Answer EITHER Question 7 below OR Question 8 printed on page 14. 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 you choose is 15 percent.

7. Answer the following questions about the structures of ions that contain only sulfur and fluorine.

(a) The compounds SF_4 and BF_3 react to form an ionic compound according to the following equation.

$$SF_4 + BF_3 \rightarrow SF_3BF_4$$

(i) Draw a complete Lewis structure for the SF_3^+ cation in SF_3BF_4.

(ii) Identify the type of hybridization exhibited by sulfur in the SF_3^+ cation.

(iii) Identify the geometry of the SF_3^+ cation that is consistent with the Lewis structure drawn in part (a)(i).

(iv) Predict whether the F–S–F bond angle in the SF_3^+ cation is larger than, equal to, or smaller than 109.5°. Justify your answer.

(b) The compounds SF_4 and CsF react to form an ionic compound according to the following equation.

$$SF_4 + CsF \rightarrow CsSF_5$$

(i) Draw a complete Lewis structure for the SF_5^- anion in $CsSF_5$.

(ii) Identify the type of hybridization exhibited by sulfur in the SF_5^- anion.

(iii) Identify the geometry of the SF_5^- anion that is consistent with the Lewis structure drawn in part (b)(i).

(iv) Identify the oxidation number of sulfur in the compound $CsSF_5$.

$GeCl_4$ $SeCl_4$ ICl_4^- ICl_4^+

6. The species represented above all have the same number of chlorine atoms attached to the central atom.

   (a) Draw the Lewis structure (electron-dot diagram) of each of the four species. Show all valence electrons in your structures.

   (b) On the basis of the Lewis structures drawn in part (a), answer the following questions about the particular species indicated.

      (i) What is the $Cl-Ge-Cl$ bond angle in $GeCl_4$?

      (ii) Is $SeCl_4$ polar? Explain.

      (iii) What is the hybridization of the I atom in ICl_4^- ?

      (iv) What is the geometric shape formed by the atoms in ICl_4^+ ?

6. Answer the following questions, which pertain to binary compounds.

(a) In the box provided below, draw a complete Lewis electron-dot diagram for the IF_3 molecule.

(b) On the basis of the Lewis electron-dot diagram that you drew in part (a), predict the molecular geometry of the IF_3 molecule.

(c) In the SO_2 molecule, both of the bonds between sulfur and oxygen have the same length. Explain this observation, supporting your explanation by drawing in the box below a Lewis electron-dot diagram (or diagrams) for the SO_2 molecule.

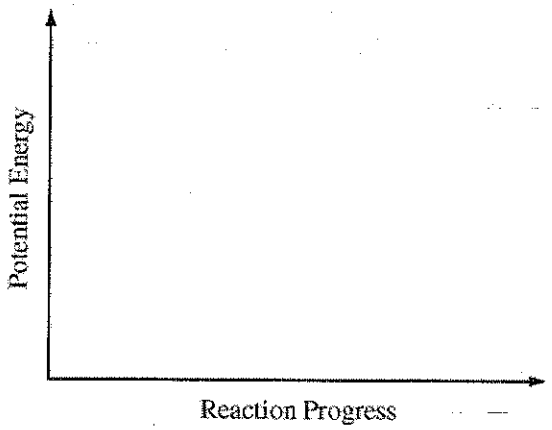
(d) On the basis of your Lewis electron-dot diagram(s) in part (c), identify the hybridization of the sulfur atom in the SO_2 molecule.

The reaction between $SO_2(g)$ and $O_2(g)$ to form $SO_3(g)$ is represented below.

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

The reaction is exothermic. The reaction is slow at 25°C; however, a catalyst will cause the reaction to proceed faster.

(e) Using the axes provided on the next page, draw the complete potential-energy diagram for both the catalyzed and uncatalyzed reactions. Clearly label the curve that represents the catalyzed reaction.



