

Chemistry: Content Knowledge (0245)

Test at a Glance

Test Name	Chemistry: Content Knowledge		
Test Code	0245		
Time	2 hours		
Number of Questions	100		
Format	Multiple-choice questions; calculator use prohibited		
	Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
	I. Matter and Energy; Heat, Thermodynamics and Thermochemistry	16	16%
	II. Atomic and Nuclear Structure	10	10%
	III. Nomenclature; The Mole, Chemical Bonding, and Geometry	14	14%
	IV. Periodicity and Reactivity; Chemical Reactions; Biochemistry and Organic Chemistry	23	23%
	V. Solutions and Solubility; Acid/Base Chemistry	12	12%
	VI. History and Nature of Science; Science, Technology and Social Perspectives	11	11%
	VII. Mathematics, Measurement, and Data Management; Laboratory Procedures and Safety	14	14%

About This Test

The Chemistry: Content Knowledge test measures the knowledge and competencies necessary for a beginning teacher of chemistry in a secondary school. Examinees have typically completed or nearly completed a bachelor's degree program in chemistry, with appropriate coursework in education. This test may contain some questions that will not count towards your score.

The 100 multiple-choice questions address examinees' breadth of knowledge of the physical and philosophical bases of chemistry, and issues related to laboratory practice (including data manipulation and analysis) and the importance of science in the community.

Topics are typically covered in introductory college-level chemistry and physical science courses, although some questions of a more advanced nature are included because secondary school instructors must understand the subject matter from a more advanced viewpoint than that presented to their students.

Examinees are not permitted to use calculators in taking this test; test books contain a periodic table and 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 printed with the text of the question.

Topics Covered

Representative descriptions of topics covered in each category are provided below.

I. Matter and Energy; Heat, Thermodynamics, and Thermochemistry

- Matter and energy
 - organization of matter
 - physical and chemical properties and changes of matter
 - forms and transformations of matter and energy
 - conservation of mass/energy
- Heat and thermodynamics
 - heat and temperature: concepts, measurement, and units
 - measurement and transfer of thermal energy and its effects on matter
 - kinetic molecular theory and gas laws
 - phase changes
 - laws of thermodynamics
 - thermochemistry

II. Atomic and Nuclear Structure

- Atomic and nuclear structure
 - atomic models and their experimental bases
 - atomic structure and spectra
 - electromagnetic radiation
 - chemical and physical properties related to electron configuration
 - characteristics of radioisotopes, radioactivity, and nuclear reactions

III. Nomenclature; the Mole, Chemical Bonding, and Geometry

- Nomenclature
 - systematic nomenclature of ionic and molecular compounds, including acids
 - nomenclature of organic compounds according to their functional groups
- The mole, chemical bonding, and molecular geometry
 - interpret and use chemical formulas
 - mole concept and chemical composition
 - ionic, covalent, and metallic bonding
 - intermolecular forces and correlation to physical properties
 - bond properties and correlation to chemical reactivity
 - structural formulas and molecular geometry

IV. Periodicity and Reactivity; Chemical Reactions; Biochemistry and Organic Chemistry

- Periodicity and reactivity
 - chemical reactivity
 - periodic trends in electron configurations, atomic properties such as radius, electronegativity, ionization potential, and chemical reactivity
 - relationship between bond types and periodicity
- Chemical reactions
 - equation balancing and stoichiometry
 - reaction types
 - reaction mechanisms and kinetics
 - chemical equilibrium
 - redox chemistry and electrochemistry
- Biochemistry and Organic Chemistry
 - organic functional groups and their reactions
 - biologically important compounds and reactions

V. Solutions and Solubility; Acid/Base Chemistry

- Solutions and solubility
 - solution terminology and types
 - factors affecting solubility and dissolution rate
 - concentration terms and calculations
 - colligative properties and conductivity of solutions
 - ionic equilibria in precipitation reactions and calculations involving K_{sp}
- Acid/Base chemistry
 - concepts and reactions
 - equilibrium and calculations
 - titrations and calculations

VI. History and Nature of Science; Science, Technology, and Social Perspectives

- Nature of scientific methodology, inquiry, and knowledge
 - scientific methods
 - science process skills
 - experimental design
- Historical perspective
 - historical roots of science
 - overarching concepts
- Science, technology, and society
 - impact of science and technology on the environment and human affairs
 - management of natural resources
 - use of science and technology in daily life
 - issues associated with energy production, transmission and use, and management
 - issues associated with the production, storage, use, management, and disposal of consumer-products
 - nuclear energy, nuclear power, nuclear waste
 - social, political, ethical, and economic issues arising from science and technology

