Lecture 4

What do you do when you encounter a very long, difficult word?

antidisestablishmenttarianism

break it up into syllables: an-ti-dis-es-tab-lish-ment-ta-ri-an-ism

meaning: antidisestablishmenttarianism - opposition to disestablishment of a church or religious body.

What should we do when we encounter a very long, difficult formula, something like this?

CH₃OCH₂CO₂CH₂CHNH₂CH₂CONHCH₂(C₆H₅)CH(NO₂)CH₂CH(CHO)CHNH₂CHOHCH₂CCHCH₂H₂CO₂H

Can be made into something like this:

CH₃OCH₂CO₂CH₂CHNH₂CH₂CONHCH₂(C₆H₅)CH(NO₂)CH₂CH(CHO)CHNH₂CHOHCH₂CCHCH₂H₂CO₂H

There are two six carbon rings present.

Common Errors

Common Error 1 – All of the following “groups” only make one additional bond.

<table>
<thead>
<tr>
<th>Hydrogen atom</th>
<th>Methyl group</th>
<th>Amine group</th>
<th>Alcohol group</th>
<th>Ether group</th>
<th>Halo substituent</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H₃C</td>
<td>H₂N</td>
<td>HO</td>
<td>CH₃O</td>
<td>X</td>
</tr>
<tr>
<td>H-C</td>
<td>H₃C</td>
<td>H₂N</td>
<td>HO</td>
<td>CH₃O</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>H₃C</td>
<td>H₂N</td>
<td>HO</td>
<td>CH₃O</td>
<td>X</td>
</tr>
<tr>
<td>-CH₂CH(C₆H₅)CH₂-</td>
<td>-CH₂CHNH₂CH₂-</td>
<td>-CH₂CHOHCH₂-</td>
<td>-CH₂CH(OCH₃)CH₂-</td>
<td>-CH₂CH(Br)CH₂-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carboxylic acid group</th>
<th>Ester group</th>
<th>Amide group</th>
<th>Acid chloride group</th>
</tr>
</thead>
<tbody>
<tr>
<td>HO₂C</td>
<td>RO₂C</td>
<td>H₂NOC</td>
<td>ClOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-CH₂CH(CO₂H)CH₂-</td>
<td>-CH₂CH(CO₂R)CH₂-</td>
<td>-CH₂CH(CONH₂)CH₂-</td>
<td>-CH₂CH(COCl)CH₂-</td>
</tr>
</tbody>
</table>
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phenyl group

\[
\begin{array}{c}
\text{C}_6\text{H}_5 \\
\end{array}
\]

aldehyde group

\[
\begin{array}{c}
\text{CHO} \\
\end{array}
\]

nitrile group

\[
\begin{array}{c}
\text{CN} \\
\end{array}
\]

\[
\begin{array}{c}
\text{NC} \\
\end{array}
\]

\[
\begin{array}{c}
\text{CN} \\
\end{array}
\]

\[
\begin{array}{c}
\text{C}_6\text{H}_5\text{CH(OH)}\text{CH}_2- \\
\end{array}
\]

(six carbon ring present)

\[
\begin{array}{c}
\text{CH}_3\text{CH(C}_6\text{H}_5\text{)CH}_{2}- \\
\end{array}
\]

\[
\begin{array}{c}
\text{CH}_3\text{CH(CN)}\text{CH}_2- \\
\end{array}
\]

Common Error 2 – The following patterns show up frequently, and are often misdrawn.

confusing pattern

\[
\begin{array}{c}
\text{-CO}_2- \\
\end{array}
\]

RCO\text{H}

\[
\begin{array}{c}
\text{R}-\text{C} \overset{\text{O}}{\text{O}} \text{-H} \\
\end{array}
\]

carboxylic acid

(example h, below)

These are "correct".

