

AP CHEMISTRY MIDTERM

Section 1 Multiple Choice Questions

75 Questions
50% of total grade

This section consists of 75 multiple-choice questions. Mark your answers carefully on the answer sheet.

General Instructions:

Do not open this booklet until you are told to do so by the proctor. Be sure to write your answers for Section I on the separate answer sheet. Use the test booklet for your scratch work or notes, but remember that no credit will be given for work, notes, or answers written only in the test booklet. Once you have selected an answer, blacken thoroughly the corresponding circle on the answer sheet. To change an answer, erase your previous mark completely, and then record your new answer. Mark only one answer for each question.

Many candidates wonder whether or not to guess the answers to questions about which they are uncertain. 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.

Because it is not expected that all test takers will complete this section, do not spend too much time on difficult questions. Answer first the questions you can answer readily, and then, if you have time, return to the difficult questions later. **Use your time effectively.**

NOTE: Unless otherwise stated, assume that for all questions involving solutions and/or chemical equations, the system is in water and at room temperature.

AP Chemistry Midterm 2007-2008

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmosphere, and solutions are aqueous unless otherwise specified.

Throughout the test the following symbols have the definitions specified unless otherwise noted.

T = temperature
P = pressure
V = volume
S = entropy
H = enthalpy
G = Gibb's free energy
R = molar gas constant
m = molal

L, mL = liter(s), milliliter(s)
g = gram(s)
nm = nanometer
atm = atmosphere(s)
mm Hg = millimeters of mercury
J, kJ = joule(s), kilojoule(s)
M = molar
mol = mole(s)

Directions Part A: Each set of lettered choices below refers to the numbered statements immediately following it. Select the one lettered choice that best fits each statement and then 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.

For questions 1-3 base your answers on a-e below:

- a. Moles
 - b. Liters
 - c. Grams
 - d. Atmospheres
 - e. Volts
1. One mole of solid zinc has a mass of 65.39 of these.
 2. These units can be calculated by dividing a quantity by 6.02×10^{23} .
 3. Four grams of helium gas occupies 22.4 of these at standard temperature and pressure.

For questions 4-6 base your answers on a-e below:

- a. BF_3
 - b. CO_2
 - c. H_2O
 - d. CF_4
 - e. PH_3
4. The central atom in this molecule forms sp^2 hybrid orbitals.
 5. This molecule contains a pi interaction.
 6. This molecule has a linear structure.

For questions 7-10 base your answers on a-e below:



The following are possible rate laws for the hypothetical reaction given above:

- a. Rate = $k[A]$
 - b. Rate = $k[B]^1$
 - c. Rate = $k[A][B]$
 - d. Rate = $k[A]^2[B]$
 - e. Rate = $k[A]^2[B]^2$
7. This is the rate law for a first order reaction.
 8. When $[A]$ is doubled and $[B]$ is held constant the initial rate of reaction will not change.
 9. This is the rate law for a third order reaction.
 10. For this rate law when $[A]$ and $[B]$ are doubled, the initial rate of reaction will increase by a factor of eight.

For questions 11-13 base your answers on a-e below:

- a. Oxidation-reduction
- b. Neutralization
- c. Fusion
- d. Combination or synthesis
- e. Decomposition

Which of the reaction types listed above best describes each of these processes?

11. $\text{CO}_2(\text{g}) + \text{CaO}(\text{s}) \rightarrow \text{CaCO}_3(\text{s})$
12. $\text{Fe}^{3+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{I}_2(\text{aq})$
13. $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

For questions 14-16 base your answers on a-e below

- a. H_2
 - b. He
 - c. O_2
 - d. N_2
 - e. CO_2
14. A 1 mole sample of this gas occupying 1 liter will have the greatest density.
 15. At a given temperature, this gas will have the greatest rate of effusion.
 16. This gas will deviate the most from the ideal gas law.
 17. The molecules of this gas contain polar bonds.

