of the recommended passing score and the number of selected-response items (*n*) on the test (see Lord, 1984):

$$CSEM = \sqrt{(SV)(n - SV)/(n - 1)}$$

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Chemistry (5246)

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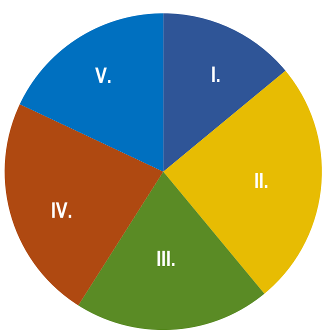
Chemistry (5246)

Test at a Glance

The *Praxis*® Chemistry test is designed to measure knowledge and competencies important for safe and effective beginning practice as a teacher of chemistry. Test takers have typically completed a bachelor's degree program with appropriate coursework in chemistry and education.

Test Name	Chemistry
Test Code	5246
Time	2 hours 30 minutes
Number of Questions	125 selected-response questions
Format	The test consists of a variety of selected-response questions, where you select one or more answer choices, and other types of questions. You can review the possible question types in Understanding Question Types.
Test Delivery	Computer Delivered



Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
I. Nature and Impact of Science and Engineering	17	14%
II. Principles and Models of Matter and Energy	31	25%
III. Chemical Composition, Bonding, and Structure	25	20%
IV. Chemical Reactions and Periodicity	29	23%
V. Solutions and Acid-Base Chemistry	23	18%

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

Content topics for the Chemistry test span the chemistry curriculum, including content related to (I) Nature and Impact of Science and Engineering, (II) Principles and Models of Matter and Energy, (III) Chemical Composition, Bonding, and Structure, (IV) Chemical Reactions and Periodicity, and (V) Solutions and Acid Base Chemistry.

The assessment is designed and developed through work with practicing chemistry teachers, teacher educators, and higher education chemistry specialists to reflect the science knowledge teachers need to teach the chemistry curriculum and to reflect state and national standards, including the National Science Teaching Association Preparation Standards for chemistry. 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 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 chemistry 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 chemistry content and processes within a teaching scenario or an instructional task. Such questions—designed to measure applications of chemistry knowledge to the kinds of decisions and evaluations a teacher must make during work with students, curriculum, and instruction—situate chemistry content questions in tasks critical for teaching. The Tasks of Teaching Science section has a list of tasks that are a routine part of chemistry 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.

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 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 with a teacher or mentor.

I. Nature and Impact of Science and Engineering

A. Nature of Science

1. Nature of scientific knowledge
   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. Forming and testing hypotheses
   e. Use of models, laws, and theories to explain natural phenomena
   f. Development and application of models to explain natural phenomena
   g. Process skills, including observing, categorizing, comparing, generalizing, inferring, and concluding
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, 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, extrapolating, and drawing conclusions from data
3. Laboratory procedures
   a. Appropriate preparation, use, storage, and disposal of materials
   b. Appropriate use of laboratory equipment (including selection, calibration, and maintenance)
   c. Safety procedures and precautions for the laboratory

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

1. Interdependence of science, engineering, and technology
   a. Engineering advances that lead to important discoveries in science
   b. Science and technology that drive each other forward
2. Engineering Design
   a. Defining problems, including identifying the success criteria and the constraints
   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. Air and water pollution
   c. Greenhouse gases
   d. Ozone layer depletion
   e. Polymers and plastics
   f. Waste disposal and recycling
4. Advantages and disadvantages associated with various types of energy production
   a. Conservation and recycling of energy
   b. Renewable and nonrenewable energy resources
   c. Pros and cons of power generation based on various sources such as fossil and nuclear fuel, hydropower, wind power, solar power, and geothermal power
5. Applications of chemistry and technology in daily life
   a. Water purification
   b. Plastics, soap, batteries, and other commercial products
   c. Mining and industrial processes
   d. Biological systems
   e. Radiation in medicine and technology

Discussion Questions: Nature and Impact of Science and Engineering

- What are the similarities and differences between laws, hypotheses, and theories?
- What is the difference between independent and dependent variables? Describe an experiment and identify the independent and the dependent variables.
- Describe something in chemistry that illustrates the relationship between form and function.
- What is Boyle's law and what is Charles's law?
- What was the role of Bohr's model of the atom in the development of modern atomic theory?
- What is the uncertainty in volume measurements made when using a buret and how many significant figures should be included in the recorded volume?
- How many significant figures are in 0.1360 grams?

