CLEP®

Test Information Guide: College-Level Examination Program®

2015-16

Chemistry

CollegeBoard

CLEP TEST INFORMATION GUIDE FOR CHEMISTRY

History of CLEP

Since 1967, the College-Level Examination Program (CLEP®) has provided over six million people with the opportunity to reach their educational goals. CLEP participants have received college credit for knowledge and expertise they have gained through prior course work, independent study or work and life experience.

Over the years, the CLEP examinations have evolved to keep pace with changing curricula and pedagogy. Typically, the examinations represent material taught in introductory college-level courses from all areas of the college curriculum. Students may choose from 33 different subject areas in which to demonstrate their mastery of college-level material.

Today, more than 2,900 colleges and universities recognize and grant credit for CLEP.

Philosophy of CLEP

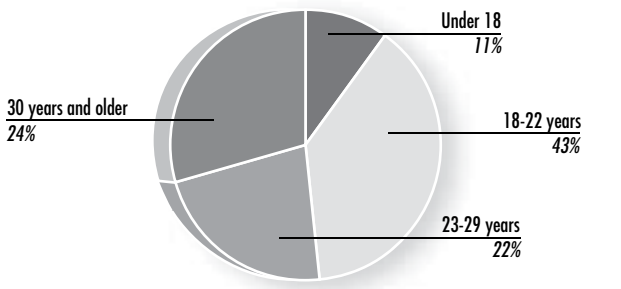
Promoting access to higher education is CLEP's foundation. CLEP offers students an opportunity to demonstrate and receive validation of their college-level skills and knowledge. Students who achieve an appropriate score on a CLEP exam can enrich their college experience with higher-level courses in their major field of study, expand their horizons by taking a wider array of electives and avoid repetition of material that they already know.

CLEP Participants

CLEP's test-taking population includes people of all ages and walks of life. Traditional 18- to 22-year-old students, adults just entering or returning to school, high-school students, home-schoolers and international students who need to quantify their knowledge have all been assisted by CLEP in earning their college degrees. Currently, 59 percent of CLEP's National (civilian) test-takers are women and 46 percent are 23 years of age or older.

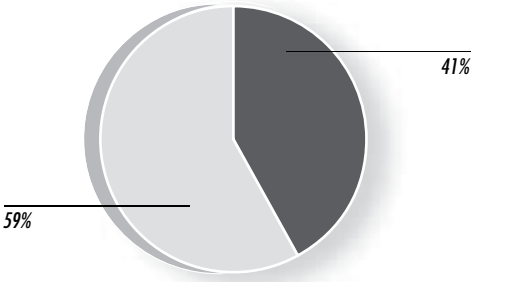
For over 30 years, the College Board has worked to provide government-funded credit-by-exam opportunities to the military through CLEP. Military service members are fully funded for their CLEP exam fees. Exams are administered at military installations worldwide through computer-based testing programs. Approximately one-third of all CLEP candidates are military service members.

2014-15 National CLEP Candidates by Age*



* These data are based on 100% of CLEP test-takers who responded to this survey question during their examinations.

2014-15 National CLEP Candidates by Gender



Computer-Based CLEP Testing

The computer-based format of CLEP exams allows for a number of key features. These include:

- a variety of question formats that ensure effective assessment
- real-time score reporting that gives students and colleges the ability to make immediate credit-granting decisions (except College Composition, which requires faculty scoring of essays twice a month)
- a uniform recommended credit-granting score of 50 for all exams
- "rights-only" scoring, which awards one point per correct answer
- pretest questions that are not scored but provide current candidate population data and allow for rapid expansion of question pools

CLEP Exam Development

Content development for each of the CLEP exams is directed by a test development committee. Each committee is composed of faculty from a wide variety of institutions who are currently teaching the relevant college undergraduate courses. The committee members establish the test specifications based on feedback from a national curriculum survey; recommend credit-granting scores and standards; develop and select test questions; review statistical data and prepare descriptive material for use by faculty (*Test Information Guides*) and students planning to take the tests (*CLEP Official Study Guide*).

College faculty also participate in CLEP in other ways: they convene periodically as part of standard-setting panels to determine the recommended level of student competency for the granting of college credit; they are called upon to write exam questions and to review exam forms; and they help to ensure the continuing relevance of the CLEP examinations through the curriculum surveys.

The Curriculum Survey

The first step in the construction of a CLEP exam is a curriculum survey. Its main purpose is to obtain information needed to develop test-content specifications that reflect the current college curriculum and to recognize anticipated changes in the field. The surveys of college faculty are conducted in each subject every few years depending on the discipline. Specifically, the survey gathers information on:

- the major content and skill areas covered in the equivalent course and the proportion of the course devoted to each area
- specific topics taught and the emphasis given to each topic
- specific skills students are expected to acquire and the relative emphasis given to them
- recent and anticipated changes in course content, skills and topics
- the primary textbooks and supplementary learning resources used
- titles and lengths of college courses that correspond to the CLEP exam

The Committee

The College Board appoints standing committees of college faculty for each test title in the CLEP battery. Committee members usually serve a term of up to four years. Each committee works with content specialists at Educational Testing Service to establish test specifications and develop the tests. Listed below are the current committee members and their institutional affiliations.

Donnie N. Byers, *Chair*	Johnson County Community College
Lisa A. Frederico-Zuraw	The Citadel
Felix Ngassa	Grand Valley State University

The primary objective of the committee is to produce tests with good content validity. CLEP tests must be rigorous and relevant to the discipline and the appropriate courses. While the consensus of the committee members is that this test has high content validity for a typical Chemistry course or curriculum, the validity of the content for a specific course or curriculum is best determined locally through careful review and comparison of test content, with instructional content covered in a particular course or curriculum.

The Committee Meeting

The exam is developed from a pool of questions written by committee members and outside question writers. All questions that will be scored on a CLEP exam have been pretested; those that pass a rigorous statistical analysis for content relevance, difficulty, fairness and correlation with assessment criteria are added to the pool. These questions are compiled by test development specialists according to the test specifications, and are presented to all the committee members for a final review. Before convening at a two- or three-day committee meeting, the members have a chance to review the test specifications and the pool of questions available for possible inclusion in the exam.