For questions 17-21 base your answers on a-e below

- a. Free energy change (ΔG)
 - b. Entropy change (ΔS)
 - c. Heat of vaporization
 - d. Heat of fusion
 - e. Heat capacity
18. If this has a negative value for a process then the process occurs spontaneously
 19. This is a measure of how the disorder of a system is changing.
 20. This is the energy given off when a substance condenses.
 21. This is a measure of how much the temperature of an object is raised when it absorbs heat.

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.

22. What is the wavelength of light that has a frequency of $4.00 \times 10^{14} \text{ s}^{-1}$? (The speed of light is $3.00 \times 10^8 \text{ m/s}$).
- 7.5 nm
 - 1333 nm
 - 750 nm
 - 1.33 cm^{-1}
 - $1.2 \times 10^{23} \text{ m}$
23. The lithium ion and the hydride ion are isoelectronic. Which of the following statements is true of these two chemical species in the ground state?
- Li^+ is a better reducing agent than H^- .
 - The H^- ion is several times larger than the Li^+ ion.
 - It requires more energy to remove an electron from H^- than from Li^+ .
 - The chemical properties of the two ions must be the same because they have the same electronic structure.
 - None of these is a true statement.
24. The Heisenberg uncertainty principle states that
- electrons have no momentum
 - the position of an electron is impossible to determine
 - the faster an electron moves, the more unreliable is its energy
 - the momentum and the position of an electron cannot be precisely defined simultaneously
 - Einstein's theory of relativity is still unproved
25. Which was used to determine the charge of an electron?
- the gold foil experiment
 - line emission spectrum
 - the oil drop experiment
 - electrolysis
 - the mass spectrometer
26. Which quantum number describes the shape of an orbital?
- n
 - l
 - m_l
 - m_s
 - s
27. What is most likely the electron configuration for a sodium ion in its ground state?
- $1s^2 2s^2 2p^5$
 - $1s^2 2s^2 2p^6$
 - $1s^2 2s^2 2p^6 3s^1$
 - $1s^2 2s^2 2p^5 3s^2$
 - $1s^2 2s^2 2p^6 3s^2$
28. The electron configuration of atoms of element X is shown below
 $[\text{Ar}] 4s^2 3d^{10}$
- Which is the most likely formula for the compound of this element and oxygen?
- XO
 - X_2O
 - XO_2
 - X_2O_3
 - X_2O_5

29. A Co^{3+} has _____ unpaired electron(s) and is _____/.

- a. 1, diamagnetic
- b. 3, paramagnetic
- c. 3, diamagnetic
- d. 4, paramagnetic
- e. 10, paramagnetic

30. Which pair of elements is expected to have the most similar properties?

- a. potassium and lithium
- b. sulfur and phosphorus
- c. silicon and carbon
- d. strontium and barium
- e. fluorine and iodine

31. Which of the following statements is true regarding sodium and chlorine?

- a. Sodium has greater electronegativity and a larger first ionization energy
- b. Sodium has a larger first ionization energy and a larger atomic radius
- c. Chlorine has a larger atomic radius and a greater electronegativity
- d. Chlorine has greater electronegativity and a larger first ionization energy
- e. Chlorine has a larger atomic radius and a larger first ionization energy

32. Which of the following ions has the smallest ionic radius?

- a. O^{2-}
- b. F^-
- c. Na^+
- d. Mg^{2+}
- e. Al^{3+}

33. Which of the following is true of the alkali metal elements?

- a. they usually take the +2 oxidation state
- b. they have oxides that act as acid anhydrides
- c. they form covalent bonds with oxygen
- d. they are generally found in nature in compounds
- e. they have relative large first ionization energies

34.