- Determine the endpoint in an acid-base titration using a plot of pH versus the volume of base added to an acid.
- What is the mass in grams of a sample that has a mass of 20 milligrams?
- Express the number 0.000450 in scientific notation.
- What is the difference between the accuracy and the precision of a data set?
- How do you prepare 200 mL of 0.5 *M* $CaSO_4$ from a stock solution of 2.0 *M* $CaSO_4$?
- Can a very dilute solution of HCl acid be disposed of in a sink with running water?
- What are each of the following pieces of equipment used for in the laboratory: buret, pipet, Erlenmeyer flask, and volumetric flask?
- When and why is a fume hood needed in a chemistry laboratory?
- In what settings is solar power most effective?
- What are the major contributors of acid rain?
- What are some of the reactions in the stratosphere that lead to ozone depletion?
- What are the acid-base properties of commonly used consumer products such as ammonia cleaner, vinegar, and orange juice?
- Describe the reverse osmosis process that is sometimes used for water purification.
- What are some examples of nonrenewable energy resources?

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. Quantum mechanical model of atom, including orbitals and subatomic particles
   c. Experimental basis of model, including gold foil experiment and atomic spectra
2. Electron configuration of the elements
   a. Aufbau principle, Hund's rule, Pauli exclusion principle
   b. Correlation between electron configuration and the periodic table
   c. Relationship between electron configuration and chemical and physical properties of elements
3. Relationship between electronic absorption and emission spectra and electron energy levels in atoms
   a. Electronic energy transitions in atoms
   b. Relationship between energy, frequency, and wavelength of electromagnetic radiation
   c. Identification of atoms based on analysis of spectra
   d. Correlation of electronic transitions to spectral lines in electromagnetic spectrum

4. Radioactivity
    a. Characteristics of alpha particles, beta particles, and gamma radiation
    b. Radioactive decay: include the process, half-life, and applications
    c. Identifying fission and fusion reactions
    d. Balancing nuclear reactions and identifying products of nuclear reactions

B. Relationships Between Energy and Matter in Chemistry

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, molecules
2. Difference between chemical and physical properties and changes
    a. Chemical versus physical properties
    b. Chemical versus physical changes
    c. Intensive versus extensive properties
    d. Conservation of matter in chemical processes
3. Conservation of energy
    a. Conservation of energy in chemical and physical processes
    b. Kinetic and potential energy concepts and particulate models
    c. Forms of energy including chemical, electrical, thermal, electromagnetic, and nuclear
    d. Conversion between different forms of energy
4. Temperature, thermal energy, and heat capacity, including calculations
    a. Temperature scales
    b. Heat transfer
    c. Heat capacity and specific heat
    d. Calorimetry
5. Energy concepts and calculations involving phase transitions, including particulate and mathematical models
    a. Phase transition 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 and the ideal gas laws
7. How thermodynamics relates to chemical and physical processes
    a. Laws of thermodynamics
    b. Spontaneous (favorable) and reversible processes
    c. Changes in enthalpy, entropy, and Gibbs energy
    d. Exothermic and endothermic processes

e. Reaction progress diagrams based on potential energy of reactants and products.

f. Energy involved in breaking and forming bonds

Discussion Questions: Principles and Models of Matter and Energy

- How are isotopes of the same element alike? How are they different?
- 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 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?
- Give an example of Hund's rule.
- Given that the half-life of carbon-14 is 5,730 years, estimate the age of a piece of charcoal that has a carbon-14 content equal to 12.5% of that in living matter.
- How is fission different than fusion or radioactive decay?
- What is the wavelength of the energy emitted for an electronic transition in a hydrogen atom from $n = 3$ to $n = 2$ electronic energy level?
- In what part of the electromagnetic spectrum are electron emission spectral lines located?
- 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 the different types of mixtures?
- What is a cation?
- In their standard state, which of the following elements are diatomic: bromine, chlorine, argon, and helium?
- 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?
- 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 is an example of the conversion of chemical energy to electrical energy?
- Convert 350 kelvin to degrees Celsius.
- Consider the following list: erg, joule, electron volt, and ohm. Which of them are units of energy?
- If a substance has high heat capacity, will its temperature increase faster as heat is absorbed than will the temperature of a substance with lower heat capacity absorbing the same amount of heat?

- How much heat is absorbed as 10 grams of ice melts at the freezing point?
- What is the boiling point of water at high altitudes compared to that at sea level, and why is it different?
- When a gas expands from 5 liters to 10 liters as its temperature increases from 300 kelvin to 500 kelvin, what is the change in the pressure of the gas?
- What are the major differences between an ideal gas and a real gas?
- Given the heats of formation of H_2O, CO_2, and CH_4, calculate the heat of combustion of CH_4.
- Is the combustion of CH_4 an exothermic or an endothermic process?
- Based on the first and second laws of thermodynamics, predict whether a reaction is spontaneous.
- Describe some processes in which the entropy of the system is increasing.