At the meeting, the committee determines whether the questions are appropriate for the test and, if not, whether they need to be reworked and pretested again to ensure that they are accurate and unambiguous. Finally, draft forms of the exam are reviewed to ensure comparable levels of difficulty and content specifications on the various test forms. The committee is also responsible for writing and developing pretest questions. These questions are administered to candidates who take the examination and provide valuable statistical feedback on student performance under operational conditions.

Once the questions are developed and pretested, tests are assembled in one of two ways. In some cases, test forms are assembled in their entirety. These forms are of comparable difficulty and are therefore interchangeable. More commonly, questions are assembled into smaller, content-specific units called testlets, which can then be combined in different ways to create multiple test forms. This method allows many different forms to be assembled from a pool of questions.

Test Specifications

Test content specifications are determined primarily through the curriculum survey, the expertise of the committee and test development specialists, the recommendations of appropriate councils and conferences, textbook reviews and other appropriate sources of information. Content specifications take into account:

- the purpose of the test
- the intended test-taker population
- the titles and descriptions of courses the test is designed to reflect
- the specific subject matter and abilities to be tested
- the length of the test, types of questions and instructions to be used

Recommendation of the American Council on Education (ACE)

The American Council on Education's College Credit Recommendation Service (ACE CREDIT) has evaluated CLEP processes and procedures for developing, administering and scoring the exams. Effective July 2001, ACE recommended a uniform credit-granting score of 50 across all subjects (with additional Level-2 recommendations for the world language examinations), representing the performance of students who earn a grade of C in the corresponding course. Every test title has a minimum score of **20**, a maximum score of **80** and a cut score of **50**. However, these score values cannot be compared across exams. The score scale is set so that a score of **50** represents the performance expected of a typical C student, which may differ from one subject to another. The score scale is not based on actual performance of test-takers. It is derived from the judgment of a panel of experts (college faculty who teach an equivalent course) who provide information on the level of student performance that would be necessary to receive college credit in the course.

Over the years, the CLEP examinations have been adapted to adjust to changes in curricula and pedagogy. As academic disciplines evolve, college faculty incorporate new methods and theory into their courses. CLEP examinations are revised to reflect those changes so the examinations continue to meet the needs of colleges and students. The CLEP program's most recent ACE CREDIT review was held in June 2015.

The American Council on Education, the major coordinating body for all the nation's higher education institutions, seeks to provide leadership and a unifying voice on key higher education issues and to influence public policy through advocacy, research and program initiatives. For more information, visit the ACE CREDIT website at www.acenet.edu/acecredit.

CLEP Credit Granting

CLEP uses a common recommended credit-granting score of 50 for all CLEP exams.

This common credit-granting score does not mean, however, that the standards for all CLEP exams are the same. When a new or revised version of a test is introduced, the program conducts a standard setting to determine the recommended credit-granting score ("cut score").

A standard-setting panel, consisting of 15–20 faculty members from colleges and universities across the country who are currently teaching the course, is appointed to give its expert judgment on the level of student performance that would be necessary to receive college credit in the course. The panel reviews the test and test specifications and defines the capabilities of the typical A student, as well as those of the typical B, C and D students.* Expected individual student performance is rated by each panelist on each question. The combined average of the ratings is used to determine a recommended number of examination questions that must be answered correctly to mirror classroom performance of typical B and C students in the related course. The panel's findings are given to members of the test development committee who, with the help of Educational Testing Service and College Board psychometric specialists, make a final determination on which raw scores are equivalent to B and C levels of performance.

*Student performance for the language exams (French, German and Spanish) is defined only at the B and C levels.

Chemistry

Description of the Examination

The Chemistry examination covers material that is usually taught in a one-year college course in general chemistry. Understanding of the structure and states of matter, reaction types, equations and stoichiometry, equilibrium, kinetics, thermodynamics, and descriptive and experimental chemistry is required, as is the ability to interpret and apply this material to new and unfamiliar problems. During this examination, an online scientific calculator function and a periodic table are available as part of the testing software.

The examination contains approximately 75 questions to be answered in 90 minutes. Some of these are pretest questions that will not be scored. Any time spent on tutorials and providing personal information is in addition to the actual testing time.

Knowledge and Skills Required

Questions on the Chemistry examination require candidates to demonstrate one or more of the following abilities.

- **Recall** — remember specific facts; demonstrate straightforward knowledge of information and familiarity with terminology
- **Application** — understand concepts and reformulate information into other equivalent terms; apply knowledge to unfamiliar and/or practical situations; use mathematics to solve chemistry problems
- **Interpretation** — infer and deduce from data available and integrate information to form conclusions; recognize unstated assumptions

The subject matter of the Chemistry examination is drawn from the following topics. The percentages next to the main topics indicate the approximate percentage of exam questions on that topic.

20% **Structure of Matter**

Atomic theory and atomic structure

- Evidence for the atomic theory
- Atomic masses; determination by chemical and physical means
- Atomic number and mass number; isotopes and mass spectroscopy
- Electron energy levels: atomic spectra, quantum numbers, atomic orbitals
- Periodic relationships, including, for example, atomic radii, ionization energies, electron affinities, oxidation states

Chemical bonding

- Binding forces
  - Types: covalent, ionic, metallic, macromolecular (or network), dispersion, hydrogen bonding
  - Relationships to structure and to properties
  - Polarity of bonds, electronegativities
- Geometry of molecules, ions and coordination complexes: structural isomerism, dipole moments of molecules, relation of properties to structure
- Molecular models
  - Valence bond theory; hybridization of orbitals, resonance, sigma and pi bonds
  - Other models; for example, molecular orbital

Nuclear chemistry: nuclear equations, half-lives, and radioactivity; chemical applications

19% **States of Matter**

Gases

- Laws of ideal gases; equations of state for an ideal gas
- Kinetic-molecular theory
  - Interpretation of ideal gas laws on the basis of this theory
  - The mole concept; Avogadro's number
  - Dependence of kinetic energy of molecules on temperature: Boltzmann distribution
  - Deviations from ideal gas laws

Liquids and solids

- Liquids and solids from the kinetic-molecular viewpoint
- Phase diagrams of one-component systems
- Changes of state, critical phenomena

Solutions

- Types of solutions and factors affecting solubility
- Methods of expressing concentration
- Colligative properties; for example, Raoult's law
- Effect of interionic attraction on colligative properties and solubility

