

SAMPLE EXAMINATION IV

Section I – Multiple Choice

Questions 1-5. The set of lettered choices, a list of oxides, below refers to the numbered phrases immediately following it. Select the one lettered choice that is most closely associated with each numbered phrase. Each lettered choice can be used once, more than once or not at all.

- (A) SO_2
- (B) BaO_2
- (C) CO_2
- (D) GeO_2
- (E) NO_2

1. an odd electron molecule
2. an ionic compound
3. at STP the gas that illustrates greatest deviation from ideal behavior
4. source of a semiconductor
5. includes a element with oxidation number of +2

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6. Which event is most likely to occur in an experiment to measure ionization energy?
 - (A) A positive ion is converted to a negative ion.
 - (B) A neutral atom is converted to a positive ion.
 - (C) A neutral atom is converted to a negative ion.
 - (D) A negative ion is converted to a neutral atom.
 - (E) A negative ion is converted to a positive ion.

7. All of these sets of quantum numbers apply to an electron in the p -sublevel EXCEPT
- (A) 2, 1, 1, $+\frac{1}{2}$
 - (B) 3, 1, 0, $+\frac{1}{2}$
 - (C) 3, 1, 0, $-\frac{1}{2}$
 - (D) 2, 0, 0, $+\frac{1}{2}$
 - (E) 2, 1, 0, $+\frac{1}{2}$
8. Which is a correct comparison of a sulfide ion to a sulfur atom?
- I. The radius of the sulfur atom is greater.
 - II. The sulfide ion contains more electrons.
 - III. The number of energy levels occupied by electrons is the same.
- (A) I only
 - (B) II only
 - (C) I and II only
 - (D) I and III only
 - (E) II and III only

Questions 9-11: The set of lettered choices below is a list of molecular formulas for certain gases. Select the one lettered choice that best fits each numbered description of the bonds within the molecules of the gas.

- (A) H_2
 - (B) N_2
 - (C) O_2
 - (D) F_2
 - (E) Cl_2
9. contains bond with greatest multiplicity
10. has the strongest bond
11. has the shortest bond length
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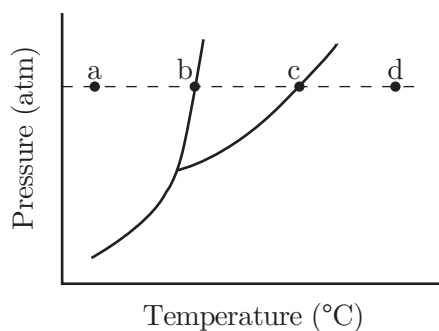
Questions 12-14: The set of lettered choices below is a list of molecular geometries. For each numbered species, select the one lettered choice that describes its molecular geometry.

- (A) linear
- (B) seesaw
- (C) square planar
- (D) square pyramidal
- (E) T-shaped

12. XeCl_4

13. I_3^-

14. IF_3



15. The dashed line, ad , in the phase diagram above represents properties of a closed system as energy is added to that system at a constant rate. The properties are observed at points a , b , c , and d . Which is associated with the longest time period?

- (A) change in temperature from a to b
- (B) equilibrium with constant temperature at b
- (C) change in temperature from b to c
- (D) equilibrium with constant temperature at c
- (E) change in temperature from c to d

16. Which gives a reason why, compared to CO_2 , SO_2 exhibits greater deviation from ideal gas behavior?
- I. The O-S-O bond angle is greater than the O-C-O bond angle.
 - II. A molecule of SO_2 contains more electrons than a molecule of CO_2 .
 - III. The bond order of the S-O bond is less than the bond order of the C-O bond.
- (A) I only
(B) II only
(C) III only
(D) I and III only
(E) II and III only
17. When these five water solution systems are listed in order of increasing vapor pressure, which position is occupied by 0.1 *m* $\text{C}_6\text{H}_{12}\text{O}_6$, glucose? (Assume ideal behavior.)
- 0.2 *m* KNO_3
0.2 *m* $(\text{NH}_2)_2\text{CO}$, urea
0.1 *m* CaCl_2
0.1 *m* $\text{C}_2\text{H}_5\text{OH}$
0.1 *m* $\text{C}_6\text{H}_{12}\text{O}_6$, glucose
- (A) first
(B) second
(C) third
(D) fourth
(E) fifth
18. A solution is prepared by dissolving 8.01 g of ammonium nitrate, NH_4NO_3 (molar mass: 80.1 g), in enough water to yield 250.0 mL of solution. What is the molarity of ammonium nitrate in this solution?
- (A) 32.0 *M*
(B) 4.00 *M*
(C) 0.400 *M*
(D) 0.100 *M*
(E) 0.0400 *M*