III. Chemical Composition, Bonding, and Structure

A. Chemical Composition

1. Mole concept and application to chemical systems
   a. Avogadro's number, molar mass, and mole conversions
   b. Calculation of empirical and molecular formulas
   c. Percent composition
2. Systematic names and chemical formulas for simple inorganic compounds
   a. Binary compounds
   b. Acids, bases, and salts
   c. Hydrates
3. Identification of common organic functional groups and compounds
   a. Alkanes, alkenes, and alkynes
   b. Alcohols, ethers, ketones, aldehydes, carboxylic acids, and amines

B. Bonding and Structure

1. Properties and models of bonding
   a. Ionic bonding
   b. Covalent bonding (polar, nonpolar, and hybridization)
   c. Metallic bonding
   d. Relative bond strengths and bond lengths
2. Molecular structure models
   a. Lewis structures, including formal charges
   b. Resonance structures
   c. Molecular geometry (shape and bond angles)
3. Identification of polar and nonpolar molecules
   a. Analysis of polarity of the bonds within a molecule
   b. Symmetry of molecular structure
4. Types of interparticle interactions
   a. London forces (instantaneous induced dipole-dipole attractions)
   b. Dipole-dipole attractive forces
   c. Dipole-induced dipole attractive forces
   d. Hydrogen bonding

5. How bonding, structure, and interparticle interactions are related to physical properties of pure substances
    a. Boiling points and melting points
    b. Solubility
    c. Equilibrium vapor pressure

Discussion Questions: Chemical Composition, Bonding, and Structure

- What are the IUPAC names for the following compounds: $HClO_4$, $CuCl_2$, and $CaSO_4 \cdot 2H_2O$?
- Write the molecular formula for each of the following compounds: acetone, ethanol, ethanal, and formic acid.
- Identify the functional group in each of the following compounds: CH_3OCH_3, CH_3NH_2, CH_3OH, and CH_3COOH.
- What are the structures in the following types of molecules that distinguish them from other biochemical compounds: carbohydrates, amino acids, and DNA?
- What is the number of moles of oxygen atoms in 5 moles of $CaSO_4 \cdot 2H_2O$?
- What is the molecular formula of a compound that has the empirical formula C_2H_4O and a molar mass of 88 grams?
- 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?
- What is the difference between a pi bond and a sigma bond?
- Why does a NH_3 molecule have trigonal pyramidal geometry?
- What are the Lewis dot and the structural formulas for CH_4?
- What are the resonance structures for the carbonate ion?
- 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 molecules with their molecular structure and intermolecular interactions: H_2O, Cl_2, Br_2, HCl, and H_2.

IV. Chemical Reactions and Periodicity

A. 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. Predicting and justifying patterns and 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. Electron affinity

d. Electronegativity

e. Physical properties

f. Chemical properties and reactivity

B. Basic Principles of Chemical Reactions

1. Balancing equations for chemical reactions
    a. Simple chemical reactions
    b. Oxidation-reduction reactions
2. Stoichiometric calculations for chemical reactions
    a. Based on balanced equations involving moles, mass, or volume
    b. Limiting reagent calculations and percent yield
3. Predicting products of simple reaction types
    a. Combustion, neutralization, synthesis, decomposition, and dehydration reactions
    b. Single and double replacement reactions
4. Oxidation states and oxidation-reduction reactions
    a. Assigning oxidation numbers
    b. Identifying oxidation-reduction reactions and half-reactions
    c. Standard reduction potentials and the electrochemical reactivity series
5. Chemical kinetics: models based on collision theory
    a. Rate laws, rate constants, and reaction order
    b. Activation energy and catalysts
6. Equilibrium in chemical systems
    a. Equilibrium constants
    b. Le Chatelier's principle

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 the atomic radii, ionization energies, and melting points change across period and down columns in the periodic table?
- Using the location of the elements on the periodic table, predict the formula of the compound that would exist containing Mg and O.
- What needs to be considered when balancing oxidation-reduction reactions that does not need to be accounted for when balancing a standard formation reaction such as $2\ H_2 + O_2 \rightarrow 2\ H_2O$?
- 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 limiting reagent in the reaction to form water when 10 grams of hydrogen is mixed with 32 grams of oxygen?
- How is a decomposition reaction different from a dehydration reaction?
- What is the effect of temperature and catalysts on reaction rates?
- How are simple rate equations determined based on experimental data?

- What changes will occur to chemical systems that are at equilibrium when pressure or concentration of one of the reactants or products is changed?
- What is the effect of temperature on equilibrium constants?
- Based on a table of standard reduction potentials, predict whether the following reaction will occur spontaneously: $Cu + FeCl_2 \rightarrow CuCl_2 + Fe$.
- What is the oxidation state of Mn in $KMnO_2$?