12% **Reaction Types**

Formation and cleavage of covalent bonds

- Acid-base reactions; concepts of Arrhenius, Brønsted-Lowry and Lewis; amphoterism
- Reactions involving coordination complexes

Precipitation reactions

Oxidation-reduction reactions

- Oxidation number
- The role of the electron in oxidation-reduction
- Electrochemistry; electrolytic cells, standard half-cell potentials, prediction of the direction of redox reactions, effect of concentration changes

10% **Equations and Stoichiometry**

Ionic and molecular species present in chemical systems; net-ionic equations

Stoichiometry: mass and volume relations with emphasis on the mole concept

Balancing of equations, including those for redox reactions

7% **Equilibrium**

Concept of dynamic equilibrium, physical and chemical; LeChâtelier's principle; equilibrium constants

Quantitative treatment

- Equilibrium constants for gaseous reactions in terms of both molar concentrations and partial pressure (K_c, K_p)
- Equilibrium constants for reactions in solutions
  - Constants for acids and bases; pK; pH
  - Solubility-product constants and their application to precipitation and the dissolution of slightly soluble compounds
  - Constants for complex ions
  - Common ion effect; buffers

4% **Kinetics**

Concept of rate of reaction

Order of reaction and rate constant: their determination from experimental data

Effect of temperature change on rates

Energy of activation; the role of catalysts

The relationship between the rate-determining step and a mechanism

5% **Thermodynamics**

State functions

First law: heat of formation; heat of reaction; change in enthalpy, Hess's law; heat capacity; heats of vaporization and fusion

Second law: free energy of formation; free energy of reaction; dependence of change in free energy on enthalpy and entropy changes

Relationship of change in free energy to equilibrium constants and electrode potentials

14% **Descriptive Chemistry**

The accumulation of certain specific facts of chemistry is essential to enable students to comprehend the development of principles and concepts, to demonstrate applications of principles, to relate fact to theory and properties to structure, and to develop an understanding of systematic nomenclature that facilitates communication. The following areas are normally included on the examination:

- Chemical reactivity and products of chemical reactions
- Relationships in the periodic table: horizontal, vertical and diagonal
- Chemistry of the main groups and transition elements, including typical examples of each
- Organic chemistry, including such topics as functional groups and isomerism (may be treated as a separate unit or as exemplary material in other areas, such as bonding)

9% **Experimental Chemistry**

Some questions are based on laboratory experiments widely performed in general chemistry and ask about the equipment used, observations made, calculations performed, and interpretation of the results. The questions are designed to provide a measure of understanding of the basic tools of chemistry and their applications to simple chemical systems.

Sample Test Questions

The following sample questions do not appear on an actual CLEP examination. They are intended to give potential test-takers an indication of the format and difficulty level of the examination and to provide content for practice and review. Knowing the correct answers to all of the sample questions is not a guarantee of satisfactory performance on the exam.

Note: For all questions involving solutions and/or chemical equations, assume that the system is in pure water and at room temperature unless otherwise stated.

Part A

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each question or best fits each statement. A choice may be used once, more than once, or not at all in each set.

Questions 1–3

(A) F
(B) S
(C) Mg
(D) Ar
(E) Mn

1. Forms monatomic ions with –2 charge in solutions

2. Forms a compound having the formula KXO_4

3. Forms oxides that are common air pollutants and that yield acidic solutions in water

Questions 4–5

(A) Hydrofluoric acid
(B) Carbon dioxide
(C) Aluminum hydroxide
(D) Ammonia
(E) Hydrogen peroxide

4. Is a good oxidizing agent

5. Has amphoteric properties

Questions 6–7

(A) A network solid with covalent bonding
(B) A molecular solid with London (dispersion) forces only
(C) A molecular solid with hydrogen bonding
(D) An ionic solid
(E) A metallic solid

6. Solid ethyl alcohol, C_2H_5OH

7. Silicon dioxide, SiO_2

Questions 8–9

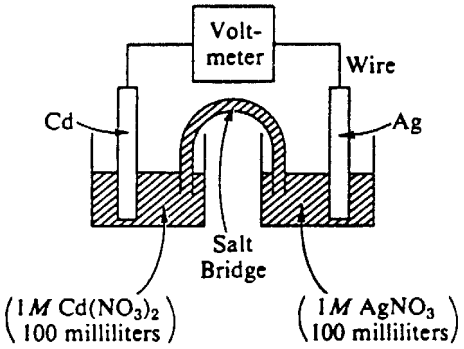
(A) CO_3^{2-}
(B) MnO_4^-
(C) NH_4^+
(D) Ba^{2+}
(E) Al^{3+}

Assume that you have several "unknowns," each consisting of an aqueous solution of a salt that contains one of the ions listed above. Which ion must be present if the following observations are made of that unknown?

8. An odor can be detected when a sample of the solution is added drop by drop to a warm solution of sodium hydroxide.

9. A precipitate is formed when a dilute solution of H_2SO_4 is added to a sample of the solution.

Questions 10–11



The spontaneous reaction that occurs when the cell above operates is

$$2\ Ag^+ + Cd(s) \rightarrow 2\ Ag(s) + Cd^{2+}.$$

(A) Voltage increases.
(B) Voltage decreases but remains above zero.
(C) Voltage becomes zero and remains at zero.
(D) No change in voltage occurs.
(E) Direction of voltage change cannot be predicted without additional information.

Which of the above occurs for each of the following circumstances?

10. The silver electrode is made larger.

11. The salt bridge is replaced by a platinum wire.

Part B

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

12.

Hydrogen Halide	Normal Boiling Point, °C
HF	+19
HCl	–85
HBr	–67
HI	–35

The liquefied hydrogen halides have the normal boiling points given above. The relatively high boiling point of HF can be correctly explained by which of the following?

(A) HF gas is more ideal.
(B) HF is the strongest acid.
(C) HF molecules have a smaller dipole moment.
(D) HF is much less soluble in water.
(E) HF molecules tend to form hydrogen bonds.

13. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

Atoms of an element, X, have the electronic configuration shown above. The compound most likely formed with magnesium, Mg, is

(A) MgX
(B) Mg_2X
(C) MgX_2
(D) Mg_2X_3
(E) Mg_3X_2

14. The density of an unknown gas is 4.20 grams per liter at 3.00 atmospheres pressure and 127°C. What is the molar mass of this gas? (R = 0.0821 liter·atm/mole·K)

(A) 14.6 g
(B) 46.0 g
(C) 88.0 g
(D) 94.1 g
(E) 138.0 g

Questions 15–16

$$H_3AsO_4 + 3\ I^- + 2\ H_3O^+ \rightarrow H_3AsO_3 + I_3^- + 3\ H_2O$$

The oxidation of iodide ions by arsenic acid in acidic aqueous solution occurs according to the balanced equation shown above. The experimental rate law for the reaction at 25°C is

$$\text{Rate} = k\,[H_3AsO_4]\,[I^-]\,[H_3O^+].$$

15. What is the order of the reaction with respect to I^- ?

(A) 1
(B) 2
(C) 3
(D) 5
(E) 6

16. According to the rate law for the reaction, an increase in the concentration of the hydronium ion has what effect on the reaction at 25°C?

(A) The rate of reaction increases.
(B) The rate of reaction decreases.
(C) The value of the equilibrium constant increases.
(D) The value of the equilibrium constant decreases.
(E) Neither the rate nor the value of the equilibrium constant is changed.

17. The critical temperature of a substance is the

(A) temperature at which the vapor pressure of the liquid is equal to the external pressure
(B) temperature at which the vapor pressure of the liquid is equal to 760 mm Hg
(C) temperature at which the solid, liquid, and vapor phases are all in equilibrium
(D) temperature at which the liquid and vapor phases are in equilibrium at 1 atmosphere
(E) lowest temperature above which a substance cannot be liquefied at any applied pressure

18. $Cu(s) + 2\ Ag^+ \rightarrow Cu^{2+} + 2\ Ag(s)$

If the equilibrium constant for the reaction above is 3.7×10^{15}, which of the following correctly describes the standard voltage, $E°$, and the standard free energy change, $\Delta G°$, for this reaction?

(A) $E°$ is positive and $\Delta G°$ is negative.
(B) $E°$ is negative and $\Delta G°$ is positive.
(C) $E°$ and $\Delta G°$ are both positive.
(D) $E°$ and $\Delta G°$ are both negative.
(E) $E°$ and $\Delta G°$ are both zero.

19. London (dispersion) forces are the only type of intermolecular forces in which of the following pure liquids?

(A) $CHF_3(l)$
(B) $H_2S(l)$
(C) $PCl_3(l)$
(D) $SO_2(l)$
(E) $SiCl_4(l)$

20. The pH of 0.1 *M* ammonia is approximately

(A) 1
(B) 4
(C) 7
(D) 11
(E) 14

21. Which of the following has polar bonds but a zero dipole moment?

(A) SO_2
(B) H_2S
(C) CO_3^{2-}
(D) NO_2
(E) ClO_3^-

22. $CuO(s) + H_2(g) \leftrightarrows Cu(s) + H_2O(g)\ \ \Delta H = -2.0$ kJ

The substances in the equation above are at equilibrium at pressure P and temperature T. The equilibrium can be shifted to favor the products by

(A) increasing the pressure by means of a moving piston at constant T
(B) increasing the pressure by adding an inert gas such as nitrogen
(C) decreasing the temperature
(D) allowing some gases to escape at constant P and T
(E) adding a catalyst

23. The molality of the glucose in a 1.0 *M* glucose solution can be obtained by using which of the following?

(A) Solubility of glucose in water
(B) Degree of dissociation of glucose
(C) Volume of the solution
(D) Temperature of the solution
(E) Density of the solution

24. The geometry of the SO_3 molecule is best described as

(A) trigonal planar
(B) trigonal pyramidal
(C) square pyramidal
(D) bent
(E) tetrahedral

25. Which of the following molecules has the shortest bond length?

(A) N_2
(B) O_2
(C) Cl_2
(D) Br_2
(E) I_2

26. What number of moles of O_2 is needed to produce 14.2 grams of P_4O_{10} (molar mass 284 g) from P?

(A) 0.0500 mole
(B) 0.0625 mole
(C) 0.125 mole
(D) 0.250 mole
(E) 0.500 mole

27. If 0.060 faraday is passed through an electrolytic cell containing a solution of In^{3+} ions, the maximum number of moles of In that could be deposited at the cathode is

(A) 0.010 mole
(B) 0.020 mole
(C) 0.030 mole
(D) 0.060 mole
(E) 0.18 mole

28. $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$
$\Delta H^\circ_{rxn} = -889.1$ kJ mol^{-1}

$\Delta H_f^\circ\ H_2O(l) = -285.8$ kJ mol^{-1}
$\Delta H_f^\circ\ CO_2(g) = -393.3$ kJ mol^{-1}

What is the standard heat of formation, ΔH_f°, of methane, $CH_4(g)$, as calculated from the data above?

(A) –210.0 kJ mol^{-1}
(B) –107.5 kJ mol^{-1}
(C) –75.8 kJ mol^{-1}
(D) 75.8 kJ mol^{-1}
(E) 210.0 kJ mol^{-1}

29. Each of the following can act as both a Brønsted acid and a Brønsted base EXCEPT

(A) HCO_3^-
(B) $H_2PO_4^-$
(C) NH_4^+
(D) H_2O
(E) HS^-

30. Two flexible containers for gases are at the same temperature and pressure. One holds 0.50 gram of hydrogen and the other holds 8.0 grams of oxygen. Which of the following statements regarding these gas samples is FALSE?

(A) The volume of the hydrogen container is the same as the volume of the oxygen container.
(B) The number of molecules in the hydrogen container is the same as the number of molecules in the oxygen container.
(C) The density of the hydrogen sample is less than that of the oxygen sample.
(D) The average kinetic energy of the hydrogen molecules is the same as the average kinetic energy of the oxygen molecules.
(E) The average speed of the hydrogen molecules is the same as the average speed of the oxygen molecules.

