



California Subject Examinations for Teachers®

TEST GUIDE

SCIENCE SUBTEST III: CHEMISTRY

Sample Questions and Responses and Scoring Information

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Sample Test Questions for CSET: Science Subtest III: Chemistry

Below is a set of multiple-choice questions and constructed-response questions that are similar to the questions you will see on CSET: Science Subtest III: Chemistry. You are encouraged to respond to the questions without looking at the responses provided in the next section. Record your responses on a sheet of paper and compare them with the provided responses.

Scientific calculators **will be provided** for the examinees taking General Science Subtests I and II, as well as the specialty subtests of Biology/Life Science, Chemistry, Earth and Planetary Science, and Physics. Refer to the California Educator Credentialing Examinations website for a list of the calculator models that may be provided. Directions for the use of the calculator will not be provided at the test administration. You will not be allowed to use your own calculator for CSET: Science subtests.

PERIODIC TABLE OF THE ELEMENTS

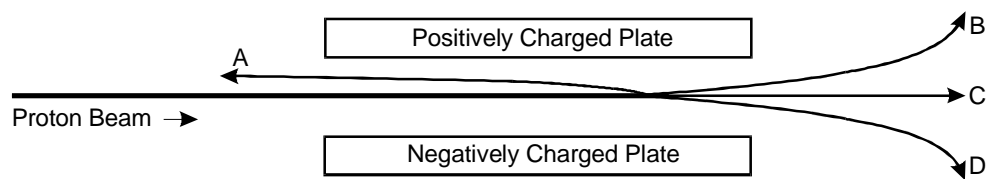
1	2	13	14	15	16	17	18
IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01	2 He 4.00	5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3 Li 6.94	4 Be 9.01	13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
11 Na 23.0	12 Mg 24.3	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
19 K 39.1	20 Ca 40.1	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
37 Rb 85.5	38 Sr 87.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
55 Cs 132.9	56 Ba 137.3	80 Hg 200.6	80 Hg 200.6	80 Hg 200.6	80 Hg 200.6	80 Hg 200.6	80 Hg 200.6
87 Fr (223)	88 Ra (226)	113 In 114.8	114 Sn 118.7	115 Sb 121.8	116 Te 127.6	117 I 126.9	118 Xe 131.3

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

Some of the elements 110 and above have been reported but not fully authenticated and named.

1. Which of the following statements about the properties of elements in the periodic table is generally true?
 - A. Elements in same period of the periodic table have the same atomic radius because they have the same number of orbitals in their electron configuration.
 - B. Elements in Group 1 (IA) and Group 3 (IIIB) have similar chemical properties because they have the same number of valence electrons.
 - C. Moving down the periodic table, the ionization energies of the elements within a group increase as the number of orbitals in their electron configurations increases.
 - D. Elements in the same group of the periodic table have similar chemical properties because they have the same number of valence electrons.
2. The bright-line spectrum of the hydrogen atom is not continuous because electron transitions:
 - A. involve discrete amounts of energy.
 - B. always involve electron pairs.
 - C. are not possible according to the quantum model.
 - D. involve random amounts of energy.

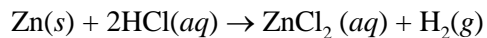
3. Use the diagram below to answer the question that follows.



Which path would a beam of protons follow in this experiment?

- A. path A
- B. path B
- C. path C
- D. path D

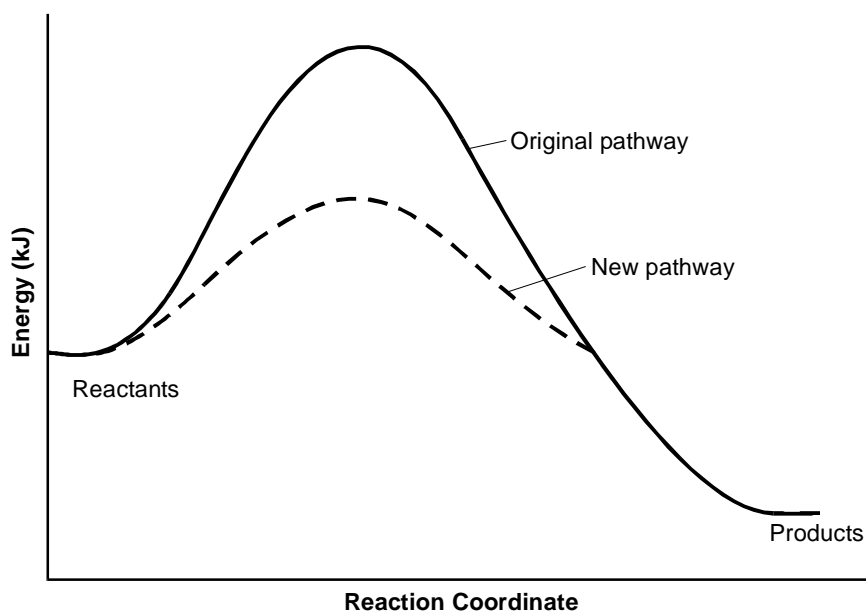
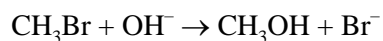
4. Use the equation below to answer the question that follows.