(f) Predict how the ratio of the equilibrium pressures, $\frac{P_{SO_2}}{P_{SO_3}}$, would change when the temperature of the uncatalyzed reaction mixture is increased. Justify your prediction.

(g) How would the presence of a catalyst affect the change in the ratio described in part (f)? Explain.

STOP

END OF EXAM

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

Your responses to these questions 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.

5. Using principles of atomic and molecular structure and the information in the table below, answer the following questions about atomic fluorine, oxygen, and xenon, as well as some of their compounds.

Atom	First Ionization Energy ($kJ\ mol^{-1}$)
F	1,681.0
O	1,313.9
Xe	?

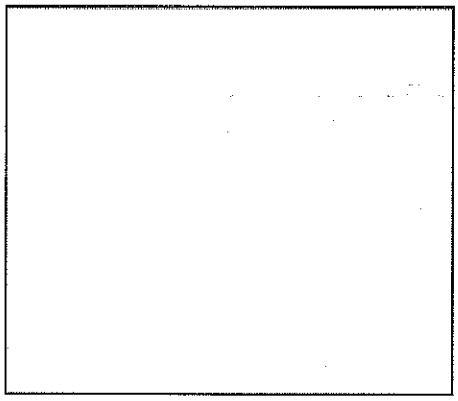
(a) Write the equation for the ionization of atomic fluorine that requires 1,681.0 $kJ\ mol^{-1}$.

(b) Account for the fact that the first ionization energy of atomic fluorine is greater than that of atomic oxygen. (You must discuss both atoms in your response.)

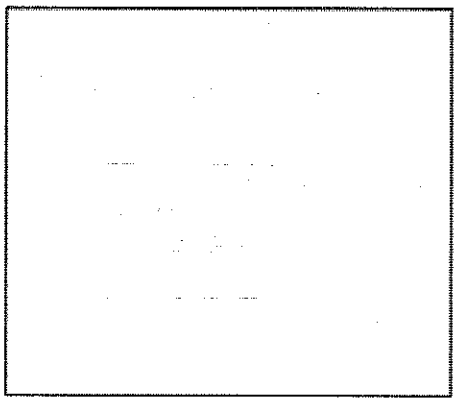
(c) Predict whether the first ionization energy of atomic xenon is greater than, less than, or equal to the first ionization energy of atomic fluorine. Justify your prediction.

(d) Xenon can react with oxygen and fluorine to form compounds such as XeO_3 and XeF_4. In the boxes provided, draw the complete Lewis electron-dot diagram for each of the molecules represented below.

XeO_3



XeF_4



(e) On the basis of the Lewis electron-dot diagrams you drew for part (d), predict the following:

(i) The geometric shape of the XeO_3 molecule

(ii) The hybridization of the valence orbitals of xenon in XeF_4

(f) Predict whether the XeO_3 molecule is polar or nonpolar. Justify your prediction.

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

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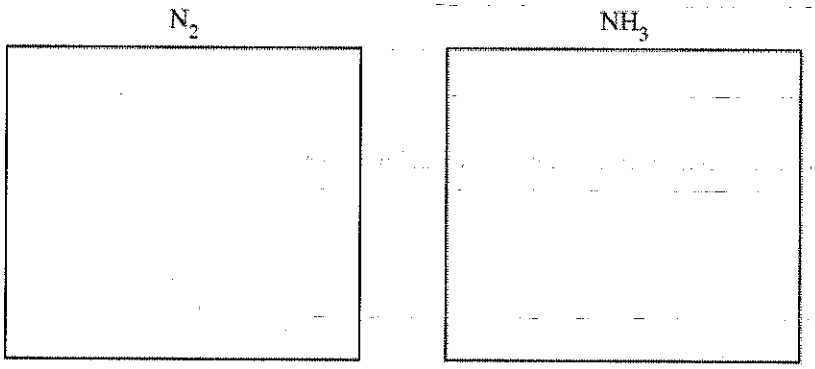
5. Answer the following questions about nitrogen, hydrogen, and ammonia.