RCO\text{R}

\[
\begin{array}{c}
\text{R}-\text{C} \overset{\text{O}}{\text{O}} \text{-R'} \\
\end{array}
\]

ester

(example i, below)

Common errors. These are "incorrect".

\[
\begin{array}{c}
\text{R}-\text{C} \overset{\text{O}}{\text{O}} \text{-H} \\
\end{array}
\]

The chain (H or R') is incorrectly connected to the carbon atom instead of being connected to an oxygen atom. The oxygen atoms, as drawn here, cannot form two bonds without exceeding the carbon atom's octet and the oxygen atoms look like they need negative formal charge.

\[
\begin{array}{c}
\text{R}-\text{C} \overset{\text{O}}{\text{O}} \text{-R'} \\
\end{array}
\]

The incorrectly drawn carbon atom only has two bonds and there is no way to form more bonds. The peroxide linkage (-O-O-) is a possible functional group, but not common and very reactive.

Correctly drawn functional group structures.

\[
\begin{array}{c}
\text{RCONHR'} \\
\end{array}
\]

amides

(example k, below)

\[
\begin{array}{c}
\text{RCOCl} \\
\end{array}
\]

acid chlorides

(example c, below)

\[
\begin{array}{c}
\text{RCHO} \\
\end{array}
\]

aldehydes

(example f and i, below)

\[
\begin{array}{c}
\text{RCOR} \\
\end{array}
\]

ketones

(example g, below)

These drawings of functional groups are incorrect, but they are common student errors.
Concise Rules for Drawing 2D Lewis Structures, including resonance structures

1. Draw a sigma skeletal framework showing all of the sigma bonds from the condensed line formula.

2. Sum all of the valence electrons available for bonding and lone pairs. Reduce this number by 1 for each positive charge and increase this number by 1 for each negative charge.

3. Each sigma bond counts for two electrons. Subtract this number of electrons from the total number of electrons to determine how many electrons are available for lone pairs and pi bonds.

4. Use any remaining electrons as lone pairs to fill in octets on electronegative atoms first (F > O > N > other halogens > C). If the electrons are still not used up, add the additional electrons to carbon atoms at alternate positions to maximize charge separation where possible (minimize electron-electron repulsion) until all electrons have been used. It is helpful for you to write in the formal charge at this point. Formal charge will suggest the best way to group lone pair electrons used to make pi bonds.

5. A lone pair of electrons on an atom next to a neighbor with an incomplete octet can be shared to form a second (double) or third (triple) bond with the neighbor atom (these will be pi bonds). If this can be done to a particular electron deficient atom by more than one neighbor atom, then resonance structures are present. The best resonance structure will have the maximum number of bonds. If two structures have the same number of bonds, then a secondary consideration is to minimize charge separation (the formal charge from rule 4 will help here). If residual charge is necessary, it is better to be consistent with electronegativity (e.g. negative formal charge is better on oxygen than on carbon). Your goals, in this order, are 1. to maximize the number of bonds and 2. to minimize formal charge and 3. to keep formal charge consistent with electronegativity, if the other two goals have been met.

6. Resonance structures require a specific use of arrows.
   a. Double headed arrows are placed between resonance structures.

   \[
   \text{resonance structure 1} \quad \longleftrightarrow \quad \text{resonance structure 2}
   \]

   A double headed resonance arrow shows that these structures both contribute to an actual structure that cannot be drawn as a simple Lewis structure.

   b. A full headed curved arrow indicates two electron movement.

   A full headed curved arrow indicates two electron movement to show where an electron pair will be located in the "next" structure, whether used in resonance structures or used in a reaction equation.

   c. A half headed curved arrow indicates one electron movement.

   A half headed curved arrow indicates one electron movement to show where an electron will be located in the "next" structure (as in free radicals), whether used in resonance structures or used in a reaction equation.
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13 Examples of 2D Lewis structures from condensed line formulas:

