MOLECULAR STRUCTURE AND BONDING

1. (18 points) Draw the Lewis electron dot structure for SO_3

Provide the following information:

The electron pair geometry of the molecule _____

The molecular geometry of the molecule _____

O–S–O bond angle _____

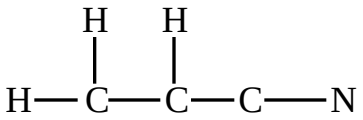
S atom hybridization _____

Formal charge on the S atom _____

The average S–O bond order _____

In the molecule is (polar)(nonpolar)? _____

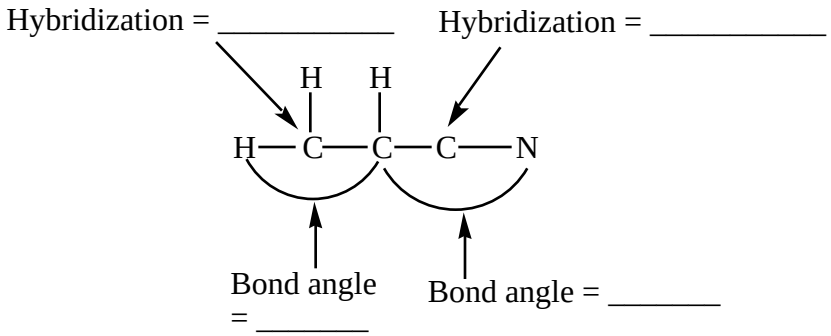
(b) Acrylonitrile is the basis of fibers such as Orlon or Acrilan. The framework of the acrylonitrile molecule is shown below.



(i) Total number of valence electrons in the molecule = _____

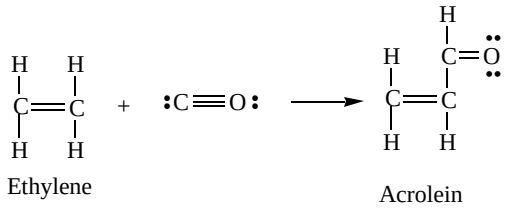
(ii) *Complete the structure* by adding bonds and/or lone pairs as needed to the line drawing above.

(iii) *Indicate the hybridization* of the two marked C atoms and *give values for the indicated bond angles.*

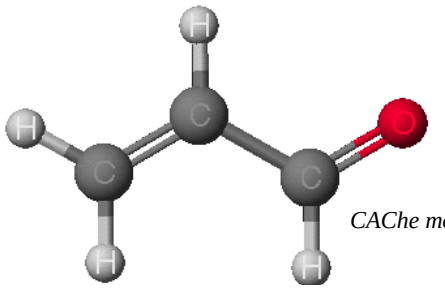


(iv) Do you expect the molecule to be polar or nonpolar? _____

2. (6 points) Acrolein is closely related to acrylonitrile (question 1), and is also used to make plastics. Suppose the compound can be prepared by inserting a carbon monoxide molecule into the C–H bond of ethylene.



Ethylene Acrolein



CAChe model of acrolein

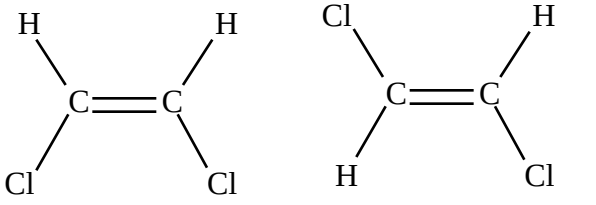
(a) Draw a circle around the *stronger* carbon-carbon bond in drawing or model of acrolein above.

(b) Draw a arrow pointing at the *longer* carbon-carbon bond in the drawing or model of acrolein above.

(c) Is the ethylene molecule (polar)(nonpolar)? _____ Is the acrolein molecule (polar)(nonpolar)? _____

(d) Is the reaction of CO with C_2H_4 to give acrolein an endothermic or exothermic reaction? _____.

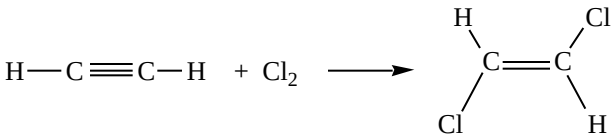
3. (6 points) *Polarity and structure*. You recently used the molecular modeling software to build a model of trans-dichloroethylene. This is closely related to cis-dichloroethylene. (These molecules are called *structural isomers*. They have the same formula but different structures.)



cis-dichloroethylene trans-dichloroethylene

Are either or both of the isomers of dichloroethylene polar? *Explain briefly*.

Dichloroethylene can be synthesized by adding Cl_2 to the carbon-carbon triple bond of acetylene.



How does the hybridization of the C atoms change on going from C_2H_2 to $C_2H_2Cl_2$?