During the reaction of zinc metal with hydrochloric acid, hydrogen is released according to the equation above. If 54.0 g of Zn reacts with excess HCl, what is the volume of H₂ gas that is formed at STP?

- A. 11.9 L
- B. 18.6 L
- C. 22.4 L
- D. 23.9 L

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

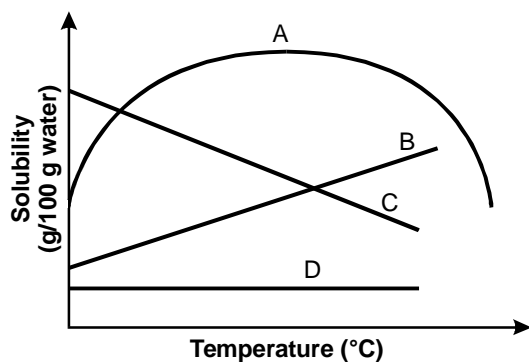


The graph above shows the energy profile for the given reaction. Which of the following actions will result in the new pathway illustrated on the graph?

- A. adding a catalyst
- B. adding Br^-
- C. adding OH^-
- D. increasing the temperature

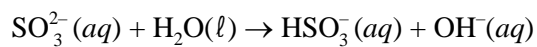
6. A sample of N_2 occupies a volume of 2.50 L at -120°C . To which of the following approximate temperatures should the gas be heated in order to double the volume of the gas without changing its pressure?
- A. -240°C
 - B. -60°C
 - C. 33°C
 - D. 306°C
7. The velocity of H_2 molecules is 1838 m/s at 0°C . Which of the following is a likely value for the velocity of O_2 molecules at the same temperature?
- A. 115 m/s
 - B. 460 m/s
 - C. 1838 m/s
 - D. 7352 m/s
8. Which of the following compounds, when dissolved in water in equal molarities, will generate the greatest number of dissolved particles?
- A. CaCl_2
 - B. $\text{C}_6\text{H}_{12}\text{O}_6$
 - C. NH_4Cl
 - D. KNO_3

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



Which of the lines in the graph above represents the general relationship between solubility and solution temperature for most soluble solids dissolved in water?

- A. Line A
 - B. Line B
 - C. Line C
 - D. Line D
10. In the following reaction, as written, which species is acting as a Brønsted-Lowry acid?



- A. H_2O
- B. SO_3^{2-}
- C. HSO_3^{-}
- D. OH^{-}

11. A solid aluminum ingot with a mass of 4110 grams cools from 660.0°C to 25.0°C . During the process, 2.36×10^6 joules of heat are released. What is the specific heat of the aluminum?

- A. $0.838 \text{ J/g}^{\circ}\text{C}$
- B. $0.870 \text{ J/g}^{\circ}\text{C}$
- C. $0.904 \text{ J/g}^{\circ}\text{C}$
- D. $23.0 \text{ J/g}^{\circ}\text{C}$

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

Specific heat of water = $4.184 \text{ J/g}^{\circ}\text{C}$

Specific heat of steam = $2.02 \text{ J/g}^{\circ}\text{C}$

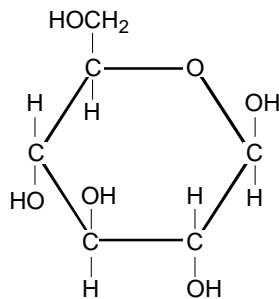
$\Delta H_{\text{fus}} = 334 \text{ J/g}$

$\Delta H_{\text{vap}} = 2.26 \times 10^3 \text{ J/g}$

A 25.0 g sample of water is heated from 52.0°C to steam at 140.0°C . How much heat is needed to complete this process?

