18

The Princeton Review AP Chemistry Practice Exam 1

CHEMISTRY

Three hours are allotted for this examination: 1 hour and 30 minutes for Section I, which consists of multiple-choice questions, and 1 hour and 35 minutes for Section II, which consists of problems and essay questions.

SECTION I

Time—1 hour and 30 minutes
Number of questions—75
Percent of total grade—50

This examination contains 75 multiple-choice questions. Therefore, for the examination questions, please be careful to fill in only the ovals that are preceded by numbers 1 through 75 on your answer sheet.

General Instructions

CALCULATORS MAY NOT BE USED IN THIS PART OF THE EXAMINATION.

INDICATE ALL YOUR ANSWERS TO QUESTIONS IN SECTION I ON THE SEPARATE ANSWER SHEET.
No credit will be given for anything written in this examination booklet, but you may use the booklet for notes or scratchwork. After you have decided which of the suggested answers is best, COMPLETELY fill in the corresponding oval on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely.

Example:

Chicago is a

(A) state
(B) city
(C) country
(D) continent
(E) village

Sample Answer

Ⓐ ● Ⓒ Ⓓ Ⓔ

Many candidates wonder whether or not to guess the answer to questions about which they are not certain. In this section of the examination, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly. It is improbable, therefore, that mere guessing will improve your score significantly; it may even lower your score, and it does take time. If, however, you are not sure of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices as wrong, your chance of getting the right answer is improved, and it may be to your advantage to answer such a question.

Use your time effectively, working as rapidly as you can without losing accuracy. Do not spend too much time on questions that are too difficult. Go on to other questions and come back to the difficult ones later if you have time. It is not expected that everyone will be able to answer all the multiple-choice questions.

GO ON TO THE NEXT PAGE

CHEMISTRY
SECTION I

Time—1 hour and 30 minutes

Material in the following table may be useful in answering the questions in this section of the examination.

PERIODIC CHART OF THE ELEMENTS

1 **H** 1.0																	2 **He** 4.0
3 **Li** 6.9	4 **Be** 9.0											5 **B** 10.8	6 **C** 12.0	7 **N** 14.0	8 **O** 16.0	9 **F** 19.0	10 **Ne** 20.2
11 **Na** 23.0	12 **Mg** 24.3											13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 39.9
19 **K** 39.1	20 **Ca** 40.1	21 **Sc** 45.0	22 **Ti** 47.9	23 **V** 50.9	24 **Cr** 52.0	25 **Mn** 54.9	26 **Fe** 55.8	27 **Co** 58.9	28 **Ni** 58.7	29 **Cu** 63.5	30 **Zn** 65.4	31 **Ga** 69.7	32 **Ge** 72.6	33 **As** 74.9	34 **Se** 79.0	35 **Br** 79.9	36 **Kr** 83.8
37 **Rb** 85.5	38 **Sr** 87.6	39 **Y** 88.9	40 **Zr** 91.2	41 **Nb** 92.9	42 **Mo** 95.9	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 ***La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0	89 **†Ac** 227.0															

*Lanthanum Series

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0

†Actinium Series

90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (258)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

DO NOT DETACH FROM BOOK.

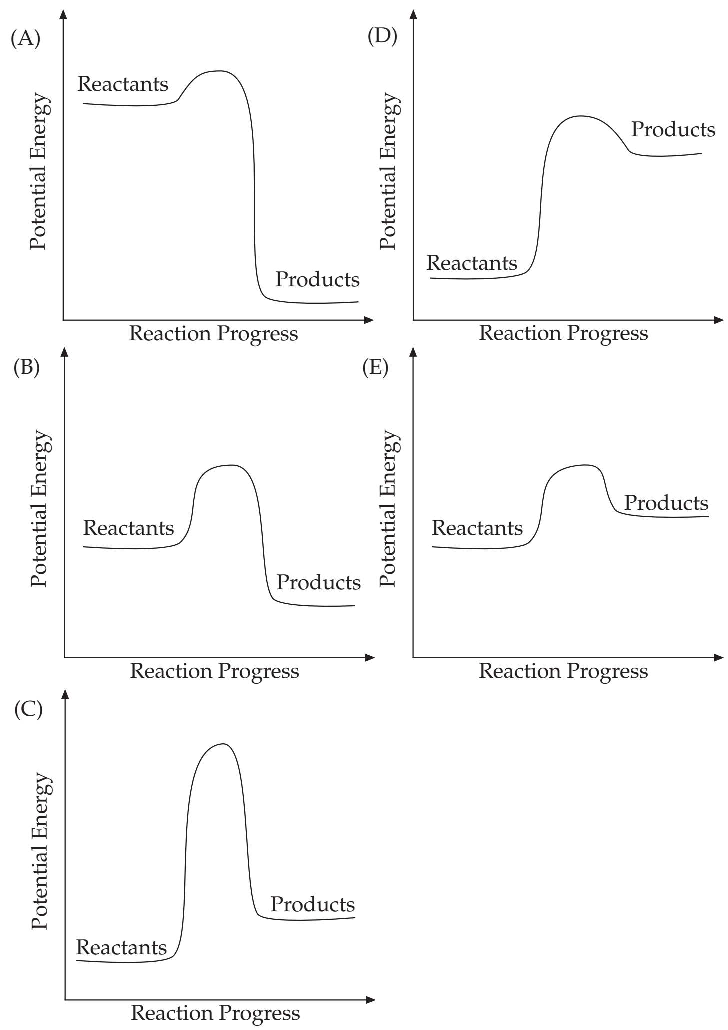
GO ON TO THE NEXT PAGE

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 and fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1–3 are based on the following energy diagrams.



1. This reaction has the largest activation energy.

2. This is the most exothermic reaction.

3. This reaction has the largest positive value for ΔH.

GO ON TO THE NEXT PAGE

Questions 4–6 refer to the following configurations.

(A) $1s^2\ 2s^2 2p^6$
(B) $1s^2\ 2s^2 2p^6\ 3s^2$
(C) $1s^2\ 2s^2 2p^6\ 3s^2 3p^4$
(D) $1s^2\ 2s^2 2p^6\ 3s^2 3p^6$
(E) $1s^2\ 2s^2 2p^6\ 3s^2 3p^6\ 4s^2$

4. The ground state configuration of an atom of a paramagnetic element.

5. The ground state configuration for both a potassium ion and a chloride ion.

6. An atom that has this ground-state electron configuration will have the smallest atomic radius of those listed above.

Questions 7–10 refer to the following molecules.

