Certification Examinations
for Oklahoma Educators™

Oklahoma Subject Area Tests™

STUDY GUIDE

004 Chemistry

Oklahoma Commission
for Teacher Preparation

OK-SG-FLD004-03

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The first two sections of the study guide are available in a separate PDF file. Click the link below to view or print these sections.

Study Guide Introduction and General Information About the Certification Examinations for Oklahoma Educators

FIELD-SPECIFIC INFORMATION

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INTRODUCTION

This section includes a list of the test competencies, as well as a set of practice selected-response (multiple-choice) questions and one or more practice constructed-response assignments (if applicable), for the test field included in this study guide.

Test Competencies

The test competencies are broad, conceptual statements that reflect the subject-matter skills, knowledge, and understanding an entry-level educator needs to teach effectively in Oklahoma public schools. The list of test competencies for each test field represents the **only** source of information about what a specific test will cover and therefore should be reviewed carefully.

The descriptive statements that follow the competencies are included to provide examples of possible content covered by each competency. These descriptive statements are neither exhaustive nor exclusionary.

Practice Test Questions

The practice selected-response questions and any practice constructed-response assignments included in this section are designed to give you an introduction to the nature of the questions included in this OSAT test field. The practice test questions represent the various types of questions you may expect to see on an actual test; however, they are **not** designed to provide diagnostic information to help you identify specific areas of individual strengths and weaknesses or to predict your performance on the test as a whole.

To help you prepare for your OSAT, each practice selected-response question in this section is preceded by the competency it measures and followed by a brief explanation of the correct response. On the actual test, the competencies, correct responses, and explanations will **not** be given.

If the test field included in this guide has a constructed-response assignment, a sample response is provided immediately following the practice constructed-response assignment. The sample response in this guide is for illustrative purposes only. Your written response should be your original work, written in your own words, and not copied or paraphrased from some other work.

A description of the process that is used for scoring the constructed-response assignment is provided in addition to the OSAT performance characteristics and score scale.

When you are finished with the practice test questions, you may wish to go back and review the entire list of test competencies and descriptive statements for your test field.

SUBAREAS:

I. Foundations of Scientific Inquiry
II. Matter and Atomic Structure
III. Energy, Chemical Bonds, and Molecular Structure
IV. Chemical Reactions
V. Quantitative Relationships
VI. Interactions of Chemistry and the Environment

SUBAREA I—FOUNDATIONS OF SCIENTIFIC INQUIRY

Competency 0001

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

The following topics are examples of content that may be covered under this competency.

Apply chemical theory to various sciences and other disciplines outside of chemistry.

Analyze the use of chemistry, mathematics (including calculus), and other sciences in the design of a technological solution to a given problem.

Analyze the role of technology in the advancement of scientific knowledge.

Apply computer and information technologies to model and solve problems in mathematics, science, and technology.

Competency 0002

Understand the historical and contemporary contexts of the study of chemistry.

The following topics are examples of content that may be covered under this competency.

Analyze the significance of key events, theories, experiments, and individuals in the history of chemistry.

Assess the societal implications of developments in chemistry.

Competency 0003

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

The following topics are examples of content that may be covered under this competency.

Analyze processes by which new scientific knowledge and hypotheses are generated.

Analyze ethical issues related to the process of scientific research.

Assess the appropriateness of a specified experimental design to test a given chemical hypothesis.

Assess the role of communication among scientists in promoting scientific progress.

Competency 0004

Understand principles of measurement and the process of gathering, organizing, reporting, and interpreting scientific data.

The following topics are examples of content that may be covered under this competency.

Evaluate the appropriateness of units of measurement, measuring devices, or methods of measurement for a given situation.

Assess the appropriateness of a given method or procedure for collecting data for a specified purpose.

Use basic statistical methods for analyzing data.

Analyze relationships between factors (e.g., inverse, linear, quadratic) as indicated by experimental data.

Competency 0005

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

The following topics are examples of content that may be covered under this competency.

Analyze the principles upon which given laboratory instruments are based (e.g., pH meters, gas chromatographs).

Apply proper methods for storing, identifying, dispensing, and disposing given chemicals.

Apply proper procedures for dealing with given accidents and injuries in the chemistry laboratory.

Apply proper procedures for safety in the laboratory (e.g., use of goggles, fire blankets, types of fire extinguishers).