V. Solutions and Acid-Base Chemistry

A. Solutions and Solubility

1. Analysis of types of solutions
   a. Dilute, concentrated, unsaturated, saturated, and supersaturated
   b. Identification of solute and solvent
   c. Representations of concentration in terms of various units, such as molarity, mole fraction, and percent by mass or volume
   d. Calculations needed to prepare solutions of varying concentrations
2. Factors affecting rate of dissolving and solubility
   a. Rate of dissolving (temperature, pressure, surface area, stirring)
   b. Solubility and solubility curves (temperature and pressure dependence)
3. Phenomena based on colligative properties of solutions
   a. Freezing point depression and boiling point elevation
   b. Vapor pressure effect
4. Equilibrium in ionic solutions
   a. Highly soluble and slightly soluble compounds
   b. Predictions of precipitation based on the solubility product (K_{sp})
   c. Common ion effect when mixing ionic solutions
   d. Electrolytes, nonelectrolytes, and electrical conductivity of solutions

B. Acid-Base Chemistry

1. Models of acids and bases and their properties
   a. Arrhenius acids and bases
   b. Brønsted-Lowry acids and bases
   c. Lewis acids and bases
2. The concept of pH and calculations involving pH and pOH
   a. pH scale
   b. Calculation of pH and pOH
   c. Calculation of $[H^+]$ and $[OH^-]$
3. Concepts, representations, and calculations involving acid-base titrations
   a. Neutralization and equivalence point
   b. Use and selection of indicators
   c. End point determination
   d. Analysis of titrations curves

4. Equilibrium relationships in acid-base systems
   a. Strong and weak acids and bases
   b. Monoprotic and polyprotic acids
   c. K_a, K_b, K_w and dissociation
   d. Buffer solutions

Discussion questions: Solutions and Acid-Base Chemistry

- How many grams of solute are present in 1.5 liters of 0.30 M KNO_3 ?
- What is the difference between a 1 molar NaCl solution and a 1 molal NaCl solution?
- Is a very concentrated solution saturated, supersaturated, or unsaturated? What else do you need to know to answer the question?
- Why is ammonia gas very soluble in water while oxygen is only slightly soluble?
- What is the relationship between surface area and dissolution rate?
- Will increasing temperature increase the solubility of any substance?
- How will the vapor pressure, boiling point, and freezing point of water change when a nonvolatile solute is added to water?
- Compare the degree of dissociation of HCl and H_2S in water.
- Write a chemical equation that illustrates the common ion effect.
- Is CCl_4 an electrolyte?
- When an aqueous solution of NaCl is mixed with an aqueous solution of $AgNO_3$ the precipitate AgCl forms. Why?
- Select an acid that is both a Brønsted-Lowry acid and a Lewis acid and explain why it fits both definitions.
- What is $[H^+]$ in an aqueous solution with pH = 5.5 ?
- What is the pOH of a solution with $[H^+] = 1 \times 10^{-8}$ M ?
- Based on a titration curve, determine the pK_a of the acid and the volume of base required to neutralize the acid.
- What indicator would be used in a titration involving a strong acid and a weak base and why?
- Is HF a strong acid? Why or why not?
- If Na_2CO_3 is dissolved in water, will the solution be acidic, basic, or neutral?
- For an acid HA, $K_a = 1 \times 10^{-8}$, what is the pH of 0.001 M HA ?

Science and Engineering Practices

Science and Engineering Practices (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 Chemistry 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, 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

Chemistry (5246) Sample Test Questions

The sample questions that follow represent a number of the types of questions and topics that appear 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: Each of the questions or incomplete statements below is followed by suggested answers or completions. Select the one that is best in each case.

1. Completely dry crystals of an unknown inorganic compound were heated in a clean, dry glass test tube. The total mass of the test tube and its solid contents was measured before and after heating. After heating, the total mass was observed to be less. Which **TWO** of the following could explain the observation?

   (A) The crystals were a hydrate, and some of the water vaporized.
   (B) The crystals were a compound that decomposed into two different solid compounds.
   (C) A reaction occurred in which one of the products was a gas.
   (D) The crystals were a compound that reacted with oxygen in the air to form a single compound of lower mass than the original compound.

2. Which **TWO** of the following processes involve a decrease in entropy?

   (A) Water freezing
   (B) Snow subliming
   (C) Dew forming on grass
   (D) Sugar dissolving in water

$$Pt(NH_3)Cl_2(aq) + Br^-(aq) \rightarrow Pt(NH_3)_2ClBr(aq) + Cl^-(aq)$$

3. For an upcoming lab activity, a teacher asks students to identify variables that should be controlled when six different trials are done to determine the rate of disappearance of Br^- in the preceding chemical reaction. Which **THREE** of following student responses are correct?