(A) CO_2
(B) H_2O
(C) SO_2
(D) NO_2
(E) O_2

7. In this molecule, oxygen forms sp^3 hybrid orbitals.

8. This molecule contains one unpaired electron.

9. This molecule contains no pi (π) bonds.

10. Oxygen has an oxidation state of zero in the molecule.

Questions 11–14 refer to the following solutions.

(A) A solution with a pH of 1
(B) A solution with a pH of greater than 1 and less than 7
(C) A solution with a pH of 7
(D) A solution with a pH of greater than 7 and less than 13
(E) A solution with a pH of 13

For CH_3COOH, $K_a = 1.8 \times 10^{-5}$

For NH_3, $K_b = 1.8 \times 10^{-5}$

11. A solution prepared by mixing equal volumes of 0.2-molar HCl and 0.2-molar NH_3.

12. A solution prepared by mixing equal volumes of 0.2-molar HNO_3 and 0.2-molar NaOH.

13. A solution prepared by mixing equal volumes of 0.2-molar HCl and 0.2-molar NaCl.

14. A solution prepared by mixing equal volumes of 0.2-molar CH_3COOH and 0.2-molar NaOH.

GO ON TO THE NEXT PAGE

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 and fill in the corresponding oval on the answer sheet.

15. A pure sample of $KClO_3$ is found to contain 71 grams of chlorine atoms. What is the mass of the sample?

(A) 122 grams
(B) 170 grams
(C) 209 grams
(D) 245 grams
(E) 293 grams

16. Which of the following experimental procedures is used to separate two substances by taking advantage of their differing boiling points?

(A) Titration
(B) Distillation
(C) Filtration
(D) Decantation
(E) Hydration

17. Which of the following sets of quantum numbers (n, l, m_l, m_s) best describes the highest energy valence electron in a ground-state aluminum atom?

(A) 2, 0, 0, $\frac{1}{2}$
(B) 2, 1, 0, $\frac{1}{2}$
(C) 3, 0, 0, $\frac{1}{2}$
(D) 3, 0, 1, $\frac{1}{2}$
(E) 3, 1, 1, $\frac{1}{2}$

18. A chemist analyzed the carbon–carbon bond in C_2H_6 and found that it had a bond energy of 350 kJ/mol and a bond length of 1.5 angstroms. If the chemist performed the same analysis on the carbon–carbon bond in C_2H_2, how would the results compare?

(A) The bond energies and lengths for C_2H_2 would be the same as those of C_2H_6.
(B) The bond energy for C_2H_2 would be smaller, and the bond length would be shorter.
(C) The bond energy for C_2H_2 would be greater, and the bond length would be longer.
(D) The bond energy for C_2H_2 would be smaller, and the bond length would be longer.
(E) The bond energy for C_2H_2 would be greater, and the bond length would be shorter.

19. $2\ MnO_4^- + 5\ SO_3^{2-} + 6\ H^+ \rightarrow 2\ Mn^{2+} + 5\ SO_4^{2-} + 3\ H_2O$

Which of the following statements is true regarding the reaction given above?

(A) MnO_4^- acts as the reducing agent.
(B) H^+ acts as the oxidizing agent.
(C) SO_3^{2-} acts as the reducing agent.
(D) Manganese is oxidized
(E) Sulfur is reduced.

20. Which of the following can function as both a Brønsted-Lowry acid and Brønsted-Lowry base?

(A) HCl
(B) H_2SO_4
(C) HSO_3^-
(D) SO_4^{2-}
(E) H^+

GO ON TO THE NEXT PAGE

21. Which of the following substances experiences the strongest attractive intermolecular forces?

(A) H_2
(B) N_2
(C) CO_2
(D) NH_3
(E) CH_4

22. A mixture of gases at equilibrium over water at 43°C contains 9.0 moles of nitrogen, 2.0 moles of oxygen, and 1.0 mole of water vapor. If the total pressure exerted by the gases is 780 mmHg, what is the vapor pressure of water at 43°C?

(A) 65 mmHg
(B) 130 mmHg
(C) 260 mmHg
(D) 580 mmHg
(E) 720 mmHg

23. $...MnO_4^- + ...e^- + ...H^+ \rightarrow ...Mn^{2+} + ...H_2O$

When the half-reaction above is balanced, what is the coefficient for H^+ if all the coefficients are reduced to the lowest whole number?

(A) 3
(B) 4
(C) 5
(D) 8
(E) 10

24. The boiling point of water is known to be lower at high elevations. This is because

(A) hydrogen bonds are weaker at high elevations.
(B) the heat of fusion is lower at high elevations.
(C) the vapor pressure of water is higher at high elevations.
(D) the atmospheric pressure is lower at high elevations.
(E) water is denser at high elevations.

25. A student examined 2.0 moles of an unknown carbon compound and found that the sample contained 48 grams of carbon, 64 grams of oxygen, and 8 grams of hydrogen. Which of the following could be the molecular formula of the compound?

(A) CH_2O
(B) CH_2OH
(C) CH_3COOH
(D) CH_3CO
(E) C_2H_5OH

26. $S(s) + O_2(g) \rightarrow SO_2(g) \qquad \Delta H = x$

$S(s) + \frac{3}{2} O_2(g) \rightarrow SO_3(g) \qquad \Delta H = y$

Based on the information above, what is the standard enthalpy change for the following reaction?

$$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

(A) $x - y$
(B) $y - x$
(C) $2x - y$
(D) $2x - 2y$
(E) $2y - 2x$

27. How much water must be added to a 50.0 ml solution of 0.60 *M* HNO_3 to produce a 0.40 *M* solution of HNO_3?

(A) 25 ml
(B) 33 ml
(C) 50 ml
(D) 67 ml
(E) 75 ml

28. In which of the following equilibria would the concentrations of the products be increased if the volume of the system were decreased at constant temperature?

(A) $H_2(g) + Cl_2(g) \rightleftharpoons 2\ HCl(g)$
(B) $2\ CO(g) + O_2(g) \rightleftharpoons 2\ CO_2(g)$
(C) $NO(g) + O_3(g) \rightleftharpoons NO_2(g) + O_2(g)$
(D) $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$
(E) $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$

GO ON TO THE NEXT PAGE

29. A 100 ml sample of 0.10 molar NaOH solution was added to 100 ml of 0.10 molar $H_3C_6H_5O_7$. After equilibrium was established, which of the ions listed below was present in the greatest concentration?

