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The Princeton Review AP Chemistry Practice Exam 2

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.

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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.

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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 refer to the following elements.

(A) Ne
(B) Li
(C) Al
(D) Cl
(E) Ca

1. Which of the elements above is most commonly found as a negatively charged ion?

2. Which of the elements above has the same electron structure as Mg^{2+}?

3. Which of the elements above is found as a diatomic gas in its uncombined state?

Questions 4–7 refer to the following substances.

(A) H_2O
(B) NH_3
(C) CH_4
(D) HF
(E) CH_3OH

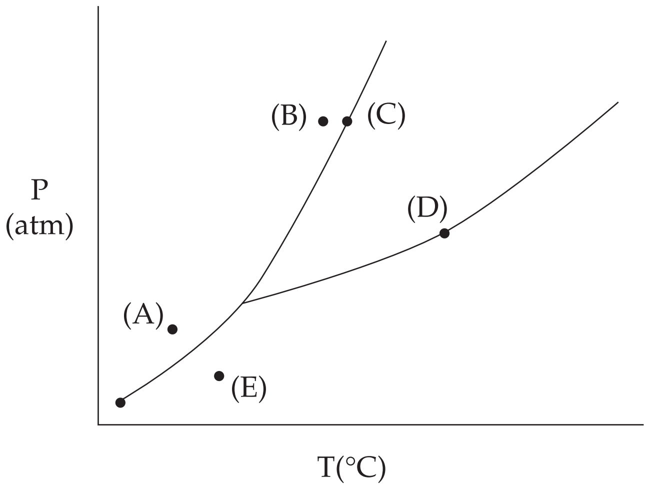
4. This molecule is nonpolar.

5. This substance forms an aqueous solution with a pH that's less than 7.

6. This molecule has a trigonal pyramidal shape.

7. This substance does NOT exhibit hydrogen bonding.

Questions 8–11 refer to the phase diagram shown below for a substance.



8. This point could be the boiling point for the substance.

9. If pressure is increased from the conditions represented by this point at constant temperature, deposition may occur.

10. At the conditions represented by this point, the substance can exist with liquid and solid phases in equilibrium.

11. If temperature is increased from the conditions represented by this point at constant pressure, no phase change will occur.

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Questions 12–14 refer to an experiment in which five individual 1-liter aqueous solutions, each containing a 1-mole sample of one of the salts listed below, were subjected to various tests at room temperature.

(A) $NaC_2H_3O_2$
(B) NaCl
(C) $MgBr_2$
(D) $HC_2H_3O_2$
(E) KBr

12. The solution containing this salt had the highest boiling point.

13. The solution containing this salt had the lowest conductivity.

14. The solution containing this salt had the highest pH.

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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 then fill in the corresponding oval on the answer sheet.

15. Titanium metal is prepared by heating rutile, an oxide of titanium, along with carbon and chlorine gas. By mass, rutile is 40% oxygen and 60% titanium. What is the empirical formula of rutile?

(A) TiO
(B) Ti_2O
(C) TiO_2
(D) Ti_2O_3
(E) Ti_3O_2

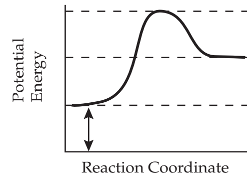
16. What is the weight of $NaNO_3$ (molecular weight 85.0) present in 100.0 ml of a 4.00-molar solution?

(A) 8.50 grams
(B) 17.0 grams
(C) 25.5 grams
(D) 34.0 grams
(E) 51.0 grams

17. A mixture of gases contains 5.0 moles of oxygen, 12 moles of nitrogen, and 4.0 moles of carbon dioxide. If the partial pressure due to carbon dioxide is 1.6 atmospheres, what is the partial pressure due to oxygen?

(A) 2.0 atm
(B) 4.8 atm
(C) 6.0 atm
(D) 6.8 atm
(E) 8.4 atm

18. Which of the diagrams below represents the enthalpy change for an endothermic reaction?

(A)


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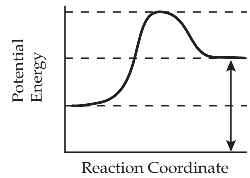
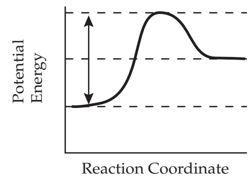


(C)


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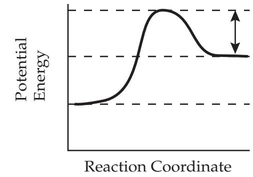
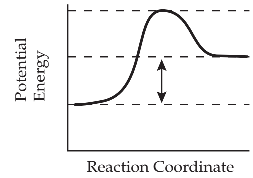


(E)


19. $$2\ NO(g) + Br_2(g) \rightarrow 2\ NOBr(g)$$

For the reaction above, the experimental rate law is given as follows:

$$\text{Rate} = k[NO]^2[Br_2]$$

Which of the statements below is true regarding this reaction?

