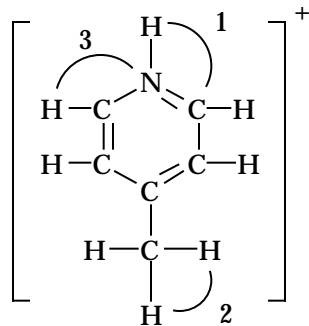


1. (14 points) The molecule pictured here is a weak acid in aqueous solution.

(a) The molecule has \_\_\_\_\_ sigma (  $\sigma$  ) bonds and \_\_\_\_\_ pi (  $\pi$  ) bonds.



(b) Estimate the values of the indicated angles:

Angle 1 = \_\_\_\_\_

Angle 2 = \_\_\_\_\_

Angle 3 = \_\_\_\_\_

(c) The orbital hybridization scheme used by all the C atoms of the benzene ring (the  $C_6$  ring) is \_\_\_\_\_. The N atom is \_\_\_\_\_ hybridized, whereas the C of the  $CH_3$  group has \_\_\_\_\_ hybridization.

If the pH of a 0.018 M solution of acid is 3.87, what is the hydronium ion concentration of the solution?

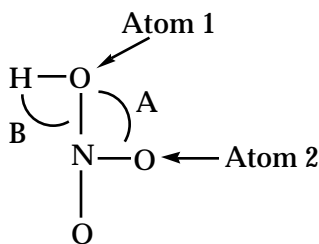
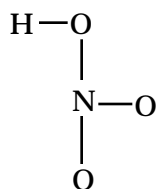
- (a)  $2.45 \times 10^{-3}$  M
- (b)  $2.61 \times 10^{-4}$  M
- (c)  $1.35 \times 10^{-4}$  M
- (d)  $4.07 \times 10^{-12}$  M

What is the value of  $K_a$  for the acid?

- (a)  $2.45 \times 10^{-3}$
- (b)  $3.62 \times 10^{-4}$
- (c)  $1.34 \times 10^{-4}$
- (d)  $1.02 \times 10^{-6}$

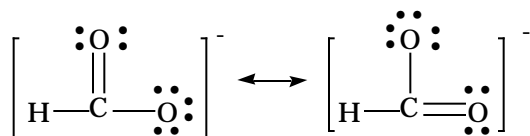
2. (7 points) Fill in the remaining electrons in the nitric acid ( $\text{HNO}_3$ ) structure below and then answer the questions that follow.

Add electrons to this structure

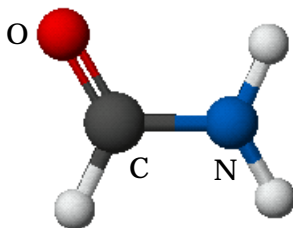


The formal charge on the central N is \_\_\_\_\_ and its hybridization is \_\_\_\_\_. The formal charge on the O atom marked 1 is \_\_\_\_\_ and its hybridization is \_\_\_\_\_. The formal charge on O atom 2 is \_\_\_\_\_. Angle A is about \_\_\_\_\_ degrees, while angle B is \_\_\_\_\_ degrees.

3. (6 points) The formate ion,  $\text{HCO}_2^-$ , is a common ion in natural systems.



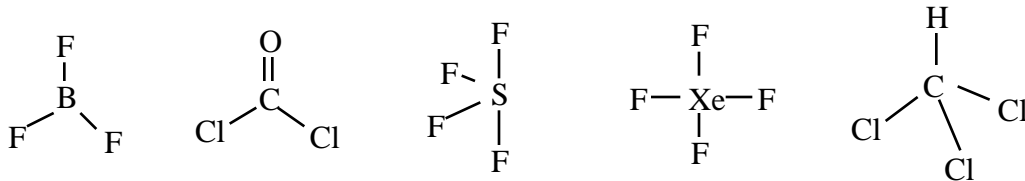
- (a) What is the carbon-oxygen bond order? \_\_\_\_\_
- (b) What is the hybridization of the C atom? \_\_\_\_\_
- (c) What is a good estimate for the carbon-oxygen bond length in this ion: 143 pm, 128 pm, or 122 pm? \_\_\_\_\_ (Hint: A CO double bond is 122 pm long, and a CO single bond is 143 pm long.)
4. (5 points) Draw an electron dot structure for formamide,  $\text{HCONH}_2$ . Include all resonance structures.



