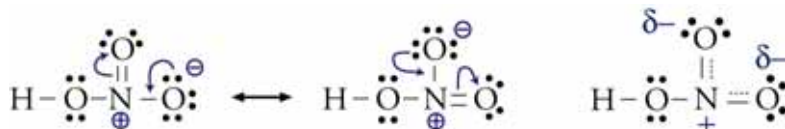




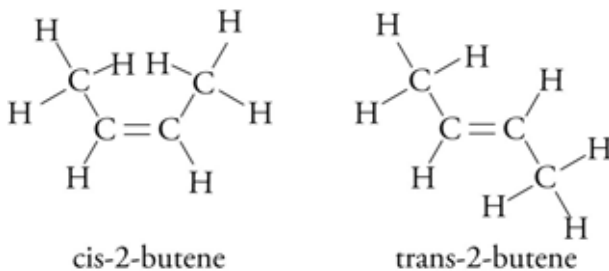
For each of the following, write the word, words, or number in each blank that best completes each sentence. (2 points each)

- The **second ionization energy** is the energy necessary to remove one mole of electrons from one mole of isolated and gaseous +1 ions to form one mole of isolated and gaseous +2 ions.
- A(n) **molecular orbital** is a volume that contains a high percentage of the electron charge for an electron in a *molecule* or a volume within which an electron in a *molecule* has a high probability of being found.
- A(n) **trans** isomer is a structure that has like groups on different carbons (which are linked by a double bond) and on different sides of the double bond.
- A polar molecule or ion (or a portion of a molecule or polyatomic ion) that is attracted to water is called **hydrophilic**.
- Of the two elements lithium, Li, and fluorine, F, **fluorine** has highest first ionization energy.
- Of the two ionic bonds, Mg-P (in  $\text{Mg}_3\text{P}_2$ ) or Mg-N (in  $\text{Mg}_3\text{N}_2$ ), the **Mg-P** bond has the most covalent character.
- Of the two ions,  $\text{Sc}^{3+}$  and  $\text{K}^+$ , the  **$\text{K}^+$**  is larger.
- Draw a reasonable Lewis structure for each of the following. Identify all formal charges. If the molecule has resonance, draw *all* the resonance structures *and* the resonance hybrid. (6 points each)

a. Nitric acid,  $\text{HNO}_3$



b. Draw Lewis structures for two isomers of 2-butene,  $\text{CH}_3\text{CHCHCH}_3$ .



9. Write abbreviated electron configurations for each of the following, Identify each as paramagnetic or diamagnetic, and write the number of unpaired electrons for each. (4 points each)

a. Nickel(II) ion,  $\text{Ni}^{2+}$

Abbreviated electron configuration  $[\text{Ar}] 3d^8$

Paramagnetic or diamagnetic? **paramagnetic**

Number of unpaired electrons **2**

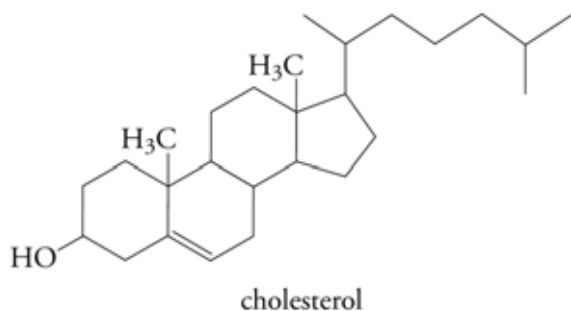
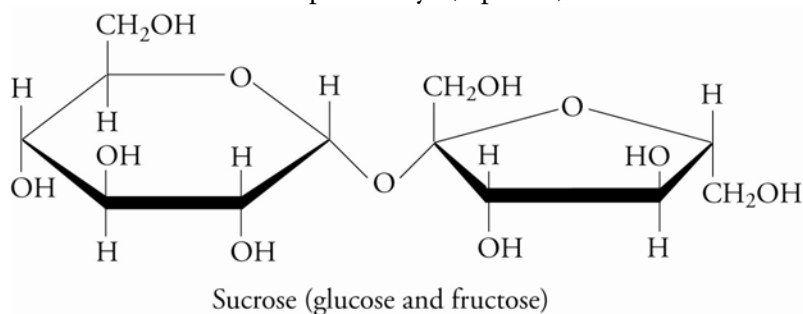
b. Gold atom, Au