SUBAREA II—MATTER AND ATOMIC STRUCTURE

Competency 0006

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

The following topics are examples of content that may be covered under this competency.

Differentiate among elements, compounds, and mixtures.

Use the physical and chemical properties of an unknown substance in order to identify it.

Analyze the methods by which chemical and physical properties of matter are determined.

Distinguish between physical and chemical changes in matter.

Competency 0007

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

The following topics are examples of content that may be covered under this competency.

Identify major contributions by various scientists (e.g., Bohr, Rutherford, Heisenberg, Schrödinger) to models of atomic structure.

Relate interactions among electrons, protons, and neutrons to their properties (e.g., mass, charge).

Analyze the relationships among electron energy levels, photons, and atomic spectra.

Analyze the electron configurations of atoms and ions.

Competency 0008

Understand the organization of the periodic table.

The following topics are examples of content that may be covered under this competency.

Analyze the organization of the periodic table in terms of atomic number and properties of the elements.

Analyze trends (e.g., ionization energies, covalent atomic radii) within periods and groups in the periodic table.

Predict physical and chemical properties of given elements based on their positions in the periodic table.

Use the periodic table to gain information (e.g., relative reactivity) about given elements.

Competency 0009

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

The following topics are examples of content that may be covered under this competency.

Compare arrangements and movements of particles in solids, liquids, and gases.

Analyze basic principles of the kinetic molecular theory (e.g., particles of matter in continual motion, real versus ideal gas behavior).

Analyze heating and cooling curves qualitatively and quantitatively.

Set up and solve problems involving relationships among temperature, pressure, and volume of a gas.

Competency 0010

Understand the process of nuclear transformation.

The following topics are examples of content that may be covered under this competency.

Compare characteristics (e.g., mass, penetrating power) of the different types of emanations from the decay of radioactive elements.

Analyze the processes of natural radioactivity and artificial transmutation.

Solve problems involving half-life of radioactive particles.

Relate nuclear mass defect to nuclear binding energy.

SUBAREA III—ENERGY, CHEMICAL BONDS, AND MOLECULAR STRUCTURE

Competency 0011

Understand the principles of thermodynamics and calorimetry.

The following topics are examples of content that may be covered under this competency.

Analyze the three laws of thermodynamics and their applications to chemical systems.

Predict the spontaneity of given reactions based on free energy changes from enthalpy changes, entropy changes, and temperatures of the systems.

Analyze the results of calorimetry experiments.

Distinguish between heat and temperature.

Competency 0012

Understand energy relationships in chemical bonding and chemical reactions.

The following topics are examples of content that may be covered under this competency.

Analyze energy changes due to the formation or breaking of chemical bonds.

Solve problems involving energy changes during chemical reactions (e.g., heat of combustion, heat of formation).

Interpret potential energy diagrams of chemical reactions.

Competency 0013

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

The following topics are examples of content that may be covered under this competency.

Compare the characteristics of various types of bonds between atoms (e.g., bond strength, polarity).

Analyze chemical bonding in terms of electron behavior (e.g., interpreting Lewis structures, predicting molecular geometry).

Analyze factors that affect bond strength (e.g., electronegativity, electron affinity).

Predict properties of a substance based on the type of bonds holding the atoms together.

Competency 0014

Understand types and characteristics of molecular interaction and properties of substances containing different types of interactive forces between molecules.

The following topics are examples of content that may be covered under this competency.

Predict the kind of interaction between molecules of a given structure.

Relate the unique properties of water to its molecular structure and intermolecular forces.

Relate the physical properties of substances to their intermolecular forces.

Competency 0015

Understand the nomenclature and structure of organic compounds.

The following topics are examples of content that may be covered under this competency.

Apply the IUPAC rules of nomenclature.

Analyze the chemical composition and basic structure of organic compounds (e.g., saturated, unsaturated, and aromatic hydrocarbons; halogen, oxygen, and nitrogen derivatives).

Distinguish among structural, geometric, and optical isomers.

SUBAREA IV—CHEMICAL REACTIONS

Competency 0016

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

The following topics are examples of content that may be covered under this competency.

Apply collision theory to situations involving factors that influence reaction rates.

Relate experimental measurements to reaction rates and rate laws.

Relate reaction mechanisms to rate laws.

Determine order of reactions and rate constants, and solve first-order rate problems.

Competency 0017

Understand the principles of chemical equilibrium.

The following topics are examples of content that may be covered under this competency.