31. Pi (π) bonding occurs in each of the following species EXCEPT

(A) CO_2
(B) C_2H_4
(C) CN^-
(D) C_6H_6
(E) CH_4

32. $3\ Ag(s) + 4\ HNO_3 \rightarrow 3\ AgNO_3 + NO(g) + 2\ H_2O$

The reaction of silver metal and dilute nitric acid proceeds according to the equation above. If 0.10 mole of powdered silver is added to 10. milliliters of 6.0-molar nitric acid, the number of moles of NO gas that can be formed is

(A) 0.015 mole
(B) 0.020 mole
(C) 0.030 mole
(D) 0.045 mole
(E) 0.090 mole

33. Which, if any, of the following species are in the greatest concentration in a 0.100 *M* solution of H_2SO_4 in water?

(A) H_2SO_4 molecules
(B) H_3O^+ ions
(C) HSO_4^- ions
(D) SO_4^{2-} ions
(E) All species are in equilibrium and therefore have the same concentrations.

34. At 20.°C, the vapor pressure of toluene is 22 mm Hg and that of benzene is 75 mm Hg. An ideal solution, equimolar in toluene and benzene, is prepared. At 20.°C, what is the mole fraction of benzene in the vapor in equilibrium with this solution?

(A) 0.23
(B) 0.29
(C) 0.50
(D) 0.77
(E) 0.83

35. Which of the following aqueous solutions has the highest boiling point?

(A) 0.10 *M* potassium sulfate, K_2SO_4
(B) 0.10 *M* hydrochloric acid, HCl
(C) 0.10 *M* ammonium nitrate, NH_4NO_3
(D) 0.10 *M* magnesium sulfate, $MgSO_4$
(E) 0.20 *M* sucrose, $C_{12}H_{22}O_{11}$

36. When 70 milliliters of 3.0 *M* Na_2CO_3 is added to 30 milliliters of 1.0 *M* $NaHCO_3$, the resulting concentration of Na^+ is

(A) 2.0 *M*
(B) 2.4 *M*
(C) 4.0 *M*
(D) 4.5 *M*
(E) 7.0 *M*

37. Which of the following species CANNOT function as an oxidizing agent?

(A) $Cr_2O_7^{2-}$
(B) MnO_4^-
(C) NO_3^-
(D) S
(E) I^-

38. A student wishes to prepare 2.00 liters of 0.100 *M* KIO_3 (molar mass 214 g). The proper procedure is to weigh out

(A) 42.8 grams of KIO_3 and add 2.00 kilograms of H_2O
(B) 42.8 grams of KIO_3 and add H_2O until the final homogeneous solution has a volume of 2.00 liters
(C) 21.4 grams of KIO_3 and add H_2O until the final homogeneous solution has a volume of 2.00 liters
(D) 42.8 grams of KIO_3 and add 2.00 liters of H_2O
(E) 21.4 grams of KIO_3 and add 2.00 liters of H_2O

39. A 20.0-milliliter sample of 0.200 *M* K_2CO_3 solution is added to 30.0 milliliters of 0.400 *M* $Ba(NO_3)_2$ solution. Barium carbonate precipitates. The concentration of barium ion, Ba^{2+}, in solution after reaction is

(A) 0.150 *M*
(B) 0.160 *M*
(C) 0.200 *M*
(D) 0.240 *M*
(E) 0.267 *M*

40. One of the outermost electrons in a strontium atom in the ground state can be described by which of the following sets of four quantum numbers?

(A) 5, 2, 0, $\frac{1}{2}$

(B) 5, 1, 1, $\frac{1}{2}$

(C) 5, 1, 0, $\frac{1}{2}$

(D) 5, 0, 1, $\frac{1}{2}$

(E) 5, 0, 0, $\frac{1}{2}$

41. Which of the following reactions does NOT proceed significantly to the right in aqueous solutions?

(A) $H_3O^+ + OH^- \rightarrow 2\ H_2O$

(B) $HCN + OH^- \rightarrow H_2O + CN^-$

(C) $Cu(H_2O)_4^{2+} + 4\ NH_3 \rightarrow Cu(NH_3)_4^{2+} + 4\ H_2O$

(D) $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$

(E) $H_2O + HSO_4^- \rightarrow H_2SO_4 + OH^-$

42. A compound is heated to produce a gas whose molar mass is to be determined. The gas is collected by displacing water in a water-filled flask inverted in a trough of water. Which of the following is necessary to calculate the molar mass of the gas but does not need to be measured during the experiment?

(A) Mass of the compound used in the experiment

(B) Temperature of the water in the trough

(C) Vapor pressure of the water

(D) Barometric pressure

(E) Volume of water displaced from the flask

43. A 27.0 gram sample of an unknown hydrocarbon was burned in excess oxygen to form 88.0 grams of carbon dioxide and 27.0 grams of water. What is a possible molecular formula of the hydrocarbon?

(A) CH_4

(B) C_2H_2

(C) C_4H_3

(D) C_4H_6

(E) C_4H_{10}

44. If the acid dissociation constant, K_a, for an acid HA is 8×10^{-4} at 25°C, what percent of the acid is dissociated in a 0.50 *M* solution of HA at 25°C?

(A) 0.08%

(B) 0.2%

(C) 1%

(D) 2%

(E) 4%

45. Which of the following indicators is most appropriate for determining the equivalence point in the titration of a weak acid with a strong base?

Indicator	pH Range of Color Change
(A) Thymol blue	1.2–2.8
(B) Methyl orange	3.1–4.4
(C) Methyl red	4.4–6.2
(D) Bromcresol purple	5.2–6.8
(E) m-cresol purple	7.6–9.2

46. Equal numbers of moles of $H_2(g)$, $Ar(g)$, and $N_2(g)$ are placed in a glass vessel at room temperature. If the vessel has a pinhole-sized leak, which of the following will be true regarding the relative values of the partial pressures of the gases remaining in the vessel after some of the gas mixture has effused?

(A) $P_{H_2} < P_{N_2} < P_{Ar}$
(B) $P_{H_2} < P_{Ar} < P_{N_2}$
(C) $P_{N_2} < P_{Ar} < P_{H_2}$
(D) $P_{Ar} < P_{H_2} < P_{N_2}$
(E) $P_{H_2} = P_{Ar} = P_{N_2}$

47. Which of the following is a correct interpretation of the results of Rutherford's experiments in which gold atoms were bombarded with alpha particles?

(A) Atoms have equal numbers of positive and negative charges.
(B) Electrons in atoms are arranged in shells.
(C) Neutrons are at the center of an atom.
(D) Neutrons and protons in atoms have nearly equal mass.
(E) The positive charge of an atom is concentrated in a small region.