- \((\text{CH}_3)_2\text{CHCH}_2\text{CH(CH}_3)\text{CH}_2\text{C(CH}_3)\text{)}_3\)
- \(\text{FCH}_2\text{CH}_2\text{OH}\)
- \(\text{CH}_3\text{OCHCH}_2\text{COCl}\)
- \(\text{CO}_3\)²⁻
- \(\text{NO}_2^\oplus\)
- \(\text{O}_2\text{NCH}_2\text{CHO}\)
- \(\text{H}_3\text{CCCOCH}_3\)
- \(\text{CH}_2\text{CHCO}_2\text{H}\)
- \((\text{CH}_3)_2\text{CHCO}_2\text{C(CH}_3)\text{)}_3\)
- \(\text{C}_6\text{H}_5\text{CHCHC}_6\text{H}_4\text{CN}\)
- \(\text{C}_6\text{H}_5\text{COH(CH}_3)\text{CHO}\)
- \((\text{CH}_3)_2\text{COHCH}_2\text{OCH}_3\)
- \((\text{CH}_3)_2\text{NOCCCH}_3\text{CCCH}_3\)
- \(\text{ClCH}_2\text{COCH}_2\text{COCl}\)
- \((\text{CH}_3)_2\text{C}_2\text{H}_5\text{CO}_3\text{H}\)
- \((\text{CH}_3)_2\text{CH(CO}_2\text{CH}_3)\text{CHO}(\text{CN})\text{CH(COCl)CH(CN)CH(COCH}_3)\text{CH}_3\)

Problem 1 - Draw two dimensional Lewis structures for the following condensed line formulas of common functional groups and carbon skeletal patterns. Include two dots for any lone pair electrons. You should be able to predict the hybridization, shape, bond angles, number of sigma bonds, pi bonds and lone pairs of electrons on every nonhydrogen atom below. Even though we have not covered nomenclature and functional groups, the functional group names are included with the following formulas to increase your familiarity with these patterns. Soon, you will need to know these.

a. \((\text{CH}_3)_2\text{CHCHCH}_3\text{CH}_2\text{C(CH}_3)\text{)}_3\) alkane
b. \((\text{CH}_3)_2\text{CCHCH(CH}_3)\text{)}_2\) alkene
c. \(\text{CH}_3\text{CCC(CH}_3)\text{)}_3\) alkyne
d. \(\text{CH}_3\text{CHCHCCH}\) alkene, alkyne
e. \((\text{CH}_3)_2\text{CC(CH}_3)\text{)}_2\text{Cl}\) chloroalkane
f. \(\text{CH}_3\text{CHOHCH(CH}_3)\text{)}_2\) secondary alcohol
g. \(\text{NH}_2\text{CH}_2\text{CHCHCH}_3\text{CH}_2\text{OH}\) primary amine, primary alcohol
h. \((\text{CH}_3)_2\text{COHCH}_2\text{OCH}_3\) tertiary alcohol, ether
i. \((\text{CH}_3)_2\text{CHOCH}_2\text{COCH(CH}_3)\text{)}_2\) ether, ketone
j. \(\text{C}_6\text{H}_5\text{COH(CH}_3)\text{CHO}\) aromatic, alcohol, aldehyde
k. \((\text{CH}_3)_2\text{CHOCH}_2\text{COCH(CH}_3)\text{)}_2\) ether, ketone
l. \(\text{OHCCCH}_2\text{COCH}_3\) aldehyde, ketone
m. \(\text{CH}_3\text{OC}_6\text{H}_4\text{CO}_2\text{CH}_3\) ether, aromatic, ester
n. \((\text{CH}_3)_2\text{CHO}_2\text{CCCC(CH}_3)\text{)}_2\text{CO}_2\text{H}\) ester, alkyne, carboxylic acid
o. \(\text{NCCCCCHCHO}\) nitrile, alkyne, alkene, aldehyde
p. \(\text{HOCH(CH}_3)\text{CH}_2\text{CONH}_2\) secondary alcohol, primary amide
q. \((\text{CH}_3)_2\text{NOCCCC(CH}_3)\text{)}_3\) tertiary amide, alkyne
r. \(\text{ClCH}_2\text{COCH}_2\text{COCl}\) chloro, ketone, acid chloride
s. \(\text{CH}_2\text{CHC}_6\text{H}_4\text{CCCH(CH}_3)\text{)}_2\) alkene, aromatic, alkyne
t. \((\text{CH}_3)_2\text{NCH}_2\text{CCCH}_3\) ammonium ion, alkyne
u. \(\text{CH}_3\text{CH}_2\text{O}_2\text{CCCO}_2\) ester, alkyne, carboxylate
v. \(\text{C}_6\text{H}_5\text{CH}_2\text{CH(CO}_2\text{CH}_3)\text{CHO}(\text{CO}_2\text{CH}_3)\text{CH(CH}_2\text{CONH}_2\text{)}\text{CH(COCl)}\text{CH(CN)}\text{CH(COCH}_3)\text{CH}_3\) A variety of branches: aromatic ring, carboxylic acid, aldehyde, ester, amide, acid chloride, nitrile, ketone
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Problem 2 - Draw two dimensional Lewis structures for the following condensed line formulas of less common functional groups and some groups with formal charge. Include two dots for any lone pair electrons and show any formal charge on atoms. Occasionally, resonance structures are possible. You should be able to predict the hybridization, shape, bond angles, number of sigma bonds, pi bonds and lone pairs of electrons on every nonhydrogen atom below.

