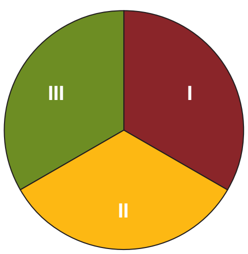
Chemistry: Content Essays (0242)

Test at a Glance

Test Name	**Chemistry: Content Essays**
Test Code	**0242**
Time	**1 hour**
Number of Questions	**3 essay questions**
Format	**Exercises pose in-depth questions requiring integrated written responses in English**



	Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
I.	Chemical Reactions	1	33.3%
II.	Structure/Property Correlations	1	33.3%
III.	The Impact of Chemistry on Technology and Society	1	33.3%

About This Test

The Chemistry: Content Essays 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.

The test assesses examinees' ability to use and analyze critical science concepts and to integrate knowledge from science, technology, and society. The three equally weighted test questions focus on chemistry content that includes knowledge of structure/property correlations, chemical reactions, and the impact of chemistry on technology and science. (For a description of these content areas, see the Chemistry: Content Knowledge Test [0245].) Two questions test both an area of content knowledge and a specific scientific skill; the third question covers science, technology, and society.

Examinees construct their responses to a content question in the context of a specific skill. For instance, a question may ask examinees to discuss structure/property correlations from the vantage of data analysis and experimental design. One question assesses scientific skills in data analysis, experimental design, and investigations; the second assesses understanding of science concepts, models, systems, and patterns; and the third assesses the ability to deal with issues in science, technology, and society:

- Data analysis, experimental design, and investigation questions evaluate examinees' ability to design experiments that test simple hypotheses, analyze and interpret data, suggest demonstrations that illustrate concepts, and propose investigations within a specific content area.
- Concepts, models, and systems questions evaluate examinees' ability to use scientific knowledge to formulate major concepts; to understand model use and limitations and communicate the process by which scientists create and use models; and to understand the interacting components of a system. Patterns content addresses examinees' ability to recognize and relate patterns in the physical world in terms of connections, trends, cycles, and irregular changes over space and time. The emphasis is on the underlying causes and mechanisms of the observed patterns.
- Science, technology, and society questions evaluate examinees' ability to discuss the impact of science and technology on society and to demonstrate an understanding of the scientific concepts and principles involved.

Sample Test Questions

This section presents sample questions and constructed-response samples along with the standards used in scoring the essays. When you read these sample responses, keep in mind that they will be less polished than if they had been developed at home, edited, and carefully presented. The examinee does not know what questions will be asked and must decide, on the spot, how to respond. Readers take these circumstances into account when scoring the responses.

Readers will assign scores based on the following scoring guide.

SCORING GUIDE

5

- Demonstrates a superior understanding of the science concepts required by the question
  - gives clear, accurate, and well-reasoned explanations
  - uses accurate scientific terminology throughout
  - when required, provides accurate and well-chosen supporting evidence (e.g., physical laws, definitions, examples)
  - any diagrams, tables, and graphs presented are complete, clear, accurate, and well organized

4

- Demonstrates a strong understanding of the science concepts required by the question
  - gives clear, accurate, and logical explanations
  - uses accurate scientific terminology
  - when required, provides accurate and relevant supporting evidence (e.g., physical laws, definitions, examples)
  - any diagrams, tables, and graphs presented are generally complete, accurate, and organized

3

- Demonstrates an adequate understanding of the science concepts required by most parts of the question
  - gives generally clear, accurate, and logical explanations
  - uses some accurate scientific terminology
  - when required, provides generally accurate and relevant supporting evidence (e.g., physical laws, definitions, examples)
  - any diagrams, tables, and graphs presented are sufficiently complete and accurate

2

- Demonstrates a limited understanding of the science concepts required by the question, as evidenced by one or more of the following characteristics:
  - may give insufficiently accurate and/or poorly developed explanations
  - may lack accurate scientific terminology
  - when required, may give very limited supporting evidence (e.g., physical laws, definitions, examples)
  - any diagrams, tables, and graphs presented may be incomplete and/or inaccurate