Analyze the effects of concentration, pressure, temperature, and catalysts on chemical equilibrium.

Apply Le Chatelier's principle to chemical systems.

Solve problems involving equilibrium constants.

Solve problems involving solubility product constants of slightly soluble salts.

Competency 0018

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

The following topics are examples of content that may be covered under this competency.

Analyze acids and bases according to operational and conceptual definitions (Arrhenius, Brönsted-Lowry, Lewis).

Analyze the principles and applications of acid-base titration.

Determine the hydronium ion concentration and the pH for various acid, base, and salt solutions.

Compare the relative strengths of given acids based on periodic relationships.

Competency 0019

Understand redox reactions and electrochemistry.

The following topics are examples of content that may be covered under this competency.

Analyze processes that occur during redox reactions.

Determine oxidation numbers, and balance redox equations (e.g., ion-electron method, half-reaction method).

Predict whether given redox reactions will occur based on standard electrode potentials.

Analyze the components (e.g., anode, cathode) and operating principles of electrochemical and electrolytic cells.

Competency 0020

Understand the nature of organic reactions.

The following topics are examples of content that may be covered under this competency.

Analyze the rates of reactions involving organic compounds based on bond types and strengths.

Analyze common types of reactions (i.e., combustion, addition, substitution, polymerization, oxidation, esterification).

SUBAREA V—QUANTITATIVE RELATIONSHIPS

Competency 0021

Understand the mole concept.

The following topics are examples of content that may be covered under this competency.

Relate the mole to Avogadro's number.

Relate the gram-atomic mass of an element to the mass of one mole of the element.

Calculate the number of moles in a given mass or volume of a substance.

Competency 0022

Understand the relationship between the mole concept and chemical formulas.

The following topics are examples of content that may be covered under this competency.

Solve problems involving molecular and formula masses.

Solve percent composition problems.

Determine empirical and molecular formulas.

Competency 0023

Understand the quantitative relationships expressed in chemical equations.

The following topics are examples of content that may be covered under this competency.

Interpret chemical notation.

Balance equations.

Recognize net ionic equations.

Solve stoichiometric problems involving moles, mass, and volume (including limiting reactant and percent yield).

Competency 0024

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

The following topics are examples of content that may be covered under this competency.

Analyze the colligative properties of solutions (i.e., freezing point depression, boiling point elevation, osmotic pressure, vapor pressure lowering).

Solve problems involving concentrations of solutions (e.g., molarity, molality, percent concentration).

Analyze factors (e.g., temperature, pressure, molecular structure) that affect solubility.

SUBAREA VI—INTERACTIONS OF CHEMISTRY AND THE ENVIRONMENT

Competency 0025

Understand industrial and household chemistry.

The following topics are examples of content that may be covered under this competency.

Analyze industrial processes (e.g., processes by which petroleum is separated into fractions).

Analyze chemical processes in the home (e.g., organic reactions involving leavening agents and fermentation) and related safety issues (e.g., mixing household chemicals).

Competency 0026

Understand the uses and hazards of nuclear reactions.

The following topics are examples of content that may be covered under this competency.

Analyze the use of radioisotopes in the life sciences and in geological and archaeological dating.

Analyze the role of the components of a nuclear reactor and the issue of waste disposal.

Assess the risks and benefits of nuclear technology.

Identify sources of radioactive emissions in the environment, and analyze the risks and benefits they pose for humans.

Competency 0027

Understand factors and processes related to the release of chemicals into the environment.

The following topics are examples of content that may be covered under this competency.

Analyze the chemical processes that result from the release of chemicals into the atmosphere (e.g., acid rain, greenhouse effect, ozone depletion, photochemical smog).

Analyze the chemical processes that result from the release of chemicals into aquatic and terrestrial environments (e.g., eutrophication, dissolved oxygen, groundwater contamination, toxic chemicals).

Analyze methods for preventing environmental damage resulting from the release of chemicals into the environment (e.g., recycling, sewage treatment plants, pollution control devices).

PERIODIC TABLE OF THE ELEMENTS

1 IA																	18 VIIIA
1 H 1.01	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 23.0	12 Mg 24.3	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc 98.9	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57–71	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89–103	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (268)	110	111	112	113	114	115	116	117	118

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.