(A) $H_2C_6H_5O_7^-$
(B) $HC_6H_5O_7^{2-}$
(C) $C_6H_5O_7^{3-}$
(D) OH^-
(E) H^+

30. Which of the following can be determined directly from the difference between the boiling point of a pure solvent and the boiling point of a solution of a nonionic solute in the solvent, if k_b for the solvent is known?

I. The mass of solute in the solution
II. The molality of the solution
III. The volume of the solution

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I and III only

31. The value of the equilibrium constant K_{eq} is greater than 1 for a certain reaction under standard state conditions. Which of the following statements must be true regarding the reaction?

(A) $\Delta G°$ is negative.
(B) $\Delta G°$ is positive.
(C) $\Delta G°$ is equal to zero.
(D) $\Delta G°$ is negative if the reaction is exothermic and positive if the reaction is endothermic.
(E) $\Delta G°$ is negative if the reaction is endothermic and positive if the reaction is exothermic.

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

(A) 0.1 *m* NaOH
(B) 0.1 *m* HF
(C) 0.1 *m* Na_2SO_4
(D) 0.1 *m* $KC_2H_3O_2$
(E) 0.1 *m* NH_4NO_3

33. The molecular formula for hydrated iron (III) oxide, or rust, is generally written as $Fe_2O_3 \bullet x\, H_2O$ because the water content in rust can vary. If a 1-molar sample of hydrated iron (III) oxide is found to contain 108 g of H_2O, what is the molecular formula for the sample?

(A) $Fe_2O_3 \bullet H_2O$
(B) $Fe_2O_3 \bullet 3\,H_2O$
(C) $Fe_2O_3 \bullet 6\,H_2O$
(D) $Fe_2O_3 \bullet 10\,H_2O$
(E) $Fe_2O_3 \bullet 12\,H_2O$

34. In which of the following reactions does the greatest increase in entropy take place?

(A) $H_2O(l) \rightarrow H_2O(g)$
(B) $2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$
(C) $CaH_2(s) + H_2O(l) \rightarrow Ca(OH)_2(s) + H_2O(g)$
(D) $NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$
(E) $2\,HCl(g) \rightarrow H_2(g) + Cl_2(g)$

35. The density of a sample of water decreases as it is heated above a temperature of 4°C. Which of the following will be true of an aqueous solution of $NaC_2H_3O_2$ when it is heated from 10°C to 60°C?

(A) The molarity will increase.
(B) The molarity will decrease
(C) The molality will increase.
(D) The molality will decrease.
(E) The molarity and molality will remain unchanged.

36. $$\ldots + n \rightarrow {}^{7}_{3}\text{Li} + {}^{4}_{2}\text{He}$$

For the nuclear reaction shown above, what is the missing reactant?

(A) ${}^{9}_{4}\text{Be}$
(B) ${}^{9}_{5}\text{B}$
(C) ${}^{10}_{4}\text{Be}$
(D) ${}^{10}_{5}\text{B}$
(E) ${}^{11}_{5}\text{B}$

GO ON TO THE NEXT PAGE

37. A boiling-water bath is sometimes used instead of a flame in heating objects. Which of the following could be an advantage of a boiling-water bath over a flame?

(A) The relatively low heat capacity of water will cause the object to become hot more quickly.
(B) The relatively high density of water will cause the object to become hot more quickly.
(C) The volume of boiling water remains constant over time.
(D) The temperature of boiling water remains constant at 100°C.
(E) The vapor pressure of boiling water is equal to zero.

38. The addition of a catalyst to a chemical reaction will bring about a change in which of the following characteristics of the reaction?

I. The activation energy
II. The enthalpy change
III. The value of the equilibrium constant

(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) II and III only

39. $2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$

The reaction above occurs by the following two-step process:

Step I: $NO(g) + O_2(g) \rightarrow NO_3(g)$

Step II: $NO_3(g) + NO(g) \rightarrow 2\,NO_2(g)$

Which of the following is true of Step II if it is the rate-limiting step?

(A) Step II has a lower activation energy and occurs more slowly than Step I.
(B) Step II has a higher activation energy and occurs more slowly than Step I.
(C) Step II has a lower activation energy and occurs more quickly than Step I.
(D) Step II has a higher activation energy and occurs more quickly than Step I.
(E) Step II has the same activation energy and occurs at the same speed as Step I.

40. $C_3H_7OH + ...O_2 \rightarrow ...CO_2 + ...H_2O$

One mole of C_3H_7OH underwent combustion as shown in the reaction above. How many moles of oxygen were required for the reaction?

(A) 2 moles

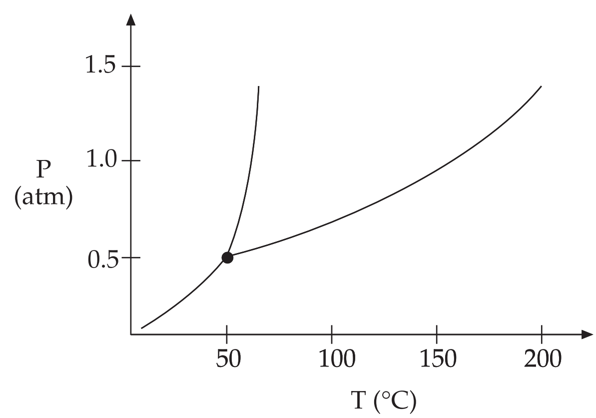
(B) 3 moles

(C) $\frac{7}{2}$ moles

(D) $\frac{9}{2}$ moles

(E) 5 moles

Questions 41–42 refer to the phase diagram below.



41. If the pressure of the substance shown in the diagram is decreased from 1.0 atmosphere to 0.5 atmosphere at a constant temperature of 100°C, which phase change will occur?

(A) Freezing
(B) Vaporization
(C) Condensation
(D) Sublimation
(E) Deposition

GO ON TO THE NEXT PAGE

42. Under what conditions can all three phases of the substance shown in the diagram exist simultaneously in equilibrium?

(A) Pressure = 1.0 atm, temperature = 150°C
(B) Pressure = 1.0 atm, temperature = 100°C
(C) Pressure = 1.0 atm, temperature = 50°C
(D) Pressure = 0.5 atm, temperature = 100°C
(E) Pressure = 0.5 atm, temperature = 50°C

43. Which of the following statements regarding atomic theory is NOT true?

(A) The Bohr model of the atom was based on Planck's quantum theory.
(B) Rutherford's experiments with alpha particle scattering led to the conclusion that positive charge was concentrated in an atom's nucleus.
(C) Heisenberg's uncertainty principle describes the equivalence of mass and energy.
(D) Millikan's oil drop experiment led to the calculation of the charge on an electron.
(E) Thomson's cathode ray experiments confirmed the existence of the electron.