(A) The reaction is first-order overall.
(B) The reaction is first-order with respect to Br_2.
(C) The reaction is first-order with respect to NO.
(D) The reaction is second-order overall.
(E) The reaction is second-order with respect to Br_2.

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20. Which of the following is the most likely electron configuration of a sulfur atom in its ground state?

(A) $1s^2\,2s^2\,2p^6$
(B) $1s^2\,2s^2\,2p^6\,3s^2\,3p^2$
(C) $1s^2\,2s^2\,2p^6\,3s^2\,3p^4$
(D) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$
(E) $1s^2\,2s^2\,2p^6\,3s^2\,3p^5\,4s^1$

21. How many grams of carbon are present in 270 grams of glucose, $C_6H_{12}O_6$?

(A) 12.0 grams
(B) 18.0 grams
(C) 67.5 grams
(D) 72.0 grams
(E) 108 grams

22. Calcium carbonate dissolves in acidic solutions as shown in the equation below.

$CaCO_3(s) + 2\,H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$

If excess $CaCO_3$ is added to 0.250 liters of a 2.00-molar HNO_3 solution, what is the maximum volume of CO_2 gas that could be produced at standard temperature and pressure?

(A) 5.60 liters
(B) 11.2 liters
(C) 16.8 liters
(D) 33.6 liters
(E) 39.2 liters

23. A monoprotic acid was titrated with a solution of NaOH. For 55.0 milliliters of the acid, 37.0 milliliters of a 0.450-molar solution of NaOH was required to reach the equivalence point. Which of the following expressions is equal to the initial concentration of the monoprotic acid?

(A) $\frac{(0.450)(0.037)}{(0.055)}\,M$

(B) $\frac{(0.450)(0.055)}{(0.037)}\,M$

(C) $\frac{(0.055)}{(0.450)(0.037)}\,M$

(D) $\frac{(0.037)}{(0.450)(0.055)}\,M$

(E) $(0.450)(0.055)(0.037)\,M$

24. $Zn(s) + NO_3^-(aq) + 10\,H^+(aq) \rightarrow Zn^{2+}(aq) + NH_4^+(aq) + 3\,H_2O(l)$

Which of the following statements regarding the reaction shown above is correct?

(A) The oxidation number of hydrogen changes from +1 to 0.
(B) The oxidation number of hydrogen changes from +1 to –1.
(C) The oxidation number of nitrogen changes from +5 to –3.
(D) The oxidation number of nitrogen changes from +5 to +3.
(E) The oxidation number of nitrogen changes from +6 to +4.

25. $HC_2H_3O_2(aq) + ClO^-(aq) \leftrightarrow HClO(aq) + C_2H_3O_2^-(aq)$

The standard free energy change for this reaction has a negative value. Based on this information, which of the following statements is true?

(A) K_a for $HC_2H_3O_2(aq)$ is less than K_a for $HClO(aq)$.
(B) K_b for $C_2H_3O_2^-(aq)$ is less than K_b for $ClO^-(aq)$.
(C) K_{eq} for the reaction is less than 1.
(D) The reaction occurs in the presence of a catalyst.
(E) $HC_2H_3O_2(aq)$ and $HClO(aq)$ are conjugates.

26. A student added 0.20 mol of NaI and 0.40 mol of KI to 3 liters of water to create an aqueous solution. What is the minimum number of moles of $Pb(C_2H_3O_2)_2$ that the student must add to the solution to precipitate out all of the I^- ions as PbI_2?

(A) 2.40
(B) 1.20
(C) 0.60
(D) 0.30
(E) 0.15

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27. A molecule with the formula XY_2 whose atoms are arranged linearly could have a central atom with which of the following hybridizations?

I. *sp*
II. sp^3
III. dsp^3

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

28. Which of the following statements regarding fluorine and nitrogen is NOT true?

(A) Fluorine has greater electronegativity.
(B) Fluorine has a greater first ionization energy.
(C) Fluorine has more valence electrons.
(D) Fluorine has a greater atomic weight.
(E) Fluorine has a greater atomic radius.