VII. Mathematics, Measurement, and Data Management; Laboratory Procedures and Safety

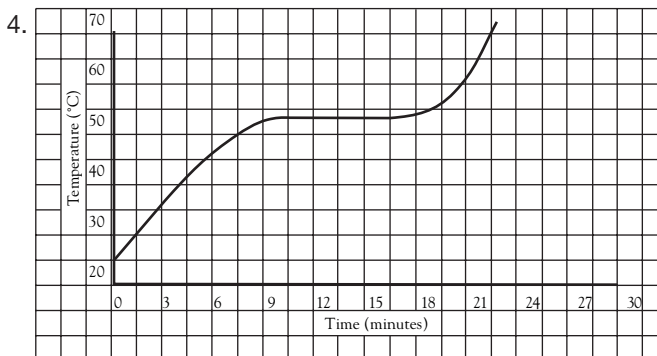
- Mathematics, measurement, and data manipulation
 - measurement and notation systems
 - data collection, manipulation, presentation and interpretation, including error analysis
- Laboratory procedures and safety
 - safe preparation, storage, use, and disposal of laboratory materials
 - use of appropriate laboratory procedures to prepare chemicals and materials
 - selection and use of appropriate laboratory equipment
 - emergency procedures for laboratory accidents

Sample Test Questions

The sample questions that follow illustrate the kinds of questions in 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 sentences or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

- In a laboratory experiment, crystals are heated in a dry glass test tube using a Bunsen burner. During heating, a clear liquid is observed inside the mouth of the test tube. Which of the following is the most reasonable conclusion drawn from this observation?
 - The gas fuel used to heat the crystals forms water as it burns.
 - The crystals give off water when heated.
 - The crystals give off both hydrogen and oxygen gases that combine to form water.
 - Condensation from the air collects on the test tube as the crystals are heated.
- Suppose that a mixture of 8 g of sugar, 5.20 g of salt, and 100.01 g of flour is prepared. What is the total mass of the mixture expressed in exponential notation and with the correct number of significant figures?
 - 1×10^2
 - 1.1×10^2
 - 1.13×10^2
 - 1.132×10^2
- Use of a small quantity of which of the following gases in a classroom requires special consideration because the gas is poisonous?
 - Steam
 - Hydrogen
 - Hydrogen sulfide
 - Carbon dioxide



A sample of a pure solid substance is heated at a constant rate and its temperature recorded as a function of time. A graph of the data is shown above. At about what temperature is the heat added being used to melt the substance?

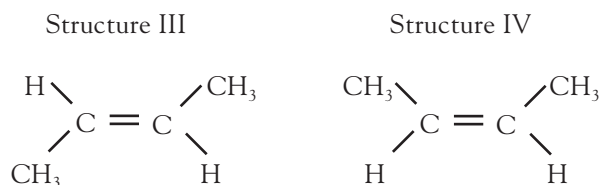
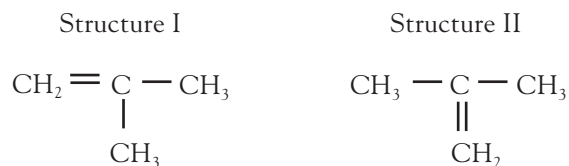
- 25°C
 - 41°C
 - 53°C
 - 60°C
- Changes in which the entropy of the system increases include which of the following?
 - Melting ice at room temperature
 - Evaporating water at room temperature
 - Dissolving NaCl in room-temperature water
 - I only
 - III only
 - I and II only
 - I, II, and III

Isotope	Isotopic Mass (g/mol)	Percent Abundance
41	40.9	10.0%
44	43.9	30.0%
46	45.9	60.0%

A fictional element with the three naturally occurring isotopes described above would be listed in the periodic table with an atomic mass of

- (A) 42.1
 (B) 43.6
 (C) 44.9
 (D) 45.9
7. In an attempt to compare the half-lives of two radioactive elements, X and Y, a student set aside 400 g of each. After six months, the student found that 25 g of X and 200 g of Y remained. Which of the following statements is true?
- (A) The half-life of Y is twice the half-life of X.
 (B) The half-life of Y is four times the half-life of X.
 (C) The half-life of Y is eight times the half-life of X.
 (D) Unless the exact time interval is established, a comparison cannot be made.
8. Which of the following statements is correct about any chemical reaction that is at equilibrium?
- (A) The molecules stop reacting.
 (B) Only side reactions continue; the main reaction stops.
 (C) Forward and backward reactions occur at equal rates.
 (D) There are as many molecules of reactant as there are molecules of product.