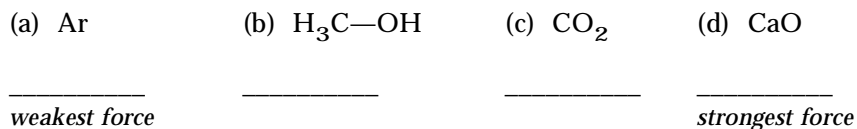
The C atom hybridization is \_\_\_\_\_. Is the molecule polar? \_\_\_\_\_ Can the molecule interact with water by hydrogen bonds? \_\_\_\_\_

As indicated in the molecular model, the molecule is flat. (This is important because the amide linkage is the linkage between amino acids in proteins.) Why is the molecule flat? (Hint: Argue on the basis of resonance structures.)

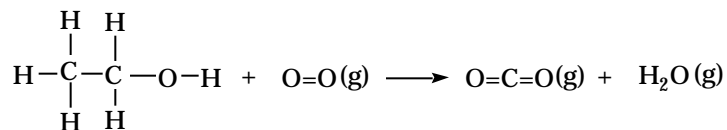
5. (14 points) Molecular geometry, polarity and intermolecular forces. Consider the following five molecules. Lone pairs of electrons are not shown.



- (a) What is the structural pair geometry (electron pair geometry) for SF<sub>4</sub>? \_\_\_\_\_
- (b) Describe the molecular geometry of XeF<sub>4</sub>. \_\_\_\_\_
- (c) Give the following atom hybridizations: Xe in XeF<sub>4</sub> \_\_\_\_\_  
C in COCl<sub>2</sub> \_\_\_\_\_
- (d) Which of the molecules above is (are) polar? \_\_\_\_\_
- (e) Rank the molecules (or atoms) below in terms of increasing strength of intermolecular forces in the pure substances:



6. (3 points) Ethanol is suggested as a fuel in automobiles in the U.S. The fuel burns to give the usual products of combustion according to the following *unbalanced* equation



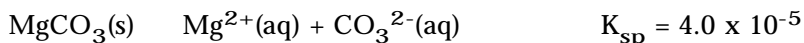
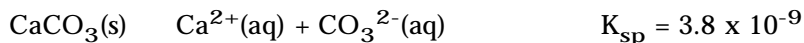
Calculate the enthalpy *per mole* of combustion of ethanol ( H for the reaction) using the bond energy data in your textbook.

- (a) +4975 kJ/mol
- (b) +5996 kJ/mol
- (c) -5996 kJ/mol
- (d) -1021 kJ/mol

**CHEMICAL EQUILIBRIA**

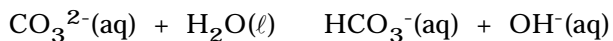
1. (5 points) Carbonates are not generally very soluble in water. Considering calcium and magnesium carbonates, which is the more soluble in water? \_\_\_\_\_

Equilibrium constants for these solids dissolving in water are



Assume you place some  $\text{MgCO}_3$  in a beaker containing 1.0 L of water. How many grams of the solid dissolve? (Molar mass of  $\text{MgCO}_3 = 84.31 \text{ g/mol}$ )

- (a) 0.0843 g  
(b) 0.533 g  
(c) 0.267 g  
(d) 1.07 g
2. (7 points) The carbonate ion in water is a Brønsted \_\_\_\_\_ because it can interact with water as follows:



What is the equilibrium constant for this reaction? \_\_\_\_\_

If you have a 0.15 M solution of  $\text{Na}_2\text{CO}_3$ , what are the concentrations of  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$  and what is the pH of the solution?