44.

Time (min)	[*A*] *M*
0	0.50
10	0.36
20	0.25
30	0.18
40	0.13

Reactant A underwent a decomposition reaction. The concentration of A was measured periodically and recorded in the chart above. Based on the data in the chart, which of the following statements is NOT true?

(A) The reaction is first order in [*A*].
(B) The reaction is first order overall.
(C) The rate of the reaction is constant over time.
(D) The half-life of reactant *A* is 20 minutes.
(E) The graph of ln [*A*] will be a straight line.

45. A solution to be used as a reagent for a reaction is to be removed from a bottle marked with its concentration. Which of the following is NOT part of the proper procedure for this process?

(A) Pouring the solution down a stirring rod into a beaker.
(B) Inserting a pipette directly into the bottle and drawing out the solution.
(C) Placing the stopper of the bottle upside down on the table top.
(D) Pouring the solution down the side of a tilted beaker.
(E) Touching the stopper of the bottle only on the handle.

46. $$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) + \text{energy}$$

Which of the following changes to the equilibrium situation shown above will bring about an increase in the number of moles of NH_3 present at equilibrium?

I. Adding N_2 gas to the reaction chamber
II. Increasing the volume of the reaction chamber at constant temperature
III. Increasing the temperature of the reaction chamber at constant volume

(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) II and III only

47. $$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

If 16 grams of CH_4 reacts with 16 grams of O_2 in the reaction shown above, which of the following will be true?

(A) The mass of H_2O formed will be twice the mass of CO_2 formed.
(B) Equal masses of H_2O and CO_2 will be formed.
(C) Equal numbers of moles of H_2O and CO_2 will be formed.
(D) The limiting reagent will be CH_4.
(E) The limiting reagent will be O_2.

GO ON TO THE NEXT PAGE

48. Which of the following sets of gases would be most difficult to separate if the method of gaseous effusion is used?

(A) O_2 and CO_2
(B) N_2 and C_2H_4
(C) H_2 and CH_4
(D) He and Ne
(E) O_2 and He

49. Which of the following equilibrium expressions represents the hydrolysis of the CN^- ion?

(A) $K = \frac{[HCN][OH^-]}{[CN^-]}$

(B) $K = \frac{[CN^-][OH^-]}{[HCN]}$

(C) $K = \frac{[CN^-][H_3O^+]}{[HCN]}$

(D) $K = \frac{[HCN][H_3O^+]}{[CN^-]}$

(E) $K = \frac{[HCN]}{[CN^-][OH^-]}$

50. Which of the following is true under any conditions for a reaction that is spontaneous at any temperature?

(A) ΔG, ΔS, and ΔH are all positive.
(B) ΔG, ΔS, and ΔH are all negative.
(C) ΔG and ΔS are negative, and ΔH is positive.
(D) ΔG and ΔS are positive, and ΔH is negative.
(E) ΔG and ΔH are negative, and ΔS is positive.

51. Which of the following pairs of compounds are isomers?

(A) HCOOH and CH_3COOH
(B) CH_3CH_3CHO and C_3H_7OH
(C) C_2H_5OH and CH_3OCH_3
(D) C_2H_4 and C_2H_6
(E) C_3H_8 and C_4H_{10}

52. A sample of an ideal gas confined in a rigid 5.00 liter container has a pressure of 363 mmHg at a temperature of 25°C. Which of the following expressions will be equal to the pressure of the gas if the temperature of the container is increased to 35°C?

(A) $\frac{(363)(35)}{(25)}$ mmHg

(B) $\frac{(363)(25)}{(35)}$ mmHg

(C) $\frac{(363)(308)}{(298)}$ mmHg

(D) $\frac{(363)(298)}{(308)}$ mmHg

(E) $\frac{(363)(273)}{(308)}$ mmHg

53. If the temperature at which a reaction takes place is increased, the rate of the reaction will

(A) increase if the reaction is endothermic and decrease if the reaction is exothermic.
(B) decrease if the reaction is endothermic and increase if the reaction is exothermic.
(C) increase if the reaction is endothermic and increase if the reaction is exothermic.
(D) decrease if the reaction is endothermic and decrease if the reaction is exothermic.
(E) remain the same for both an endothermic and an exothermic reaction.

54. The acid dissociation constant for HClO is 3.0×10^{-8}. What is the hydrogen ion concentration in a 0.12 M solution of HClO?

(A) 3.6×10^{-9} M
(B) 3.6×10^{-8} M
(C) 6.0×10^{-8} M
(D) 2.0×10^{-5} M
(E) 6.0×10^{-5} M

GO ON TO THE NEXT PAGE

55. $2\ NO(g) + 2\ H_2(g) \rightarrow N_2(g) + 2\ H_2O(g)$

Which of the following is true regarding the relative molar rates of disappearance of the reactants and appearance of the products?

I. N_2 appears at the same rate that H_2 disappears.
II. H_2O appears at the same rate that NO disappears.
III. NO disappears at the same rate that H_2 disappears.

(A) I only
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III

56. $SO_4^{2-}, PO_4^{3-}, ClO_4^{-}$

The geometries of the polyatomic ions listed above can all be described as

(A) square planar.
(B) square pyramidal.
(C) seesaw-shaped.
(D) tetrahedral.
(E) trigonal bipyramidal.

57. $2\ ZnS(s) + 3\ O_2(g) \rightarrow 2\ ZnO(s) + 2\ SO_2(g)$

If the reaction above took place at standard temperature and pressure, what was the volume of $O_2(g)$ required to produce 40.0 grams of ZnO(*s*)?

(A) $\frac{(40.0)(2)}{(81.4)(3)(22.4)}$ L

(B) $\frac{(40.0)(3)}{(81.4)(2)(22.4)}$ L

(C) $\frac{(40.0)(2)(22.4)}{(81.4)(3)}$ L

(D) $\frac{(40.0)(3)(22.4)}{(81.4)(2)}$ L

(E) $\frac{(81.4)(2)(22.4)}{(40.0)(3)}$ L

58. Which of the following salts will produce a colorless solution when added to water?

(A) $Cu(NO_3)_2$
(B) $NiCl_2$
(C) $KMnO_4$
(D) $ZnSO_4$
(E) $FeCl_3$

59. A beaker contains 300.0 ml of a 0.20 *M* $Pb(NO_3)_2$ solution. If 200.0 ml of a 0.20 *M* solution of $MgCl_2$ is added to the beaker, what will be the final concentration of Pb^{2+} ions in the resulting solution?