- A. $4.44 \times 10^3 \text{ J}$
- B. $6.35 \times 10^4 \text{ J}$
- C. $6.57 \times 10^4 \text{ J}$
- D. $7.49 \times 10^4 \text{ J}$

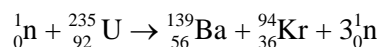
13. Use the diagram below to answer the question that follows.



The structural formula shown above is the monomer for which of the following types of molecules?

- A. polysaccharide
- B. polypeptide
- C. phospholipid
- D. nucleotide polymer

14. Use the equation below to answer the question that follows.



The equation above represents one of the possible nuclear reactions that takes place during the fission of uranium-235 as currently used in power plants. Which of the following statements regarding mass in this reaction is true?

- A. The mass of the products equals the mass of the reactants.
- B. The mass of the products is less than the mass of the reactants.
- C. The mass of the products is more than the mass of the reactants.
- D. The mass of the products is unpredictable compared to the mass of the reactants.

15. Thyroid cancer can be treated by giving the patient radioactive iodine-131. Iodine-131 accumulates exclusively in the thyroid gland, thus exposing the cancerous cells to the radiation. If a patient is given a 1.0 g dose of iodine-131 and 0.0625 g remains after 32 days, what is the half-life of iodine-131?

- A. 2 days
- B. 8 days
- C. 17 days
- D. 30 days

CONSTRUCTED-RESPONSE ASSIGNMENT DIRECTIONS

For each constructed-response assignment in this section, you are to prepare a written response.

Read each assignment carefully before you begin your response. Think about how you will organize your response. You may use the erasable notebooklet to make notes, write an outline, or otherwise prepare your response. **However, your final response must be either:**

- 1) typed into the on-screen response box,
- 2) written on a response sheet and scanned using the scanner provided at your workstation, or
- 3) provided using both the on-screen response box (for typed text) and a response sheet (for calculations or drawings) that you will scan using the scanner provided at your workstation.

Instructions for scanning your response sheet(s) are available by clicking the “Scanning Help” button at the top of the screen.

Your responses will be evaluated based on the following criteria.

PURPOSE: the extent to which the response addresses the constructed-response assignment's charge in relation to relevant CSET subject matter requirements

SUBJECT MATTER KNOWLEDGE: the application of accurate subject matter knowledge as described in the relevant CSET subject matter requirements

SUPPORT: the appropriateness and quality of the supporting evidence in relation to relevant CSET subject matter requirements

The assignments are intended to assess subject matter knowledge and skills, not writing ability. Your responses, however, must be communicated clearly enough to permit a valid judgment of your knowledge and skills. Your responses should be written for an audience of educators in the field.

Your responses should be your original work, written in your own words, and not copied or paraphrased from some other work. Please write legibly when using the response sheets. You may not use any reference materials during the testing session. Remember to review your work and make any changes you think will improve your responses.

Any time spent responding to an assignment, including scanning the response sheet(s), is part of your testing time. Monitor your time carefully. When your testing time expires, a pop-up message will appear on-screen indicating the conclusion of your test session. Only response sheets that are scanned before you end your test or before time has expired will be scored. Any response sheet that is not scanned before testing ends will NOT be scored.

16. **Complete the exercise that follows.**

Both covalent and hydrogen bonds are responsible for important properties of water.

Using your knowledge of these two types of chemical bonds and the properties of water (H₂O):

- compare the covalent bonds and the hydrogen bonds found in a sample of liquid water; and
- explain how hydrogen bonding influences two characteristic properties of water.

17. **Complete the exercise that follows.**

A solution of ammonia (NH_3) is created by dissolving 10.0 g of ammonia gas in 750 mL of water.

Using your knowledge of solution chemistry:

- express the concentration of this solution as molarity;
- express the concentration of this solution in parts per million (ppm); and
- express the concentration of this solution as a percent by mass.

Be sure to show your work for each part.

18. **Complete the exercise that follows.**

Alkanes and alkenes are two types of organic compounds having similar physical properties.

