The last page of the booklet is the answer sheet. Fold the last page along the perforations and, slowly and carefully, tear off the answer sheet. Then fill in the heading of your answer sheet.

All of your answers are to be recorded on the separate answer sheet. For each question, decide which of the choices given is the best answer. Then on the answer sheet, in the row of numbers for that question, circle with pencil the number of the choice that you have selected. The sample below is an example of the first step in recording your answers.

SAMPLE:  1 2 3 4

If you wish to change an answer, erase your first penciled circle and then circle with pencil the number of the answer you want. After you have completed the examination and you have decided that all of the circled answers represent your best judgment, signal a proctor and turn in all examination material except your answer sheet. Then and only then, place an X in ink in each penciled circle. Be sure to mark only one answer with an X in ink for each question. No credit will be given for any question with two or more X’s marked. The sample below indicates how your final choice should be marked with an X in ink.

SAMPLE:  ✗ 2 3 4

The “Reference Tables for Chemistry,” which you may need to answer some questions in this examination, are supplied separately. Be certain you have a copy of these reference tables before you begin the examination.

When you have completed the examination, you must sign the statement printed at the end of the answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet cannot be accepted if you fail to sign this declaration.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.
Part I

Answer all 56 questions in this part. [65]

Directions (1–56): For each statement or question, select the word or expression that, of those given, best completes the statement or answers the question. Record your answer on the separate answer sheet in accordance with the directions on the front page of this booklet.

1 A sample of oxygen gas in a closed system has a volume of 200 milliliters at 600 K. If the pressure is held constant and the temperature is lowered to 300 K, the new volume of the gas will be
   (1) 100 mL  (3) 300 mL
   (2) 200 mL  (4) 400 mL

2 Which sample of water will have the highest vapor pressure?
   (1) 10.0 mL at 62°C  (3) 30.0 mL at 42°C
   (2) 20.0 mL at 52°C  (4) 40.0 mL at 32°C

3 Which statement best describes the molecules of \( \text{H}_2\text{O} \) in the solid phase?
   (1) They move slowly in straight lines.
   (2) They move rapidly in straight lines.
   (3) They are arranged in a regular geometric pattern.
   (4) They are arranged in a random pattern.

4 What occurs when a substance melts?
   (1) It changes from solid to liquid, and heat is absorbed.
   (2) It changes from solid to liquid, and heat is released.
   (3) It changes from liquid to solid, and heat is absorbed.
   (4) It changes from liquid to solid, and heat is released.

5 An assumption of the kinetic theory of gases is that the particles of a gas have
   (1) little attraction for each other and a significant volume
   (2) little attraction for each other and an insignificant volume
   (3) strong attraction for each other and a significant volume
   (4) strong attraction for each other and an insignificant volume

6 Which graph best shows the change in the volume of 1 mole of nitrogen gas as pressure increases and temperature remains constant?

   ![Graph 1](image)
   ![Graph 2](image)
   ![Graph 3](image)
   ![Graph 4](image)

7 What is the total number of electrons needed to completely fill all of the orbitals in an atom's second principal energy level?
   (1) 16  (2) 2  (3) 8  (4) 4

8 An atom in the excited state can have an electron configuration of
   (1) \( 1s^22s^2 \)  (3) \( 1s^22s^22p^5 \)
   (2) \( 1s^22p^1 \)  (4) \( 1s^22s^22p^6 \)

9 Compared to the charge and mass of a proton, an electron has
   (1) the same charge and a smaller mass
   (2) the same charge and the same mass
   (3) an opposite charge and a smaller mass
   (4) an opposite charge and the same mass
10 Which nuclear equation represents beta decay?
(1) $^{27}_{13}\text{Al} + \frac{4}{2}\text{He} \rightarrow ^{30}_{15}\text{P} + \frac{0}{0}\text{n}
(2) $^{238}_{92}\text{U} \rightarrow ^{234}_{90}\text{Th} + \frac{2}{0}\text{He}
(3) $^{14}_{6}\text{C} \rightarrow ^{14}_{6}\text{N} + \frac{0}{0}\text{e}
(4) $^{37}_{18}\text{Ar} + \frac{0}{0}\text{e} \rightarrow ^{37}_{17}\text{Cl}$