29. Which of the groups below is (are) listed in order from lowest to highest melting point?

I. KI, LiF, BeO
II. F_2, Cl_2, Br_2
III. K, Na, Li

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

30. Which of the statements below regarding elemental nitrogen is NOT true?

(A) It contains one sigma bond.
(B) It contains two pi bonds.
(C) It has a bond order of 3.
(D) It has a large dipole moment.
(E) It exists as a diatomic gas.

31. The reaction of elemental chlorine with ozone in the atmosphere occurs by the two-step process shown below.

I. $Cl + O_3 \rightarrow ClO + O_2$
II. $ClO + O \rightarrow Cl + O_2$

Which of the statements below is true regarding this process?

(A) Cl is a catalyst.
(B) O_3 is a catalyst.
(C) ClO is a catalyst.
(D) O_2 is an intermediate.
(E) O is an intermediate.

32. A student examined the line spectrum of a hydrogen atom and was able to conclude that when the electron in the hydrogen atom made the transition from the $n = 3$ to the $n = 1$ state, the frequency of the ultraviolet radiation emitted was 2.92×10^{15} Hz. When the same transition occurred in a He^+ ion, the frequency emitted was 1.17×10^{16} Hz. Which of the following best accounts for the difference?

(A) More energy is released by the He^+ transition because of the greater molar mass of the He^+ ion.
(B) More energy is released by the He^+ transition because of the greater nuclear charge of the He^+ ion.
(C) More energy is released by the He^+ transition because the ionic radius of He^+ is greater than the atomic radius of H.
(D) Less energy is released by the He^+ transition because the ionic radius of He^+ is smaller than the atomic radius of H.
(E) Less energy is released by the He^+ transition because of the greater nuclear charge of the He^+ ion.

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33. $CH_3CH_2OH(g)$ + ...$O_2(g)$ →

...$CO_2(g)$ + ...$H_2O(g)$

The reaction above represents the oxidation of ethanol. How many moles of O_2 are required to oxidize 1 mole of CH_3CH_2OH?

(A) $\frac{3}{2}$ moles

(B) $\frac{5}{2}$ moles

(C) 3 moles

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

(E) 4 moles

34. How many milliliters of water must be added to 10 milliliters of an HCl solution with a pH of 1 to produce a solution with a pH of 2?

(A) 10 ml
(B) 90 ml
(C) 100 ml
(D) 990 ml
(E) 1,000 ml

35. Elemental iodine (I_2) is more soluble in carbon tetrachloride (CCl_4) than it is in water (H_2O). Which of the following statements is the best explanation for this?

(A) I_2 is closer in molecular weight to CCl_4 than it is to H_2O.
(B) The freezing point of I_2 is closer to that of CCl_4 than it is to that of H_2O.
(C) I_2 and CCl_4 are nonpolar molecules, while H_2O is a polar molecule.
(D) The heat of formation of I_2 is closer to that of CCl_4 than it is to that of H_2O.
(E) CCl_4 has a greater molecular weight than does H_2O.

36. A sample of water was electrolyzed to produce hydrogen and oxygen gas, as shown in the reaction below.

$$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$$

If 33.6 liters of gas were produced at STP, how many grams of water were consumed in the reaction?

(A) 11.1 grams
(B) 18.0 grams
(C) 24.0 grams
(D) 36.0 grams
(E) 44.8 grams

37. The following data were gathered in an experiment to determine the density of a sample of an unknown substance.

Mass of the sample = 7.50 grams

Volume of the sample = 2.5 milliliters

The density of the sample should be reported as

(A) 3.00 grams per ml.
(B) 3.0 grams per ml.
(C) 3 grams per ml.
(D) 0.3 grams per ml.
(E) 0.33 grams per ml.

38. $2\ H_2O_2(g) + S(s) \rightarrow SO_2(g) + 2\ H_2O(g)$

Based on the information given in the table below, what is the enthalpy change in the reaction represented above?

Substance	**ΔH_f (kJ/mol)**
$H_2O_2(g)$	–150
$SO_2(g)$	–300
$H_2O(g)$	–250
S(s)	0

(A) –500 kJ
(B) –200 kJ
(C) 200 kJ
(D) 400 kJ
(E) 600 kJ

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39. A chemist creates a buffer solution by mixing equal volumes of a 0.2-molar HOCl solution and a 0.2-molar KOCl solution. Which of the following will occur when a small amount of KOH is added to the solution?

I. The concentration of undissociated HOCl will increase.
II. The concentration of OCl^- ions will increase.
III. The concentration of H^+ ions will increase.

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

40. A 15-gram sample of neon is placed in a sealed container with a constant volume of 8.5 liters. If the temperature of the container is 27 C, which of the following expressions gives the correct pressure of the gas? The ideal gas constant, *R*, is 0.08 (L-atm)/(mole-K).