Using your knowledge of organic chemistry:

- describe the chemical structure of each type of molecule and explain how the structure relates to chemical reactivity;
- identify the type of reaction that occurs and the type of compound produced in a reaction between an alkene and Br_2 ; and
- draw a structural diagram that shows the reaction between an alkene and Br_2 .

Annotated Responses to Sample Multiple-Choice Questions for CSET: Science Subtest III: Chemistry

Atomic and Molecular Structure

1. **Correct Response: D.** (SMR Code: 1.1) Valence electrons occupy the outermost energy level of an atom and are primarily responsible for determining an element's chemical properties. Elements with the same number of valence electrons belong to the same group, or column, of the periodic table. For example, the elements in Group 1 (IA) have one valence electron and are highly reactive, whereas the elements in Group 18 (VIIIA) have eight valence electrons that fill the outermost level, making these elements chemically unreactive.
2. **Correct Response: A.** (SMR Code: 1.2) Electron transitions from one orbit to another result in specific amounts of energy being released or absorbed. These quanta of energy appear as characteristic lines on the spectrum for each element. Since the released or absorbed energy is not continuous over a range of values, the bright-line spectrum also is not continuous.
3. **Correct Response: D.** (SMR Code: 1.2) A proton has a unit-positive charge, so protons in the beam will be repelled by the positively charged plate and be attracted by the negatively charged plate. This will tend to deflect the beam of protons downward, as shown by path D.

Chemical Reactions

4. **Correct Response: B.** (SMR Code: 2.1) The number of moles of zinc reacted is calculated by dividing the molar mass of zinc into the mass used, $54.0 \text{ g} \div 65.4 \text{ g/mol} = 0.826 \text{ moles}$. Since the coefficients for Zn and H₂ in the balanced reaction are both 1, 0.826 moles of H₂ gas must be formed. The ideal gas equation can be used to determine the volume of H₂ at STP. Solving for volume gives $V = \frac{nRT}{P}$. The known values can be inserted into the equation, giving $V = \frac{(0.826 \text{ mol})(0.08206 \text{ L}\cdot\text{atm/K}\cdot\text{mol})(273 \text{ K})}{1 \text{ atm}} = 18.6 \text{ L}$.
5. **Correct Response: A.** (SMR Code: 2.2) Adding a catalyst will result in the new pathway indicated on the graph. Catalysts increase the rate of reaction, almost always by lowering the amount of activation energy needed to initiate the reaction. The catalyzed reaction will follow a path requiring less energy than if the catalyst had not been present.

Kinetic Molecular Theory

6. **Correct Response: C.** (SMR Code: 3.1) According to Charles's law, the volume of a fixed amount of gas at a constant pressure is directly proportional to the gas's absolute temperature. Therefore, doubling the absolute temperature of the sample of N₂ gas will double its volume. The gas's starting absolute temperature is $-120^\circ\text{C} + 273 = 153 \text{ K}$. Doubling the absolute temperature gives 306 K, or 33°C.

7. **Correct Response: B.** (SMR Code: 3.1) When two gas samples are at the same temperature, the particles of both samples have the same average kinetic energy. The kinetic energy of a particle is given by $KE = \frac{1}{2}mv^2$. Therefore, in this example:

$$KE_{H_2} = KE_{O_2}$$

$$\frac{1}{2}(m_{H_2})(v_{H_2})^2 = \frac{1}{2}(m_{O_2})(v_{O_2})^2$$

$$(m_{H_2})(v_{H_2})^2 = (m_{O_2})(v_{O_2})^2$$

$$(2.02 \text{ amu})(1838 \text{ m/s})^2 = (32.0 \text{ amu})(v_{O_2})^2$$

$v_{O_2} = 461.8 \text{ m/s}$, so of the options listed, 460 m/s is the most reasonable velocity for the O_2 molecules.

Solution Chemistry

8. **Correct Response: A.** (SMR Code: 4.1) Of the compounds listed, $CaCl_2$ is the one that will dissociate into the greatest number of separate particles. Each mole of $CaCl_2$ will dissociate in water into 3 moles of ions—1 mole of Ca^{2+} ions and 2 moles of Cl^- ions.
9. **Correct Response: B.** (SMR Code: 4.1) The solubility of many solids in water increases as the temperature increases, as represented by Line B on the graph. As the temperature of the solution increases, there is more energy available to overcome ionic or intermolecular forces in the solid.
10. **Correct Response: A.** (SMR Code: 4.2) According to the Brønsted-Lowry definition of acids and bases, an acid is a proton (H^+) donor, while a base is a proton acceptor. In the acid-base reaction shown in this example, water acts as the Brønsted-Lowry acid, donating a proton to the Brønsted-Lowry base, SO_3^{2-} , resulting in OH^- and HSO_3^- .