48. A 0.1 *M* solution of which of the following ions is orange?

(A) $Fe(H_2O)_4^{2+}$
(B) $Cu(NH_3)_4^{2+}$
(C) $Zn(OH)_4^{2-}$
(D) $Zn(NH_3)_4^{2+}$
(E) $Cr_2O_7^{2-}$

49. In the formation of 1.0 mole of the following crystalline solids from the gaseous ions, the most energy is released by

(A) NaF
(B) MgF_2
(C) $MgBr_2$
(D) AlF_3
(E) $AlBr_3$

50. If 1 mole of a nonvolatile nonelectrolyte dissolves in 9 moles of water to form an ideal solution, what is the vapor pressure of this solution at 25°C? (The vapor pressure of pure water at 25°C is 23.8 mm Hg.)

(A) 23.8 mm Hg
(B) $\frac{9}{10}$ 23.8 mm Hg
(C) $\frac{10}{9}$ 23.8 mm Hg
(D) $\frac{1}{10}$ 23.8 mm Hg
(E) It cannot be determined from the information given.

51. $\ldots MnO_4^-(aq) + \ldots NO_2^-(aq) + \ldots H_2O(l) \rightarrow \ldots MnO_2(s) + \ldots NO_3^-(aq) + \ldots OH^-(aq)$

When the redox equation shown above is balanced by using coefficients reduced to lowest whole numbers, the coefficient for MnO_4^- is

(A) 1
(B) 2
(C) 3
(D) 4
(E) 6

52. If a certain solid solute dissolves in water with the evolution of heat, which of the following is most likely to be true?

(A) The temperature of the solution decreases as the solute dissolves.
(B) The resulting solution is ideal.
(C) The solid has a large lattice energy.
(D) The solid has a large heat of fusion.
(E) The solid has a large energy of hydration.

53. A 0.1-molar aqueous solution of which of the following is neutral?

(A) $NaNO_3$
(B) Na_2CO_3
(C) NH_4Br
(D) KCN
(E) $AlCl_3$

54. Which of the following is a true statement about the halogens?

(A) Fluorine is the weakest oxidizing agent.
(B) Bromine is more electronegative than chlorine.
(C) The halide ions are larger than their respective halogen atoms.
(D) Adding $I_2(s)$ to a solution containing $Br^-(aq)$ will produce $Br_2(l)$.
(E) The first ionization energies increase as the atomic number increases.

$CH_3CHOHCH_2OH$ $CH_3CH_2CH_2CH_3$ $CH_3CH_2CHOHCH_3$
X *Y* *Z*

55. Considering the structures of the three compounds, *X*, *Y*, and *Z*, shown above, the ranking of their solubility in water from least to greatest is which of the following?

(A) $X < Y < Z$
(B) $X < Z < Y$
(C) $Z < Y < X$
(D) $Y < Z < X$
(E) $Y < X < Z$

56. Of the following compounds, which is involved in the environmental problem known as acid rain?

(A) CO_2
(B) CF_2Cl_2
(C) SO_2
(D) H_2S
(E) SiO_2

$\ldots P_4O_{10} + \ldots Ca(OH)_2 \rightarrow \ldots Ca_3(PO_4)_2 + \ldots H_2O$

57. When the chemical equation above is balanced in terms of lowest whole-number coefficients, the coefficient for H_2O is

(A) 1
(B) 2
(C) 3
(D) 6
(E) 8

58. Which of the following best describes the role of a catalyst in a chemical reaction?

(A) The catalyst lowers the activation energy by changing the mechanism of the reaction.
(B) The catalyst increases the strength of the chemical bonds in the reactant molecules.
(C) The catalyst increases the value of the equilibrium constant.
(D) The catalyst provides kinetic energy to reactant molecules to increase the reaction rate.
(E) The catalyst bonds to the reaction products and drives the equilibrium toward the products.

59. On the basis of trends in the periodic table, an atom of which of the following elements is predicted to have the lowest first ionization energy?

(A) Ar
(B) Cl
(C) K
(D) Rb
(E) I

$$X(g) + Y(g) \rightleftarrows Z(g)$$

60. Which of the following statements is true for the chemical system represented above when the system has reached a state of equilibrium at a constant temperature and pressure?

(A) The forward and reverse reactions have stopped.
(B) The forward and reverse reactions occur at the same rate.
(C) The rate of formation of $Z(g)$ is equal to half the rate of consumption of $X(g)$.
(D) Introducing a catalyst will result in an increased amount of $Z(g)$ at equilibrium.
(E) Introducing more $Y(g)$ to the system will cause more $X(g)$ to form.

61. If a 1.0 *M* solution of HA, a weak acid, has a pH of 2.0, then the value of K_a, the acid-dissociation constant, for HA is closest to

(A) 1.0×10^{-4}
(B) 1.4×10^{-4}
(C) 1.0×10^{-2}
(D) 1.4×10^{-2}
(E) 1.4×10^{-1}

62. Which of the following elements is <u>never</u> found pure (i.e., chemically uncombined with one or more other elements) in Earth's crust?

(A) S
(B) K
(C) Cu
(D) Pt
(E) Au

63. If an endothermic reaction occurs spontaneously, then it can be correctly inferred that

(A) a catalyst must be present
(B) the reaction occurs at a slow rate
(C) $\Delta G_{rxn} > 0$
(D) $\Delta H_{rxn} < 0$
(E) $\Delta S_{rxn} > 0$

64. Which of the following single covalent bonds is the most polar?

(A) B – F
(B) F – F
(C) Cl – F
(D) P – Br
(E) Si – Cl

65. In which of the following are the compounds listed correctly in order of <u>increasing</u> strength of their oxygen-to-oxygen bonds?

(A) $O_2 < O_3 < H_2O_2$
(B) $O_2 < H_2O_2 < O_3$
(C) $O_3 < O_2 < H_2O_2$
(D) $H_2O_2 < O_3 < O_2$
(E) $H_2O_2 < O_2 < O_3$

66. An atom of which of the following elements has the smallest radius?

(A) K
(B) Ca
(C) Br
(D) Rb
(E) Sr

67. Which of the following is a Brønsted-Lowry acid-base pair?

(A) H^+ and Cl^-
(B) Na^+ and Cl^-
(C) HCl and NaOH
(D) H_2SO_4 and SO_4^{2-}
(E) HCO_3^- and CO_3^{2-}

68. A sample of gas has a volume of 1.0 L at 300. K and 2.0 atm. If the volume and the absolute temperature are both doubled, what is the final pressure of the sample?