(A) $\frac{(15)(0.08)(300)}{(20)(8.5)}$ atm

(B) $\frac{(20)(0.08)(300)}{(15)(8.5)}$ atm

(C) $\frac{(20)(300)}{(15)(8.5)(0.08)}$ atm

(D) $\frac{(15)(300)}{(20)(8.5)(0.08)}$ atm

(E) $\frac{(15)(0.08)}{(20)(8.5)(300)}$ atm

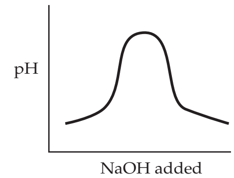
41. $C(s) + CO_2(g) + \text{energy} \leftrightarrow 2\,CO(g)$

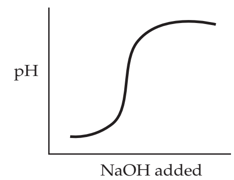
The system above is currently at equilibrium in a closed container. Which of the following changes to the system would serve to increase the number of moles of CO present at equilibrium?

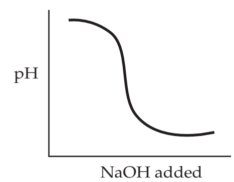
I. Raising the temperature
II. Increasing the volume of the container
III. Adding more C(*s*) to the container

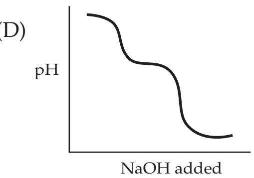
(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) I, II, and III

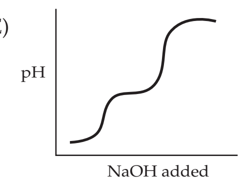
42. In a titration experiment, a 0.10-molar $H_2C_2O_4$ solution was completely neutralized by the addition of a 0.10-molar NaOH solution. Which of the diagrams below illustrates the change in pH that accompanied this process?

(A)


(B)


(C)


(D)


(E)


43. If 52 grams of $Ba(NO_3)_2$ (molar mass 260 grams) are completely dissolved in 500 milliliters of distilled water, what are the concentrations of the barium and nitrate ions?

(A) $[Ba^{2+}] = 0.10\,M$ and $[NO_3^-] = 0.10\,M$
(B) $[Ba^{2+}] = 0.20\,M$ and $[NO_3^-] = 0.40\,M$
(C) $[Ba^{2+}] = 0.40\,M$ and $[NO_3^-] = 0.40\,M$
(D) $[Ba^{2+}] = 0.40\,M$ and $[NO_3^-] = 0.80\,M$
(E) $[Ba^{2+}] = 0.80\,M$ and $[NO_3^-] = 0.80\,M$

44. An acid solution of unknown concentration is to be titrated with a standardized hydroxide solution that will be released from a buret. The buret should be rinsed with

(A) hot distilled water.
(B) distilled water at room temperature.
(C) a sample of the unknown acid solution.
(D) a sample of the hydroxide solution.
(E) a neutral salt solution.

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45. All of the following statements concerning the alkali metals are true EXCEPT

(A) They are strong oxidizing agents.
(B) They form ions with a +1 oxidation state.
(C) As the atomic numbers of the alkali metals increase, the electronegativity decreases.
(D) As the atomic numbers of the alkali metals increase, their first ionization energy decreases.
(E) They form ions that are soluble in water.

46. As a beaker of water is heated over a flame, the temperature increases steadily until it reaches 373 K. At that point, the beaker is left on the open flame, but the temperature remains at 373 K as long as water remains in the beaker. This is because at 373 K, the energy supplied by the flame

(A) no longer acts to increase the kinetic energy of the water molecules.
(B) is completely absorbed by the glass beaker.
(C) is less than the energy lost by the water through electromagnetic radiation.
(D) is dissipated by the water as visible light.
(E) is used to overcome the heat of vaporization of the water.

47. For which of the following reactions will the equilibrium constants K_c and K_p have the same value?

(A) $2\ N_2O_5(g) \leftrightarrow 2\ NO_2(g) + O_2(g)$
(B) $2\ CO_2(g) \leftrightarrow 2\ CO(g) + O_2(g)$
(C) $H_2O\ (g) + CO(g) \leftrightarrow H_2(g) + CO_2(g)$
(D) $3\ O_2(g) \leftrightarrow 2\ O_3(g)$
(E) $CO(g) + Cl_2(g) \leftrightarrow COCl_2(g)$

48. A student added solid potassium iodide to 1 kilogram of distilled water. When the KI had completely dissolved, the freezing point of the solution was measured to be –3.72°C. What was the mass of the potassium iodide added? (The freezing point depression constant, k_f, for water is 1.86 K-kg/mol.)