Chemical Thermodynamics

11. **Correct Response: C.** (SMR Code: 5.1) The heat transfer relationship is given by the equation $q = mc\Delta T$, where q = heat transfer, m = mass, c = specific heat, and ΔT = change in temperature. Inserting the known quantities and solving gives $2.36 \times 10^6 \text{ J} = (4110 \text{ g})(c)(635^\circ\text{C})$, or $c = 0.904 \text{ J/g}^\circ\text{C}$.

12. **Correct Response: B.** (SMR Code: 5.1) The heating process can be divided into three distinct segments.

- 1) heating the liquid water from 52°C to 100°C
 using the equation $q = mc\Delta T$
 $q = (25.0 \text{ g})(4.184 \text{ J/g}^\circ\text{C})(48^\circ\text{C}) = 5.02 \times 10^3 \text{ J}$
- 2) the phase change from liquid to vapor at 100°C
 using the equation phase change energy = $m\Delta H_{\text{vap}}$
 phase change energy = $(25.0 \text{ g})(2.26 \times 10^3 \text{ J/g}) = 5.65 \times 10^4 \text{ J}$
- 3) heating the steam from 100°C to 140°C
 using the equation $q = mc\Delta T$
 $q = (25.0 \text{ g})(2.02 \text{ J/g}^\circ\text{C})(40^\circ\text{C}) = 2.02 \times 10^3 \text{ J}$

The total energy for this heating process is the sum of the energy for all the segments.
 $(5.02 \times 10^3 \text{ J}) + (5.65 \times 10^4 \text{ J}) + (2.02 \times 10^3 \text{ J}) = 6.35 \times 10^4 \text{ J}$

Organic Chemistry and Biochemistry

13. **Correct Response: A.** (SMR Code: 6.1) The structural formula represents a glucose monomer. When many of these monomers chemically join together, they form a polysaccharide, such as cellulose or glycogen.

Nuclear Processes

14. **Correct Response: B.** (SMR Code: 7.1) In this nuclear reaction, the combined mass of $^{139}_{56}\text{Ba}$ and $^{94}_{36}\text{Kr}$ ($139 + 94 = 233$) is less than the mass of $^{235}_{92}\text{U}$. Since the total number of protons remains the same (92) between reactant and products, the loss in mass must result from the release of free neutrons during the reaction.

15. **Correct Response: B.** (SMR Code: 7.1) The half-life of a radioactive isotope is the time it takes for half of a sample of the isotope to decay. In this example, since 0.0625 g is one-sixteenth of the original 1.0 g of iodine-131, the iodine must have undergone four half-lives during the 32 days, since $\frac{1}{16} = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$. Therefore, the half-life of iodine-131 is $32 \div 4 = 8$ days.

Examples of Strong Responses to Sample Constructed-Response Questions for CSET: Science Subtest III: Chemistry

Atomic and Molecular Structure

Question #16 (Score Point 3 Response)

Covalent bonds between hydrogen and oxygen in a water molecule involve a sharing of a pair of electrons. This type of bond is much stronger than the hydrogen bonds between hydrogen and oxygen in separate molecules. The hydrogen bond occurs because of the high polarity of each water molecule, with the negative dipole of the oxygen being attracted to the positive dipole of a hydrogen atom on a nearby water molecule.

Several properties of water are influenced by hydrogen bonding. Water is liquid at room temperature, not a gas like many compounds of similar molecular weight and polarity, because of the strong hydrogen bonding between molecules. Also, it has a fairly high heat of vaporization because of the additional energy needed to overcome the hydrogen bonds.

Solution Chemistry**Question #17 (Score Point 3 Response)**

Molarity $M = \text{moles/liter}$; number of moles = $\frac{\text{grams}}{\text{MW (g/mol)}}$

Molecular weight MW of ammonia is roughly 17 g/mol.