Mass of an empty container	3.0 grams
Mass of the container plus the solid sample	25.0 grams
Volume of the solid sample	11.0 cm^3

The data above were gathered in order to determine the density of an unknown solid. The density of the sample should be reported as

- a. 0.5 g/cm^3
- b. 0.50 g/cm^3
- c. 2.0 g/cm^3
- d. 2.00 g/cm^3
- e. 2.27 g/cm^3

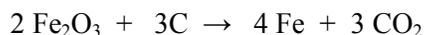
35. Chemical properties of elements are defined by the

- a. electrons
- b. ionization energy
- c. protons
- d. neutrons
- e. electronegativity

36. An element in the ground state

- a. has all of its electrons in the lowest possible energy levels is an element is found in nature
- b. is an element that is unreactive and found free in nature
- c. has all of its electrons paired
- d. has all of its orbitals occupied

37. What is the theoretical yield of iron when 2.00 grams of carbon is reacted with 26.0 grams of Fe_2O_3 ? Given the reaction:



- a. 9.1 g
- b. 12.4 g
- c. 74.6 g
- d. 37.3 g
- e. 18.2 g

38. The temperature of a sample of an ideal gas confined in a 2.0 L container was raised from 27°C to 77°C . If the initial pressure of the gas was 1200 mm Hg, what was the final pressure of the gas?

- a. 300 mm Hg
- b. 600 mm Hg
- c. 1400 mm Hg
- d. 2400 mm Hg
- e. 3600 mm Hg

39. What is the mass of oxygen in 148 grams of calcium hydroxide ($\text{Ca}(\text{OH})_2$)?

- a. 16 grams
- b. 24 grams
- c. 32 grams
- d. 48 grams
- e. 64 grams

40. A sample of propane C_3H_8 , was completely burned in air at STP. The reaction occurred as shown below:



If 67 liters of CO_2 were produced and all of the carbon in the CO_2 came from the propane, what was the mass of the propane sample?

- a. 11 grams
- b. 22 grams
- c. 33 grams
- d. 44 grams
- e. 55 grams

41. What is the formula of a compound formed by combining 50. grams of element X (atomic weight = 100.) and 32 grams of oxygen gas?

- a. XO_2
- b. XO_4
- c. X_4O
- d. X_2O
- e. XO

42. A sample of 3.30 grams of an ideal gas at 150.0°C and 1.25 atmospheres pressure has a volume of 2.00 liters. What is the molar mass of the gas? The gas constant, R, is $0.0821 \text{ (L}\cdot\text{atm)/ (mol}\cdot\text{K)}$

- a. 0.0218 g/mol
- b. 16.2 g/mol
- c. 37.0 g/mol
- d. 45.8 g/mol
- e. 71.6 g/mol

43. The kinetic molecular theory predicts that at a given temperature

- a. all gas molecules have the same kinetic energy
- b. all gas molecules have the same average velocity
- c. only real gas molecules collide with each other
- d. on the average, heavier molecules move more slowly
- e. elastic collisions result in the loss of energy

44. When a 1.00 gram sample of limestone (CaCO_3) was dissolved in acid, 0.38 grams of CO_2 was generated. If the rock contained no carbonate other than CaCO_3 , what was the percent of CaCO_3 by mass in the limestone?

- a. 17.0%
- b. 51.0%
- c. 64.0%
- d. 86.0%
- e. 100.0%

45. Under which conditions will a real gas behave most like an ideal gas?
- high pressure and high temperature
 - low pressure and low temperature
 - low volume and high temperature
 - low pressure and high temperature
 - high pressure and low temperature
46. Hydrogen gas is collected over water at 24°C . the total pressure of the sample is 755 mmHg. At 24°C , the vapor pressure of water is 22 mmHg. What is the partial pressure of the hydrogen gas?
- 22 mmHg
 - 733 mmHg
 - 755 mm Hg
 - 760 mmHg
 - 777 mmHg
47. Which of the following is an insoluble compound?
- $\text{Ca}(\text{OH})_2$
 - Fe_2S_3
 - MnO_2
 - SO_4^{2-}
 - MnO_4^-
48. The correct name for $\text{Fe}(\text{NO}_3)_3$ is
- iron nitrate
 - iron (II) nitrate
 - ferrous nitroxide
 - iron (II) sulfate
 - iron (III) nitrate
49. Element X is found in two forms: 90.0% is an isotope that has a mass of 20.0, and 10.0% is an isotope that has a mass of 22.0. What is the atomic mass of element X?
- 20.1
 - 20.2
 - 20.8
 - 21.2
 - 21.8
50. Which of the following is true when a $\text{C}=\text{C}$ and $\text{C}\equiv\text{C}$ bonds are compared?
- the triple bond is shorter than the double bond
 - the double bond vibrates at a lower frequency than the triple bond
 - the double bond energy is lower than the triple bond energy
 - both are composed of sigma and pi bonds
 - all of the above is true
51. The F-B-F bond angle in the BF_3 molecule is
- 109.5°
 - 60°
 - 120°
 - 90°
 - 180°
52. Molecules that have planar configurations include which of the following?
- I. BCl_3 II. CHCl_3 III. NCl_3
- I only
 - III only
 - I and II only
 - II and III only
 - I, II, and III