11 What is the total number of sublevels in the fourth principal energy level?
(1) 1 (3) 3
(2) 2 (4) 4

12 Which atom in the ground state has only one unpaired electron in its valence shell?
(1) aluminum (3) phosphorus
(2) silicon (4) sulfur

13 Which electron dot symbol represents the atom in Period 4 with the highest first ionization energy?
(1) \(\text{X}\) (3) \(\text{X}\)
(2) \(\text{X}\) (4) \(\text{X}\)

14 Which of these elements in Period 3 has the least tendency to attract electrons?
(1) Mg (3) S
(2) Al (4) Cl

15 Which terms describe a substance that has a low melting point and poor electrical conductivity?
(1) covalent and metallic
(2) covalent and molecular
(3) ionic and molecular
(4) ionic and metallic

16 Which chemical formula is both an empirical formula and a molecular formula?
(1) \(\text{CH}_4\)
(2) \(\text{C}_2\text{H}_6\)
(3) \(\text{CH}_3\text{COOH}\)
(4) \(\text{CH}_3\text{CH}_2\text{COOCH}_3\)

17 How many grams of sodium are represented by the symbol Na?
(1) 1.0 g of Na (3) 11 g of Na
(2) 10. g of Na (4) 23 g of Na

18 The shape and bonding in a diatomic bromine molecule are best described as
(1) symmetrical and polar
(2) symmetrical and nonpolar
(3) asymmetrical and polar
(4) asymmetrical and nonpolar

19 What is the total number of moles of hydrogen atoms contained in 1 mole of \((\text{NH}_4)_2\text{C}_2\text{O}_4\)?
(1) 6 (3) 8
(2) 2 (4) 4

20 Which element at STP is a poor conductor of electricity and has a relatively high electronegativity?
(1) Cu (3) Mg
(2) S (4) Fe

21 The element arsenic (As) has the properties of
(1) metals, only
(2) nonmetals, only
(3) both metals and nonmetals
(4) neither metals nor nonmetals

22 The elements calcium and strontium have similar chemical properties because they both have the same
(1) atomic number
(2) mass number
(3) number of valence electrons
(4) number of completely filled sublevels

23 Which element is malleable and ductile?
(1) S (3) Ge
(2) Si (4) Au

24 Which gas is monatomic at STP?
(1) nitrogen (3) fluorine
(2) neon (4) chlorine
25 Which physical characteristic of a solution may indicate the presence of a transition element?
   (1) its density
   (2) its color
   (3) its effect on litmus
   (4) its effect on phenolphthalein

26 The observed regularities in the properties of elements are periodic functions of their
   (1) atomic numbers
   (2) mass numbers
   (3) oxidation states
   (4) nonvalence electrons

27 Given the reaction:
   \[4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}\]
   What is the maximum number of moles of \(\text{H}_2\text{O}\) that can be produced when 2.0 moles of \(\text{NH}_3\)
   are completely reacted?
   (1) 1.0
   (2) 2.0
   (3) 3.0
   (4) 6.0

28 A compound has an empirical formula of \(\text{HCO}_2\)
   and a molecular mass of 90. grams per mole.
   What is the molecular formula of this compound?
   (1) \(\text{HCO}\)
   (2) \(\text{H}_2\text{C}_2\text{O}_4\)
   (3) \(\text{H}_4\text{C}_4\text{O}_8\)
   (4) \(\text{H}_6\text{C}_6\text{O}_{12}\)

29 What is the volume occupied by 2.00 moles of
   \(\text{Ar(g)}\) at STP?
   (1) 22.4 L
   (2) 44.8 L
   (3) 89.6 L
   (4) 179 L

30 What is the percent by mass of water present in
   1.0 mole of \(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}\)?
   (1) 10.7%
   (2) 12%
   (3) 21%
   (4) 79%