All examinees taking the Chemistry OSAT will be provided with a scientific calculator with functions that include the following: addition, subtraction, multiplication, division, square root, percent, sine, cosine, tangent, exponents, and logarithms. Please see the current CEOE registration bulletin for information regarding the brand and model of calculator that will be supplied. **You may NOT bring your own calculator to the test.**

Practice Selected-Response Questions

Competency 0002

Understand the historical and contemporary contexts of the study of chemistry.

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1. In the late eighteenth century, Antoine and Marie Lavoisier conducted a series of experiments involving combustion reactions. These experiments were significant primarily because they were the first to document that:

   A. atoms of different elements are present in fixed proportions in a given compound.

   B. combustion involves the splitting of molecules and the recombination of the atoms into different molecules.

   C. the total mass of the products of a reaction equals the total mass of the original substances.

   D. the elemental identities of individual atoms are not changed during a chemical reaction.

Correct Response: C. The experiments of the Lavoisiers demonstrated that the total mass of the products of a reaction equals the mass of the reactants. These experiments were critical in demonstrating the principle of the conservation of matter.

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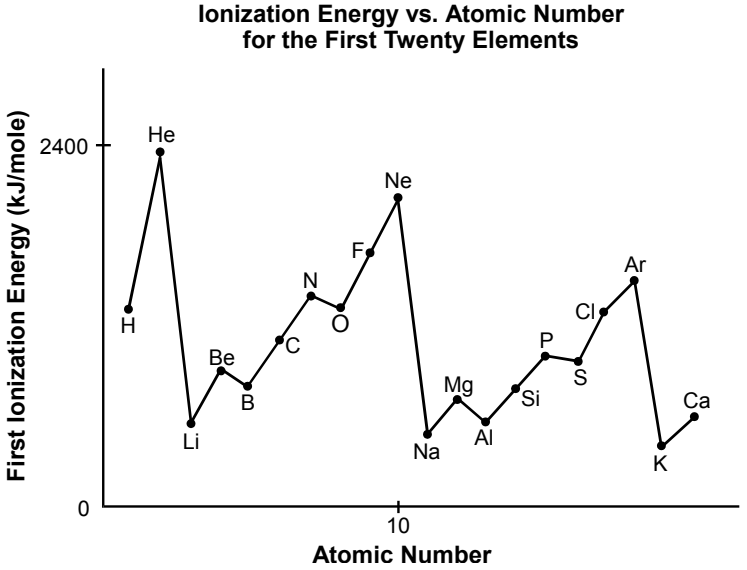
2. **Use the diagram below to answer the question that follows.**



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

A. atomic radius.

B. electron configuration.

C. nuclear binding energy.

D. atomic mass.

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

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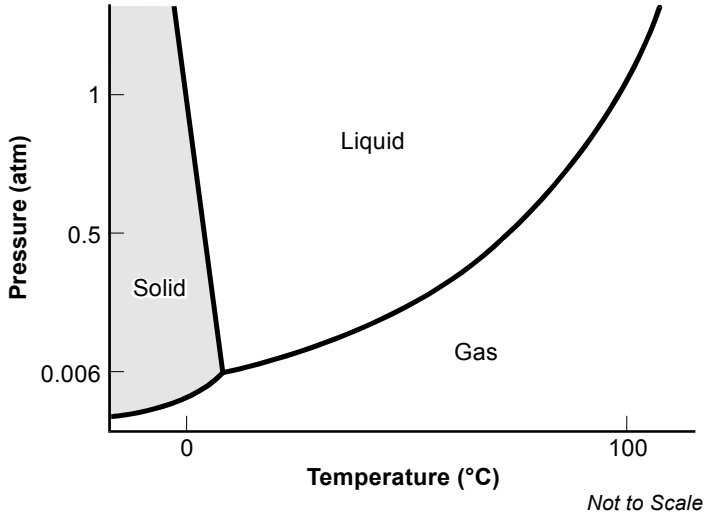
3. **Use the phase diagram below to answer the question that follows.**



Which of the following statements is supported by the phase diagram?

A. The substance sublimes at pressures above 0.006 atm.

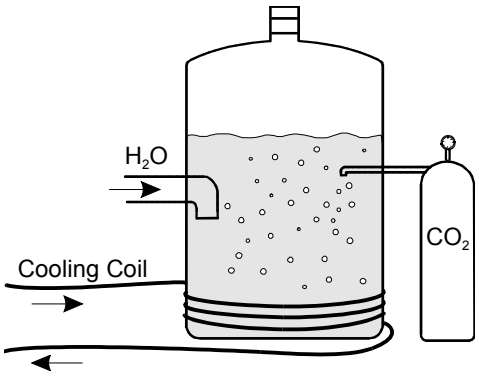
B. The substance occurs as a liquid at room temperature and pressure.