(a) In the boxes below, draw the complete Lewis electron-dot diagrams for N_2 and NH_3.



(b) Calculate the standard free-energy change, $\Delta G°$, that occurs when 12.0 g of $H_2(g)$ reacts with excess $N_2(g)$ at 298 K according to the reaction represented below.

$$N_2(g) + 3\ H_2(g) \rightleftarrows 2\ NH_3(g) \qquad \Delta G°_{298} = -34\ \text{kJ mol}^{-1}$$

(c) Given that $\Delta H°_{298}$ for the reaction is -92.2 kJ mol^{-1}, which is larger, the total bond dissociation energy of the reactants or the total bond dissociation energy of the products? Explain.

(d) The value of the standard entropy change, $\Delta S°_{298}$, for the reaction is -199 J mol^{-1}K^{-1}. Explain why the value of $\Delta S°_{298}$ is negative.

(e) Assume that $\Delta H°$ and $\Delta S°$ for the reaction are independent of temperature.

(i) Explain why there is a temperature above 298 K at which the algebraic sign of the value of $\Delta G°$ changes.

(ii) Theoretically, the best yields of ammonia should be achieved at low temperatures and high pressures. Explain.

GO ON TO THE NEXT PAGE.

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

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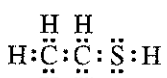
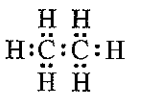
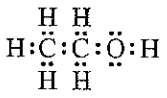
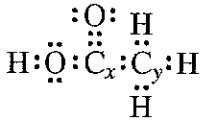
5. Use the information in the table below to respond to the statements and questions that follow. Your answers should be in terms of principles of molecular structure and intermolecular forces.

Compound	Formula	Lewis Electron-Dot Diagram
Ethanethiol	CH_3CH_2SH	
Ethane	CH_3CH_3	
Ethanol	CH_3CH_2OH	
Ethyne	C_2H_2	

(a) Draw the complete Lewis electron-dot diagram for ethyne in the appropriate cell in the table above.

(b) Which of the four molecules contains the shortest carbon-to-carbon bond? Explain.

(c) A Lewis electron-dot diagram of a molecule of ethanoic acid is given below. The carbon atoms in the molecule are labeled x and y, respectively.



Identify the geometry of the arrangement of atoms bonded to each of the following.

(i) Carbon x

(ii) Carbon y

(d) Energy is required to boil ethanol. Consider the statement "As ethanol boils, energy goes into breaking C–C bonds, C–H bonds, C–O bonds, and O–H bonds." Is the statement true or false? Justify your answer.

(e) Identify a compound from the table above that is nonpolar. Justify your answer.

(f) Ethanol is completely soluble in water, whereas ethanethiol has limited solubility in water. Account for the difference in solubilities between the two compounds in terms of intermolecular forces.

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

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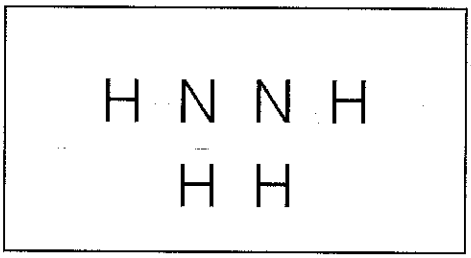
5. Hydrazine is an inorganic compound with the formula N_2H_4.

   (a) In the box below, complete the Lewis electron-dot diagram for the N_2H_4 molecule by drawing in all the electron pairs.



   (b) On the basis of the diagram you completed in part (a), do all six atoms in the N_2H_4 molecule lie in the same plane? Explain.

   (c) The normal boiling point of N_2H_4 is 114°C, whereas the normal boiling point of C_2H_6 is −89°C. Explain, in terms of the intermolecular forces present in <u>each</u> liquid, why the boiling point of N_2H_4 is so much higher than that of C_2H_6.

   (d) Write a balanced chemical equation for the reaction between N_2H_4 and H_2O that explains why a solution of hydrazine in water has a pH greater than 7.