a. \( \text{CH}_3\text{CH}_2\text{CHCH}_3\text{N(CH}_3)_2\text{O} \)  
   amine oxide, has formal charge

b. \( \text{(CH}_3)_2\text{CHNO}_2 \)  
   nitroalkane, has formal charge

c. \( \text{H}_3\text{NCHCH}_2\text{CO}_2 \)  
   amino acid, has formal charge

d. \( \text{(CH}_3)_2\text{CHC}_6\text{H}_4\text{O} \)  
   aromatic phenoxide

e. \( \text{CH}_3\text{CHN}_2 \)  
   diazoalkane, has formal charge

f. \( \text{(CH}_3)_2\text{CCO} \)  
   ketene

g. \( \text{(CH}_3)_3\text{CN}_3 \)  
   azidoalkane, has formal charge

h. \( \text{(CH}_3)_2\text{CCHCH}_2\text{CHO} \)  
   enolate

i. \( \text{CH}_3\text{CHCCCH}_3 \)  
   allene

j. \( \text{CH}_3\text{CHCCCHCH}_3 \)  
   cumulene

k. \( \text{HOHCCHCHCH(C}_3\text{)}_2 \)  
   protonated carbonyl group

Problem 3 - Draw 2D Lewis structures for the following condensed line formulas. Include two dots for any lone pair electrons. These are more challenging than the previous structures, but they are doable, if you break them into simpler pieces as described earlier.

a. \( \Theta \text{O}_2\text{CCC}(\text{CH}_3)\text{CH\text{COCH(OH)CH(NO}_2\text{)CO}_2\text{CH(N}_3\text{)C}(\text{CH}_3)\text{O} \)  
   6 carbon ring present
   formal charge in this group

b. \( \text{HO}_2\text{CC(CH}_3)_2\text{CCCH(N}_2\text{)COCH(CN)CH(N}_2\text{H}_2\text{CH(OCH}_2\text{CH}_2\text{)}\text{C}_6\text{H}_4\text{CONHCH(CH}_3\text{)CHO} \)  
   6 carbon ring present
   formal charge in this group

c. \( \text{OHCCHOHCH}_2\text{CCCH C(CH}_3\text{)COCH(NO}_2\text{)C(CH}_3)_2\text{C}_6\text{H}_4\text{CH(OCH}_3\text{)CON(CH}_3\text{)CH}_2\text{CO}_2\text{CH(N}_3\text{)COC} \)  
   6 carbon ring present
   formal charge in this group

d. \( \text{OHCC}_4\text{H}_4\text{CH(NO}_2\text{)C(CH}_3\text{)(OCH}_3\text{)CCCH(OH)CH(CN)CHNH}_2\text{CH(CH(CH}_3)\text{)COCO}_2\text{CH}_2\text{CO}_2 \)  
   six carbon ring
   formal charge in this group

It’s time to go back and take another look at that “hopelessly complex molecule” on page 2. I bet you can do it now.
Guidelines for Three Dimensional Lewis Structures – build molecular models to visualize the structures

Guideline 1 – Draw a 2D Lewis structure as described above. This will allow you to determine the connections of the atoms, the hybridization, the shape, the bond angles, the number of sigma and pi bonds and the nature of any lone pairs of electrons.

Guideline 2 – Draw all reasonable 2D resonance structures to allow a determination of each atom’s hybridization. We mentioned this idea several times in the 2D examples above, but we will explicitly state it again. The hybridization of any atom is determined by the resonance structure in which that atom has its maximum number of bonds. This is a very important idea that you will probably overlook on occasion. If I make a big deal about it here, maybe you won’t forget about it…but you probably will!