53. A liquid whose molecules are held together by which of the following forces would be expected to have the lowest boiling point?

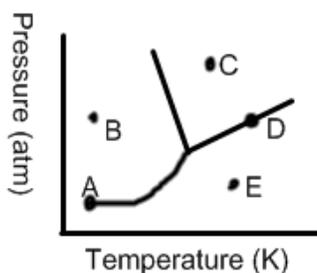
- a. ionic bonds
- b. london dispersion forces
- c. hydrogen bonds
- d. metallic bonds
- e. network bonds

54. Which of the following do exhibit resonance?

- i. SO_2
- ii. SO_3
- iii. CO_3^{2-}

- a. II only
- b. I and II only
- c. I and III only
- d. II and III only
- e. I, II, and III

For questions 55-58 base your answers on the phase diagram below



55. At this point the substance represented by the phase diagram will be solely in the solid phase at equilibrium

56. This point represents a boiling point of the substance

57. At this point, the substance represented by the phase diagram could be undergoing sublimation

58. At this point the substance represented by the phase diagram will be solely in the liquid phase at equilibrium

59. A substance that exhibits low intermolecular attractions is expected to have

- a. low viscosity, low boiling point, and low heat of vaporization
- b. high viscosity, low boiling point, and low heat of vaporization
- c. low viscosity, high boiling point, and low heat of vaporization
- d. low viscosity, low boiling point, and high heat of vaporization
- e. high viscosity, high boiling point, and high heat of vaporization

60. Which of the following actions would be likely to change the boiling point of a sample of a pure liquid in an open container?

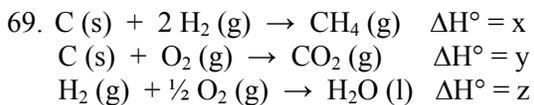
- I. Placing it in a smaller container
- II. Increasing the number of moles of the liquid in the container
- III. Moving the container and liquid to a higher altitude

- a. I only
- b. II only
- c. III only
- d. II and III only
- e. I, II, and III

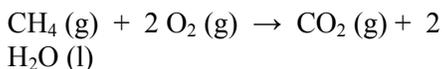
61. How many milliliters of 50.0% (by mass) HNO_3 solution, with a density of 2.00 grams per milliliter, are required to make 500. mL of a 2.00M HNO_3 solution?