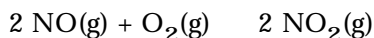
$[\text{H}_3\text{O}^+]$	$[\text{OH}^-]$	pH
(a) $5.61 \times 10^{-3}$	$1.78 \times 10^{-12}$	5.61
(b) $1.78 \times 10^{-12}$	$5.61 \times 10^{-3}$	11.75
(c) $5.61 \times 10^{-3}$	$1.78 \times 10^{-12}$	11.75
(d) $1.78 \times 10^{-12}$	$5.61 \times 10^{-3}$	5.61

3. (4 points) Nitrosyl bromide,  $\text{NOBr(g)}$ , decomposes according to the equation



with an equilibrium constant of  $K_c = 0.021$  at  $350^\circ\text{C}$ . If 1.5 mol of  $\text{NOBr}$ , 0.40 mol of  $\text{NO}$ , and 0.40 mol of  $\text{Br}_2$  are mixed at  $350^\circ\text{C}$ , will any net reaction occur? \_\_\_\_\_ If a net reaction is observed, will  $\text{NO}$  be formed or consumed? \_\_\_\_\_

4. (6 points) The oxidation of  $\text{NO}$  to  $\text{NO}_2$ , which occurs in the atmosphere,



is exothermic. Predict the effect of the following changes on the position of the equilibrium; that is, state which way the equilibrium will shift (*left*, *right*, or *no change*) when each of the following changes is made.

- (a) Add more  $\text{O}_2\text{(g)}$ . \_\_\_\_\_
- (b) Add more  $\text{NO}_2\text{(g)}$ . \_\_\_\_\_
- (c) Lower the temperature. \_\_\_\_\_
5. (12 points) For each solution below, tell if the pH is less than 7, equal to 7, or greater than 7.

<b>SOLUTION</b>	<b>pH</b>
(a) 0.10 M $\text{HNO}_3$	_____
(b) 0.012 M $\text{KOH}$	_____
(c) 0.15 M formic acid	_____
(d) 0.45 M $\text{KBr}$	_____
(e) 0.25 M $\text{Na}_3\text{PO}_4$	_____
(f) 0.095 M $\text{AlCl}_3$	_____

6. (3 points) What is the pH of the buffer solution that consists of 12.6 g of ammonium chloride dissolved in 150 mL of 1.8 M ammonia? (Molar mass for  $\text{NH}_4\text{Cl}$  = 53.49 g/mol and for  $\text{NH}_3$  = 17.03 g/mol)
- (a) 4.69  
(b) 4.94  
(c) 9.06  
(d) 9.31  
(e) 10.14
9. (4 points) Consider the reactions below. In each case you mix the acid and base so that they exactly react with one another; none of the original acid or base remains unreacted in solution. What is the pH of the solution after the acid-base reaction has occurred?

Reaction	pH (=7, <7, >7)
$\text{KOH}(\text{aq}) + \text{HCl}(\text{aq})$ products	_____
$\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{NaOH}(\text{aq})$ products	_____

### GASES

1. (3 points) A bicycle tire that holds 0.406 mol of air, and which has a volume of 1.52 L, will burst if the pressure reaches 7.25 atm. What must the temperature be in order to burst the tire?
- (a) 30 °C  
(b) 37 °C  
(c) 58 °C  
(d) 100 °C
2. (3 points) A 250. mL flask holds 0.0156 g of an unknown gaseous boron-hydrogen compound. The pressure of the gas is 21.5 mm Hg and the temperature is 22 °C. The unknown compound is
- (a)  $\text{BH}_3$   
(b)  $\text{B}_2\text{H}_6$   
(c)  $\text{B}_4\text{H}_{10}$   
(d)  $\text{B}_5\text{H}_9$   
(e)  $\text{B}_6\text{H}_{12}$

3. (3 points) Air contains  $O_2$ ,  $N_2$ ,  $H_2O$ , and  $CO_2$ . Place these gas molecules in order of increasing average molecular velocity at 25 °C.