Guideline 3 – Place as many atoms as possible in the plane of the paper when you begin to draw your 3D structure. You only need to know how to draw three different shapes (sp, sp$^2$ and sp$^3$), but you really need to know how to draw them well.

a. If any triple bonds are present in your 2D Lewis structure, begin here. Sp hybridization is possible with neutral carbon and nitrogen and positively charged oxygen. As much as possible, draw any additional pi bonds parallel to the plane of the paper and to the first drawn pi bond. Show the pi electrons as two dots between the 2p orbitals in your 3D structures. These will be the electrons you push in most of the mechanisms of alkene, alkyne and aromatic chemistry, to be studied later.

\[ R\begin{array}{c}C\end{array}R \]
\[ \text{R is a variable position.} \]
\[ \text{The sigma skeleton is drawn first.} \]

\[ R\begin{array}{c}C\end{array}N \]
\[ \text{The sigma skeleton is shown with the lone pair electrons in a hybrid orbital, which are shown as two dots inside a circle.} \]

\[ R\begin{array}{c}C\end{array}O \]
\[ \text{The sigma skeleton is shown with the lone pair electrons in a hybrid orbital, which are shown as two dots inside a circle.} \]

\[ R\begin{array}{c}C\end{array}C \]
\[ \text{Draw the first pi bond in the plane of the paper with simple plain lines. Add two dots for the pi bonds.} \]
\[ R\begin{array}{c}C\end{array}C \]
\[ \text{Draw the second pi bond perpendicular to the first pi bond, in and out of the plane of the paper, with 3D perspective indicated by heavy and dashed lines. Add two dots for the pi bonds.} \]

\[ R\begin{array}{c}C\end{array}N \]
\[ \text{Draw the first pi bond in the plane of the paper with simple plain lines. Add two dots for the pi bonds.} \]
\[ R\begin{array}{c}C\end{array}N \]
\[ \text{Draw the second pi bond perpendicular to the first pi bond, in and out of the plane of the paper, with 3D perspective indicated by heavy and dashed lines. Add two dots for the pi bonds.} \]

\[ R\begin{array}{c}C\end{array}O \]
\[ \text{Draw the first pi bond in the plane of the paper with simple plain lines. Add two dots for the pi bonds.} \]
\[ R\begin{array}{c}C\end{array}O \]
\[ \text{Draw the second pi bond perpendicular to the first pi bond, in and out of the plane of the paper, with 3D perspective indicated by heavy and dashed lines. Add two dots for the pi bonds.} \]

b. If only double bonds are present, begin by drawing one of the double bonds in the plane of the paper. As much as possible, draw any additional pi bonds parallel to the plane of the paper and your original pi bond. Only certain perspectives are allowed for wedges and dashes. There are a number of parallel sigma bonds that, if recognized, make it easier to draw a 3D structure. Show the pi electrons as two dots between the 2p orbitals in
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your 3D structures. Show any lone pair electrons in hybrid orbitals in a circle at the end of the line showing the hybrid orbital (simple, wedged or dashed line). Additional pi bonds, not included below, are -N=O and -N=N-.

R is a variable position.

Draw the pi bond in the plane of the paper with simple lines. The wedged and dashed lines add the 3D perspective. Add two dots for the pi bonds.

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Draw the pi bond in the plane of the paper with simple lines. The wedged and dashed lines add the 3D perspective. Add two dots for the pi bonds.

Draw the pi bond in the plane of the paper with simple lines. The wedged and dashed lines add the 3D perspective. Add two dots for the pi bonds.

There are only two possible shapes for an sp\(^2\) hybridized atom, if the pi bond is drawn in the plane of the paper. The sp\(^2\) hybrid orbital in the plane of the paper either points to the left or to the right (drawn as a simple plain line). One of the other two sp\(^2\) hybrid orbitals will be a wedged line and the other will be a dashed line. X (below) represents any sp\(^2\) hybridized atom (C, N, O, F). The dashed line pointing left in A and the wedged line pointing right in B are parallel. Similarly, the wedged line pointing left in A and the dashed line pointing right in B are parallel.
There are additional ways that an sp² π bond can be drawn when the π bond is in or out of the plane of the paper.