31 How many grams of \(\text{KCl}\) must be dissolved in
   200 grams of water to make a saturated solution
   at 60\(^\circ\)C?
   (1) 30 g
   (2) 45 g
   (3) 56 g
   (4) 90 g

32 Based on Reference Table G, which compound
   forms spontaneously under standard conditions?
   (1) \(\text{NaCl}\)
   (2) \(\text{HI}\)
   (3) \(\text{C}_2\text{H}_4\)
   (4) \(\text{NO}_2\)

33 Given the reaction:
   \[A(s) + B(\text{aq}) \rightarrow C(\text{aq}) + D(s)\]
   Which change would increase the rate of this reaction?
   (1) a decrease in pressure
   (2) an increase in pressure
   (3) a decrease in temperature
   (4) an increase in temperature

34 When a catalyst is added to a system at equilibrium, a decrease occurs in the
   (1) heat of the reaction
   (2) activation energy
   (3) potential energy of the reactants
   (4) potential energy of the products

35 Which reaction results in an increase in entropy?
   (1) \(\text{CO}_2(\text{g}) \rightarrow \text{CO}_2(\text{s})\)
   (2) \(\text{H}_2\text{O}(\ell) \rightarrow \text{H}_2\text{O}(\text{s})\)
   (3) \(\text{Ca(s)} + 2\text{H}_2\text{O}(\ell) \rightarrow \text{Ca(OH)}_2(\text{aq}) + \text{H}_2(\text{g})\)
   (4) \(\text{NaCl(aq)} + \text{AgNO}_3(\text{aq}) \rightarrow \text{AgCl(s)} + \text{NaNO}_3(\text{aq})\)

36 Given the reaction at equilibrium:
   \[X_3Y_2(\text{s}) \rightleftharpoons 3X^{2+}(\text{aq}) + 2Y^{3-}(\text{aq})\]
   What is the correct solubility product \((K_{sp})\) for this reaction?
   (1) \(K_{sp} = [X^{2+}]^3[Y^{3-}]^2\)
   (2) \(K_{sp} = [X^{2+}]^3 + 2[Y^{3-}]^2\)
   (3) \(K_{sp} = 3[X^{2+}]^2[Y^{3-}]\)
   (4) \(K_{sp} = 3[X^{2+}] + 2[Y^{3-}]\)

37 Which of the following Brönsted bases has the
   strongest conjugate acid?
   (1) \(\text{OH}^-\)
   (2) \(\text{F}^-\)
   (3) \(\text{HS}^-\)
   (4) \(\text{NO}_3^-\)
38 Which compound is a salt?

(1) Na₃PO₄  
(2) H₃PO₄  
(3) CH₃COOH  
(4) Ca(OH)₂

39 At 1 atm and 298 K, which of the Kₐ values listed below represents the strongest acid?

(1) 1.1 × 10⁻⁷  
(2) 1.8 × 10⁻⁵  
(3) 5.6 × 10⁻¹¹  
(4) 4.6 × 10⁻⁴

40 Which compound will conduct an electric current when dissolved in water?

(1) NaOH  
(2) C₂H₅OH  
(3) C₆H₁₂O₆  
(4) C₁₂H₂₂O₁₁

41 According to the Arrhenius theory of acids, citric acid in oranges and acetic acid in vinegar are classified as acids because their aqueous solutions contain

(1) hydrogen ions  
(2) hydrogen atoms  
(3) hydroxide ions  
(4) hydroxide atoms

42 If 20. milliliters of a 1.0 M solution of HCl is exactly neutralized by 40. milliliters of NaOH, the molarity of the NaOH solution is

(1) 1.0 M  
(2) 2.0 M  
(3) 0.50 M  
(4) 4.0 M

43 Given the reaction:

CH₃COOH(aq) + H₂O(ℓ) ⇌ CH₃COO⁻(aq) + H₃O⁺(aq)

In this reaction, which substances are Brønsted-Lowry bases?