9. Which, if any, of the following structural formulas represent the same compound?



- (A) I and II only
 (B) III and IV only
 (C) I, II, III, and IV
 (D) None of the formulas represent identical compounds.
10. The correct formula for copper (I) sulfate is
- (A) CuSO_4
 (B) Cu_2SO_4
 (C) Cu_4SO
 (D) Cu_4SO_4
11. The pH of a 4.0×10^{-4} M HCl solution is between
- (A) 2 and 3
 (B) 3 and 4
 (C) 4 and 5
 (D) 5 and 6

12. $\text{Ag}^+ + e^- \rightarrow \text{Ag}(s) \quad E^0 = +0.80 \text{ V}$
 $\text{Cr}^{3+} + 3e^- \rightarrow \text{Cr}(s) \quad E^0 = -0.74 \text{ V}$
- Based on the standard reduction potentials for chromium and silver shown above, what is the cell potential for the reaction below?
- $$3\text{Ag}^+ + \text{Cr}(s) \rightarrow 3\text{Ag}(s) + \text{Cr}^{3+}$$
- (A) 0.06 V
 (B) 1.54 V
 (C) 1.66 V
 (D) 3.14 V
13. Which of the following is an important function of carbohydrates in living organisms?
- (A) They are the primary component of enzymes.
 (B) They constitute a source of energy for the organism.
 (C) They contain the genetic information of the cell.
 (D) They comprise structural parts such as cartilage and tendons.
14. Liquids with molecules held together by van der Waals forces have which of the following properties?
- (A) High solubilities in water
 (B) High melting points
 (C) Low boiling points
 (D) Significant electrical conductivities in the solid phase
15. The solubility product, K_{sp} , for $\text{Mg}(\text{OH})_2$ is 1.0×10^{-11} . What is the concentration of Mg^{2+} in a saturated solution of this base?
- (A) $\sqrt{5.0 \times 10^{-12}} \text{ M}$
 (B) $\sqrt{1.0 \times 10^{-11}} \text{ M}$
 (C) $\sqrt[3]{2.5 \times 10^{-12}} \text{ M}$
 (D) $\sqrt[3]{1.0 \times 10^{-11}} \text{ M}$
16. When 0.50 mol of octane, C_8H_{18} , is burned completely and the reaction products are brought to 10°C and 1 atmosphere, the products include approximately
- (A) 18 moles of water
 (B) Close to 90 liters of carbon dioxide
 (C) Close to 180 liters of carbon dioxide
 (D) Close to 200 liters of water vapor
17. Which of the following properties of a substance depends on the amount of the sample?
- (A) Temperature
 (B) Half-life
 (C) Density
 (D) Inertia
18. What quantity of oxygen, O_2 , contains very nearly the same number of molecules as 36.0 grams of water, H_2O ?
- (A) 64.0 grams
 (B) 32.0 grams
 (C) 16.0 grams
 (D) 8.0 grams
19. In the reaction of solutions of silver nitrate and sodium phosphate, a silver precipitate is formed. The balanced ionic equation for this reaction is
- (A) $\text{Ag}^+ + \text{PO}_4^{3-} \rightleftharpoons \text{Na}^+ + \text{Ag}(\text{PO}_4)_3(s)$
 (B) $\text{Ag}^+ + \text{PO}_4^{3-} \rightleftharpoons \text{Ag}_3(\text{PO}_4)_3(s)$
 (C) $3\text{Ag}^+ + \text{PO}_4^{3-} \rightleftharpoons \text{Ag}_3(\text{PO}_4)_3(s)$
 (D) $4\text{Ag}^+ + \text{PO}_4^{3-} \rightleftharpoons \text{Ag}_4(\text{PO}_4)_3(s)$
20. The two elements in which of the following pairs have a valence of +3?
- (A) Al and Ga
 (B) N and O
 (C) Li and Na
 (D) F and Cl

Answers

1. The crystals when heated may give off water in the form of steam. When this moist air reaches the top of the tube, condensation occurs inside the top of the tube because the tube is cooler than the rising warmer air. The correct answer is B.