C. The substance's freezing point increases with increasing pressure.

D. The substance's freezing point is between 0°C and –100°C at pressures below 1 atm.

Correct Response: B. In most naturally occurring situations on the earth's surface, the pressure is approximately 1 atmosphere. At a room temperature of approximately 22°C (72°F) and a pressure of 1 atmosphere, the substance will be in the liquid phase.

Use the diagram below to answer the two questions that follow.



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

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

   A. a leak in the pressure vessel

   B. a decrease in the temperature of the cooling coil

   C. an increase in the length of time the carbon dioxide is left in contact with the sugar water

   D. an increase in the level to which the vessel is filled with sugar water

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

Competency 0011

Understand the principles of thermodynamics and calorimetry.

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

   I. desired temperature decrease

   II. specific heat of the sugar water

   III. mass of the sugar water

   IV. molecular weight of the sugar

   A. I and IV only

   B. II and III only

   C. I, II, and III only

   D. I, III, and IV only

Correct Response: C. Several pieces of information are required to determine the amount of energy needed to cool the contents of the vessel. First, one must know how many degrees Celsius the contents are to be cooled. Another important piece of information is this particular solution's specific heat, i.e., the amount of energy necessary to change the temperature of one gram of the solution by one degree Celsius. Finally, it is important to know the mass of the contents of the vessel since cooling a smaller mass will require less energy than cooling a larger mass. Therefore the information identified in options I, II, and III is required to make the calculation.

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

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(\ell)$ $\quad \Delta H_c$ –890.31 kJ/mol

ΔH_f for $CO_2(g)$ is –393.51 kJ/mol

ΔH_f for $H_2O(\ell)$ is –285.81 kJ/mol

The combustion of methane forms carbon dioxide and water as shown above. Which of the following expressions represents the heat of formation for methane?

A. [–393.51 + 2(–285.81) + (–890.31)] kJ/mol

B. [–890.31 + (–393.51) – 2(–285.81)] kJ/mol

C. [–393.51 + 2(–285.81) – (–890.31)] kJ/mol

D. [–890.31 – (–393.51) + 2(–285.81)] kJ/mol

Correct Response: C. The combustion of 1 mole of CH_4 forms 1 mole of CO_2 and 2 moles of H_2O. The heat of formation of methane is equal to the sum of ΔH_f (products) minus ΔH_c (methane). Thus the heat of formation of methane is equal to $\Delta H_f(CO_2) + 2\Delta H_f(H_2O) - \Delta H_c(CH_4)$.

Competency 0019

Understand redox reactions and electrochemistry.

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7. Which of the following is a redox reaction?

   A. $HCl(aq) + H_2O(\ell) \longrightarrow H_3O^+(aq) + Cl^-(aq)$

   B. $NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$

   C. $2HNO_3(aq) + MgO(s) \longrightarrow Mg(NO_3)_2(aq) + H_2O(\ell)$

   D. $2H_2O_2(aq) \longrightarrow 2H_2O(\ell) + O_2(g)$

Correct Response: D. A redox reaction is characterized by the transfer of electrons. By assigning oxidation numbers to the elements in the reactions, it can be seen that in the reaction

$$2H_2O_2\,(aq) \longrightarrow 2H_2O(\ell) + O_2\,(g)$$

the oxidation number of oxygen changes from −1 in the H_2O_2 molecule to −2 in the H_2O molecule and 0 in the O_2 molecule, indicating a transfer of electrons. This reaction is the only one of those given in which the oxidation numbers of the elements change.

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8. Equal molar amounts of NaC1 and $CaC1_2$ are dissolved in two containers containing equal amounts of water. How will the freezing points in the two containers compare?