19. Which aqueous solution has the highest boiling point?
- (A) 0.1 *m* SrBr₂
 - (B) 0.1 *m* KBr
 - (C) 0.1 *m* MgSO₄
 - (D) 0.1 *m* CH₃COOH
 - (E) 0.1 *m* C₂H₅OH
20. Which of these chlorine-containing compounds is most soluble in water?
- (A) AgCl
 - (B) CCl₃OH
 - (C) CCl₄
 - (D) PbCl₂
 - (E) HClO₄
21. Which conditions of pressure and temperature favor greatest solubility of a gas into a liquid?
- | P | T |
|--------------|----------|
| (A) low | low |
| (B) low | high |
| (C) high | low |
| (D) high | high |
| (E) moderate | moderate |
22. A solution is prepared by dissolving 1.0 mol of acetic acid, CH₃COOH (molar mass: 60.0 g), in 5.0 mol water (molar mass: 18 g). Which expression gives the molality of this solution.
- (A) $\frac{1}{0.090}$
 - (B) $\frac{1}{5}$
 - (C) $\frac{1}{6}$
 - (D) $\frac{60}{5 \times 18}$
 - (E) $\frac{60}{0.090}$

23. Consider a solution that is 0.50 X (mole fraction) of ethanol (molar mass: 46 g) in water (molar mass: 18 g). Which value gives the best approximation for percent by mass ethanol in that solution?
- (A) 10%
(B) 25%
(C) 50%
(D) 75%
(E) 90%
24. The mass percent of one oxide of manganese is determined to be 69.6% Mn and 30.4% O. Which expression is the best representation of the empirical formula of this compound?
- (A) $\text{Mn}_{\frac{69.6}{6.02}} \text{O}_{\frac{30.4}{6.02}}$
(B) $\text{Mn}_{\frac{69.6}{30.4}} \text{O}_{\frac{30.4}{30.4}}$
(C) $\text{Mn}_{\frac{69.6}{30.4}} \text{O}_{\frac{30.4}{69.6}}$
(D) $\text{Mn}_{\frac{69.6}{55.0}} \text{O}_{\frac{30.4}{16.0}}$
(E) $\text{Mn}_{\frac{55.0}{69.6}} \text{O}_{\frac{16.0}{30.4}}$
25. When zinc reacts with nitric acid, one product is ammonium nitrate. When the corresponding half-reaction as shown below is balanced using the lowest integers, what is the sum of the coefficients?
- $$\text{..?.. NO}_3^- + \text{..?.. H}^+ + \text{..?.. e}^- \rightarrow \text{..?.. NH}_4^+ + \text{..?.. H}_2\text{O}$$
- (A) 13
(B) 15
(C) 19
(D) 21
(E) 23
26. Consider a mixture of gases that contains 0.10 mol of $\text{N}_2\text{O}_{5(g)}$ and 0.10 mol of $\text{NO}_{2(g)}$ at STP. Which gives a correct description of a quantity of material present?
- I. The number of atoms is greater than 5×10^{23} .
II. The number of molecules is greater than 1×10^{23} .
III. The volume of the sample is greater than 2.24 liters.
- (A) I and II only
(B) II and III only
(C) III only
(D) I and III only
(E) I, II and III only

Section II

Section II - Free Response Total Time – 90 Minutes
(Multiple-Choice Questions are found in Section I.)

Part A: Question 76
and
Question 77 or Question 78
Time: 40 minutes

Access to calculators, Periodic Table, lists of standard reduction potentials, and
Equations and Constants

(2004 Examination directions) Clearly show the method used and the steps involved in arriving at your answers. It is to your advantage to do this, because 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 all your answers to the questions on the lined pages following each question in the booklet with the pink cover. Do not write your answers on the green insert.