- a. 50.0 mL
- b. 63.0 mL
- c. 100. mL
- d. 200. mL
- e. 250. mL

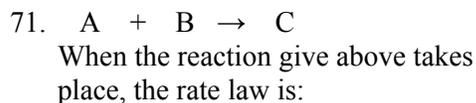
62. Which of the following is expected to be most soluble in hexane, C_6H_{14} ?
- KCl
 - C_2H_5OH
 - C_6H_6
 - H_2O
 - $HC_2H_2O_2$
63. If 20.0 g of ethanol (molar mass = 46) and 30.0 g of water (molar mass = 18) are mixed together, the mole fraction of ethanol in this mixture is
- 0.207
 - 0.261
 - 0.739
 - 0.793
 - 4.83
64. When 5.92 grams of a nonvolatile, nonionizing compound is dissolved in 186 grams of water, the freezing point (at normal pressure) of the resulting solution is $-0.592^\circ C$. What is the molecular weight of the compound? (The freezing point depression constant, K_f , for water is $1.86^\circ C/m$).
- 10.0 g/mol
 100. g/mol
 110. g/mol
 200. g/mol
 210. g/mol
65. To make a solution, 3.45 mole of $C_6H_{13}Cl$ and 1.26 mole of C_5H_{12} are mixed. Which of the following is needed, but not readily available, to calculate the molarity of this solution?
- the density of the solution
 - the densities of $C_6H_{13}Cl$ and C_5H_{12}
 - the temperature
 - the molar masses of $C_6H_{13}Cl$ and C_5H_{12}
 - the volume of $C_6H_{13}Cl$ and C_5H_{12}
66. When algae decay in a pond, the process uses up the available oxygen. Which of the following factors will also contribute to a decrease in oxygen in a pond?
- decreasing salinity (salt concentration)
 - increasing acidity due to acid rain
 - increasing temperature
 - increasing surface tension of water
 - increasing atmospheric pressure
67. Ethyl alcohol, C_2H_5OH , and water become noticeably warmer when mixed. This is due to
- the decrease in volume when they are mixed
 - smaller attractive forces in the mixture than in the pure liquids
 - the hydrogen bonding of the two liquids
 - the change in vapor pressure observed
 - stronger attractive forces in the mixture than in the pure liquids
68. The first law of thermodynamics can be given as
- $\Delta E = q + w$
 - $\Delta H^\circ_{rxn} = \sum n\Delta H^\circ_f(\text{products}) - \sum n\Delta H^\circ_f(\text{reactants})$
 - for any spontaneous process, the entropy of a system increases
 - the entropy of a pure crystalline substance at absolute zero is zero
 - $\Delta S = q_{rev}/T$ at constant temperature



Based on the information above, what is ΔH° for the reaction



- a. $x + y + z$
 - b. $x + y - z$
 - c. $2z + y - x$
 - d. $z + y - x$
 - e. $2z + y - 2x$
70. When 0.400 g of CH_4 is burned in excess oxygen in a bomb calorimeter that has a heat capacity of $3245 \text{ J/}^\circ\text{C}$, a temperature increase of 6.795°C is observed. What is the value of q ?
- a. 220 J/mol
 - b. -882 kJ
 - c. 477 kJ
 - d. -22.04 kJ
 - e. 8.82 kJ



$$\text{Rate} = k [A]$$

If the temperature of the reaction chamber were increased, which of the following would be true?

- a. the rate of reaction and the rate constant will increase
- b. the rate of reaction and the rate constant will not change
- c. the rate of reaction will increase and the rate constant will decrease
- d. the rate of reaction will increase and the rate constant will not change
- e. the rate of reaction will not change and the rate constant will increase

72. A multistep reaction takes place by the following mechanism.



Which of the species shown above is an intermediate in the reaction?

- a. A
- b. B
- c. C
- d. D
- e. E



Based on the following experimental data, what is the rate law for the hypothetical reaction given above?

Experiment	[A] (M)	[B] (M)	Initial Rate of Formation of C (mol/L-sec)
1	0.20	0.10	3×10^{-2}
2	0.20	0.20	6×10^{-2}
3	0.40	0.20	6×10^{-2}

- Rate = $k[A]$
- Rate = $k[A]^2$
- Rate = $k[B]$
- Rate = $k[B]^2$
- Rate = $k[A][B]$

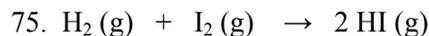


The rate law for the hypothetical reaction shown above is as follows:

$$\text{Rate} = k[A]$$

Which of the following changes to the system will increase the rate of the reaction?

- An increase in the concentration of A
 - An increase in the concentration of B
 - An increase in the temperature
- i only
 - i and ii only
 - i and iii only
 - ii and iii only
 - i, ii, and iii



When the reaction given above takes place in a sealed isothermal container, the rate law is:

$$\text{Rate} = k[H_2][I_2]$$

If a mole of H_2 gas is added to the reaction chamber, which of the following will be true?