(1) CH₃COOH(aq) and H₂O(ℓ)  
(2) CH₃COOH(aq) and CH₃COO⁻(aq)  
(3) H₂O(ℓ) and H₃O⁺(aq)  
(4) H₂O(ℓ) and CH₃COO⁻(aq)

44 What is the oxidation number of sulfur in H₂SO₄?

(1) 0  
(2) -2  
(3) +6  
(4) +4

45 Given the unbalanced equation:

___Br₂ + ___Sn → ___Br⁻ + ___Sn²⁺

When the equation is correctly balanced using the smallest whole-number coefficients, the coefficient of Br⁻ is

(1) 1  
(2) 2  
(3) 3  
(4) 4

46 Given the redox reaction in an electrochemical cell:

Ni(s) + Pb²⁺(aq) ⇌ Ni²⁺(aq) + Pb(s)

A salt bridge is used to connect

(1) Ni(s) and Pb(s)  
(2) Pb²⁺(aq) and Ni²⁺(aq)  
(3) Ni(s) and Ni²⁺(aq)  
(4) Pb²⁺(aq) and Pb(s)

47 Which half-reaction correctly represents oxidation?

(1) Sn²⁺ + 2e⁻ → Sn⁰  
(2) Sn⁴⁺ + 2e⁻ → Sn²⁺  
(3) Sn²⁺ → Sn⁰ + 2e⁻  
(4) Sn²⁺ → Sn⁴⁺ + 2e⁻

48 In a redox reaction, the reducing agent will

(1) lose electrons and be reduced  
(2) lose electrons and be oxidized  
(3) gain electrons and be reduced  
(4) gain electrons and be oxidized

49 Which element is present in all organic compounds?

(1) hydrogen  
(2) nitrogen  
(3) oxygen  
(4) carbon

50 Which products are obtained when CH₄(g) burns completely in an excess of oxygen?

(1) CO and H₂O  
(2) CO and C  
(3) CO₂ and H₂O  
(4) CO₂ and CO
51 Which hydrocarbon is a member of the alkene series?

(1) C₂H₂  (3) C₄H₁₀
(2) C₃H₆  (4) C₅H₁₂

52 Which formula represents butane?

(1) CH₃CH₃
(2) CH₂CH₂CH₃
(3) CH₃CH₂CH₂CH₃
(4) CH₃CH₂CH₂CH₂CH₃

53 A hydrocarbon molecule is considered to be saturated if the molecule contains

(1) single covalent bonds, only
(2) a double covalent bond, only
(3) a triple covalent bond
(4) single and double covalent bonds

Note that questions 54 through 56 have only three choices.

54 In a chemical reaction, as a species is oxidized, its oxidation number

(1) decreases
(2) increases
(3) remains the same

55 Given the reaction:

Zn(s) + HCl(aq) → ZnCl₂(aq) + H₂(g)

As the concentration of the HCl(aq) decreases at constant temperature, the rate of the reaction

(1) decreases
(2) increases
(3) remains the same

56 As a chemical bond forms between two hydrogen atoms in a system, energy is released and the stability of the system

(1) decreases
(2) increases
(3) remains the same
Part II

This part consists of twelve groups, each containing five questions. Each group tests a major area of the course. Choose seven of these twelve groups. Be sure that you answer all five questions in each group chosen. Record the answers to these questions on the separate answer sheet in accordance with the directions on the front page of this booklet. [35]

Group 1 — Matter and Energy

If you choose this group, be sure to answer questions 57–61.

57 The graph below represents the uniform heating of a substance, starting with the substance as a solid below its melting point.

![Graph showing phases of a substance](image)

Which segment of the graph represents a time when both the solid and liquid phases are present?