   (A) Concentration of Cl^-
   (B) Temperature
   (C) Initial amount of $Pt(NH_3)Cl_2(aq)$
   (D) Initial volume of the reaction mixture

4. In which of the following compounds do molecules interact through London dispersion forces only?

   (A) H_2O
   (B) CF_4
   (C) CH_3Cl
   (D) CO

5. Of the following, which best describes a solution with $pOH = 12.0$ at $25°C$?

   (A) An acidic solution that will turn blue litmus paper red because $[H^+] = 1.0 \times 10^{-2} M$
   (B) An acidic solution that will turn red litmus paper blue because $[H^+] = 1.0 \times 10^{-2} M$
   (C) A basic solution that will turn red litmus paper blue because $[H^+] = 1.0 \times 10^{-12} M$
   (D) A basic solution that will turn blue litmus paper red because $[H^+] = 1.0 \times 10^{-12} M$

$$CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$$

6. Which of the following species is reduced in the preceding oxidation-reduction reaction?

   (A) Zn
   (B) Cu^{2+}
   (C) S^{6+}
   (D) O^{2-}

7. Based on its position on the periodic table, which of the following has the largest atomic radius?

   (A) Cs
   (B) Mg
   (C) I
   (D) Se

8. If $50\,\text{mL}$ of $0.02\,M$ Na_2SO_4 is diluted with sufficient water to make a total volume of $200\,\text{mL}$, which of the following is the concentration of Na^+ ions in the diluted solution?

(A) 0.005 *M*
(B) 0.01 *M*
(C) 0.02 *M*
(D) 0.04 *M*

9. Of the following, which best describes smoke?

(A) A suspension
(B) An alloy
(C) A solution
(D) A homogeneous mixture

10. Which of the following is the ground-state electron configuration of Mg^{2+} ?

(A) $1s^2 2s^2 2p^6$
(B) $1s^2 2s^2 2p^6 3s^2$
(C) $1s^2 2s^2 2p^6 3s^2 3p^6$
(D) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

11. How many oxygen atoms are in two moles of $CuSO_4$?

(A) 4
(B) 8
(C) 6.02×10^{23}
(D) 4.82×10^{24}

12. If a 20 g sample of a substance is compared to a 10 g sample of the same substance, both at 25°C, the 20 g sample will have a higher

(A) density
(B) thermal heat content
(C) temperature
(D) boiling point

13. A well-designed experiment always includes which of the following?

(A) A scientific law
(B) A well-written conclusion
(C) Multiple independent variables
(D) A plan about how to measure the dependent variable

14. If a weak acid is titrated with a strong base, which of the following could be the pH at the equivalence point?

(A) 2.0
(B) 6.0
(C) 7.0
(D) 8.0

15. Of the following molecules, which has the most polar covalent bonds?

(A) HBr
(B) CH_4
(C) Cl_2
(D) H_2

16. At standard temperature and pressure, what volume of CO_2 is produced when 1.000 mol of C_8H_{18} undergoes complete combustion?

(A) 8.00 L
(B) 22.4 L
(C) 89.6 L
(D) 179.2 L

17. Ozone in the atmosphere is most closely related to which of the following?

(A) Acid rain production
(B) Water pollution
(C) Absorption of ultraviolet radiation in the stratosphere
(D) Nuclear power plant waste

18. Which of the following is a carboxylic acid?

(A) CH_3CH_2COOH
(B) CH_3OCH_3
(C) CH_3CH_2OH
(D) CH_3NH_2

19. For $Mg(OH)_2$ at room temperature, the solubility product K_{sp} is approximately 7×10^{-12}. The magnitude of the solubility constant indicates which of the following about $Mg(OH)_2$?

(A) If sufficient $Mg(OH)_2$ is mixed with water, it can form $11\,M$ $Mg(OH)_2(aq)$.
(B) It cannot form a saturated solution.
(C) It is a weak acid.
(D) It is only slightly soluble.

$$MnO_2 + 4\ HCl \rightarrow MnCl_2 + Cl_2 + 2\ H_2O$$

20. Based on the preceding balanced equation, what is the maximum number of moles of Cl_2 that can be produced if 2.0 mol of MnO_2 and 6.0 mol of HCl are initially provided in a reaction vessel?

(A) 1.0 mol
(B) 1.5 mol
(C) 2.0 mol
(D) 4.0 mol

21. The elements F, Cl, Br and I all form compounds with Na and are in the same column of the periodic table. The elements in this group are known as

(A) transition elements
(B) alkaline earth metals
(C) noble gases
(D) halogens

22. Which of the following is a balanced equation for a chemical reaction?

(A) $2\ K + 2\ H_2O \rightarrow 2\ KOH + H_2$
(B) $Mg + O_2 \rightarrow 2\ MgO$
(C) $NaOH + H_2SO_4 \rightarrow NaSO_4 + H_2O$
(D) $Cl_2 + NaI \rightarrow NaCl + I_2$

23. In an experiment to investigate the photoelectric effect, a clean surface of a certain metal was illuminated with light of different but sufficiently high frequencies. This resulted in electrons being emitted from the surface of the metal. The kinetic energy of the emitted electrons varied with the frequency of the incident light. Which of the following is the dependent variable in the experiment?

(A) Atomic number of the metal
(B) Atomic mass of the metal
(C) Frequency of the incident light
(D) Kinetic energy of the emitted electrons

$$2\ AB(g) \rightleftharpoons A_2(g) + B_2(g)$$

24. The preceding reaction is at equilibrium. Which of the following is true if the volume of the reaction vessel is decreased?