- The rate of reaction and the rate constant will increase
- The rate of reaction and the rate constant will not change
- The rate of reaction will increase and the rate constant will decrease
- The rate of reaction will increase and the rate constant will not change
- The rate of reaction will not change and the rate constant will increase

**END OF PART 1
MOVE ON TO PART II**

Section II: Free Response Questions
Parts A and B: 50% of Total Grade

General Instructions:

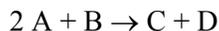
Part A is problem solving. Question 1 is required; you must do either questions 2 or 3.

Part B is theory. Questions 4 and 5 are required, you must do two of the following three questions (6, 7, 8).

PART A Problem Solving:

Directions: CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. 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.

1 REQUIRED – you must complete this question. The Section II score weighing for this question is 20%.



The following results were obtained when the reaction represented above was studied at 25°C.

Experiment	Initial [A]	Initial [B]	Initial Rate of Formation of C (mol L ⁻¹ min ⁻¹)
1	0.25	0.75	4.3×10^{-4}
2	0.75	0.75	1.3×10^{-3}
3	1.50	1.50	5.3×10^{-3}
4	1.75	?	8.0×10^{-3}

- (a) Determine the order of the reaction with respect to A and to B. Justify your answer
- (b) Write the rate law for the reaction. Calculate the value of the rate constant, specifying units.
- (c) Determine the initial rate of change of [A] in Experiment 3.
- (d) Determine the initial value of [B] in Experiment 4.
- (e) Identify which of the reaction mechanisms represented below is consistent with the rate law developed in part (b). Justify your choice.
- $A + B \rightarrow C + M$ *Fast*
 $M + A \rightarrow D$ *Slow*
 - $B \leftrightarrow M$ *Fast equilibrium*
 $M + A \rightarrow C + X$ *Slow*
 $A + X \rightarrow D$ *Fast*
 - $A + B \rightarrow M$ *Fast equilibrium*
 $M + A \rightarrow C + X$ *Slow*
 $X \rightarrow D$ *Fast*

Answer EITHER Question 2 or Question 3. Choose one of the following two questions. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The section II score weighing for the question you choose is 20%.

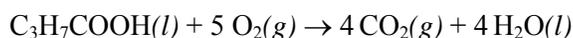
2.

- (a) A solution containing 3.23 grams of an unknown compound dissolved in 100.0 grams of water freezes at -0.97°C . The solution does not conduct electricity. Calculate the molecular weight of the compound. (The molal freezing point depression constant for water is $1.86^{\circ}\text{C kg/m}$)
- (b) Elemental analysis of this unknown compound yields the following percentages by weight H = 9.74%; C = 38.70; O = 51.56%. Determine the molecular formula for the compound.
- (c) Complete the combustion of a 1.05 gram sample of compound with excess oxygen gas produces a mixture of $\text{H}_2\text{O}(g)$ and $\text{CO}_2(g)$. What is the pressure of this gas mixture when it is contained in a 3.00 liter flask at 127°C .

3.

Substance	Standard Heat of Formation, ΔH_f° , in kJ mol^{-1}	Absolute Entropy, S° , in $\text{J mol}^{-1} \text{K}^{-1}$
C(s)	0.00	5.69
CO ₂ (g)	-393.5	213.6
H ₂ (g)	0.00	130.6
H ₂ O(l)	-285.85	69.91
O ₂ (g)	0.00	205.0
C ₃ H ₇ COOH(l)	?	226.3

The enthalpy change for the combustion of butyric acid at 25°C , $\Delta H_f^{\circ},_{\text{comb}}$, is $-2,183.5$ kilojoules per mole. The combustion reaction is