\_\_\_\_\_

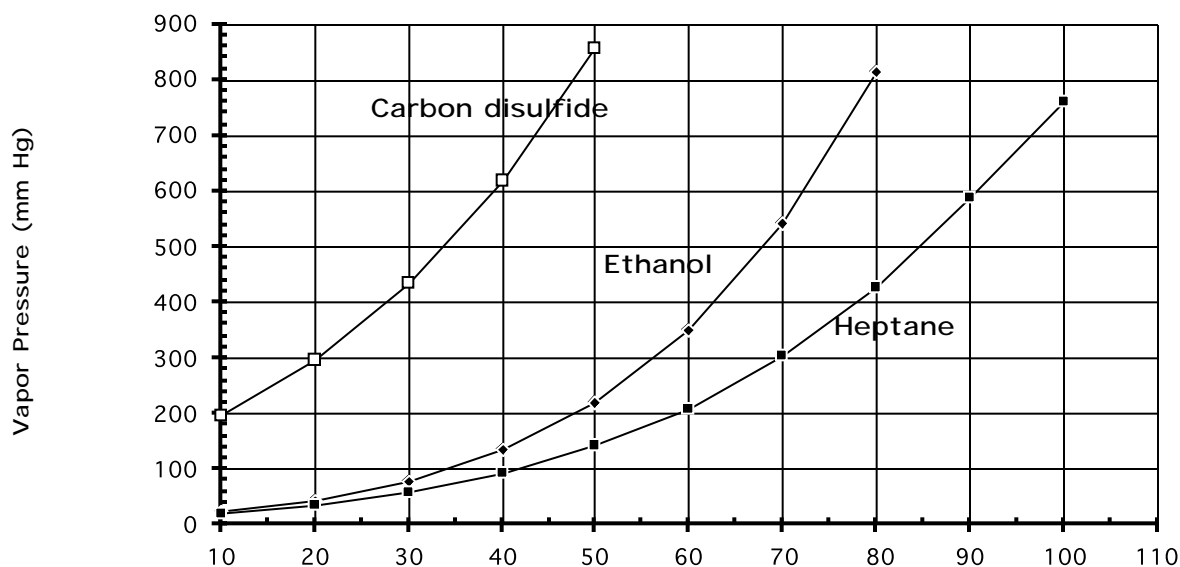
slowest molecule

\_\_\_\_\_

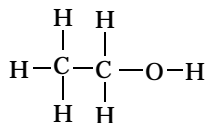
fastest molecule

## LIQUIDS AND SOLIDS

1. (8 points) **Properties of Liquids.** Use the vapor pressure curve to answer the questions below.



- (a) What is the equilibrium vapor pressure of ethanol at 70 °C? \_\_\_\_\_
- (b) What is the temperature at which the equilibrium vapor pressure of heptane,  $C_7H_{16}$ , is 600 mm Hg? \_\_\_\_\_
- (c) Acetic acid,  $CH_3CO_2H$ , has a vapor pressure of about 90 mm Hg at 60 °C. The intermolecular forces in liquid acetic acid are (*stronger, weaker*) \_\_\_\_\_ than in liquid ethanol.
- (d) Carefully draw a “picture” showing how ethanol molecules ( $CH_3CH_2OH$ ) can interact with water molecules.



2. (6 points) The unit cell of molybdenum fluoride is pictured below. (The dark circles are Mo ions and the open circles are F<sup>-</sup> ions.)

(a) How many molybdenum ions are there per unit cell? \_\_\_\_\_

(b) How many fluoride ions are there per unit cell? \_\_\_\_\_

(a) What is the formula of molybdenum fluoride?

\_\_\_\_\_

3. (3 points) The unit cell of a copper-gold alloy, Cu<sub>3</sub>Au, is pictured below. (The dark circles are Cu atoms and the open circles are Au atoms.) The length of a unit cell edge is  $3.74 \times 10^{-8}$  cm. What is the density of the solid?

(a) 1.22 g/cm<sup>3</sup>

(b) 3.88 g/cm<sup>3</sup>

(c) 10.4 g/cm<sup>3</sup>

(d) 12.3 g/cm<sup>3</sup>

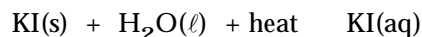
(e) What!?

**SOLUTIONS**

## 1. (6 points) Solution Properties

(a) Which solution is expected to have the higher boiling point, 0.10 molal  $\text{NaNO}_3$  or 0.15 molal sugar? \_\_\_\_\_ In which aqueous solutions is the vapor pressure of water higher?  
\_\_\_\_\_

(b) The enthalpy of solution of potassium iodide is endothermic.



This means the solid is (more)(less) \_\_\_\_\_ soluble as the temperature goes up.