(A) 334 grams
(B) 167 grams
(C) 84 grams
(D) 42 grams
(E) 21 grams

49. Each of the following compounds was added to distilled water at 25°C. Which one produced a solution with a pH that was less than 7?

(A) N_2
(B) O_2
(C) NaI
(D) MgO
(E) SO_2

50. $...Be_2C\ +\ ...H_2O \rightarrow ...Be(OH)_2\ +\ ...CH_4$

When the equation for the reaction above is balanced with the lowest whole-number coefficients, the coefficient for H_2O will be

(A) 1
(B) 2
(C) 3
(D) 4
(E) 5

51. A sample of an ideal gas is placed in a sealed container of constant volume. If the temperature of the gas is increased from 40°C to 70°C, which of the following values for the gas will NOT increase?

(A) The average speed of the molecules of the gas
(B) The average kinetic energy of the molecules of the gas
(C) The pressure exerted by the gas
(D) The density of the gas
(E) The frequency of collisions between molecules of the gas

52. A $^{222}_{86}Rn$ nuclide decays through the emission of two beta particles and two alpha particles. The resulting nuclide is

(A) $^{214}_{84}Po$
(B) $^{210}_{84}Po$
(C) $^{214}_{83}Bi$
(D) $^{210}_{83}Bi$
(E) $^{214}_{82}Pb$

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53. When 80.0 ml of a 0.40 *M* NaI solution is combined with 20.0 ml of a 0.30 *M* CaI_2 solution, what will be the molar concentration of I^- ions in the solution?

(A) 0.70 *M*
(B) 0.44 *M*
(C) 0.38 *M*
(D) 0.35 *M*
(E) 0.10 *M*

54.

Compound	K_{sp} at 25°C
FeS	6.33×10^{-18}
PbS	8.03×10^{-28}
MnS	1.03×10^{-13}

A solution at 25 C contains Fe^{2+}, Pb^{2+}, and Mn^{2+} ions. Which of the following gives the order in which precipitates will form, from first to last, as Na_2S is steadily added to the solution?

(A) FeS, PbS, MnS
(B) MnS, PbS, FeS
(C) FeS, MnS, PbS
(D) MnS, FeS, PbS
(E) PbS, FeS, MnS

55. Hydrogen sulfide is a toxic waste product of some industrial processes. It can be recognized by its distinctive rotten egg smell. One method for elimininating hydrogen sulfide is by reaction with dissolved oxygen, as shown below.

$$2\,H_2S + O_2 \rightarrow 2\,S + 2H_2O$$

If 102 grams of H_2S are combined with 64 grams of O_2, what is the maximum mass of elemental sulfur that could be produced by the reaction?

(A) 16 grams
(B) 32 grams
(C) 48 grams
(D) 64 grams
(E) 96 grams

56. $$Mn(s) + Cu^{2+}(aq) \rightarrow Mn^{2+}(aq) + Cu(s)$$

A voltaic cell based on the reaction above was constructed from manganese and zinc half-cells. The standard cell potential for this reaction was 1.52 volts, but the observed voltage at 25°C was 1.66 volts. Which of the following could explain this observation?

(A) The Mn^{2+} solution was more concentrated than the Cu^{2+} solution.
(B) The Cu^{2+} solution was more concentrated than the Mn^{2+} solution.
(C) The manganese electrode was larger than the copper electrode.
(D) The copper electrode was larger than the manganese electrode.
(E) The atomic weight of copper is greater than the atomic weight of manganese.

57. The rate of effusion of helium gas (atomic weight 4.0) at a given temperature and pressure is known to be *x*. What would be the expected rate of effusion for hydrogen gas (molecular weight 2.0) at the same temperature and pressure?

(A) $\frac{x}{2}$

(B) $\frac{x}{\sqrt{2}}$

(C) x

(D) $x\sqrt{2}$

(E) $2x$

58. $$H_2O(g) \rightarrow H_2O(l)$$

Which of the following is true of the values of ΔH, ΔS, and ΔG for the reaction shown above at 25°C?

	ΔH	ΔS	ΔG
(A)	Positive	Positive	Positive
(B)	Positive	Negative	Negative
(C)	Negative	Positive	Negative
(D)	Negative	Negative	Positive
(E)	Negative	Negative	Negative

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59. A student added 1 liter of a 1.0 *M* Na_2SO_4 solution to 1 liter of a 1.0 *M* $Ag(C_2H_3O_2)$ solution. A silver sulfate precipitate formed, and nearly all of the silver ions disappeared from the solution. Which of the following lists the ions remaining in the solution in order of decreasing concentration?