(A) The partial pressure of AB will decrease.
(B) The partial pressure of both A_2 and B_2 will decrease.
(C) The total pressure of the system will remain constant.
(D) The decrease in volume will have no effect on the equilibrium.

25. Of the following $0.05\ M$ aqueous solutions, which is most likely to have the lowest freezing point?

(A) KBr
(B) CsI
(C) $MgCl_2$
(D) CH_3OH

Compound	K_a
HOCN	3.5×10^{-4}
HIO_4	2.2×10^{-2}
$ClCH_2COOH$	1.4×10^{-3}
C_6H_6COOH	6.3×10^{-5}

26. A teacher asks students to use the data in the preceding table to identify the strongest acid among the weak acids listed and explain their choice. A student says that C_6H_6COOH is the strongest acid because it has the smallest K_a. Of the following, which statement, if true, would best help correct the student's misconception?

(A) In general, an acid that contains a Cl atom in its chemical formulas is a strong acid, regardless of the value of its K_a.
(B) In general, an acid that contains a large number of atoms is a very weak acid, regardless of the value of its K_a.
(C) The acid with the largest value for K_a is the strongest acid because the K_a indicates the degree to which the acid dissociates.
(D) The acid with the smallest value for its K_a will dissociate to the largest degree and therefore be a very weak acid.

27. Which of the following molecules is nonpolar?

(A) CCl_4
(B) H_2O
(C) HF
(D) CO

28. Which of the following gases is produced when concentrated aqueous HF is added to an aqueous solution of Na_2CO_3 ?

(A) CO_2
(B) O_2
(C) H_2
(D) Cl_2

$$^{232}Th \rightarrow X + \text{alpha particle}$$

29. When a thorium-232 atom emits an alpha particle, as represented in the preceding equation, which of the following is X?

(A) ^{228}Th
(B) ^{230}Ac
(C) ^{228}Ra
(D) ^{230}Rn

30. Which of the following is an exothermic change of state?

(A) Solid to liquid
(B) Liquid to gas
(C) Gas to solid
(D) Solid to gas

31. Based on the valence shell electron pair repulsion (VSEPR) model, which of the following gives the approximate bond angles about the carbon atom in a CCl_4 molecule?

(A) 30°
(B) 45°
(C) 90°
(D) 109.5°

32. Which of the following compounds contained in some beverages is a strong electrolyte?

    (A) Sucrose
    (B) Citric acid
    (C) Starch
    (D) Sodium chloride

Chemistry (5246) Answers

1. **Options (A) and (C) are correct.** The correct answers are (A) and (C). Inorganic hydrates are compounds that in their solid state contain some water molecules within their crystal lattice. When heated, the water can vaporize, resulting in a lower mass for the remaining solid. An example of a hydrate is $MgCO_3{\cdot}5H_2O$. When a reaction occurs in an open vessel in which one of the products is a gas, the gas can escape, resulting in a loss of mass. A decomposition reaction that produced two solid compounds would NOT result in a loss of mass. If an oxide had been produced in a reaction with oxygen, the mass of the contents would have increased, NOT decreased.

Content	I A
Science and Engineering	7
Task of Teaching	20

2. **Options (A) and (C) are correct.** Entropy decreases as liquid water becomes solid water and as water vapor condenses on grass as dew. Entropy increases as snow changes to gaseous water as it sublimates and as sugar dissolves in water.

Content	II B

3. **Options (B), (C) and (D) are correct.** The rate of a chemical reaction depends on the temperature and can also depend on the concentrations of the reactants. To determine the rate with respect to Br^-, the concentration of $Pt(NH_3)Cl_2(aq)$ must be kept constant. Hence, the initial volume of the reaction mixture must also be kept constant to avoid changes in concentration of $Pt(NH_3)Cl_2(aq)$.

Content	IV B
Science and Engineering	3
Task of Teaching	7

4. **Option (B) is correct.** CF_4 molecules interact through London dispersion forces only because they are nonpolar molecules. The other three compounds consist of polar molecules that can interact by dipole-dipole interactions and H_2O molecules can also interact through hydrogen bonding.

Content	III B

5. **Option (A) is correct.**
$pOH = -\log[OH^-]$ for an aqueous solution. Hence, $[OH^-] = 1.0 \times 10^{-12} M$ if $pOH = 12.0$. At $25°C$, $[H^+][OH^-] = K_w = 1.0 \times 10^{-14}$. Based on this relationship,
$[H^+] = \frac{1.0 \times 10^{-14}}{1.0 \times 10^{-12}} = 1.0 \times 10^{-2}$. Since $pH = -\log[H^+] = -\log(1 \times 10^{-2}) = 2.0$ pH, the solution is acidic and will turn blue litmus paper red.