- (a) From the above data, calculate the standard heat of formation, ΔH_f° , for butyric acid.
- (b) Write a correctly balanced equation for the formation of butyric acid from its elements.
- (c) Calculate the standard entropy change, ΔS_f° , for the formation of butyric acid at 25°C . The entropy change, ΔS° , for the combustion reaction above is -117.1 J K^{-1} at 25°C .
- (d) Calculate the standard free energy of formation, ΔG_f° , for butyric acid at 25°C

END OF PART A
MOVE TO NEXT PAGE FOR PART B

Part B Theory:

Answer Question 4 below. The Section II score weighing for this question is 15%

4. You are given eight options for this question. Answer only five. Write an unbalanced net ionic equation for the following reactions. All reactants are assumed to be aqueous unless otherwise stated. All reactions do occur.
- Solutions of cobalt (II) nitrate and sodium hydroxide are mixed.
 - Equal volumes of equimolar solutions of phosphoric acid and potassium hydroxide are mixed.
 - Ethanol is burned in oxygen
 - Solid barium oxide is added to distilled water
 - A solution of hydrogen peroxide is heated
 - A solution of copper (II) sulfate is added to a solution of barium hydroxide
 - A strip of magnesium is added to a solution of silver nitrate
 - Solid calcium is added to warm water

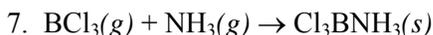
Your responses to the rest of the questions in this part of the examination will be graded on the basis of accuracy and the relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

Answer BOTH question 5 and 6. Both of these questions will be graded. The Section II score weighing for these questions is 30% (15% each).

5. Explain each of the following observations in terms of the electronic structure and/or bonding of the compounds involved.
- At ordinary conditions, HF (normal boiling point = 20°C) is a liquid, whereas HCl (normal boiling point = -114°C) is a gas.
 - Molecules of AsF_3 are polar, whereas molecules of AsF_5 are nonpolar.
 - The N-O bonds in the NO_2^- ion are equal in length, whereas they are unequal in HNO_2 .
 - For sulfur, the fluorides SF_2 , SF_4 , and SF_6 are known to exist, whereas for oxygen only OF_2 is known to exist.

6. Use the details of modern atomic theory to explain each of the following experimental observations.
- Within a family such as the alkali metals, the ionic radius increases as the atomic number increases.
 - The radius of the chlorine atom is smaller than the radius of the chloride ion, Cl^- . (Radii : Cl atom = 0.99\AA ; Cl^- ion = 1.81\AA)
 - The first ionization energy of aluminum is lower than the first ionization energy of magnesium. (First ionization energies: ${}_{12}\text{Mg} = 7.6\text{ eV}$; ${}_{13}\text{Al} = 6.0\text{ eV}$)
 - For magnesium, the difference between the second and third ionization energies is much larger than the difference between the first and second ionization energies. (Ionization energies for Mg: $1^{\text{st}} = 7.6\text{ eV}$; $2^{\text{nd}} = 14\text{ eV}$; $3^{\text{rd}} = 80\text{ eV}$)

Answer EITHER Question 7 or Question 8. Only one of these questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighing for the question you choose is 15%.



The reaction represented above is a reversible reaction.

- Predict the sign of the entropy change, ΔS , as the reaction proceeds to the right. Explain your prediction.
 - If the reaction spontaneously proceeds to the right, predict the sign of the enthalpy change, ΔH . Explain your prediction.
 - The direction in which the reaction spontaneously proceeds changes as the temperature is increased above a specific temperature. Explain.
 - What is the value of the equilibrium constant at the temperature referred to in (c); that is, the specific temperature at which the direction of the spontaneous reaction changes? Explain.
8. Give scientific explanation for the following observations. Use equations or diagrams if they are relevant.
- It takes longer to cook an egg until it is hard-boiled in Denver (altitude 1 mile above sea level) than it does in New York City (near sea level)
 - Burning coal containing a significant amount of sulfur leads to “acid rain”
 - Perspiring is a mechanism for cooling the body
 - The addition of antifreeze to water in a radiator decreases the likelihood that the liquid in the radiator will either freeze or boil.

END OF EXAMINATION