2. For addition, the correct number of significant figures to the right of the decimal point in the answer is the same as the smallest number of digits to the right of the decimal point in any of the terms to be added. In this example, that number is zero.

$$\begin{array}{r} 8.0 \\ 5.20 \\ \hline 100.01 \\ 113. \end{array}$$

The number is then converted to exponential notation. The correct answer is C.

3. Of the gases listed, only hydrogen sulfide is poisonous in small quantities. The correct answer is C.

4. When a substance is heated, its temperature increases unless it is undergoing a phase change. During melting, the temperature remains constant since the energy absorbed is being used to do work against the attractive forces in becoming liquid particles. In the diagram, melting begins around 9 minutes and a temperature around 53°C. The correct answer is C.

5. Entropy is a measure of disorder. In all three cases, the disorder of the system increases. The correct answer is D.

6. A quick calculation using the isotope number, $(0.1 \times 41) + (0.3 \times 44) + (0.6 \times 46) = 44.9$, gives the correct answer, C.

7. Element X decayed from 400 g to 25 g, a time period of 4 half-lives. Element Y decayed from 400 g to 200 g, a time period of 1 half-life. Y decays slower than X, and the half-life of Y is 4 times that of X. The correct answer is B.

8. The correct answer is C. The definition of an equilibrium is that the forward and backward reactions occur at equal rates.

9. The correct answer is E. I and II are the same compound, 2-methyl-1-propene. III and IV are *cis* and *trans* isomers. They are geometric isomers with different properties.

10. The correct answer is B. Copper (I) is Cu^+ and sulfate is SO_4^{2-} ; therefore, for charge neutrality the compound is Cu_2SO_4 .

11. Choice B is the correct answer. HCl dissociates completely, $[\text{H}^+] = 4.0 \times 10^{-4} \text{ M}$ and the pH is between 3 and 4.

12. The correct answer is B.

$$E = E^0(\text{Ag}) - E^0(\text{Cr}) = 0.80 + 0.74 = 1.54$$

13. Choice B is the correct answer. Carbohydrates are broken down to glucose during digestion and glucose is oxidized in the cell to produce energy in the form of ATP.

14. Van der Waals forces is the collective name for weak attractive forces between molecules. In general, liquids held together only by these forces have low boiling points relative to their molecular weights since only weak forces must be overcome during vaporization. Thus, C is the correct answer.

15. The K_{sp} of a salt is the product of the ion concentrations in a saturated solution. In the present case, $K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2$.

$$\text{Since } [\text{OH}^-] = 2[\text{Mg}^{2+}], K_{sp} = [\text{Mg}^{2+}](2[\text{Mg}^{2+}])^2 = 4[\text{Mg}^{2+}]^3 = 1.0 \times 10^{-11}.$$

Solving for Mg^{2+} one obtains $[\text{Mg}^{2+}] = [1.0 \times 10^{-11} / 4]^{1/3}$. The correct answer is C.

16. The equation for the reaction is $2 \text{C}_8\text{H}_{18} + 25 \text{O}_2 \rightarrow 16 \text{CO}_2 + 18 \text{H}_2\text{O}$.

Choice B is correct; 0.5 mol octane produces 4 mol of CO_2 , which, at 10°C, occupies

$$\frac{(4 \text{ mol} \times 22.4 \text{ L/mol}) 293\text{K}}{273 \text{ K}} = 96 \text{ L} \cong 100 \text{ L}$$

17. Inertia is a property of a substance, proportional to its mass, and therefore depends on the amount of the sample. The correct answer is D.

18. The correct answer is A. 36 grams of water is 2 moles ($2 \times 18 \text{ grams}$). A 2-mole sample of O_2 contains the same number of molecules as does 2 moles of any other substance. A 2-mole sample of O_2 would have a mass of

$$2 \times 32.0 \text{ grams} = 64.0 \text{ grams}.$$

19. The correct answer is C. The precipitate formed is Ag_3PO_4 . Atoms and net charge must be conserved in a chemical reaction, so the reactants and products must have equal numbers of each type of atom and the same net charge.

20. The correct answer is A. The valences of Al and Ga are both +3.



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