Abbreviated electron configuration  $[\text{Xe}] 4f^{14} 5d^{10} 6s^1$

Paramagnetic or diamagnetic? **paramagnetic**

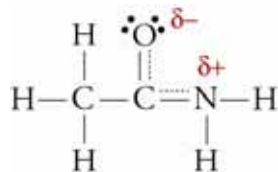
Number of unpaired electrons **1**

10. Sucrose, which is a disaccharide composed of glucose and fructose, is white table sugar. Cholesterol is a natural substance that is both essential for the normal operation of the body and a potential cause of health problems. Which compound would you expect to be more soluble in water? Explain why. (4 points)



*Sucrose has a proportionally larger polar portion and is therefore more soluble in water than cholesterol. The much higher proportion of the cholesterol structure that is nonpolar makes it almost insoluble in water.*

11. Consider the following Lewis Structure for the resonance hybrid for acetamide,  $\text{CH}_3\text{CONH}_2$ . (10 points)



- What is the hybridization for the left carbon atom?  $\text{sp}^3$
- What is the hybridization for the right carbon atom?  $\text{sp}^2$
- What is the hybridization for the oxygen atom?  $\text{sp}^2$
- What is the hybridization for the nitrogen atom?  $\text{sp}^2$
- Write a description of the bonding, stating whether each bond is sigma, pi, or part of a delocalized pi system and by stating which atomic orbitals overlap to form the bonds.

3 sigma C-H bonds due to  $\text{sp}^3$ -1s overlap

1 sigma C-C bonds due to  $\text{sp}^3$ - $\text{sp}^2$  overlap

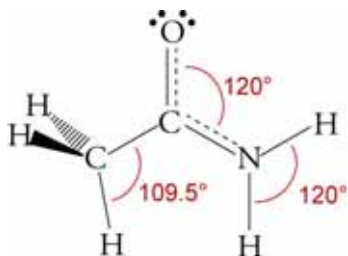
1 sigma C-O bonds due to  $\text{sp}^2$ - $\text{sp}^2$  overlap

1 sigma C-N bonds due to  $\text{sp}^2$ - $\text{sp}^2$  overlap

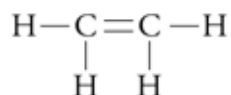
2 sigma N-H bonds due to  $\text{sp}^2$ -1s overlap

1 delocalized pi system due to 3 p orbitals overlapping, one on the carbon atom, one on the oxygen atom, and one on the nitrogen atom

- What is the name of the electron group geometry around the left C? **tetrahedral**
- What is the name of the electron group geometry around the right C? **trigonal planar**
- Draw a sketch with bond angles.

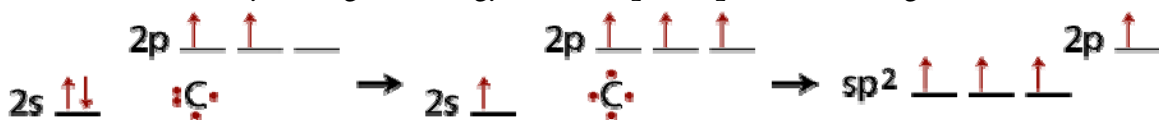


12. Consider the following Lewis Structure for C<sub>2</sub>H<sub>4</sub>. (11 points)



- What is the hybridization for each carbon  $\text{sp}^2$
- With reference to the assumptions of the valence bond model of covalent bonding, and using orbital diagrams for the valence electrons of carbon, explain how carbon atoms are able to form the bonds in C<sub>2</sub>H<sub>4</sub>. Describe each bonds as a sigma or pi bonds and tell how each is formed from the overlap of atomic orbitals.

**Only the highest energy electrons participate in bonding.**



**Covalent bond form to pair unpaired electrons.**

**Two  $\text{sp}^2$  atomic orbitals for each carbon overlap  $1s$  orbitals of the hydrogen atoms to form 2 sigma bonds.**

**One  $\text{sp}^2$  atomic orbital for each carbon overlaps an  $\text{sp}^2$  orbital of the other carbon to form a sigma bond.**

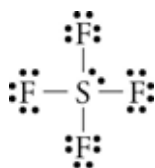
**The unhybridized 2p atomic orbitals of the carbons overlap to form a pi bond.**

- Explain why one of the bonds in the double bond is weaker than the other.