(1) AB  
(2) BC  
(3) DE  
(4) EF

58 A gas at STP has a volume of 1.0 liter. If the pressure is doubled and the temperature remains constant, the new volume of the gas will be

(1) 0.25 L  
(2) 2.0 L  
(3) 0.50 L  
(4) 4.0 L

59 What is the normal boiling point of methane?

(1) 20 K  
(2) 109 K  
(3) 121 K  
(4) 240 K

60 Which gas is least likely to obey the ideal gas laws at very high pressures and very low temperatures?

(1) He  
(2) Ne  
(3) Kr  
(4) Xe

61 The diagram below shows the collection of H₂ gas over water at 25°C. The total pressure in the tube is 760.0 torr.

![Diagram of gas collection](image)

What is the pressure exerted by the hydrogen gas alone?

(1) 23.8 torr  
(2) 736.2 torr  
(3) 760.0 torr  
(4) 793.8 torr
Group 2 — Atomic Structure

If you choose this group, be sure to answer questions 62–66.

62 In the ground state, which element's atoms have five completely filled orbitals?
   (1) Li  (2) B  (3) C  (4) Ne

63 Which element has no stable isotopes?
   (1) Ar  (2) Kr  (3) Rn  (4) Xe

64 When alpha particles are used to bombard gold foil, most of the alpha particles pass through undeflected. This result indicates that most of the volume of a gold atom consists of
   (1) neutrons  (2) protons  (3) deuterons  (4) unoccupied space

65 What mass of a 60.0-gram sample of $^{16}$N will remain unchanged after 28.8 seconds?
   (1) 3.75 g  (2) 7.50 g  (3) 15.0 g  (4) 30.0 g

66 When an alpha particle is emitted by an atom, the atomic number of the atom will
   (1) decrease by 2  (2) increase by 2  (3) decrease by 4  (4) increase by 4

Group 3 — Bonding

If you choose this group, be sure to answer questions 67–71.

67 Which compound has the greatest degree of ionic character?
   (1) NaF  (2) MgF$_2$  (3) AlF$_3$  (4) SiF$_4$

68 Which molecule is a dipole?
   (1) $\text{H} \cdots \text{S}$
   (2) $\text{H} \cdots \text{C} \cdots \text{H}$
   (3) $\text{O} \cdots \text{C} \cdots \text{O}$
   (4) $\text{N} \equiv \text{N}$

69 Which substance can form a coordinate covalent bond with a hydrogen ion?
   (1) H$_2$  (2) He  (3) NH$_3$  (4) CH$_4$

70 What is the chemical formula for copper (II) chlorate?
   (1) Cu$_2$Cl  (2) CuCl$_2$  (3) Cu$_2$ClO$_3$  (4) Cu(ClO$_3$)$_2$

71 Which element has a crystalline lattice composed of positive ions through which electrons flow freely?
   (1) bromine  (2) calcium  (3) carbon  (4) sulfur
Group 4 — Periodic Table

If you choose this group, be sure to answer questions 72–76.

72 In which area of the Periodic Table are the elements with the strongest nonmetallic properties located?
   (1) lower left  (3) lower right
   (2) upper left  (4) upper right

73 All of the atoms of the elements in Period 2 have the same number of:
   (1) protons
   (2) neutrons
   (3) valence electrons
   (4) occupied principal energy levels

74 Which of these metals loses electrons most readily?
   (1) calcium
   (2) magnesium
   (3) potassium
   (4) sodium

75 If $M$ represents an element in Group 2, the formula of its chloride would be:
   (1) $MCl$
   (2) $MCl_2$
   (3) $M_2Cl$
   (4) $M_2Cl_2$

76 Which statement best compares the atomic radius of a potassium atom and the atomic radius of a calcium atom?
   (1) The radius of the potassium atom is smaller because of its smaller nuclear charge.
   (2) The radius of the potassium atom is smaller because of its larger nuclear charge.
   (3) The radius of the potassium atom is larger because of its smaller nuclear charge.
   (4) The radius of the potassium atom is larger because of its larger nuclear charge.

Group 5 — Mathematics of Chemistry

If you choose this group, be sure to answer questions 77–81.