(A) 0.50 atm
(B) 1.0 atm
(C) 2.0 atm
(D) 4.0 atm
(E) 8.0 atm

69. In coordination compounds, the ligands have in common the fact that they

(A) act as Lewis acids
(B) are positively charged ions
(C) form bonds using lone pairs of electrons
(D) form long chains of atoms
(E) have a relatively large molar mass

70. The oxidation number of silicon in the compound $Na_2Mg_2Si_6O_{15}$ is

(A) +1
(B) +2
(C) +3
(D) +4
(E) +6

71. If a 0.15 molal aqueous solution of solute X has the same boiling point as a 0.30 molal aqueous solution of glucose, which of the following statements is true?

(A) Solute X has a molar mass that is twice that of glucose.
(B) The ideal van't Hoff factor of solute X is 2.
(C) The 0.15 molal solution has a higher vapor pressure than the 0.30 molal solution.
(D) The 0.30 molal solution has a lower freezing point than the 0.15 molal solution.
(E) The 0.30 molal solution has a higher osmotic pressure than the 0.15 molal solution.

72. As intermolecular forces become stronger for pure liquids, which of the following tends to decrease?

(A) Density
(B) Viscosity
(C) Vapor pressure
(D) Surface tension
(E) Heat of vaporization

73. A sample of argon gas and a sample of xenon gas at low temperature do not exhibit ideal gas behavior. Which gas deviates more from ideal gas behavior, and what is the major cause of the deviation?

	Greater Deviation	Cause of Deviation
(A)	Argon	Attractive forces between atoms
(B)	Argon	Volume of the atoms
(C)	Argon	Mass of the atoms
(D)	Xenon	Attractive forces between atoms
(E)	Xenon	Mass of the atoms

74. Each of three flexible vessels contains a gas at the same temperature and pressure. The first contains 2.0 g of $H_2(g)$, the second contains 32.0 g of $O_2(g)$, and the third contains 44.0 g of $CO_2(g)$. Which of the following statements about the gases is FALSE?

(A) The densities of the gases increase in the order $H_2 < O_2 < CO_2$.

(B) The number of molecules in each of the three vessels is the same.

(C) The volume of each of the three vessels is the same.

(D) The average kinetic energy of the molecules in each of the vessels is the same.

(E) The average speed of the molecules in each of the vessels is the same.

75. Four pure substances are used to make 1 *M* aqueous solutions: NaOH, Na_2CO_3, $NaNO_3$, and HNO_3. Which of the following correctly ranks the substances in order of increasing pH of the solution they produce?

	Lowest pH			Highest pH
(A)	HNO_3	<	$NaNO_3$ < Na_2CO_3	< NaOH
(B)	HNO_3	<	Na_2CO_3 < $NaNO_3$	< NaOH
(C)	HNO_3	<	$NaNO_3$ < NaOH	< Na_2CO_3
(D)	$NaNO_3$	<	HNO_3 < Na_2CO_3	< NaOH
(E)	Na_2CO_3	<	HNO_3 < NaOH	< $NaNO_3$

Study Resources

Most textbooks used in college-level chemistry courses cover the topics in the outline given earlier, but the approaches to certain topics and the emphases given to them may differ. To prepare for the Chemistry exam, it is advisable to study one or more college textbooks, which can be found in most college bookstores. When selecting a textbook, check the table of contents against the knowledge and skills required for this test.

Visit clep.collegeboard.org/test-preparation for additional chemistry resources. You can also find suggestions for exam preparation in Chapter IV of the *Official Study Guide*. In addition, many college faculty post their course materials on their schools' websites.

Answer Key

1.	B	39.	B
2.	E	40.	E
3.	B	41.	E
4.	E	42.	C
5.	C	43.	D
6.	C	44.	E
7.	A	45.	E
8.	C	46.	A
9.	D	47.	E
10.	D	48.	E
11.	C	49.	D
12.	E	50.	B
13.	E	51.	B
14.	B	52.	E
15.	A	53.	A
16.	A	54.	C
17.	E	55.	D
18.	A	56.	C
19.	E	57.	D
20.	D	58.	A
21.	C	59.	D
22.	C	60.	B
23.	E	61.	A
24.	A	62.	B
25.	A	63.	E
26.	D	64.	A
27.	B	65.	D
28.	C	66.	C
29.	C	67.	E
30.	E	68.	C
31.	E	69.	C
32.	A	70.	D
33.	B	71.	B
34.	D	72.	C
35.	A	73.	D
36.	D	74.	E
37.	E	75.	A
38.	B		

Test Measurement Overview

Format

There are multiple forms of the computer-based test, each containing a predetermined set of scored questions. The examinations are not adaptive. There may be some overlap between different forms of a test: any of the forms may have a few questions, many questions, or no questions in common. Some overlap may be necessary for statistical reasons.

In the computer-based test, not all questions contribute to the candidate's score. Some of the questions presented to the candidate are being pretested for use in future editions of the tests and will not count toward his or her score.

Scoring Information

CLEP examinations are scored without a penalty for incorrect guessing. The candidate's raw score is simply the number of questions answered correctly. However, this raw score is not reported; the raw scores are translated into a scaled score by a process that adjusts for differences in the difficulty of the questions on the various forms of the test.

Scaled Scores

The scaled scores are reported on a scale of 20–80. Because the different forms of the tests are not always exactly equal in difficulty, raw-to-scale conversions may in some cases differ from form to form. The easier a form is judged to be, the higher the raw score required to attain a given scaled score. **Table 1** indicates the relationship between number correct (raw score) and scaled score across all forms.

The Recommended Credit-Granting Score

Table 1 also indicates the recommended credit-granting score, which represents the performance of students earning a grade of C in the corresponding course. The recommended B-level score represents B-level performance in equivalent course work. These scores were established as the result of a Standard Setting Study, the most recent having been conducted in 2007. The recommended credit-granting scores are based upon the judgments of a panel of experts currently teaching equivalent courses at various colleges and universities. These experts evaluate each question in order to determine the raw scores that would correspond to B and C levels of performance. Their judgments are then reviewed by a test development committee, which, in consultation with test content and psychometric specialists, makes a final determination. The standard-setting study is described more fully in the earlier section entitled "CLEP Credit Granting" on page 5.