1

- Demonstrates very little understanding of the science concepts required by the question, as evidenced by one or more of the following characteristics:
  - may give inaccurate, illogical, incoherent, or seriously incomplete explanations
  - may fail to use accurate scientific terminology
  - may give little or no supporting evidence (e.g., physical laws, definitions, examples)
  - any diagrams, tables, and graphs presented may be seriously inaccurate, confusing, or incomplete

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- Completely inaccurate or inappropriate, blank, or off topic

Sample Question 1

A student prepared an oxide of tin by the following procedure. First, an empty crucible was fired, cooled, and its mass determined. Then a sample of tin was introduced into the crucible and the combined mass (crucible plus tin) was determined. Excess concentrated nitric acid was next added to the crucible, resulting in a chemical reaction that produced the oxide along with water and nitrogen dioxide gas. After gas stopped bubbling out of the crucible, the crucible was again fired, cooled, and the mass of the crucible plus any product present was determined. The following data were taken and recorded.

Mass of empty crucible. . . . . .19.862 g
Mass of crucible with the tin . . . . . . 20.457 g
Mass of crucible after firing . . . . 20.633 g

(A) What mass of oxygen reacted with the tin?

(B) Based on the experimental data, what is the empirical formula for the tin oxide?

(Atomic weight: O = 16, Sn = 119)

(C) Write a balanced chemical reaction for the oxidation process that took place.

(D) What is the purpose of firing the crucible before the initial mass determination?

(E) What is the purpose of firing the crucible after the reaction has apparently stopped?

(F) Analysis of the data suggests an experimental error.

1. What basic concept of chemistry appears to be contradicted by the data given above?
2. Other than a weighing error, what error might have been made that would lead to this apparent contradiction?

Sample Response that Received a Score of 5:

(A) Oxygen consumed is mass of crucible after firing less mass before firing = 20.633 – 20.457 = 0.176 g.

(B) 20.457 — 19.862 = 0.595 g = mass of tin, which corresponds to 0.595/119 = 0.0050 mol of tin.

0.176 g oxygen corresponds to 0.176/16 = 0.0110 mol of oxygen.

The ratio of these moles of oxygen to tin is 0.0110/0.0050, or slightly more than 2:1.

So the empirical formula is SnO_2.

(C) $Sn + 4\ HNO_3 \rightarrow SnO_2 + 2\ H_2O + 4\ NO_2$

(D) To remove any water (or other material that would react with the tin or that would be vaporized in the later firing) that may be present on the crucible walls. Leaving this material on the walls would make subsequent determinations of mass inaccurate.

(E) To remove any of the water formed that remains after the reaction has stopped.

(F) 1. The number of moles of oxygen atoms added to the tin should have been exactly twice the number of moles of tin, or 2 × 0.0050 = 0.0110. Experimentally it is slightly more than this. This contradicts the law of simple combining proportions.

2. Either the measured weight of the tin is too low or the measured weight of the oxide is too high. The latter can be rationalized if the crucible was not adequately fired, resulting in incomplete removal of the water; i.e., the oxide appears to weigh too much because it contains some water.

Sample Response that Received a Score of 3:

(A) Oxygen consumed = 20.633 – 20.457 = 0.176 g.

(B) Mass of tin = 20.457 – 19.862 = 0.595 g
Moles of tin atoms = 0.595/119 = 0.0050 mol
Mass of oxygen = 0.176 g
Moles of oxygen atoms = 0.176/16 = 0.0110 mol

So moles of oxygen atoms is about twice the number of moles of tin atoms.