77 The table below lists four gases and their molecular mass.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Molecular Mass (g/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>17</td>
</tr>
<tr>
<td>D</td>
<td>20</td>
</tr>
</tbody>
</table>

Which gas diffuses at the slowest rate at STP?
   (1) $A$
   (2) $B$
   (3) $C$
   (4) $D$

78 At 1 atmosphere of pressure, 25.0 grams of a compound at its normal boiling point is converted to a gas by the addition of 8,180 calories. What is the heat of vaporization for this compound, in calories per gram?
   (1) 25.0 cal/g
   (2) 327 cal/g
   (3) 540. cal/g
   (4) 8,180 cal/g

79 If 11 grams of a gas occupies 5.6 liters at STP, what is its gram molecular mass?
   (1) 11 g/mol
   (2) 22 g/mol
   (3) 44 g/mol
   (4) 88 g/mol

80 An 80-g gram sample of water at 10.0°C absorbs 400 calories of heat energy. What is the final temperature of the water?
   (1) 50.0°C
   (2) 15°C
   (3) 5.0°C
   (4) 4.0°C

81 Given the reaction: $4Al + 3O_2 \rightarrow 2Al_2O_3$

What is the total number of moles of aluminum oxide that can be formed when 54 grams of aluminum reacts completely with oxygen?
   (1) 1.0 mole
   (2) 2.0 moles
   (3) 3.0 moles
   (4) 4.0 moles
Group 6 — Kinetics and Equilibrium

If you choose this group, be sure to answer questions 82-86.

82 Based on Reference Table E, which salt is least soluble?

(1) FeCO₃
(2) Na₂CO₃
(3) BaCl₂
(4) CaCl₂

83 Given the reaction at equilibrium:

\[ \text{AgI(s)} \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \]

What happens as KI(s) is added to the solution?

(1) The concentration of Ag⁺(aq) decreases and the concentration of I⁻(aq) increases.
(2) The concentration of Ag⁺(aq) decreases and the concentration of I⁻(aq) remains the same.
(3) The concentration of Ag⁺(aq) increases and the concentration of I⁻(aq) increases.
(4) The concentration of Ag⁺(aq) increases and the concentration of I⁻(aq) remains the same.

84 A reaction will be spontaneous if it results in products that have

(1) lower potential energy and less randomness
(2) lower potential energy and more randomness
(3) greater potential energy and less randomness
(4) greater potential energy and more randomness

85 In the diagram below, which letter represents the activation energy for the reverse reaction?

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

86 Given the equation: \( \Delta G = \Delta H - T\Delta S \)

The \( \Delta S \) represents a change in

(1) entropy
(2) free energy
(3) enthalpy
(4) temperature
Group 7 — Acids and Bases

If you choose this group, be sure to answer questions 87–91.

87 Which relationship is present in a solution that has a pH of 7?

(1) \([\text{H}^+] = [\text{OH}^-]\)
(2) \([\text{H}^+] > [\text{OH}^-]\)
(3) \([\text{H}^+] < [\text{OH}^-]\)
(4) \([\text{H}^+] + [\text{OH}^-] = K_w\)

88 According to Reference Table N, which metal will react spontaneously with hydrochloric acid?

(1) Ag
(2) Hg
(3) Cu
(4) Ni

89 According to Reference Table L, which substance is amphoteric (amphiprotic)?

(1) HI
(2) OH\(^{-}\)
(3) HF
(4) NH\(_4\)\(^{+}\)

90 The pH of a 0.1 M solution is 11. What is the concentration of H\(_3\)O\(^{+}\) ions, in moles per liter?

(1) \(1 \times 10^{-1}\)
(2) \(1 \times 10^{-3}\)
(3) \(1 \times 10^{-11}\)
(4) \(1 \times 10^{-13}\)

91 Red litmus will turn blue when placed in an aqueous solution of

(1) KCl
(2) KOH
(3) CH\(_3\)OH
(4) CH\(_3\)COOH

Group 8 — Redox and Electricity

If you choose this group, be sure to answer questions 92–96.