2. (6 points) **Concentration Units.** Assume you dissolve 45.0 g of dimethyl glyoxime (DMG) ( $\text{C}_4\text{H}_8\text{N}_2\text{O}_2$ , molar mass = 116.12 g/mol) in 500 mL of ethyl alcohol,  $\text{C}_2\text{H}_5\text{OH}$  (molar mass = 46.0 g/mol). (Density of ethanol = 0.790 g/mL)

The molality of the glyoxime in the solution is

(a) 0.00078 m

(b) 0.388 m

(c) 0.776 m

(d) 0.981 m

The weight percent of the glyoxime in the solution is

(a) 8.26 %

(b) 9.00 %

(c) 10.2 %

(d) 11.4 %

3. (6 points) **Molar Mass from Colligative Properties** Isoprene is a simple hydrocarbon used to make synthetic rubber. Assume you dissolve 1.235 g in 50.0 g of benzene. The melting point of pure benzene is 5.50 °C, but the melting point of the solution is 3.64 °C. What is the molar mass of isoprene?

What is the molality of the solution?

- (a) 0.106 m
- (b) 0.363 m
- (c) 1.78 m
- (d) 2.76 m

What is the molar mass of the compound?

- (a) 14.7 g/mol
- (b) 18.2 g/mol
- (c) 36.3 g/mol
- (d) 67.9 g/mol
- (e) Help me, said the Gummi Bear!

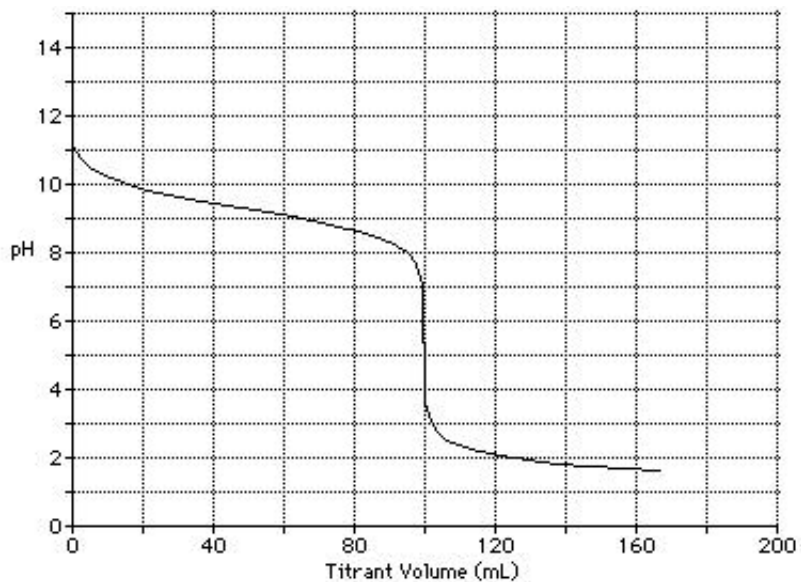
4. (3 points) Instead of using NaCl to melt the ice on your sidewalk, you decide to use CaCl<sub>2</sub>. (Like NaCl, CaCl<sub>2</sub> is a strong electrolyte.) If you add 35.0 g of CaCl<sub>2</sub> (molar mass = 111 g/mol) to 150. g of water, what is the freezing point of the solution?

- (a) -1.86 °C
- (b) -7.86 °C
- (c) -3.91 °C
- (d) -11.73 °C

5. (3 points) Describe in some detail how you would make up a quantity of a solution that has a NaCl concentration of 0.10 molal.

**ACIDS-BASES AND THE LABORATORY**

(10 points) Ammonia is a widely used substance in commerce and the laboratory. The curve for the titration of 0.10 M ammonia with 0.10 M aqueous HCl is shown here.



(a) What is the approximate pH of the solution at the equivalence point?

\_\_\_\_\_

(b) Explain briefly why this solution is acidic or basic at the equivalence point.

(c) In the experiment involving the separation and identification of the silver group ions ( $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ , and  $\text{Hg}_2^{2+}$ ), you used aqueous ammonia to dissolve silver chloride. Write a balanced equation to illustrate this reaction.

(d) Adding  $\text{Cl}^-$  to the ions of the Silver Group gives  $\text{AgCl}$ ,  $\text{PbCl}_2$ , and  $\text{Hg}_2\text{Cl}_2$ . Which is the most soluble of these three solid chlorides? \_\_\_\_\_

(e) In several laboratory experiments, you added ammonia to metal ions in solution but saw a metal hydroxide precipitate. Write a balanced equation to illustrate the formation of a hydroxide on adding aqueous ammonia to a solution of iron(III) ion.