   A. NaC1 and $CaC1_2$ will lower the freezing point by the same amount.

   B. NaC1 will lower the freezing point twice as much as $CaC1_2$.

   C. $CaC1_2$ will lower the freezing point three times as much as NaC1.

   D. $CaC1_2$ will lower the freezing point one-and-a-half times as much as NaCI.

Correct Response: D. Freezing point depression in solutions is a colligative property that is dependent on the number of solute particles. In this problem, both NaCl and $CaCl_2$ are electrolytes that dissociate into ions in solution, but each unit of NaCl dissociates into only two ions (one Na^+ and one Cl^-), while $CaCl_2$ dissociates into three ions (one Ca^{2+} and two Cl^-). Thus, a solution of $CaCl_2$ will have one-and-a-half times the number of solute particles as an equal molar solution of NaCl. Since the decrease in freezing point of a solution is directly proportional to the concentration of solute particles, the freezing point of the $CaCl_2$ solution will be depressed one-and-a-half times more than the freezing point of the NaCl solution.

Competency 0026

Understand the uses and hazards of nuclear reactions.

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9. $^{60}_{27}Co$ has a half-life of 5.27 years. How much of a sample with an original mass of 3.2 μg will remain after 21 years?

   A. 0.03 μg

   B. 0.20 μg

   C. 0.80 μg

   D. 1.60 μg

Correct Response: B. Half-life is the length of time it takes half the mass of a sample of radioactive element to decompose. Since 21 years is about four times the half-life of this element, the sample will be reduced by half, four times in succession. Thus it is reduced first to one-half, then one-quarter, then one-eighth, and finally one-sixteenth its original mass. Taking the original mass, 3.2 μg, and dividing by 16 gives 0.20 μg.

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10. A farmer is interested in using an insecticide that is biodegradable and causes little harm to birds and mammals. An insecticide that would best meet these criteria is one that:

    A. contains organohalides.

    B. makes use of heavy metal ions.

    C. has a long half-life.

    D. is readily oxidized.

Correct Response: D. The process of oxidation breaks down the complex toxic substances of the insecticides into simpler, nontoxic substances. The more readily this process occurs, the lower the risk of harm to birds and mammals, since the amount of time the toxic compounds are in the environment is reduced.

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

A student is performing a chemistry laboratory investigation to determine the molar mass of an unknown solute from freezing point depression.

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

1. Prepare an ice bath by filling a 500 mL beaker about two-thirds full of ice.
2. Pipette 25 mL of cyclohexane into a test tube and lower the test tube into the ice bath.
3. Place a thermometer in the test tube to record the temperature of the cyclohexane.
4. Observe the test tube, noting the temperature at which solid crystals first begin to form.
5. Remove the test tube from the ice bath, and reheat the test tube until all of the cyclohexane has melted.
6. Replenish the ice in the ice bath if necessary.
7. Measure 2.0 g of the unknown solute and transfer the solute to the test tube containing the cyclohexane.
8. Lower the test tube into the ice bath and reinsert the thermometer in the test tube.
9. Observe the test tube, noting the temperature at which solid crystals first begin to form.
10. Compare the freezing points determined in steps 4 and 9.
11. Determine the molar mass of the solute from the freezing point depression.

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

- identify two weaknesses of the procedure described above and explain why, from a scientific perspective, they are weaknesses;
- describe modifications that should be made to the procedure to address the identified weaknesses and explain how these changes would enhance the scientific validity of the results; and
- describe safety issues (e.g., safety equipment, safety procedures, safety precautions) that should be considered before performing this investigation.

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FOR YOUR REFERENCE ONLY—*The constructed-response item is written to assess understanding in Subarea I, Foundations of Scientific Inquiry, which consists of the competencies listed below.*

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

Understand the historical and contemporary contexts of the study of chemistry.

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

Understand principles of measurement and the process of gathering, organizing, reporting, and interpreting scientific data.

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

A Very Good Response to the Practice Constructed-Response Assignment

There are several weaknesses in the described procedure. There are a couple of related factors that might call into question the accuracy of the results. First, neither the cyclohexane nor the solute is measured with a high enough degree of accuracy for this experiment. In terms of significant figures, 25 mL of cyclohexane indicates that the measurement could vary by as much as 1 mL above or below 25 mL (25 ± 1 mL). The same reasoning applies to the solute–measuring to a tenth of a gram may not be precise enough to allow for accurate calculations of its molar mass. The second related factor that may affect the accuracy of the results is the volatility of cyclohexane. Cyclohexane tends to evaporate, so by not measuring out a fresh 25.00 mL sample of cyclohexane in step 7, there may actually be less than 25.00 mL left in the test tube after completing steps 2–6. So again, there is some uncertainty in the amount of cyclohexane in the test tube when the unknown is added, and this would undermine the validity of the results.