Content	V B
Science and Engineering	6

6. **Option (B) is correct.** Reduction involves gaining electrons which results in a reduction of the oxidation number of the species. Cu^{2+} in $CuSO_4$ is reduced to Cu, with oxidation number of 0. Zn, with oxidation number of 0, loses electrons and is oxidized to Zn^{2+} in $ZnSO_4$. S^{6+} and O^{2-} do not undergo a change in oxidation number during the reaction.

Content	IV B
Science and Engineering	2

7. **Option (A) is correct.** An atom of Cs has a radius that is larger than the radius of an atom of Mg, I, or Se based on the location of Cs on the periodic table. Going down a column, the atomic radius generally increases, and going from left to right across a row, the atomic radius generally decreases. Cs is located near the lower corner on the left side of the periodic table.

Content	IV A
Science and Engineering	2

8. **Option (B) is correct.** The concentration of Na^+ ions is $0.01\,M$, and it is found from
$$\frac{0.05\text{ L} \times 0.02\,M\text{ Na}_2\text{SO}_4}{0.2\text{ L}} \times \frac{2\text{ Na}^+}{\text{Na}_2\text{SO}_4} = 0.10\,M,$$
where $50\text{ mL} = 0.05\text{ L}$ and $200\text{ mL} = 0.2\text{ L}$.

Content	V A
Science and Engineering	5

9. **Option (A) is correct.** Smoke is a suspension. Tiny particles are temporarily suspended in the air as they are randomly moving as a result of collisions with molecules of nitrogen, oxygen, and other gases. Eventually, the particles may settle and collect on surfaces.

Content	II B
Science and Engineering	15

10. **Option (A) is correct.** The electron configuration for the Mg^{2+} ion based on the Aufbau principle is $1s^2 2s^2 2p^6$. Mg atoms each have 12 electrons, but Mg^{2+} ions each have 10 electrons.

Content	II A
Science and Engineering	2
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11. **Option (D) is correct.** Two moles of $CuSO_4$ contain 8 moles of oxygen atoms. The number of oxygen atoms is equal to $8 \times 6.02 \times 10^{23} = 4.82 \times 10^{24}$ oxygen atoms.

Content	III A
Science and Engineering	5

12. **Option (B) is correct.** The 20 g sample will have a higher thermal heat content because heat content depends on both the temperature and the amount of the substance. Since both samples contain the same substance, they will have the same density, temperature, and boiling point.

Content	II B

13. **Option (D) is correct.** The experimental design should have only one independent variable and should include a procedure.

Content	I A
Science and Engineering	3
Task of Teaching	7

14. **Option (D) is correct.** The pH at the equivalence point for a titration of a weak acid with a strong base will not be at 7.0 but will be greater than 7.0 because the hydrolysis of the salt of the weak acid will produce OH^- ions, resulting in the formation of a basic solution. An example is the titration of the weak acid CH_3COOH with the strong base $NaOH$. At the equivalence point of the titration, Na^+, CH_3COO^-, and H_2O have been produced. But there is a hydrolysis equilibrium that exists: $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$. Hence, the pH will be greater than 7.0.

Content	V B

15. **Option (A) is correct.** Since the difference in electronegativity between H and Br is greater than the difference in electronegativity between C and H, the covalent bond between H and Br in HBr is more polar than the covalent bonds between C and H in CH_4. There is a nonpolar bond in Cl_2 and in H_2.

Content	III B

16. **Option (D) is correct.** The balanced equation for the complete combustion reaction is $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$. Based on the balanced equation, 8 mol of CO_2 would be produced. The volume of 8 mol of CO_2 at standard temperature and pressure is approximately $8 \times 22.4\ L = 179.2\ L$.

Content	II B
Science and Engineering	5

17. **Option (C) is correct.** Ozone absorbs harmful ultraviolet radiation in the stratosphere.

Content	I B

18. **Option (A) is correct.** Carboxylic acids include the carboxyl functional group, which contains a carbonyl group bonded to a hydroxyl group. Answer choice (B) is an ether, answer choice (C) is carbonic acid, and answer choice (D) is an amine.

Content	III A
Science and Engineering	15

19. **Option (D) is correct.** A very low K_{sp} indicates that $Mg(OH)_2$ is only slightly soluble and can form a saturated solution that will have a very small concentration of Mg^{2+} ions and OH^- ions present in solution. Hence, an $11M$ solution cannot be prepared. It is a base, not an acid.

Content	V A
Science and Engineering	7
Task of Teaching	20

20. **Option (B) is correct.** Based on the balanced equation, the maximum possible number of moles of Cl_2 that can be produced is 1.5 mol. This is found from $6\ mol\ HCl \times \frac{1\ mol\ Cl_2}{4\ mol\ HCl} = 1.5\ mol\ Cl_2$. In this case, MnO_2 is in excess and HCl is the limiting reagent, since to use up all the 2.0 mol of MnO_2 would require 8.0 mol of HCl.