Using the table of bond energies in your textbook, calculate the energy of the reaction of acetylene with chlorine to give dichloroethylene.

i) +1077 kJ

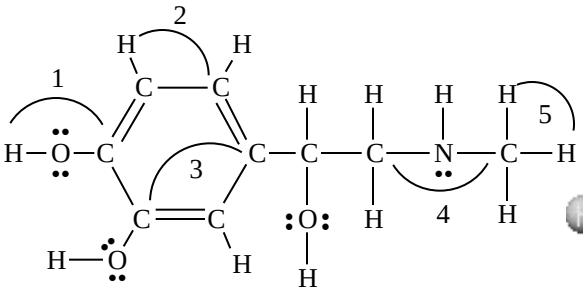
ii) -1280 kJ

iii) -136 kJ

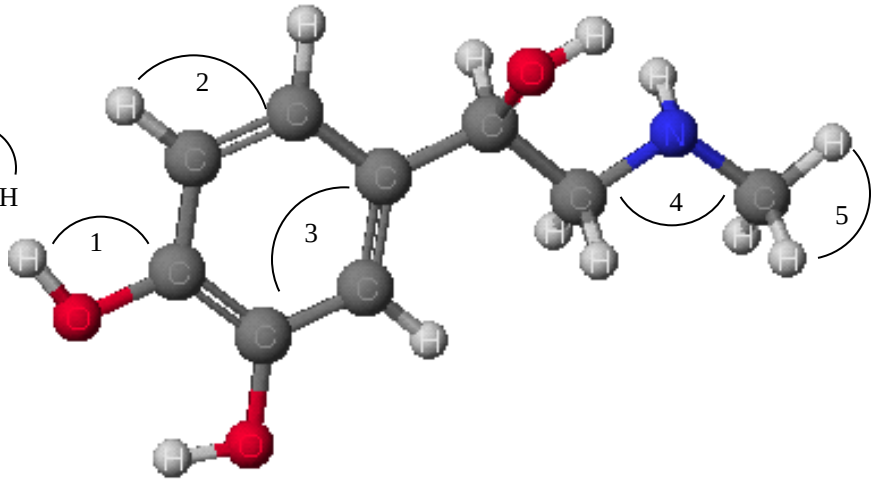
iv) -203 kJ

v) none of the above

3. (12 points) The molecule pictured below is epinephrine, a compound used as a bronchodilator and antiglaucoma agent.



Epinephrine



(a) Indicate the following atom hybridizations:

C atom in the C_6 ring (benzene ring) = _____

N atom = _____

O atoms in OH groups = _____

C atom in CH_3 (methyl) group = _____

(b) There are _____ π (pi) bonds and _____σ (sigma) bonds in the molecule.

(c) Bond angles: 1 = _____ 2 = _____ 3 = _____ 4 = _____ 5 = _____

(d) In this molecule there are CC, CH, OH, and NH bonds. The *most* polar are _____

GASES AND THEIR BEHAVIOR

1. (5 points) A flask contains C_2H_2 gas with a pressure of 162 mm Hg. This is equivalent to _____ atmospheres.

Acetylene can be burned in air to give CO_2 and H_2O.

$$2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(g)$$

If C_2H_2 and O_2 are mixed in a flask in the correct stoichiometric ratio for the combustion reaction, and if the partial pressure of C_2H_2 is 162 mm Hg, what must the partial pressure of O_2 be?

(i) 81 mm Hg (iii) 243 mm Hg

(ii) 162 mm Hg (iv) 405 mm Hg

2. (3 points) Suppose you have a flask containing C_2H_2 (acetylene), CO_2, H_2O, and O_2. Place these gases in order of increasing molecular speed.

_____ _____ _____ _____

slowest *fastest*

3. (3 points) A gaseous compound with a simple formula is an important material in the chemical industry. You have 0.425 g of the compound in a 178-mL flask. The gas has a pressure of 436 mm Hg, and the temperature is 20.0 ˚C. What is the *molecular* formula of the gas?

   (a) CF_2

   (b) C_2F_4

   (c) CFCl

   (d) $C_2F_2Cl_2$

   (e) CHF

   (f) $C_2H_2F_2$

4. (9 points) A geologist can analyze a mineral sample for its carbonate content by reacting a weighed sample with acid and collecting the evolved CO_2.

   $$MgCO_3(g) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(liq)$$

   Suppose you have a 2.567 g sample of impure magnesite (magnesium carbonate). After reacting it with aqueous HCl, you collect the CO_2. The dry gas has a pressure of 312 mm Hg in a 1.56 L flask at 22 ˚C. What is the weight percent of $MgCO_3$ (molar mass = 84.3 g/mol) in the impure 2.567 g sample?

5. (8 points) Suppose equal masses of O_2 and N_2 are placed in separate containers. Each has a volume of 25 L and both are in the snow outside the Chemistry Building.