Panel members participating in the most recent study were:

Bal Barot	Lake Michigan College
Deborah Booth	University of Southern Mississippi
G. Lynn Carlson	University of Wisconsin — Parkside
Allen Clabo	Francis Marion University
Larry Funck	Wheaton College
John Gelder	Oklahoma State University
Noemi Jesalva	Central Piedmont Community College
Martha Joseph	Westminster College
Philip Keller	University of Arizona
Boon Loo	Towson University
Craig McClure	University of Alabama — Birmingham
Victor Okereke	SUNY Morrisville State College
Dilip Paul	Pittsburg State University
Margaret Reid	Austin Community College
Richard Schwenz	University of Northern Colorado
Steven Socol	McHenry County College
David Stanislawski	Chattanooga State Technical Community College
Koni Stone	California State University — Stanislaus
Laura Strauss	University of Northern Iowa
Duane Swank	Pacific Lutheran University
M. Rachel Wang	Spokane Falls Community College
Linda Wozniewski	Indiana University — Northwest

After the recommended credit-granting scores are determined, a statistical procedure called scaling is applied to establish the exact correspondences between raw and scaled scores. Note that a scaled score of 50 is assigned to the raw score that corresponds to the recommended credit-granting score for C-level performance, and a high but usually less-than-perfect raw score is selected and assigned a scaled score of 80.

Table 1: Chemistry Interpretive Score Data

American Council on Education (ACE) Recommended Number of Semester Hours of Credit: 6

Course Grade	Scaled Score	Number Correct
	80	66-68
	79	65
	78	64
	77	63
	76	61-62
	75	60-61
	74	59-60
	73	58
	72	57
	71	56
	70	55
	69	54
	68	53
	67	51-52
	66	50-51
B	**65**	**49-50**
	64	48-49
	63	47-48
	62	46-47
	61	45
	60	44
	59	43
	58	42
	57	40-41
	56	39-40
	55	38-39
	54	37-38
	53	36-37
	52	35-36
	51	34-35
C	**50***	**33-34**
	49	32
	48	31
	47	30
	46	28-29
	45	27-28
	44	26-27
	43	25-26
	42	24-25
	41	23-24
	40	22-23
	39	21-22
	38	20-21
	37	19-20
	36	18-19
	35	17-18
	34	16
	33	15
	32	14
	31	13
	30	12
	29	11
	28	10
	27	9
	26	8
	25	7
	24	6
	23	5
	22	4
	21	3
	20	0-2

*Credit-granting score recommended by ACE.

Note: The number-correct scores for each scaled score on different forms may vary depending on form difficulty.

Validity

Validity is a characteristic of a particular use of the test scores of a group of examinees. If the scores are used to make inferences about the examinees' knowledge of a particular subject, the validity of the scores for that purpose is the extent to which those inferences can be trusted to be accurate.

One type of evidence for the validity of test scores is called content-related evidence of validity. It is usually based upon the judgments of a set of experts who evaluate the extent to which the content of the test is appropriate for the inferences to be made about the examinees' knowledge. The committee that developed the CLEP Chemistry examination selected the content of the test to reflect the content of Chemistry courses at most colleges, as determined by a curriculum survey. Since colleges differ somewhat in the content of the courses they offer, faculty members should, and are urged to, review the content outline and the sample questions to ensure that the test covers core content appropriate to the courses at their college.

Another type of evidence for test-score validity is called criterion-related evidence of validity. It consists of statistical evidence that examinees who score high on the test also do well on other measures of the knowledge or skills the test is being used to measure. Criterion-related evidence for the validity of CLEP scores can be obtained by studies comparing students' CLEP scores with the grades they received in corresponding classes, or other measures of achievement or ability. CLEP and the College Board conduct these studies, called Admitted Class Evaluation Service or ACES, for individual colleges that meet certain criteria at the college's request. Please contact CLEP for more information.

Reliability

The reliability of the test scores of a group of examinees is commonly described by two statistics: the reliability coefficient and the standard error of measurement (SEM). The reliability coefficient is the correlation between the scores those examinees get (or would get) on two independent replications of the measurement process. The reliability coefficient is intended to indicate the stability/consistency of the candidates' test scores, and is often expressed as a number ranging from .00 to 1.00. A value of .00 indicates total lack of stability, while a value of 1.00 indicates perfect stability. The reliability coefficient can be interpreted as the correlation between the scores examinees would earn on two forms of the test that had no questions in common.

Statisticians use an internal-consistency measure to calculate the reliability coefficients for the CLEP exam.[1] This involves looking at the statistical relationships among responses to individual multiple-choice questions to estimate the reliability of the total test score. The SEM is an estimate of the amount by which a typical test-taker's score differs from the average of the scores that a test-taker would have gotten on all possible editions of the test. It is expressed in score units of the test. Intervals extending one standard error above and below the true score for a test-taker will include 68 percent of that test-taker's obtained scores. Similarly, intervals extending two standard errors above and below the true score will include 95 percent of the test-taker's obtained scores. The standard error of measurement is inversely related to the reliability coefficient. If the reliability of the test were 1.00 (if it perfectly measured the candidate's knowledge), the standard error of measurement would be zero.

An additional index of reliability is the conditional standard of error of measurement (CSEM). Since different editions of this exam contain different questions, a test-taker's score would not be exactly the same on all possible editions of the exam. The CSEM indicates how much those scores would vary. It is the typical distance of those scores (all for the same test-taker) from their average. A test-taker's CSEM on a test cannot be computed, but by using the data from many test-takers, it can be estimated. The CSEM estimate reported here is for a test-taker whose average score, over all possible forms of the exam, would be equal to the recommended C-level credit-granting score.

Scores on the CLEP examination in Chemistry are estimated to have a reliability coefficient of 0.91. The standard error of measurement is 3.30 scaled-score points. The conditional standard error of measurement at the recommended C-level credit-granting score is 3.56 scaled-score points.

[1] The formula used is known as Kuder-Richardson 20, or KR-20, which is equivalent to a more general formula called coefficient alpha.

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