This means empirical formula is SnO_2

(C) $Sn + O_2 \rightarrow SnO_2$

(D) To dry it so it gives a more accurate weight

(E) To get rid of water

(F) 1. The number of moles of oxygen atoms was 0.0110 which is a little more than two times the number of moles of tin. It should have been exactly two times the number of moles of tin if the reaction followed the law of combining proportions.

2. Calculation error.

Sample Response that Received a Score of 1:

(A) Mass of O_2 consumed

0.176 g O_2 appeared in the oxide

(B) – oxygen: 0.176 g
– tin: 0.595 g
– ratio: 3.4, or about 7:2
– Empirical formula of tin oxide: Sn_7O_2

(C) $Sn + 2\ HNO_3 \rightarrow Sn_7O_2 + 2\ NO_2 + H_2O$

(D) The crucible is fired to remove water.

(E) The crucible is fired to remove water.

(F) 1. Tin appears to have an oxidation state of +7, which is not possible.

2. An error could have been made in arithmetic.

Sample Question 2

The periodic table of the elements in its modern form was first prepared by Dmitry Mendeleyev (1834–1907). Many of the chemical and physical properties of the elements change in a regular fashion, with successive elements in either the same row or the same column of this table.

(A) Name three quantifiable properties, other than atomic weight or atomic number, that change in the manner described.

(B) How do each of these properties change across rows and down columns in the table?

(C) Explain, in terms of atomic structure, why each of these changes occurs in the manner observed.

Sample Response that Received a Score of 5:

(A)	(B)
Atomic size (radius):	becomes smaller across rows, becomes larger down columns
First ionization potential:	increases across rows, decreases down columns
Electronegativity:	increases across rows, decreases down columns

(C) Atomic size (radius) becomes smaller across rows because the number of electron shells is constant and the increasing charge of the nucleus pulls the electrons in with progressively greater force to decrease the size of the atom. Size becomes larger down columns because the number of electron shells increases and the increasing nuclear charge is not a sufficiently potent factor to overcome the increasing number of electron shells.

First ionization potential increases across rows because the outer-shell electrons are held with increasing force because of the increasing nuclear charge and the decreasing atomic size. First ionization potential decreases down columns because the increasing atomic size, which increases the distance between outer electrons and the nucleus and decreases the force with which outer electrons are held, is the predominant factor.

Electronegativity, or the tendency to attract electrons, increases across rows because the increasing nuclear charge and decreasing atomic size both increase the electrical force of attraction of the nucleus for electrons. Electronegativity decreases down columns because the increasing size and accompanying decrease in electrical force predominates over the increasing nuclear charge.

Sample Response that Received a Score of 3:

(A)	(B)
Atomic size (radius):	becomes smaller across rows,
	becomes larger down columns
First ionization potential:	increases across rows,
	decreases down columns
Electronegativity:	increases across rows,
	decreases down columns

(C) Atomic size (radius) becomes smaller across rows because the increasing charge of the nucleus pulls the electrons in with increasing force. This results in smaller and smaller size. Size becomes larger down columns because the number of electron shells increases, thus resulting in larger and larger atoms.

First ionization potential increases across rows because the electron that is removed is held with increasing force because of the increasing nuclear charge and the decreasing atomic size and thus becomes more difficult to remove First ionization potential decreases down columns because of increasing atomic size. This means the electron to be removed is farther and farther away.

Electronegativity increases across rows because of the increasing nuclear charge. This means increasing attraction for electrons. Electronegativity decreases down columns because of the increasing size.

Sample Response that Received a Score of 1:

(A)	(B)
Atomic size (radius):	becomes larger across rows,
	larger down columns
First ionization potential:	decreases across rows,
	decreases down columns
Electronegativity:	increases across rows,
	increases down columns

(C) Atomic size (radius) becomes larger across rows and down columns because the nuclear charge increases in this manner.

First ionization potential decreases across rows and down columns because the outer-shell electrons are held with increasing force because of the increasing nuclear charge.

Electronegativity increases across rows and down columns because of the increasing nuclear charge.

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