Problem Set 5

Practice problems:

If you didn’t do these last week, take a look at them now. Check your answers against those in the back of the book or against your friends’ answers, or bring questions to office hours.

9-10, 9-12, 9-15, 9-16, 9-22, 9-40, 9-73, 9-74, 9-81

Discussion problems:

We will discuss this in class (3:30) on Wednesday the 30th. Be prepared to present answers to and to discuss any of these up at the blackboard.

1. Use hybrid orbitals and $\pi$ bonding to draw three-dimensional structures for the following molecules; pay attention to small details. Determine bond angles where possible.
   
   (a) CH$_3$C≡CH
   (b) CH$_3$ON=O
   (c) H$_2$C=C=CH$_2$

2. The following are illustrations of the four $\pi$ molecular orbitals in the NO$_3^-$ anion:

   ![Molecular Orbitals]

   (a) Indicate whether each one is bonding, non-bonding, or anti-bonding.
(b) Arrange them from lowest in energy to highest. (Two are very close in energy; as long as they are next to each other, don’t worry which to put first.) How many electrons are in this $\pi$ system, and which orbitals are filled?

(c) What would you predict for N–O bond order?

(d) If you use the same MO diagram for the molecule SO$_3$, what S–O bond order do you get?

(e) Does the MO description tell you something different about bonding in NO$_3^-$ or SO$_3$ than what you’d expect from Lewis structures for these molecules?

**Graded problem:**

This should be written up and handed in before tutorial begins on Wednesday the 30th. This problem may also be discussed in class.

1. Cyanamide, H$_2$NCN, has the following structure:

   ![Cyanamide Structure]

   (a) Draw Lewis structures for all important resonance structures of cyanamide. Rank the relative importance of each resonance structure.

   (b) What are the hybridizations for the N, C, and N atoms? Does your answer change for different resonance structures ... and what does that tell you?

   (c) Below are representations of five $\pi$ molecular orbitals for cyanamide (drawn twice, one stippled and the other schematically):
Rank these from lowest to highest energy, label them as bonding, antibonding, or non-bonding, and fill the orbitals with the appropriate number of electrons.