(A) $[SO_4^{2-}] > [C_2H_3O_2^-] > [Na^+]$
(B) $[C_2H_3O_2^-] > [Na^+] > [SO_4^{2-}]$
(C) $[C_2H_3O_2^-] > [SO_4^{2-}] > [Na^+]$
(D) $[Na^+] > [SO_4^{2-}] > [C_2H_3O_2^-]$
(E) $[Na^+] > [C_2H_3O_2^-] > [SO_4^{2-}]$

60. Iron ore is converted to pure iron by the following reaction, which occurs at extremely high temperatures:

$$Fe_2O_3 + 3\,CO \rightarrow 2\,Fe + 3\,CO_2$$

A 1,600 gram sample of iron ore reacted completely to form 558 grams of pure iron. What was the percent of Fe_2O_3 (molecular weight 160) by mass in the original sample?

(A) 25%
(B) 33%
(C) 50%
(D) 67%
(E) 100%

61. Gold and silver have been used throughout history to make coins. Which of the following statements could account for the popularity of these metals for use in coins?

(A) Network bonds make these metals especially durable.
(B) Negative oxidation potentials for these metals make them especially unreactive with their surroundings.
(C) These metals are among the lightest of the elements.
(D) These metals are commonly found in nature.
(E) These metals form ions that are extremely soluble in water.

62. A student added a salt to an aqueous solution of sodium sulfate. After the salt was added, a sulfate compound was observed as a precipitate. Which of the following could have been the salt added in this experiment?

I. $BaCl_2$
II. $Pb(NO_3)_2$
III. $AgC_2H_3O_2$

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

63. $$2\,HI(g) \rightarrow H_2(g) + I_2(g)$$

For the reaction given above, $\Delta H°$ is –50 kJ. Based on the information given in the table below, what is the average bond energy of the H–I bond?

Bond	Average Bond Energy (kJ/mol)
H–H	440
I–I	150

(A) 270 kJ/mol
(B) 540 kJ/mol
(C) 590 kJ/mol
(D) 640 kJ/mol
(E) 1,180 kJ/mol

64. A solid piece of barium hydroxide is immersed in water and allowed to come to equilibrium with its dissolved ions. The addition of which of the following substances to the solution would cause more solid barium hydroxide to dissolve into the solution?

(A) NaOH
(B) HCl
(C) NaCl
(D) $BaCl_2$
(E) NH_3

65. All of the elements listed below are gases at room temperature. Which gas would be expected to show the greatest deviation from ideal behavior?

(A) He
(B) Ne
(C) Ar
(D) Kr
(E) Xe

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Questions 66 and 67 refer to the information given below.

$$F_2(g) + 2\ ClO_2(g) \rightarrow 2\ FClO_2(g)$$

Experiment	$[F_2]$ (*M*)	$[ClO_2]$ (*M*)	Initial rate of disappearance of F_2 (*M*/ sec)
1	0.10	0.010	1.2×10^{-3}
2	0.20	0.010	2.4×10^{-3}
3	0.40	0.020	9.6×10^{-3}

66. Based on the data given in the table, which of the following expressions is equal to the rate law for the reaction given above?

(A) Rate = $k[F_2]$
(B) Rate = $k[ClO_2]$
(C) Rate = $k[F_2][ClO_2]$
(D) Rate = $k[F_2]^2[ClO_2]$
(E) Rate = $k[F_2][ClO_2]^2$

67. What is the initial rate of disappearance of ClO_2 in experiment 2?

(A) 1.2×10^{-3} *M*/sec
(B) 2.4×10^{-3} *M*/sec
(C) 4.8×10^{-3} *M*/sec
(D) 7.0×10^{-3} *M*/sec
(E) 9.6×10^{-3} *M*/sec

68. Hypobromous acid, HBrO, is added to distilled water. If the acid dissociation constant for HBrO is equal to 2×10^{-9}, what is the concentration of HBrO when the pH of the solution is equal to 5?

(A) 5-molar
(B) 1-molar
(C) 0.1-molar
(D) 0.05-molar
(E) 0.01-molar

69. $N_2(g) + 3\ Cl_2(g) \rightarrow 2\ NCl_3(g)$ $\Delta H = 460$ kJ

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

(A) It is not spontaneous at any temperatures.
(B) It is spontaneous only at very high temperatures.
(C) It is spontaneous only at very low temperatures.
(D) It is spontaneous only at very high concentrations.
(E) It is spontaneous only at very low concentrations.