Flask A = O_2 Flask B = N_2

(a) Which flask contains more molecules of gas? _____

(b) In which flask is the pressure greater? _____

(c) In which flask is the average kinetic energy of molecules greater or do they have the same average energy? _____

(d) In which flask are the molecules moving at the greater speed? _____

GENERAL EQUILIBRIUM

1. (9 points) The hydrogen iodide equilibrium has been thoroughly studied.

$$2\ HI(g) \quad , \quad H_2(g) + I_2(g)$$

(a) Write the equilibrium constant expression for this reaction.

$K_c =$

(b) Suppose you place 2.0 mol HI in a 1.00 L flask at a certain temperature. You find 22% of the HI has been converted to H_2 and I_2 when equilibrium has been achieved.

(i) Complete the following table by entering a numerical value in *each* cell:

	[HI]	[H_2]	[I_2]
Initial concentration (M)			
Change in concentration (M)			
Equilibrium concentration (M)			

(ii) Using the data in your table, calculate the value of K_c.

2. (6 points) Solid ammonium iodide decomposes according to the equation

$$NH_4I(s) \quad , \quad NH_3(g) + HI(g)$$

$$K_c = 7.2 \times 10^{-5} \text{ at } 25\ ^\circ C$$

(a) If you place some solid NH_4I in a flask at 25 °C and wait for equilibrium to be achieved, what will be the concentrations of NH_3 and HI?

i) $[NH_3] = [HI] = 7.2 \times 10^{-5}$ M

ii) $[NH_3] = [HI] = 8.5 \times 10^{-3}$ M

iii) $[NH_3] = 7.2 \times 10^{-5}$ M and $[HI] = 8.5 \times 10^{-3}$ M

iv) $[NH_3] = 8.5 \times 10^{-3}$ M and $[HI] = 7.2 \times 10^{-5}$ M

(b) The equilibrium constant for the decomposition of NH_4I is 7.2×10^{-5} at 25 °C. What is the equilibrium constant for the *formation* of solid ammonium iodide from ammonia and hydrogen iodide?

$$NH_3(g) + HI(g) \quad , \quad NH_4I(s)$$

K_c = _____

3. (8 points) K_c for the *endothermic* decomposition of ammonium hydrogen sulfide is 1.8×10^{-4} at 25 °C.

$$NH_4HS(s) \quad , \quad NH_3(g) + H_2S(g)$$

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) adding more solid NH_4HS _____

(b) adding more $NH_3(g)$ _____

(d) lowering the temperature _____

(e) increasing the volume of the reaction flask _____

4. (4 points) Nitrosyl chloride, NOCl, decomposes to NO and chlorine at higher temperatures.

$$2\ NOCl(g) \rightleftharpoons 2\ NO(g) + Cl_2(g)$$

$$K_c = 3.9 \times 10^{-3} \text{ at } 300\ ^\circ C.$$

(a) Is the reaction product-favored or reactant-favored at 300 ˚C? _____

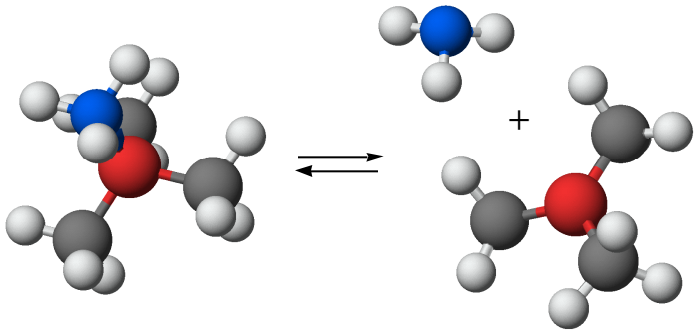
(b) A mixture contains the gases at the following concentrations: [NOCl] = 5.0×10^{-3} mol/L, [NO] = 2.5×10^{-3} mol/L, and $[Cl_2] = 2.0 \times 10^{-3}$ mol/L. Which of the following statements is true?

(i) Additional NOCl will decompose to form more NO and more Cl_2.

(ii) Some NO and Cl_2 will combine to form NOCl.

(iii) The system is at equilibrium. No concentration changes occur.

5. (3 points) The ammonia complex of trimethylborane, $(NH_3)B(CH_3)_3$, dissociates at 100 ˚C to its components with $K_p = 4.62$.



$$(NH_3)B(CH_3)_3(g) \rightleftharpoons NH_3(g) + B(CH_3)_3(g)$$

If NH_3 is changed to some other molecule, the equilibrium constant is different.

(a) For $(NH_3)B(CH_3)_3$, $K_p = 4.62$

(b) For $[(CH_3)_3P]B(CH_3)_3$, $K_p = 0.128$

(c) For $[(CH_3)_3N]B(CH_3)_3$, $K_p = 0.472$

If you begin an experiment by placing 0.010 mole of each complex in a flask, which of the three compounds above (*a*, *b*, or *c* would have the largest partial pressure of $B(CH_3)_3$ in the flask at 100 ˚C?

Answer = _____