(A) 0.020 *M*
(B) 0.040 *M*
(C) 0.080 *M*
(D) 0.120 *M*
(E) 0.150 *M*

60. Which of the following procedures will produce a buffered solution?

I. Equal volumes of 1 *M* NH_3 and 1 *M* NH_4Cl solutions are mixed.
II. Equal volumes of 1 *M* H_2CO_3 and 1 *M* $NaHCO_3$ solutions are mixed.
III. Equal volumes of 1 *M* NH_3 and 1 *M* H_2CO_3 solutions are mixed.

(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

61. $H_2(g) + I_2(g) \rightarrow 2\ HI(g)$

At 450 C the equilibrium constant, K_c, for the reaction shown above has a value of 50. Which of the following sets of initial conditions at 450 C will cause the reaction above to produce more H_2?

I. [HI] = 5-molar, $[H_2]$ = 1-molar, $[I_2]$ = 1-molar
II. [HI] = 10-molar, $[H_2]$ = 1-molar, $[I_2]$ = 1-molar
III. [HI] = 10-molar, $[H_2]$ = 2-molar, $[I_2]$ = 2-molar

(A) I only
(B) II only
(C) I and II only
(D) II and III only
(E) I, II, and III

GO ON TO THE NEXT PAGE

62. $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$

A galvanic cell that uses the reaction shown above has a standard state electromotive force of 1.1 volts. Which of the following changes to the cell will increase the voltage?

I. An increase in the mass of $Zn(s)$ in the cell.
II. An increase in the concentration of $Cu^{2+}(aq)$ in the cell.
III. An increase in the concentration of $Zn^{2+}(aq)$ in the cell.

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I and III only

63. The nuclide $^{61}_{26}Fe$ decays through the emission of a single beta (β^-) particle. What is the resulting nuclide?

(A) $^{60}_{26}Fe$
(B) $^{62}_{26}Fe$
(C) $^{61}_{27}Co$
(D) $^{62}_{27}Co$
(E) $^{61}_{25}Mn$

64. Which of the following statements is true regarding sodium and potassium?

(A) Sodium has a larger first ionization energy and a larger atomic radius.
(B) Sodium has a larger first ionization energy and a smaller atomic radius.
(C) Sodium has a smaller first ionization energy and a larger atomic radius.
(D) Sodium has a smaller first ionization energy and a smaller atomic radius.
(E) Sodium and potassium have identical first ionization energies and atomic radii.

65. $HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3(aq)$

One-half liter of a 0.20-molar HCl solution is mixed with one-half liter of a 0.40-molar solution of $AgNO_3$. A reaction occurs forming a precipitate as shown above. If the reaction goes to completion, what is the mass of AgCl produced?

(A) 14 grams
(B) 28 grams
(C) 42 grams
(D) 70 grams
(E) 84 grams

66. $H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g)$

Based on the information given in the table below, what is ΔH for the above reaction?

Bond	Average Bond Energy (kJ/mol)
H–H	440
Cl–Cl	240
H–Cl	430

(A) –860 kJ
(B) –620 kJ
(C) –440 kJ
(D) –180 kJ
(E) +240 kJ

67. The first ionization energy for magnesium is 730 kJ/mol. The third ionization energy for magnesium is 7700 kJ/mol. What is the most likely value for magnesium's second ionization energy?

(A) 490 kJ/mol
(B) 1,400 kJ/mol
(C) 4,200 kJ/mol
(D) 7,100 kJ/mol
(E) 8,400 kJ/mol

GO ON TO THE NEXT PAGE

68. Molten NaCl is electrolyzed with a constant current of 1.00 ampere. What is the shortest amount of time, in seconds, that it would take to produce 1.00 mole of solid sodium?
(1 faraday = 96,500 coulombs)

(A) 19,300 seconds
(B) 32,200 seconds
(C) 48,300 seconds
(D) 64,300 seconds
(E) 96,500 seconds

69. How many moles of KCl must be added to 200 milliliters of a 0.5-molar NaCl solution to create a solution in which the concentration of Cl^- ion is 1.0-molar? (Assume the volume of the solution remains constant.)

(A) 0.1 moles
(B) 0.2 moles
(C) 0.3 moles
(D) 0.4 moles
(E) 0.5 moles

70. A student placed solid barium oxalate in a beaker filled with distilled water and allowed it to come to equilibrium with its dissolved ions. The student then added a nickel (II) nitrate solution to the beaker to create the following equilibrium situation.

$$BaC_2O_4 + Ni^{2+} \leftrightarrow Ba^{2+} + NiC_2O_4$$

If the solubility product for BaC_2O_4 is 2×10^{-7} and the solubility product for NiC_2O_4 is 4×10^{-10}, which of the following gives the value of the equilibrium constant for the reaction above?

(A) 2×10^3
(B) 5×10^2
(C) 5×10^{-2}
(D) 2×10^{-3}
(E) 8×10^{-17}

71. A 100-gram sample of pure ${}^{37}_{18}Ar$ decays by electron capture with a half-life of 35 days. How long will it take for 90 grams of ${}^{37}_{17}Cl$ to accumulate?

(A) 31 days
(B) 39 days
(C) 78 days
(D) 116 days
(E) 315 days

72. The solubility product, K_{sp}, of CaF_2 is 4×10^{-11}. Which of the following expressions is equal to the solubility of CaF_2?

(A) $\sqrt{4\times10^{-11}}\ M$
(B) $\sqrt{2\times10^{-11}}\ M$
(C) $\sqrt[3]{4\times10^{-11}}\ M$
(D) $\sqrt[3]{2\times10^{-11}}\ M$
(E) $\sqrt[3]{1\times10^{-11}}\ M$

73. When excess hydroxide ions were added to 1.0 liter of $CaCl_2$ solution, $Ca(OH)_2$ precipitate was formed. If all of the calcium ions in the solution were precipitated in 7.4 grams of $Ca(OH)_2$, what was the initial concentration of the $CaCl_2$ solution?

(A) 0.05-molar
(B) 0.10-molar
(C) 0.15-molar
(D) 0.20-molar
(E) 0.30-molar

GO ON TO THE NEXT PAGE

74. When a solution of $KMnO_4$ was mixed with a solution of HCl, Cl_2 gas bubbles formed and Mn^{2+} ions appeared in the solution. Which of the following has occurred?

