

# 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. Scientific Procedure and Techniques; History and Nature of Science; Science, Technology and Society	25	25%

## 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.

## Chemistry: Content Knowledge (0245)

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 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
  - structure and 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
  - understand heat and temperature
  - measurement and transfer of thermal energy and its effects on matter
  - kinetic molecular theory (gas laws)
  - phase changes
  - laws of thermodynamics
  - thermodynamics of chemical reactions

#### II. Atomic and Nuclear Structure

- Atomic and nuclear structure
  - atomic models and their experimental bases
  - structure of the atom
  - electron configurations
  - electromagnetic radiation and atomic spectra
  - chemical and physical properties related to electron configuration

- concept of isotopes
- characteristics of radioisotopes and radioactivity
- 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
  - empirical formulas
  - 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 chemical reactivity
  - meaning of 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
  - 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
- conductivity of solutions
- colligative properties 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. Scientific Procedures and Techniques; History and Nature of Science; Science, Technology, and Society

- 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
- 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

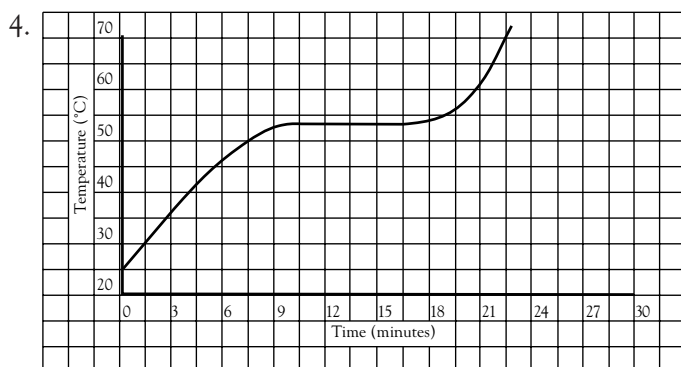
Sample Test Questions **Chemistry: Content Knowledge (0245)**

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 questions or incomplete statements below is followed by four 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.
- When a pesticide is submitted to the United States Department of Agriculture for registration, the conditions of use must be clearly specified, along with data indicating the amount of residue that will remain after the pesticide has been applied as directed. Which of the following statements best explains why the required information may not fully reveal the environmental hazards associated with the use of the pesticide?
  - The costs in time and money required to gather accurate data are high.
  - The chemical structure of the pesticide may not be known.
  - The side effects associated with applications of the pesticide may alter the results.
  - The conditions under which the pesticide will be used cannot be controlled.

- 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
    - None
    - I only
    - I and II only
    - I, II, and III

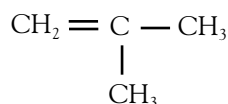
Isotope	Isotopic Mass (grams per mole)	Percent Abundance
41	40.9	10.0%
44	43.9	30.0%
46	45.9	60.0%

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

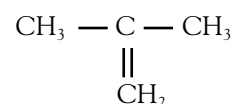
- (A) 42.1  
 (B) 43.6  
 (C) 44.9  
 (D) 45.9
7. In an attempt to compare the half-lives of two radioactive elements, X and Y, a student set aside 400 grams of each. After six months, the student found that 25 grams of X and 200 grams of Y remained. Which of the following statements is true?
- (A) The 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?

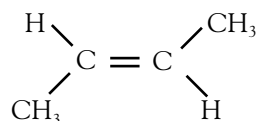
Structure I



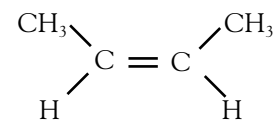
Structure II



Structure III



Structure IV



- (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)  $\text{CuSO}_4$   
 (B)  $\text{Cu}_2\text{SO}_4$   
 (C)  $\text{Cu}_4\text{SO}$   
 (D)  $\text{Cu}_4\text{SO}_4$
11. The pH of a  $4.0 \times 10^{-4}$ -molar HCl solution is between
- (A) 2 and 3  
 (B) 3 and 4  
 (C) 4 and 5  
 (D) 5 and 6



## 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. Data from “ideal” use of a pesticide may not indicate the problems associated with the pesticide since, when it is applied, its use is complicated by the lack of control (temperature, moisture, catalysts, etc.) under which the decomposition reactions of the pesticide must proceed. Therefore, the effects of every application may vary. The correct answer is D.

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 grams to 25 grams, a time period of 4 half-lives. Element Y decayed from 400 grams to 200 grams, 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 A. I and II are the same compound, 2-methyl-1-propane. III and IV are *cis* and *trans* isomers. They are geometric isomers with different properties.

10. The correct answer is B. Copper (I) is  $\text{Cu}^{+1}$  and sulfate is  $\text{SO}_4^{-2}$ ; therefore, for charge neutrality the compound is  $\text{Cu}_2\text{SO}_4$ .

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

12. The correct answer is B.  
 $E = E^\circ(\text{Ag}) - E^\circ(\text{Cr}) = 0.80 + 0.74 = 1.54$

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

Solving for  $[\text{Mg}^{++}]$  one obtains  $[\text{Mg}^{++}] = [1 \times 10^{-11}/4]^{1/3}$ .  
 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 mole octane produces 4 moles of  $\text{CO}_2$ , which, at STP, occupies ca. 4 moles  $\times$  22.4 liters/mole  $\approx$  90 liters.