92 Equilibrium is attained in a chemical cell when the cell voltage is equal to

(1) +1.00 V
(2) +2.00 V
(3) 0.00 V
(4) −1.00 V

93 Given the reaction:

\[3\text{Zn}(s) + 2\text{Au}^{3+}(aq) \rightarrow 3\text{Zn}^{2+}(aq) + 2\text{Au}(s)\]

What is the maximum cell voltage (\(E^0\)) for the overall reaction?

(1) +1.50 V
(2) +2.26 V
(3) +5.28 V
(4) +0.74 V

94 Based on Reference Table N, which ion will oxidize Pb to Pb\(^{2+}\)?

(1) Cu\(^{2+}\)
(2) Ni\(^{2+}\)
(3) Fe\(^{2+}\)
(4) Zn\(^{2+}\)

95 Which net reaction occurs by the process of electrolysis?

(1) 2H\(_2\)O(\(\ell\)) → 2H\(_2\)(g) + O\(_2\)(g)
(2) 2HgO(s) → 2Hg(\(\ell\)) + O\(_2\)(g)
(3) 2KClO\(_3\)(\(\ell\)) → 2KCl(s) + 3O\(_2\)(g)
(4) MgCO\(_3\)(s) → MgO(s) + CO\(_2\)(s)

96 Which reaction is a nonspontaneous redox reaction under standard conditions?

(1) Sn(s) + 2HCl(aq) → SnCl\(_2\)(aq) + H\(_2\)(g)
(2) Cu(s) + 2HCl(aq) → CuCl\(_2\)(aq) + H\(_2\)(g)
(3) Ba(s) + 2HCl(aq) → BaCl\(_2\)(aq) + H\(_2\)(g)
(4) Mg(s) + 2HCl(aq) → MgCl\(_2\)(aq) + H\(_2\)(g)
Group 9 — Organic Chemistry
If you choose this group, be sure to answer questions 97–101.

97 Which structural formula represents a dihydroxy alcohol?

- (1) \( \text{H} - \text{C} - \text{C} - \text{H} \)
  \[ \text{H OH} \]
- (2) \( \text{H} - \text{C} - \text{C} - \text{H} \)
  \[ \text{OH OH} \]
- (3) \( \text{H} - \text{C} - \text{C} - \text{H} \)
  \[ \text{OH OH OH} \]
- (4) \( \text{H} - \text{C} - \text{C} - \text{H} \)
  \[ \text{OH OH} \]

99 Which set contains one natural polymer and one synthetic polymer?

- (1) cellulose and starch
- (2) polyethylene and nylon
- (3) protein and starch
- (4) protein and nylon

100 Aldehydes can be synthesized by the oxidation of

- (1) primary alcohols
- (2) secondary alcohols
- (3) organic acids
- (4) inorganic acids

101 What is the general formula for an ether?

- (1) \( R_1 - O - R_2 \)
- (2) \( R - \text{OH} \)
- (3) \( R - C - H \)
- (4) \( R - C - O \)
  \[ \text{O} \]
Group 10 — Applications of Chemical Principles

If you choose this group, be sure to answer questions 102–106.

102 Which type of chemical reaction occurs when an iron nail rusts?
   (1) neutralization  
   (2) condensation  
   (3) oxidation-reduction  
   (4) ionization-dissociation

103 Which of these gases obtained from petroleum is also known as bottled gas?
   (1) ethane  
   (2) ethene  
   (3) propane  
   (4) propene

104 Which element is obtained only by the electrolysis of its fused salt?
   (1) K  
   (2) Zn  
   (3) Cr  
   (4) Fe

105 Which metals occur naturally as sulfide ores and then are changed to oxides and reduced to free metals?
   (1) Au and Ag  
   (2) K and Li  
   (3) Cu and Zn  
   (4) Cu and K

106 Which compound is produced in the first step of the contact process?
   (1) SO₂  
   (2) SO₃  
   (3) H₂S  
   (4) H₂SO₃

Group 11 — Nuclear Chemistry

If you choose this group, be sure to answer questions 107–111.