N_2H_4 reacts in air according to the equation below.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2\,H_2O(g) \qquad \Delta H^\circ = -534\ \text{kJ mol}^{-1}$$

   (e) Is the reaction an oxidation-reduction, acid-base, or decomposition reaction? Justify your answer.

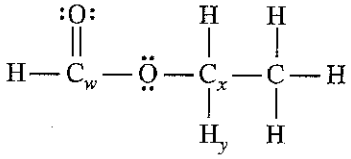
   (f) Predict the sign of the entropy change, ΔS, for the reaction. Justify your prediction.

   (g) Indicate whether the statement written in the box below is true or false. Justify your answer.

The large negative ΔH° for the combustion of hydrazine results from the large release of energy that occurs when the strong bonds of the reactants are broken.

6. Use principles of molecular structure, intermolecular forces, and kinetic molecular theory to answer the following questions.

(a) A complete Lewis electron-dot diagram of a molecule of ethyl methanoate is given below.



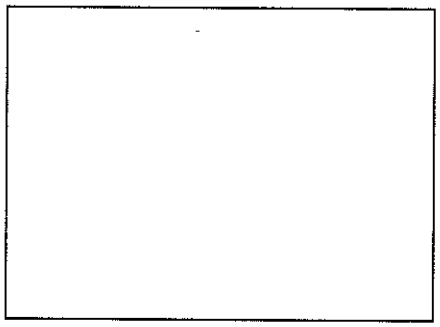
(i) Identify the hybridization of the valence electrons of the carbon atom labeled C_w.

(ii) Estimate the numerical value of the $H_y - C_x - O$ bond angle in an ethyl methanoate molecule. Explain the basis of your estimate.

(b) Ethyl methanoate, CH_3CH_2OCHO, is synthesized in the laboratory from ethanol, C_2H_5OH, and methanoic acid, $HCOOH$, as represented by the following equation.

$$C_2H_5OH(l) + HCOOH(l) \rightleftarrows CH_3CH_2OCHO(l) + H_2O(l)$$

(i) In the box below, draw the complete Lewis electron-dot diagram of a methanoic acid molecule.

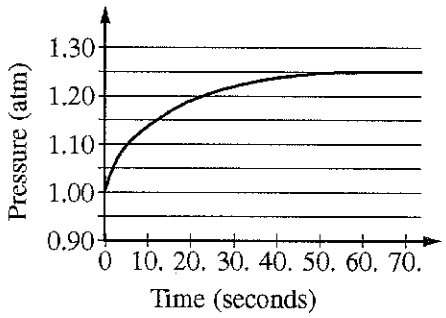


Methanoic Acid

(ii) In the box below, draw the complete Lewis electron-dot diagrams of a methanoic acid molecule and a water molecule in an orientation that allows a hydrogen bond to form between them.

Hydrogen Bonding Between Methanoic Acid and Water

(c) A small amount of liquid ethyl methanoate (boiling point 54°C) was placed in a rigid closed 2.0 L container containing argon gas at an initial pressure of 1.00 atm and a temperature of 20°C. The pressure in the container was monitored for 70. seconds after the ethyl methanoate was added, and the data in the graph below were obtained. It was observed that some liquid ethyl methanoate remained in the flask after 70. seconds. (Assume that the volume of the remaining liquid is negligible compared to the total volume of the container.)



(i) Explain why the pressure in the flask increased during the first 60. seconds.

(ii) Explain, in terms of processes occurring at the molecular level, why the pressure in the flask remained constant after 60. seconds.

(iii) What is the value of the partial pressure of ethyl methanoate vapor in the container at 60. seconds?

(iv) After 80. seconds, additional liquid ethyl methanoate is added to the container at 20°C. Does the partial pressure of the ethyl methanoate vapor in the container increase, decrease, or stay the same? Explain. (Assume that the volume of the additional liquid ethyl methanoate in the container is negligible compared to the total volume of the container.)

STOP

END OF EXAM