To address these problems associated with accuracy, a couple of modifications should be made. First, the solvent and solute should be measured out with a higher degree of precision. This may mean using different measuring instruments that allow greater precision. Second, a fresh sample of the solvent should be measured out before adding the unknown in step 7. Both of these modifications will produce more accurate and reliable data, enhancing the validity of the investigation's results.

Another weakness of the described procedure is the lack of information on whether the unknown is an electrolyte or nonelectrolyte, and if it is an electrolyte, how many ions are formed when it ionizes. This information is needed in order to calculate the molality of the solution, which is then used along with the amount of solvent to calculate the molar mass of the unknown. The more particles a solute forms in solution, the greater the freezing point depression. So if the student does not have this information about the unknown, then calculations of molar mass based on how much the freezing point is lowered could be wrong depending on what assumptions the student makes.

For the student to be able to make the appropriate calculations that will lead to an accurate determination of the unknown's molar mass, the number of particles the solute forms in solution must be provided. Providing this information will not give away the identity of the unknown, but it will allow a more certain determination of the unknown's molar mass.

(continued)

A Very Good Response to the Practice Constructed-Response Assignment *(continued)*

There are several safety precautions that should be considered and taken in performing this investigation. When working with any chemical in the laboratory, safety goggles should be worn to protect against splatters and splashes. Also, more specific to cyclohexane, because it is a volatile chemical, it can cause irritation to the respiratory passages and eyes. It is also highly flammable. For both of these reasons, if cyclohexane is to be used as the solvent, then the investigation should be carried out under a fume hood. Given the purpose of the investigation, determining the molar mass of an unknown solute, the best way to minimize some of these safety risks would be to select a less dangerous solvent in place of cyclohexane.

CONSTRUCTED-RESPONSE ASSIGNMENT SCORING

All responses to OSAT constructed-response assignments (written and oral) are scored using scoring scales that describe varying levels of performance. These scales were approved by committees of Oklahoma educators who reviewed both the performance characteristics and the scoring scales.

Each response is scored by multiple scorers according to standardized procedures during scoring sessions held immediately after each administration of the CEOE. Scorers with relevant professional backgrounds are oriented to these procedures before the scoring session and are carefully monitored during the scoring sessions.

A constructed-response assignment response is designated unscorable if it is blank, not on the assigned topic, illegible or unintelligible, not in the appropriate language, or of insufficient length to score. If you do not provide a scorable response for each constructed-response assignment on your test, you cannot pass the test regardless of your scores on the other section(s) of the test.

Sample Performance Characteristics for Constructed-Response Assignments

PURPOSE	The extent to which the response achieves the purpose of the assignment
SUBJECT MATTER KNOWLEDGE	Accuracy and appropriateness in the application of subject matter knowledge
SUPPORT	Quality and relevance of supporting details
RATIONALE	Soundness of argument and degree of understanding of the subject matter

Sample Scoring Scale for Constructed-Response Assignments

SCORE POINT	SCORE POINT DESCRIPTION
4	**The "4" response reflects a thorough knowledge and understanding of the subject matter.** • The purpose of the assignment is fully achieved. • There is a substantial, accurate, and appropriate application of subject matter knowledge. • The supporting evidence is sound; there are high-quality, relevant examples. • The response reflects an ably reasoned, comprehensive understanding of the topic.
3	**The "3" response reflects a general knowledge and understanding of the subject matter.** • The purpose of the assignment is largely achieved. • There is a generally accurate and appropriate application of subject matter knowledge. • The supporting evidence generally supports the discussion; there are some relevant examples. • The response reflects a general understanding of the topic.
2	**The "2" response reflects a partial knowledge and understanding of the subject matter.** • The purpose of the assignment is partially achieved. • There is a limited, possibly inaccurate or inappropriate application of subject matter knowledge. • The supporting evidence is limited; there are few relevant examples. • The response reflects a limited, poorly reasoned understanding of the topic.
1	**The "1" response reflects little or no knowledge and understanding of the subject matter.** • The purpose of the assignment is not achieved. • There is little or no appropriate or accurate application of subject matter knowledge. • The supporting evidence, if present, is weak; there are few or no relevant examples. • The response reflects little or no reasoning about or understanding of the topic.
U	**The response is unscorable because it is illegible, not written to the assigned topic, written in a language other than English, or of insufficient length to score.**
B	**There is no response to the assignment.**

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