Answer question 76 below. The Section II score weighting for this question is 20 percent.

76. Ammonium hydrogen sulfide is a white crystalline solid that decomposes according to the equation



In one experiment, solid NH_4HS was placed in a 5.0 L rigid container at 298 K. At equilibrium, the total pressure was 0.660 atm with the gas phase in contact with excess solid.

- Write the mass action expression, K_p , for this equilibrium system.
- Calculate the numerical value for K_p at 298 K.
- Equilibrium in this system was disturbed by the addition of $\text{NH}_{3(g)}$. A new equilibrium including the solid phase was established in which the pressure of $\text{NH}_{3(g)}$ was equal to three times the pressure of $\text{H}_2\text{S}_{(g)}$: $P_{\text{NH}_3} = 3 P_{\text{H}_2\text{S}}$
 - Calculate the partial pressure of H_2S at this new equilibrium.
 - Calculate the change in moles of $\text{NH}_4\text{HS}_{(s)}$ present in the system; include the correct sign for this change.
- In a different experiment in a different vessel at the same temperature, $\text{NH}_{3(g)}$ and $\text{H}_2\text{S}_{(g)}$ were mixed. At the time of mixing, the partial pressure of H_2S was 1.00 atm. The initial partial pressure of $\text{NH}_{3(g)}$ was unknown. After equilibrium was established, the partial pressure of H_2S was 0.75 atm.
 - Calculate the partial pressure of NH_3 at equilibrium.
 - Calculate the original pressure of NH_3 at the time of mixing.

Answer either question 77 or question 78 below.

(2004 examination directions) 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 weighting for the question that you choose is 20 percent.

77. The following data were obtained from a study of the kinetics of the reaction below at 298 K.



Trial	initial concentration mol L ⁻¹			rate of formation moles sec ⁻¹
	[Br ⁻]	[BrO ₃ ⁻]	[H ⁺]	Br ₂
I.	1.0 × 10 ⁻³	5.0 × 10 ⁻³	10. × 10 ⁻³	2.5 × 10 ⁻⁴
II.	2.0	5.0	10.	5.0
III.	1.0	10.	10.	2.5
IV.	1.0	5.0	20.	10.
V.	2.0	10.	20.	?

- Write the rate law for this reaction. What is the overall order for this reaction?
- Calculate the rate constant, k , for this reaction. Specify units.
- What is the predicted initial rate of formation of bromine in trial V?
- When trial III has reached completion, the concentration of one of the dissolved species is greater than either of the other two dissolved species.
 - Which of the dissolved species has the highest concentration? Explain your choice.
 - Calculate that concentration.

78. The following problems concern quantitative analysis of two chemical compounds.
- (a) A compound known to contain only the elements carbon, hydrogen, nitrogen, and oxygen was analyzed in the laboratory.
 - (i) A sample of the compound with mass 0.4788 g was sent through a series of tests that converted all combined nitrogen into nitrogen gas. The nitrogen gas was collected by water displacement and yielded a volume of 37.80 mL, measured at 23.8°C and 746.0 mmHg. According to a chemical handbook, at this temperature, the vapor pressure of water is 22.1 mmHg. Using the results of this experiment, calculate the mass percent of nitrogen in the compound.
 - (ii) In a separate experiment, 12.96 mg of the compound was burned in a pure oxygen atmosphere. Products collected were 35.14 mg carbon dioxide and 8.638 mg water. Using the results of this experiment, calculate the mass percent of carbon and hydrogen in the compound.
 - (iii) Explain how to use data from both experiments to calculate the mass percent of oxygen in the compound.
 - (b) In a separate experiment, a different compound is shown to consist of 25.4% by mass carbon, 3.20% by mass hydrogen, 37.5% by mass chlorine, and 33.9% by mass oxygen.
 - (i) Determine the empirical formula of the compound.
 - (ii) Identify additional information about the compound that is needed in order to determine the molecular formula.