(A) K^+ has been oxidized by Cl^-.
(B) K^+ has been oxidized by H^+.
(C) Cl^- has been oxidized by K^+.
(D) Cl^- has been oxidized by MnO_4^-.
(E) MnO_4^- has been oxidized by Cl^-.

75. $2\ Cu^+(aq) + M(s) \rightarrow 2\ Cu(s) + M^{2+}(aq)$
$E^o = +0.92$ V

$Cu^+(aq) + e^- \rightarrow Cu(s)$
$E^o = +0.52$ V

Based on the reduction potentials given above, what is the standard reduction potential for the following half-reaction?

$M^{2+}(aq) + 2\ e^- \rightarrow M(s)$

(A) +0.40 V
(B) +0.12 V
(C) –0.12 V
(D) –0.40 V
(E) –1.44 V

STOP

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS SECTION.
DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

CHEMISTRY
SECTION II

Time—1 hour and 35 minutes

Percent of total grade—50

Parts A: Time—55 minutes

Part B: Time—40 minutes

General Instructions

CALCULATORS MAY NOT BE USED IN PART B.

Calculators, including those with programming and graphing capabilities, may be used in Part A. However, calculators with typewriter-style (QWERTY) keyboards are NOT permitted.

Pages containing a periodic table, the electrochemical series, and equations commonly used in chemistry will be available for your use.

You may write your answers with either a pen or a pencil. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

Write all your answers in the essay booklet. Number your answers as the questions are numbered in the examination booklet.

GO ON TO THE NEXT PAGE

MATERIAL IN THE FOLLOWING TABLE AND IN THE TABLES ON THE NEXT 3 PAGES MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

PERIODIC CHART OF THE ELEMENTS

1 **H** 1.0																	2 **He** 4.0
3 **Li** 6.9	4 **Be** 9.0											5 **B** 10.8	6 **C** 12.0	7 **N** 14.0	8 **O** 16.0	9 **F** 19.0	10 **Ne** 20.2
11 **Na** 23.0	12 **Mg** 24.3											13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 39.9
19 **K** 39.1	20 **Ca** 40.1	21 **Sc** 45.0	22 **Ti** 47.9	23 **V** 50.9	24 **Cr** 52.0	25 **Mn** 54.9	26 **Fe** 55.8	27 **Co** 58.9	28 **Ni** 58.7	29 **Cu** 63.5	30 **Zn** 65.4	31 **Ga** 69.7	32 **Ge** 72.6	33 **As** 74.9	34 **Se** 79.0	35 **Br** 79.9	36 **Kr** 83.8
37 **Rb** 85.5	38 **Sr** 87.6	39 **Y** 88.9	40 **Zr** 91.2	41 **Nb** 92.9	42 **Mo** 95.9	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 ***La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0	89 **†Ac** 227.0															

*Lanthanum Series

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0

†Actinium Series

90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (258)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

DO NOT DETACH FROM BOOK.

GO ON TO THE NEXT PAGE

ADVANCED PLACEMENT CHEMISTRY EQUATIONS AND CONSTANTS

ATOMIC STRUCTURE

$E = h\nu$ $\quad c = \lambda\nu$

$\lambda = \dfrac{h}{mv}$ $\quad p = mv$

$E_n = \dfrac{-2.178 \times 10^{-18}}{n^2}$ joule

EQUILIBRIUM

$K_a = \dfrac{[H^-][A^-]}{[HA]}$

$K_b = \dfrac{[OH^-][HB^+]}{[B]}$

$K_w = [OH^-][H^+] = 10^{-14}$ @ 25°C

$= K_a \times K_b$

pH $= -\log [H^+]$, pOH $= -\log [OH^-]$

14 = pH + pOH

pH $= pK_a + \log \dfrac{[A^-]}{[HA]}$

pOH $= pK_b + \log \dfrac{[HB^+]}{[B]}$

$pK_a = -\log K_a$, $pK_b = -\log K_b$

$K_p = K_c(RT)^{\Delta n}$,

where Δn = moles product gas – moles reactant gas

THERMOCHEMISTRY / KINETICS

$\Delta S^\circ = \sum S^\circ_{\text{products}} - \sum S^\circ_{\text{reactants}}$

$\Delta H^\circ = \sum \Delta H^\circ_{f\ \text{products}} - \sum \Delta H^\circ_{f\ \text{reactants}}$

$\Delta G^\circ = \sum \Delta G^\circ_{f\ \text{products}} - \sum \Delta G^\circ_{f\ \text{reactants}}$

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$
$= -RT \ln K = -2.303\ RT \log K$
$= -nFE^\circ$

$\Delta G = \Delta G^\circ + RT \ln Q = \Delta G^\circ + 2.303\ RT \log Q$

$q = mc\Delta T$

$C_p = \dfrac{\Delta H}{\Delta T}$

$\ln[A]_t - \ln[A]_o = -kt$

$\dfrac{1}{[A]_t} - \dfrac{1}{[A]_o} = kt$

$\ln k = \dfrac{-E_a}{R}\left(\dfrac{1}{T}\right) + \ln A$

E = energy
ν = frequency
λ = wavelength
p = momentum
v = velocity
n = principal quantum number
m = mass

Speed of light, $c = 3.00 \times 10^8$ m s^{-1}

Planck's constant, $h = 6.63 \times 10^{-34}$ J s

Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J K^{-1}

Avogadro's number $= 6.022 \times 10^{23}$ mol^{-1}

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

1 electron volt/atom = 96.5 kJ mol^{-1}

Equilibrium Constants

K_a (weak acid)
K_b (weak base)
K_w (water)
K_p (gas pressure)
K_c (molar concentrations)

S° = standard entropy
H° = standard enthalpy
G° = standard free energy
E° = standard reduction potential
T = temperature
n = moles
m = mass
q = heat
c = specific heat capacity
C_p = molar heat capacity at constant pressure
E_a = activation energy
k = rate constant
A = frequency factor

Faraday's Constant, F = 96,500 coulombs per mole of electrons

Gas Constant, R = 8.31 J mol^{-1} K^{-1}
= 0.0821 L atm mol^{-1} K^{-1}
= 8.31 volt coulomb mol^{-1} K^{-1}