107 Which substance can be used as a fuel in a fission reactor?
   (1) ²H  
   (2) ⁴H  
   (3) ²²⁶Ra  
   (4) ²³⁵U

108 Which characteristics should a radioactive isotope have if it is to be used for medical diagnosis?
   (1) short half-life and slow elimination from the body  
   (2) short half-life and fast elimination from the body  
   (3) long half-life and slow elimination from the body  
   (4) long half-life and fast elimination from the body

109 Which particles can be accelerated in an electric or magnetic field?
   (1) alpha and gamma  
   (2) beta and neutron  
   (3) alpha and beta  
   (4) beta and gamma

110 Which is a gaseous radioactive waste product that is released into the atmosphere after it has decayed to a safe radiation level?
   (1) radon-222  
   (2) radium-226  
   (3) cesium-137  
   (4) cobalt-60

111 During a fission reaction, which type of particle is captured by a nucleus?
   (1) deuteron  
   (2) electron  
   (3) neutron  
   (4) proton
112 Which diagram best represents a piece of glass tubing that has been properly bent?

(1)  

(2)  

(3)  

(4)  

114 The diagram below shows a portion of a buret.

What is the meniscus reading in milliliters?

(1) 16.00  
(2) 16.40  
(3) 17.00  
(4) 17.60

113 Beakers A, B, C, and D shown below each contain a different solution.

NaCl(aq)  
C₆H₁₂O₆(aq)  
CH₃OH(aq)  
CH₃COOH(aq)  

A  
B  
C  
D

The bulb will glow when the conductivity apparatus is placed into which beakers?

(1) A and B  
(2) B and C  
(3) A and D  
(4) C and D

115 The volume of a gas sample is 22.4 liters at STP. The density of the gas is 1.34 grams per liter. What is the mass of the gas sample, expressed to the correct number of significant figures?

(1) 16.7 g  
(2) 17 g  
(3) 30 g  
(4) 30.0 g

116 A student determined that the percent of H₂O in a hydrate was 39.0%. The percent of H₂O in this hydrate is 36.0% according to an accepted chemistry reference. What is the student's percent of error?

(1) 9.1%  
(2) 8.3%  
(3) 3.0%  
(4) 11%
Record all of your answers on this answer sheet in accordance with the instructions on the front cover of the test booklet.

### Part I (65 credits)

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   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Your answers for Part II should be placed in the proper spaces on the back of this sheet.
Part II (35 credits)

Answer the questions in only seven of the twelve groups in this part. Be sure to mark the answers to the groups of questions you choose in accordance with the instructions on the front cover of the test booklet. Leave blank the five groups of questions you do not choose to answer.

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I do hereby affirm, at the close of this examination, that I had no unlawful knowledge of the questions or answers prior to the examination and that I have neither given nor received assistance in answering any of the questions during the examination.

Signature

Chem.-Aug. '98 [15] [OVER]
FOR TEACHERS ONLY

The University of the State of New York
REGENTS HIGH SCHOOL EXAMINATION
CHEMISTRY

Thursday, August 13, 1998 — 12:30 to 3:30 p.m., only

SCORING KEY

Part I
Refer to the table on the answer sheet for the number of credits to be given on Part I.

<table>
<thead>
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Directions to the teacher:
Use only red ink or red pencil in rating Regents examination papers. Do not correct the student's work by making insertions or changes of any kind.
Scan each answer sheet to make certain that the student has marked only one answer for each question. If a student has marked two or more answers with an X in ink, draw a red line through the row of numbers for that question to indicate that no credit is to be allowed for that question when the answer sheet is scored.
To facilitate scoring, the scoring key has been printed in the same format as the answer sheet. The scoring key may be made into a scoring stencil by punching out the correct answers. Be sure that the stencil is aligned with the answer sheet so that the holes correspond to the correct answers. To aid in proper alignment, punch out the first and last item numbers in each part and place the stencil on the answer sheet so that these item numbers appear through the appropriate holes.
Part II

Allow a total of 35 credits, one credit for each question, for only seven of the twelve groups in this part. If more than seven groups are answered, only the first seven answered should be considered.

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Chem.—Aug. '98