Part B: Questions 79, 80, 81 and
Question 82 or Question 83
Time: 50 minutes

Access to Periodic Table, lists of standard reduction potentials
and *Equations and Constants*
No access to calculators

Answer question 79 below: The Section II score weighting for this question is 15 percent.

79. (2004 Examination directions) Write the formulas to show the reactants and the products for any FIVE of the laboratory situations described below. In all cases a reaction occurs. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solution as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You need not balance the equations.
- (a) Excess concentrated sodium hydroxide is poured onto solid aluminum hydroxide.
 - (b) Acidified solutions of iron(II) sulfate and potassium permanganate are mixed.
 - (c) A sample of 2-decanol is burned in excess oxygen.
 - (d) Solutions of dilute sulfuric acid and strontium hydroxide are mixed.
 - (e) Solutions of silver nitrate and sodium dichromate are mixed.
 - (f) A piece of calcium is heated in an atmosphere of pure nitrogen.
 - (g) A small quantity of dilute potassium hydroxide solution is poured into dilute nitrous acid solution.
 - (h) Solutions of tin(II) nitrate and cobalt(III) nitrate are mixed.

(2004 Examination directions) Your responses to the rest of the questions in this part of the examination will be graded on the basis of the accuracy and 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.

(2004 examination directions) **Answer both Question 80 and Question 81 below.**

Both questions will be graded.

The Section II score weighting for these questions is 30 percent (15 percent each).

80. In order to determine the degree of hydration of Epsom salts, a hydrated form of magnesium sulfate, a student performs several laboratory tests. The student weighs a clean, dry crucible and lid. The student then adds several grams of Epsom salts to the crucible and reweighs it. The crucible and salt sample are heated over a Bunsen burner flame for five minutes; the crucible is allowed to cool, then reweighed. The crucible is then returned to the Bunsen burner flame for an additional five minutes of heating. It is allowed to cool, then is reweighed.
- Prepare a data table to specify the measurements that should be taken during this procedure.
 - How can the student tell when this lab procedure is completed? Explain.
 - If the crucible is initially overheated so that some of the salt appears as a white wisp drifting away from the crucible, what effect will this have on the data recorded and on the final determination of degree of hydration? Explain.
 - If the empty crucible selected initially is clean but not dry, what effect will this have on the final determination of degree of hydration? Explain.
81. Consider an aqueous solution that is 10% NaCl by mass.
- Identify the additional facts about the solution that are needed (can be calculated or must be determined) in order to:
 - calculate the molality, m , of the NaCl in the solution.
 - calculate the molarity, M , of the solution.
 - calculate the mole fraction, χ , of water in the solution.
 - determine the freezing point of the solution at 1 atm. Assume complete dissociation of the solute.
 - The original solution of NaCl is heated from 20°C to 30°C at constant pressure. Which of the four measures of concentration is affected? Explain.
 - molarity
 - molality
 - mass percent
 - mole fraction

(2004 examination directions) **Answer either question 82 or question 83 below.** 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 weighting for the question that you choose is 15 percent.

82. Carbon monoxide and nitrogen monoxide are both gases that are found in small quantities in Earth's atmosphere.
- Which gas has molecules with the greater root-mean-square speed at 25°C? Explain.
 - What is the ratio of the rates of effusion of CO to NO? Show a set-up for your calculation. A calculated numerical answer is not required.
 - Draw a reasonable Lewis structure for each molecule. Which structure does not illustrate the usual principles for construction of Lewis structures? Explain.
 - Both of these gases causes some pollution of the air due to burning fossil fuels in the internal combustion engines of automobiles? Explain.
83. Although the elements scandium and selenium are both found in the Period 4 (fourth row) of the Periodic Table, the physical and chemical characteristics of these two elements are quite different. Explain the following differences in properties of the elements scandium and selenium in terms of atomic structure and/or bonding.
- The atomic radius of Sc is 160 *pm* while that of Se is 121 *pm*.
 - Scandium forms only one oxidation state but selenium has several, ranging from -2 to +6.
 - Scandium is a good conductor of electricity. Selenium is a poor conductor of electricity.
 - The reaction product of scandium with pure oxygen is Sc₂O₃ while selenium reacts with pure oxygen to form SeO₂.