Assuming solute moles does not change solvent volume,

$$\frac{10.0 \text{ g}}{17 \text{ g/mol}} = 0.59 \text{ moles, molarity} = \frac{0.59 \text{ moles}}{0.750 \text{ liters}} = 0.79 \text{ M}$$

The mass of 750 mL of H_2O is 750 g, because its density is 1 g/mL.

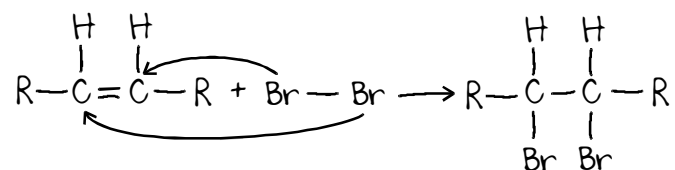
$$\frac{10.0 \text{ g}}{760 \text{ g}} = \frac{x}{10^6} \quad x = \frac{10 \times 10^6}{760} = 1.3 \times 10^4 \text{ ppm}$$

$$\% \text{ by mass: } \frac{10.0 \text{ g}}{760 \text{ g}} \times 100 = 1.3\%$$

Organic Chemistry and Biochemistry**Question #18 (Score Point 3 Response)**

Alkanes are hydrocarbons in which the carbon atoms form only single covalent bonds to the other carbon atoms in the chain, and to the hydrogen atoms (or halogens) attached. Alkenes, on the other hand, are unsaturated with one or more double bonds between carbon atoms. This causes more reactivity than the single-bonded alkanes.

The double bond of alkenes reacts by addition. For example, bromine reacts with an alkene to form an alkyl bromide. This halogenation occurs when the double bond is broken to form single bonds with bromine atoms:



Scoring Information for CSET: Science Subtest III: Chemistry

Responses to the multiple-choice questions are scored electronically. Scores are based on the number of questions answered correctly. There is no penalty for guessing.

There are three constructed-response questions in Subtest III: Chemistry of CSET: Science. Each of these constructed-response questions is designed so that a response can be completed within a short amount of time—approximately 10–15 minutes. Responses to constructed-response questions are scored by qualified California educators using focused holistic scoring. Scorers will judge the overall effectiveness of your responses while focusing on the performance characteristics that have been identified as important for this subtest (see below). Each response will be assigned a score based on an approved scoring scale (see page 21).

Your performance on the subtest will be evaluated against a standard determined by the Commission on Teacher Credentialing based on professional judgments and recommendations of California educators.

Performance Characteristics for CSET: Science Subtest III: Chemistry

The following performance characteristics will guide the scoring of responses to the constructed-response questions on CSET: Science Subtest III: Chemistry.

PURPOSE	The extent to which the response addresses the constructed-response assignment's charge in relation to relevant CSET subject matter requirements.
SUBJECT MATTER KNOWLEDGE	The application of accurate subject matter knowledge as described in the relevant CSET subject matter requirements.
SUPPORT	The appropriateness and quality of the supporting evidence in relation to relevant CSET subject matter requirements.

Scoring Scale for CSET: Science Subtest III: Chemistry

Scores will be assigned to each response to the constructed-response questions on CSET: Science Subtest III: Chemistry according to the following scoring scale.

SCORE POINT	SCORE POINT DESCRIPTION
3	<p>The "3" response reflects a command of the relevant knowledge and skills as defined in the subject matter requirements for CSET: Science.</p> <ul style="list-style-type: none"> • The purpose of the assignment is fully achieved. • There is an accurate application of relevant subject matter knowledge. • There is appropriate and specific relevant supporting evidence.
2	<p>The "2" response reflects a general command of the relevant knowledge and skills as defined in the subject matter requirements for CSET: Science.</p> <ul style="list-style-type: none"> • The purpose of the assignment is largely achieved. • There is a largely accurate application of relevant subject matter knowledge. • There is acceptable relevant supporting evidence.
1	<p>The "1" response reflects a limited or no command of the relevant knowledge and skills as defined in subject matter requirements for CSET: Science.</p> <ul style="list-style-type: none"> • The purpose of the assignment is only partially or not achieved. • There is limited or no application of relevant subject matter knowledge. • There is little or no relevant supporting evidence.
U	<p>The "U" (Unscorable) is assigned to a response that is unrelated to the assignment, illegible, primarily in a language other than English, or does not contain a sufficient amount of original work to score.</p>
B	<p>The "B" (Blank) is assigned to a response that is blank.</p>