70. At 25°C, the vapor pressure of water is 24 mmHg. Which of the following expressions gives the vapor pressure of a solution created by adding 2.0 moles of sucrose to 55 moles of water?

(A) $\frac{(24)(2.0)}{(55)}$ mmHg
(B) $\frac{(2.0)}{(24)(55)}$ mmHg
(C) $\frac{(24)(55)}{(57)}$ mmHg
(D) $\frac{(55)}{(24)(57)}$ mmHg
(E) $\frac{(24)(57)}{(55)}$ mmHg

71. $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$

When PCl_5 is placed in an evacuated container at 250°C, the above reaction takes place. The pressure in the container before the reaction takes place is 6 atm and is entirely due to the PCl_5 gas. After the reaction comes to equilibrium, the partial pressure due to Cl_2 is found to be 2 atm. What is the value of the equilibrium constant, K_p, for this reaction?

(A) 0.5
(B) 1
(C) 2
(D) 5
(E) 10

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72. $Co^{2+} + 2\,e^- \rightarrow Co$ $E^o = -0.28$ V

$Cr^{3+} + e^- \rightarrow Cr^{2+}$ $E^o = -0.41$ V

According to the information shown above, which of the following statements is true regarding the reaction below?

$$2\,Co + Cr^{3+} \rightarrow 2\,Co^{2+} + Cr^{2+}$$

(A) Cr^{3+} acts as the reducing agent.
(B) The reaction would take place in a galvanic cell.
(C) K_{eq} for the reaction is less than 1.
(D) Cobalt metal is reduced in the reaction.
(E) Chromium metal will plate out in the reaction.

73. What is the pH of a solution made by mixing 200 milliliters of a 0.20-molar solution of NH_3 with 200 milliliters of a 0.20-molar of an NH_4Cl solution? (The base dissociation constant, K_b, for NH_3 is 1.8×10^{-5}.)

(A) Between 3 and 4
(B) Between 4 and 5
(C) Between 5 and 6
(D) Between 8 and 9
(E) Between 9 and 10

74. $$POCl_3(l) \rightarrow POCl_3(g)$$

For the reaction above, ΔH is 50 kilojoules per mole and ΔS is 100 joules per mole. What is the boiling point of $POCl_3$? (Assume that ΔH and ΔS remain constant with changing temperature.)

(A) 0.5 K
(B) 2 K
(C) 50 K
(D) 200 K
(E) 500 K

75. When fluorine gas is bubbled through a concentrated aqueous solution of potassium chloride at room temperature, which of the following would be expected to occur?

(A) A reaction will occur, and chlorine gas will be produced.
(B) A reaction will occur, and potassium fluoride will precipitate.
(C) A reaction will occur, and solid chlorine will precipitate.
(D) A reaction will occur, and solid potassium will precipitate.
(E) No reaction will occur, and the fluorine gas will bubble through.

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.

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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.

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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

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

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

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

$K_w = [OH^-][H^+] = 10^{-14}$ @ 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

Equilibrium Constants

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

THERMOCHEMISTRY / KINETICS

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

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

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

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

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

$q = mc\Delta T$

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

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

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

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

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}

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ADVANCED PLACEMENT CHEMISTRY EQUATIONS AND CONSTANTS

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

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

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

$$P_{total} = P_A + P_B + P_C + \ldots$$

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

$$K = °C + 273$$

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

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

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

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

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

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

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

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

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

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

$$\log K = \frac{nE°}{0.0592}$$

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

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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

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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. At 25°C, the solubility product consant, K_{sp}, for nickel hydroxide, $Ni(OH)_2$, is 1.6×10^{-14}.

   (a) Write a balanced equation for the solubility equilibrium for $Ni(OH)_2$.

   (b) What is the molar solubility of $Ni(OH)_2$ in pure water at 25°C?

   (c) A 1.0-molar NaOH solution is slowly added to a saturated solution of $Ni(OH)_2$ at 25°C. If excess solid $Ni(OH)_2$ remains in the solution throughout the procedure, what is the concentration of Ni^{2+} ions in the solution at the moment when the pH is equal to 11?

   (d) Predict whether a precipitate will form when 200.0 milliliters of a 5.0×10^{-5}-molar KOH solution is mixed with 300.0 milliliters of a 2.0×10^{-4}-molar $Ni(NO_3)_2$ solution at 25°C. Show calculations to support your prediction.

   (e) At 25°C, 100 ml of a saturated $Ni(OH)_2$ solution was prepared.

      (i) Calculate the mass of $Ni(OH)_2$ present in the solution.