GO ON TO THE NEXT PAGE

ADVANCED PLACEMENT CHEMISTRY EQUATIONS AND CONSTANTS

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

$$P_A = P_{total} \cdot X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + ...$$

$$n = \frac{m}{\boldsymbol{M}}$$

$$K = °C + 273$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$D = \frac{m}{V}$$

$$U_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{\boldsymbol{M}}}$$

$$KE \text{ per molecule} = \frac{1}{2}mv^2$$

$$KE \text{ per mole} = \frac{3}{2}RT$$

$$\frac{r_1}{r_2} = \sqrt{\frac{\boldsymbol{M}_2}{\boldsymbol{M}_1}}$$

molarity, M = moles solute per liter solution

molality = moles solute per kilogram solvent

$$\Delta T_f = iK_f \times \text{molality}$$

$$\Delta T_b = iK_b \times \text{molality}$$

$$\pi = MRT$$

$$A = abc$$

P = pressure
V = volume
T = temperature
n = number of moles
D = density
m = mass
v = velocity

U_{rms} = root-mean-square speed
KE = kinetic energy
r = rate of effusion
$\boldsymbol{M}$ = molar mass
π = osmotic pressure
i = van't Hoff factor
K_f = molal freezing-point depression constant
K_b = molal boiling-point elevation constant
A = absorbance
a = molar absorptivity
b = path length
c = concentration
Q = reaction quotient
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
$E°$ = standard reduction potential
K = equilibrium constant

OXIDATION REDUCTION; ELECTROCHEMISTRY

$$Q = \frac{[C]^c [D]^d}{[A]^a [B]^b} \text{ where } a\text{ A} + b\text{ B} \rightarrow c\text{ C} + d\text{ D}$$

$$I = \frac{q}{t}$$

$$E_{cell} = E°_{cell} - \frac{RT}{nF}\ln Q = E°_{cell} - \frac{0.0592}{n}\log Q \text{ @ } 25°C$$

$$\log K = \frac{nE°}{0.0592}$$

Gas constant, R = 8.31 J mol^{-1} K^{-1}
= 0.0821 L atm mol^{-1} K^{-1}
= 8.31 volt coulomb mol^{-1} K^{-1}
Boltzmann's constant, k = 1.38×10^{-23} J K^{-1}
K_f for H_2O = 1.86 K kg mol^{-1}
K_b for H_2O = 0.512 K kg mol^{-1}
1 atm = 760 mm Hg
= 760 torr
STP = 0.000°C and 1.000 atm
1 faraday, F = 96,500 coulumbs per mole of electrons

GO ON TO THE NEXT PAGE

STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25 C (in V)

$F_2(g) + 2\ e^-$	→	$2\ F^-$	2.87
$Co^{3+} + e^-$	→	Co^{2+}	1.82
$Au^{3+} + 3e^-$	→	$Au(s)$	1.50
$Cl_2(g) + 2\ e^-$	→	$2\ Cl^-$	1.36
$O_2(g) + 4H^+ + 4\ e^-$	→	$2\ H_2O$	1.23
$Br_2(l) + 2\ e^-$	→	$2\ Br^-$	1.07
$2\ Hg^{2+} + 2\ e^-$	→	$Hg_2^{\ 2+}$	0.92
$Hg^{2+} + 2\ e^-$	→	$Hg(l)$	0.85
$Ag^+ + e^-$	→	$Ag(s)$	0.80
$Hg_2^{\ 2+} + 2\ e^-$	→	$2\ Hg(l)$	0.79
$Fe^{3+} + e^-$	→	Fe^{2+}	0.77
$I_2(s) + 2\ e^-$	→	$2\ I^-$	0.53
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$Cu^{2+} + 2\ e^-$	→	$Cu(s)$	0.34
$Cu^{2+} + e^-$	→	Cu^+	0.15
$Sn^{4+} + 2\ e^-$	→	Sn^{2+}	0.15
$S(s) + 2\ H^+ + 2\ e^-$	→	H_2S	0.14
$2\ H^+ + 2\ e^-$	→	$H_2(g)$	0.00
$Pb^{2+} + 2\ e^-$	→	$Pb(s)$	–0.13
$Sn^{2+} + 2\ e^-$	→	$Sn(s)$	–0.14
$Ni^{2+} + 2\ e^-$	→	$Ni(s)$	–0.25
$Co^{2+} + 2\ e^-$	→	$Co(s)$	–0.28
$Tl^+ + e^-$	→	$Tl(s)$	–0.34
$Cd^{2+} + 2\ e^-$	→	$Cd(s)$	–0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	–0.41
$Fe^{2} + 2\ e^-$	→	$Fe(s)$	–0.44
$Cr^{3+} + 3\ e^-$	→	$Cr(s)$	–0.74
$Zn^{2+} + 2\ e^-$	→	$Zn(s)$	–0.76
$Mn^{2+} + 2\ e^-$	→	$Mn(s)$	–1.18
$Al^{3+} + 3\ e^-$	→	$Al(s)$	–1.66
$Be^{2+} + 2\ e^-$	→	$Be(s)$	–1.70
$Mg^{2+} + 2\ e^-$	→	$Mg(s)$	–2.37
$Na^+ + e^-$	→	$Na(s)$	–2.71
$Ca^{2+} + 2\ e^-$	→	$Ca(s)$	–2.87
$Sr^{2+} + 2\ e^-$	→	$Sr(s)$	–2.89
$Ba^{2+} + 2\ e^-$	→	$Ba(s)$	–2.90
$Rb^+ + e^-$	→	$Rb(s)$	–2.92
$K^+ + e^-$	→	$K(s)$	–2.92
$Cs^+ + e^-$	→	$Cs(s)$	–2.92
$Li^+ + e^-$	→	$Li(s)$	–3.05

GO ON TO THE NEXT PAGE

CHEMISTRY

Section I

(Total time—95 minutes)

Part A

Time—55 minutes

YOU MAY USE YOUR CALCULATOR FOR PART A

THE METHODS USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS MUST BE SHOWN CLEARLY. It is to your advantage to do this since you may obtain partial credit if you do, and you will receive little or no credit if you do not. Attention should be paid to significant figures.

Be sure to write your answers in the space provided following each question.

Answer Questions 1, 2, and 3. The Section II score weighting for each question is 20 percent.

1. A 0.20-molar solution of acetic acid, $HC_2H_3O_2$, at a temperature of 25°C, has a pH of 2.73.

   (a) Calculate the hydroxide ion concentration, $[OH^-]$.

   (b) What is the value of the acid ionization constant, K_a, for acetic acid at 25°C?

