Question 1 (14 pts.)
a) Give a line-angle structure for the following condensed formula. Do not forget to add all non-bonding electrons where appropriate.
\[(\text{CH}_3\text{CH}_2)_2\text{CC(}\text{CH}_2\text{CH}_3)\text{CH}_2\text{COCH(}\text{CH}_3)\text{CCCHO}\]

Extra Credit (5 pts.) In the "Organic Chemistry in Real Life" pages, anti-bonding molecular orbitals were described as playing an important role in which of the following:
- color
- burning hydrocarbons
- ATP energy conversion

Question 2 (27 pts.) Directly ON TOP of the structures below, draw a picture of the \(\Psi\) or \(\Psi^2\) as requested, for the indicated orbitals, AND, in each case write down the atomic orbital or orbitals that you used, as appropriate

\[\Psi\] for the C-O \(\pi^*\) M.O.
\[
\begin{array}{c}
\text{H}_3\text{C} \\
\text{H} \\
\text{p A.O. (carbon)} \\
p \text{A.O. (oxygen)}
\end{array}
\]

\(\Psi^2\) for the C-Cl \(\sigma^*\) M.O.
\[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{sp} \text{A.O. (nitrogen)} \\
\text{1s A.O. (hydrogen)}
\end{array}
\]

Question 3 (6 pts.) Give one property of electrons that can only be explained by taking into account their wave behavior

this was DIRECTLY from the problem set

there are several, the most obvious for us are:
- we can only explain the formation of both bonding and anti-bonding molecular orbitals this way
- the wave behavior requires quantization of electron energies, which forces them to occupy distinct orbitals, this is why we have orbitals, if we have no wave behavior, we have no orbitals!
- the fact that we can only give a probability of finding an electron in a particular position is a consequence of the wave behavior

Extra Credit (5 pts.) In the "Organic Chemistry in Real Life" pages, anti-bonding molecular orbitals were described as playing an important role in which of the following
- color
- burning hydrocarbons
- ATP energy conversion

the graders do not get an absolute grading rubric for my tests, there are always too many possible ways to get partial credit in my exams, the guidelines in blue therefore are guidelines ONLY

~3 pts each for the functional groups
-2pts for incorrect alkyl groups
-3pts for this at the end:
Question 4 (22 pts.) For the structures A and B below:

a) State (in words, do not draw on top of the structures) which is the largest BOND DIPOLE moment(s) in A and which is the largest bond dipole moment(s) in B.

b) Between these two largest dipole moments (one from A and one from B), which would be larger? Give a brief explanation.

c) Draw the MOLECULAR DIPOLE MOMENTS ON TOP OF THE STRUCTURES. Your drawing does not need to illustrate the size of the dipole, only the direction. If there is no molecular dipole, indicate so.

d) Indicate which structure would have the larger MOLECULAR dipole moment, give a brief explanation.

```
the largest bond dipole moment in A is that associated with the C-N triple bonds
the largest dipole moment in B is that associated with the C-F bond
the C-N triple bond dipole moment is larger because even though F is more electronegative than N, the electrons in the pi-bonds in the triple bond are highly polarizable
```

A has a larger MOLECULAR dipole moment because it has two larger bond dipole moments that add in (roughly) the same direction as the two smaller bond dipole moments in B

too many options for a rubric, but if 2 of the 4 parts are correct then 12 pts, if 3 of the 4 parts are correct then 17 pts, but generally half correct = half points.

Question 5 (14pts.) For the vinyl anion shown to the right:

a) give the hybridization for the circled carbon atom

b) state, in words, exactly what the various pairs of electrons around the circled atom "do", e.g. in a σ-bond to atom X, in a π-bond to atom Z, are non-bonding, etc.

c) list the hybridized valence orbitals for the circled carbon, and how these are used to accommodate the electron pairs mentioned in part b)

```
the C has an sp2 hybrid A.O. containing one pair of non-bonding electrons
the C has an sp2 hybrid A.O. that is used to build the σ-bond to the hydrogen atom
the C uses an sp2 hybrid A.O. to build the σ-bond to carbon, which contains one of the pairs of electrons in the C=C double bond
the C uses an unhybridized p A.O. to build the π-bond to carbon, which contains the second of the pairs of electrons in the C=C double bond
```

too many options for a rubric, generally half correct = half points.
	there were 4 questions JUST LIKE THIS ONE on the problem set.

Question 6 (44 pts.) For the molecular formula $C_4H_8O$

a) Give the degrees of unsaturation

1 degree of unsaturation 2pts

b) Draw SIX structural isomers that obey the normal rules of valence for each atom. Include all non-bonding electrons. You can draw Lewis structures or line-angle structures (your choice). If you draw line-angle structures, don't forget to include the H atoms that are normally included as part of the functional groups. **CIRCLE AND IDENTIFY ALL FUNCTIONAL GROUPS IN YOUR STRUCTURES!!**

-1 missing H atoms in funct. groups 24 pts
-2 for a stereoisomer here

-1 for missing non-bonding electrons  -1 for wrong functional group  -4 incorrect structure

C

-4 if structure also in part b

18 pts

-4 if structure also in part b

here are four pairs

DO NOT INCLUDE ANY STRUCTURES in part c) THAT WERE DRAWN AS PART OF YOUR ANSWER TO PART b) OF THIS QUESTION

-4 if structure also in part b

here are four pairs

-4 if structure also in part b

here are four pairs
Question 7 (24 pts.) Rank the pairs of electrons indicated, A, B, C, D and E in order of increasing energy. Give an explanation for your choice.

non-bonding electrons are higher in energy than bonding electrons, therefore A and C are highest in energy, phosphorus is larger and less electronegative than oxygen, C are thus highest.

π-bonding electrons are higher in energy than σ-bonding electrons, thus E is next highest.

bonding M.O. B is built by combining sp3 + sp3 hybrid A.O.s, bond D is built from sp2 + sp3 sp2 A.O.s are smaller and electrons in them are lower in energy than electrons in sp3 A.O.s, which have higher p character, thus the electrons in bond D are lowest in energy of all.

in general 1/2 correct = 1/2 point etc.

Question 8 (24 pts.)

a) Rank the bonds indicated A, B and C in terms of increasing bond dissociation energy, give a brief explanation.

bond B is from H to an sp hybridized carbon, sp A.O. is smaller lower in energy, this is the strongest bond and thus has the largest BDE 10pts.

both A and C are to sp3 hybridized carbons, but cleavage of C generates a 3° radical whereas cleavage of A generates a 1° radical, 3° radicals are more stable due to hyperconjugation, it takes less energy to form the more stable radical, thus C has the smallest BDE.

many different answers, 1/2 correct = 1/2 pts

b) Treat homolytic bond dissociation as a simple chemical reaction. For BOND A below, add the curved arrows to the structure that illustrate bond-breaking and show the products of homolytic bond breaking (i.e. what you get after breaking the bond) on the "product side" of the reaction arrow below.

8pts