**The p orbitals, which form the pi bond by parallel overlap, overlap less than the  $\text{sp}^2$  atomic orbitals, which form the sigma bond by end-on overlap.**

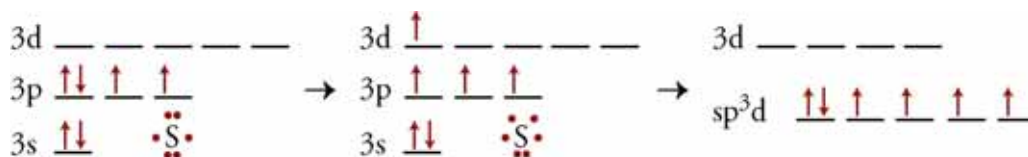
**Less overlap leads to less of an increase in negative charge between the nuclei and therefore, less of a stabilization of the molecule.**

13. Consider the SF<sub>4</sub> molecule. (8 points)



- a. With reference to the assumptions of the valence bond model, explain how sulfur atoms are able to form four *equivalent* covalent bonds, have one lone pair, and have zero formal charge.

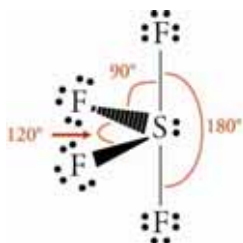
According to the valence bond model, only the highest energy electrons are important for covalent bonding. If an electron is promoted from the pair of electrons in the 3p sublevel to a 3d orbital, there will be four unpaired electrons. The valence bond model says that covalent bonds form to pair unpaired electrons, so sulfur would be able to form four covalent bonds. To explain how the bonds are equivalent, we say that the 3s orbital, all three 3p orbitals, and one 3d orbital blend to form five equivalent sp<sup>3</sup>d hybrid orbitals. Four of these hybrid orbitals form the four covalent bonds and the fifth contains the lone pair.



- b. What's the name of the electron group geometry around the sulfur atom?

Trigonal bipyramid

- c. Sketch the molecule, including bond angles.



- d. What's the name of the molecular geometry around the sulfur atom?

See-saw

14. For each of the following, write the name of the type of attraction holding these particles in the solid and liquid form. Indicate the formula in each pair that represents the substance that you would expect to have the stronger attractions among particles.

(3 points each)

a. Formaldehyde,  $\text{H}_2\text{CO}$

type of attraction **dipole-dipole**

or carbon (diamond),  $\text{C}(\text{dia})$

type of attraction **covalent bond**

stronger attractions?  **$\text{C}(\text{dia})$**

b. 2-Propanol,  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

type of attraction **hydrogen bond and London forces**

or butane,  $\text{C}_4\text{H}_{10}$

type of attraction **London forces**

stronger attractions?  **$\text{CH}_3\text{CHOHCH}_3$**

c. 2-Propanol,  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

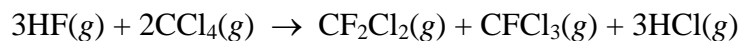
type of attraction **hydrogen bond and London forces**

or 1-hexanol,  $\text{CH}_3(\text{CH}_2)_5\text{OH}$

type of attraction **hydrogen bond and London forces**

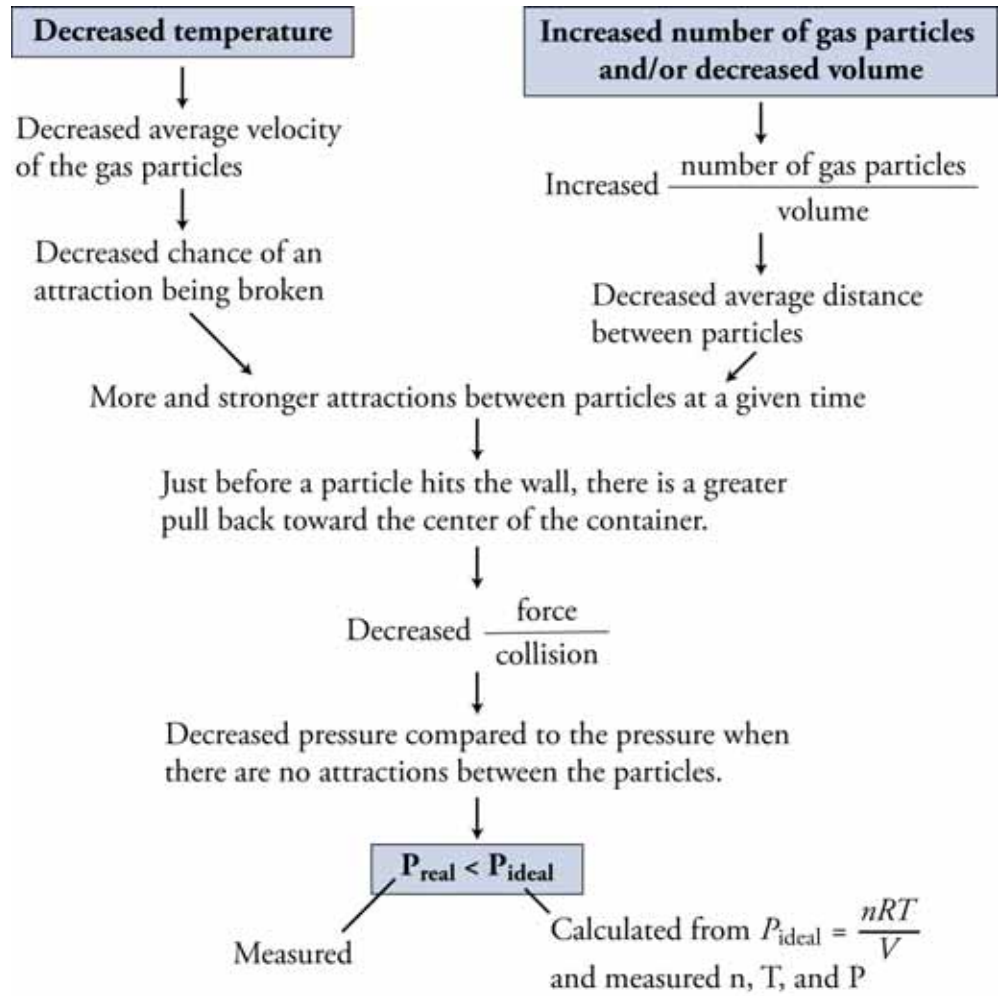
stronger attractions?  **$\text{CH}_3(\text{CH}_2)_5\text{OH}$**