   (c) How many moles of sodium acetate must be added to 500.0 ml of a 0.200-molar solution of acetic acid to create a buffer with a pH of 4.00? Assume that the volume of the solution is not changed by the addition of sodium acetate.

   (d) In a titration experiment, 100.0 ml of sodium hydroxide solution was added to 200 ml of a 0.400-molar solution of acetic acid until the equivalence point was reached. What was the pH at the equivalence point?

   (e) The pK_a values for several indicators are given in the table below. Which of the indicators on the table is most suitable for this titration? Justify your answer.

Indicator	pK_a
Thymol Blue	2
Bromcresol Purple	6
Phenolphthalein	9

GO ON TO THE NEXT PAGE

2. $2\,NO(g) + Cl_2(g) \rightarrow 2\,NOCl(g)$

The following data were collected for the reaction above. All of the measurements were taken at a temperature of 263 K.

Experiment	Initial [NO] (*M*)	Initial [Cl_2] (*M*)	Initial rate of disappearance of Cl_2 (*M*/min)
1	0.15	0.15	0.60
2	0.15	0.30	1.2
3	0.30	0.15	2.4
4	0.25	0.25	?

(a) Write the expression for the rate law for the reaction above.
(b) Calculate the value of the rate constant for the above reaction, and specify the units.
(c) What is the initial rate of appearance of NOCl in experiment 2?
(d) What is the initial rate of disappearance of Cl_2 in experiment 4?
(e) Each of the experimental trials took place in a closed container. Explain or calculate each of the following:
(i) What was the partial pressure due to NO(*g*) at the start of experiment 1?
(ii) What was the total pressure at the start of experiment 1? Assume that no NOCl is present.

3. $CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(l)$

The above reaction for the combustion of methane gas has a standard entropy change, $\Delta S°$, with a value of –242.7 J/mol-K. The following data are also available:

Compound	ΔH_f (kJ/mol)
$CH_4(g)$	–74.8
$H_2O\ (l)$	–285.9
$CO_2\ (g)$	–393.5

(a) What are the values of $\Delta H°_f$ and $\Delta G°_f$ for $O_2(g)$?
(b) Calculate the standard change in enthalpy, $\Delta H°$, for the combustion of methane.
(c) Calculate the standard free energy change, $\Delta G°$, for the combustion of methane.
(d) How would the value of $\Delta S°$ for the reaction be affected if the water produced in the combustion remained in the gas phase?
(e) A 20.0-gram sample of $CH_4(g)$ underwent combustion in a bomb calorimeter with excess oxygen gas.
(i) Calculate the mass of carbon dioxide produced.
(ii) Calculate the heat released by the reaction.

STOP

END OF SECTION II, PART A

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO PART B UNTIL YOU ARE TOLD TO DO SO.

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B

Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. You will be given three chemical reactions below. In part (i), write the balanced equation for the reaction, leaving coefficients in terms of lowest whole numbers. Then answer the question pertaining to that reaction in part (ii). For each of the following three reactions, assume that solutions are aqueous unless it says otherwise. Substances in solutions should be represented as ions if these substances are extensively ionized. Omit formulas for ions or molecules that are not affected by the reaction. Only equations inside the answer boxes will be graded.

EXAMPLE:

A piece of solid zinc is placed in a solution of silver(I) acetate

(i) Write the balanced equation in this box:

$$Zn + 2Ag^{+} \rightarrow Zn^{2+} + 2Ag$$

(ii) Which substance is reduced in the reaction?

Ag^{+} is reduced

(a) Sulfur dioxide gas is bubbled through cold water.

(i) Write the balanced equation in this box:

(ii) As the reaction progresses, will the hydroxide concentration in the solution increase, decrease, or remain the same?

GO ON TO THE NEXT PAGE

(b) Ethane is burned in air.

(i) Write the balanced equation in this box:

(ii) If the enthalpy change for the reaction was measured to be –3,100 kJ and the total heat of formation for all products formed is –3,300 kJ, what is the approximate heat of formation of ethane measured in kJ/mole?

____

____

(c) Chlorine gas is bubbled through a solution of sodium bromide.

(i) Write the balanced equation in this box:

(ii) Which substance is reduced in this reaction?

____

____

GO ON TO THE NEXT PAGE

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Answering these questions provides an opportunity to demonstrate your ability to present your material in logical, coherent, and convincing English. Your responses will be judged on the basis of accuracy and importance of the detail cited and on the appropriateness of the descriptive material used. Specific answers are preferable to broad, diffuse responses. Illustrative examples and equations may be helpful.

5. Oxygen is found in the atmosphere as a diatomic gas, O_2, and as ozone, O_3. Ozone has a dipole moment of 0.5 debye. Oxygen gas has a dipole moment of zero.

    (a) Draw the Lewis dot structures for both molecules.

    (b) Use the principles of bonding and molecular structure to account for the fact that ozone has a higher boiling point than diatomic oxygen.

    (c) Use the principles of bonding and molecular structure to account for the fact that ozone is more soluble than diatomic oxygen in water.

    (d) Explain why the two bonds in O_3 are of equal length and are longer than the bond length of the bond in diatomic oxygen.

    (e) Elemental oxygen is strongly affected by a magnetic field. Explain why.

    (f) For the equilibrium reaction below at 25°C and 1 atm, $K_{eq} = 10^{-57}$.

    $3\ O_2(g) \leftrightarrow 2\ O_3(g)$

    Which form of oxygen is more abundant under normal conditions? Explain.

GO ON TO THE NEXT PAGE

6. $NaC_2H_3O_2$, $Ba(NO_3)_2$, KCl

(a) Aqueous solutions of equal concentration of the three compounds listed above are prepared. What would an experimenter expect to observe when each of the following procedures is performed on each of the solutions?

(i) The pH of each solution is measured.

(ii) SO_4^{2-} ions are introduced into each solution.

(iii) The freezing point of each solution is measured, and the three temperatures are compared.

(iv) Each solution is subjected to a flame test.

(b) At 25°C and 1.0 atmosphere pressure, a balloon contains a mixture of four ideal gases: oxygen, nitrogen, carbon dioxide, and helium. The partial pressure due to each gas is 0.25 atmosphere. Use the ideas of kinetic molecular theory to answer each of the following questions.

(i) Rank the gases in increasing order of average molecular velocity and explain:

(ii) How would the volume of the balloon be affected if the temperature of the gases in the balloon were increased at constant pressure?

(iii) What changes to the temperature and pressure of the gases would cause deviation from ideal behavior, and which gas would be most affected?

END OF EXAMINATION