      (ii) Calculate the pH of the solution.

      (iii) If the solution is allowed to evaporate to a final volume of 50 ml, what will be the pH? Justify your answer.

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2. In two separate experiments, a sample of an unknown hydrocarbon was burned in air, and a sample of the same hydrocarbon was placed into an organic solvent.

   (a) When the hydrocarbon sample was burned in a reaction that went to completion, 2.2 grams of water and 3.6 liters of carbon dioxide were produced under standard conditions. What is the empirical formula of the hydrocarbon?

   (b) When 4.05 grams of the unknown hydrocarbon was placed in 100.0 grams of benzene, C_6H_6, the freezing point of the solution was measured to be 1.66°C. The normal freezing point of benzene is 5.50°C and the freezing-point depression constant for benzene is 5.12°C/*m*. What is the molecular weight of the unknown hydrocarbon?

   (c) What is the molecular formula and name of the hydrocarbon?

   (d) Write the balanced equation for the combustion reaction that took place in (a).

   (e) Draw two isomers for the hydrocarbon.

3. A strip of Ni metal is placed in a 1-molar solution of $Ni(NO_3)_2$ and a strip of Ag metal is placed in a 1-molar solution of $AgNO_3$. An electrochemical cell is created when the two solutions are connected by a salt bridge and the two metal strips are connected by wires to a voltmeter.

   (a) Write the balanced chemical equation for the overall reaction that occurs in the cell, and calculate the cell potential, E^o.

   (b) Calculate how many grams of metal will be deposited on the cathode if the cell is allowed to run at a constant current of 1.5 amperes for 8.00 minutes.

   (c) Calculate the value of the standard free energy change, ΔG^o, for the cell reaction.

   (d) Calculate the cell potential, E, at 25°C for the cell shown above if the initial concentration of $Ni(NO_3)_2$ is 0.100-molar and the initial concentration of $AgNO_3$ is 1.20-molar.

   (e) Is the reaction in the cell spontaneous under conditions described in part (d)? Justify your answer.

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) Solutions of sodium acetate and nitric acid are mixed.

(i) Write the balanced equation in this box:

(ii) Identify the spectator ion in this reaction.

______

______

(b) A piece of solid calcium is heated in oxygen gas.

(i) Write the balanced equation in this box:

(ii) Is the entropy change for this reaction positive or negative? Briefly explain.

______

______

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(c) Ammonia and boron trichloride gases are mixed.

(i) Write the balanced equation in this box:

(ii) Identify the Lewis acid in this reaction.

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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. Use your knowledge of chemical principles to answer the following questions.

	First ionization energy (kJ/mol)	**Second ionization energy (kJ/mol)**
Na	490	4,560
K	420	3,050

(a) The table above shows the first and second ionization energies for potassium and sodium.

(i) Explain the difference between the first ionization energies of potassium and sodium.

(ii) Explain why the second ionization energy for potassium is so much larger than the first ionization energy.

	Atomic radius (pm)
Na	190
Na^+	120
K	230
K^+	150
Cl	100
Cl^-	170
Br	110
Br^-	190

(b) The table above shows the atomic radii of several atoms and ions.

(i) The atomic radius of bromine is smaller than the atomic radius of potassium. Explain.

(ii) The potassium and chlorine ions have the same electronic structure. Explain the difference in their atomic radii.

(iii) When potassium bromide and sodium chloride are compared, which will have the higher melting point? Explain.

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Name	Formula	Boiling point (°C)
Methane	CH_4	–164
Methoxymethane	CH_3OCH_3	–23
Ethanol	CH_3CH_2OH	78

(c) The table above shows the boiling points for several organic compounds. Explain the trend in increasing boiling point.

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6. An experiment is to be performed involving the titration of a solution of benzoic acid, $HC_7H_5O_2$, of unknown concentration with a standardized 1.00-molar NaOH solution. The pK_a of benzoic acid is 4.2.

(a) What measurements and calculations must be made if the concentration of the acid is to be determined?

(b) An indicator must be chosen for the titration. If methyl red (pH interval for color change: 4.2–6.3) and thymol blue (pH interval for color change: 8.0–9.6) are the only indicators available, which one should be used? Explain your choice.

(c) Describe how you would use the titration apparatus and benzoic acid and NaOH solutions to create a buffer solution with a pH of 4.2 after you had measured the volume of NaOH solution required to reach the equivalence point for a given volume of benzoic acid solution.

(d) Describe a way to test whether the neutralization of benzoic acid by a strong base is an exothermic process, using readily available school laboratory equipment.

END OF EXAMINATION