Content	III B
Science and Engineering	5

21. **Option (D) is correct.** F, Cl, Br, and I are nonmetals in a group called the halogens and are found in the next-to-last column of the periodic table. Transition elements are metals located in columns 3 through 12 in rows in the middle of the periodic table, starting in row 4. The alkaline earth metals are in the second column of the periodic table. The noble gases are located in the last column of the periodic table.

Content	IV A
Science and Engineering	2

22. **Option (A) is correct.**
$2\ K + 2\ H_2O \rightarrow 2\ KOH + H_2$ is a balanced equation for a chemical reaction because it has an equal number of atoms of each element in the reactants and in the products. The other response choices are unbalanced chemical reaction equations.

Content	III B
Science and Engineering	2

23. **Option (D) is correct.** The kinetic energy of the emitted electrons is the dependent variable because the kinetic energy varied as the independent variable changed. The frequency of the incident light is the independent variable. As different frequencies of light are used, the kinetic energy of the emitted electrons will be different. The atomic number and atomic mass were not variables that changed during the experiment, since one particular metal was used.

Content	II A
Science and Engineering	1

24. **Option (D) is correct.** Although the total pressure will increase, the decrease in volume will have no effect on the equilibrium because there is an equal number of moles of gas on the reactant side and the product side of the reaction equation.

Content	IV B
Science and Engineering	6

25. **Option (C) is correct.** Based on colligative properties, $MgCl_2$ will have the lowest freezing point. Assuming complete dissociation, it will form three particles per formula unit, one Mg^{2+} ion and two Cl^- ions. Assuming complete dissociation, KBr and CsI will each form only two particles per formula unit. CH_3OH has an extremely low ability to dissociate in water to form H^+ and CH_3O^- ions, and thus has a total of approximately one particle per formula unit.

Content	V A
Science and Engineering	5

26. **Option (C) is correct.** The student's assertion that C_6H_6COOH is the strongest acid of those listed is incorrect. The teacher can help correct the student's misconception by explaining that the strongest acid is the one with the highest degree of dissociation. Since all of the acids are monoprotic, and can be represented by HA, the K_a will indicate the degree of dissociation since

$$K_a = \frac{[H^+][A^-]}{[HA]}.$$

Content	V B
Science and Engineering	4
Task of Teaching	14

27. **Option (A) is correct.** All of the compounds are composed of molecules with polar bonds. But based on a symmetrical tetrahedral molecular geometry, CCl_4 is a nonpolar molecule with a net dipole moment of zero. H_2O is a polar molecule with bent molecular geometry and a nonzero net dipole moment, and HF and CO are each polar molecules with linear molecular geometry and a nonzero net dipole moment.

Content	III B

28. **Option (A) is correct.** The reaction will produce CO_2. The reaction is $Na_2CO_3(aq) + 2\ HCl(aq) \rightarrow CO_2(aq) + 2\ NaCl(aq) + H_2O(l)$.

Content	IV B

29. **Option (C) is correct.** The nucleus of thorium-232 contains 90 protons and can be represented by ${}^{232}_{90}Th$, which undergoes a radioactive decay and emits an alpha particle as represented in the balanced nuclear equation ${}^{232}_{90}Th \rightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$. An alpha particle is a helium nucleus and is represented by ${}^{4}_{2}He$. To balance the nuclear equation, X must have 88 protons and a mass number of 228. Thus, X is ${}^{228}_{88}Ra$.

Content	II A
Science and Engineering	2

30. **Option (C) is correct.** When a gas is converted to a solid, the process is exothermic because energy is released. The conversion of a solid to a liquid and the conversion of a liquid to a gas both involve the absorption of energy and are endothermic processes.

Content	II B

31. **Option (D) is correct.** Based on the valence shell electron pair repulsion (VSEPR) model, the bond angles about a central carbon atom in a CCl_4 molecule are $109.5°$ because CCl_4 is predicted to have a tetrahedral molecular geometry.

Content	III B
Science and Engineering	2

32. **Option (D) is correct.** Of the compounds listed, only sodium chloride is a strong electrolyte, which means that it undergoes a high degree of dissociation in aqueous solutions. Sucrose is a nonelectrolyte, some starches are weak electrolytes, and citric acid is a weak electrolyte.

Content	I B

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 selecting 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. Numeric-entry questions typically appear on mathematics-related tests.
- 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

Some tests include constructed-response questions, which 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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Planning your study time is important to help ensure that you review all content areas covered on the test. View a sample plan and learn how to create your own. Learn more at Develop a Study Plan.

Helpful Links

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Disability Accommodations – Testing accommodations are available for test takers who meet ETS requirements.

PLNE Accommodations (ESL) – If English is not your primary language, you may be eligible for extended testing time.

What To Expect on Test Day – Knowing what to expect on test day can make you feel more at ease.

Getting Your Scores – Find out where and when you will receive your test scores.

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