15. Some chlorofluorocarbons, CFCs, such as CFC-12,  $\text{CF}_2\text{Cl}_2$ , and CFC-11,  $\text{CFCl}_3$ , are formed from carbon tetrachloride,  $\text{CCl}_4$  and hydrogen fluoride, HF. What is the minimum volume of HF(g) in cubic meters at 1.2 atm and 19 °C that would be necessary to react with 235 kg of  $\text{CCl}_4$  in the reaction below? (6 points)



$$\begin{aligned} ? \text{ m}^3 \text{ HF} &= 235 \text{ kg CCl}_4 \left( \frac{10^3 \text{ g}}{1 \text{ kg}} \right) \left( \frac{1 \text{ mol CCl}_4}{153.822 \text{ g CCl}_4} \right) \left( \frac{3 \text{ mol HF}}{2 \text{ mol CCl}_4} \right) \left( \frac{0.082058 \text{ L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \right) \left( \frac{292 \text{ K}}{1.2 \text{ atm}} \right) \left( \frac{1 \text{ m}^3}{10^3 \text{ L}} \right) \\ &= \mathbf{46 \text{ m}^3 \text{ HF}} \end{aligned}$$

16. Explain why lowering the temperature of a gas and/or increasing its concentration leads to a greater difference between the measured pressure of a gas and the pressure calculated from the ideal gas equation. (8 points)



17. Answer the following questions that relate to the ozone layer in the stratosphere and the threat to it from CFCs. (12 points)

- a. Explain why we are fortunate that UV-C radiation is almost completely filtered out by gases in the atmosphere.

*UV-C radiation is the highest-energy ultraviolet radiation, so it can cause the most chemical changes for substances on the surface of the earth. For example, UV-C photons associated with wavelengths of about 260 nm alter DNA, causing genetic changes in crops, and UV-C photons associated with wavelengths of about 280 nm alter protein, which also damages plants and animals.*

- b. Explain how oxygen molecules, O<sub>2</sub>, and ozone molecules, O<sub>3</sub>, work together to protect us from high-energy ultraviolet radiation.

*Photons of UV-C radiation that are associated with wavelengths less than 242 nm are absorbed by oxygen molecules and convert them to oxygen atoms. Note that oxygen does not absorb the photons in the range that damage DNA and proteins.*

*Photons of UV-C radiation that are associated with wavelengths less than 320 nm are absorbed by ozone molecules and convert them to oxygen molecules and oxygen atoms. Note that ozone does absorb the photons in the range that damage DNA and proteins.*

- c. Explain why CFCs eventually make their way into the stratosphere when most chemicals released into the atmosphere do not.

*CFCs are gaseous, very stable, and not water-soluble. Therefore, they can stay in the atmosphere long enough to migrate to the stratosphere without being rained out.*

- d. Briefly explain why the chlorine atoms liberated from CFCs are thought to be a serious threat to the ozone layer.

*CFCs liberate chlorine atoms in the stratosphere. The chlorine atoms act as a catalyst to destroy up to 100,000 ozone molecules per chlorine atom.*