![Six alternate ways of drawing a π bond between sp² atoms that is not in the plane of the page.](image)

c. Pi bonds can be joined together in an almost endless number of possible ways. (two triples, triple plus a double, two doubles, cumulated, aromatic…etc.).

![2D Lewis structure](image)

![3D Lewis structure](image)

Notice that several bonds are parallel. R₁-Cₐ is parallel with Cₐ-Cₐ and Cₐ-Cₐ. R₂-C₂ is parallel with C₃-C₃, C₃-C₃ and C₃-C₃. Cₐ-Cₐ is parallel with Cₐ-Cₐ.

The front π bond was drawn first so the sigma bond between the two π bonds is a dashed line. Use the parallel relationship of the sigma bonds to help you draw the correct perspective in these structures.
If you have to draw a 3D structure with an aromatic ring, draw the ring big so that the 2p orbitals in the front do not cover the 2p orbitals in the back. In this structure the sigma bonds of the substituents on the aromatic ring are supplying the 3D perspective. If you want to get more fancy, you can add that perspective to the sigma bonds in the ring. We can see clearly that all of the 2p orbitals of the pi bonds are parallel, except for the second pi bond of the alkyne which is perpendicular to the other pi bonds. There is resonance among the parallel pi bonds. There are a number of places where we could switch in a heteroatom and some lone pairs of electrons.

\[
\text{2D Lewis structure}
\]

\[
\begin{array}{c}
\text{3D Lewis structures}
\end{array}
\]

If you have to draw a 3D structure with an aromatic ring, draw the ring big so that the 2p orbitals in the front do not cover the 2p orbitals in the back. In this structure the sigma bonds of the substituents on the aromatic ring are supplying the 3D perspective. If you want to get more fancy, you can add that perspective to the sigma bonds in the ring. We can see clearly that all of the 2p orbitals of the pi bonds are parallel, except for the second pi bond of the alkyne which is perpendicular to the other pi bonds. There is resonance among the parallel pi bonds. There are a number of places where we could switch in a heteroatom and some lone pairs of electrons.

d. Sp\(^3\) hybridization may be the most difficult to represent in three dimensions. Simple single bonds allow unlimited rotations. To simplify our 3D drawing problems as much as possible, we will assume that tetrahedral atoms are in a zig-zag conformation (shape) in the plane of the paper. Only certain perspectives will be allowed for wedges and dashes. Usually, we will draw two simple lines, in the plane of the paper and one wedged line and one dashed line. The two simple lines will have to be drawn close to one another, as will the dashed and wedged lines. These can be difficult to draw accurately and we will allow shapes to be drawn that are “pretty close”. Examples of these are shown below, along with some of the common problems.

\[
\begin{array}{c}
\text{Simple lines can be drawn close together four different ways, pointing up, pointing right, pointing down and pointing left.}
\end{array}
\]

\[
\begin{array}{c}
\text{Wedged and dashed lines can be drawn close together four different ways, pointing up, pointing right, pointing down and pointing left.}
\end{array}
\]

These lines are drawn correctly.

These lines are drawn incorrectly.

Drawing the simple lines or the wedged and dashed lines opposite one another implies that there are 180° bond angles...but we know that sp\(^3\) atoms have approximately 109° bond angles.
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Point of view provides yet another complication in drawing tetrahedral 3D atoms. Are you viewing a structure from the left or from the right? Whichever it is, you will want stay consistent in your drawing for all of the sp³ atoms.

The perspective of these two atoms is consistent when viewed from the left. The dashes are parallel and the wedges are parallel.

The perspective of these two atoms is consistent when viewed from the left. The dashes are parallel and the wedges are parallel.

The perspective of these two atoms is consistent when viewed from the right. The dashes are parallel and the wedges are parallel.

The perspective of these two atoms is consistent when viewed from the right. The dashes are parallel and the wedges are parallel.

The perspective of these two atoms is consistent when viewed from the left. The wedges pointing up are parallel to the dashes pointing down, and vice versa.

The perspective of these two atoms is consistent when viewed from the right. The wedges pointing up are parallel to the dashes pointing down, and vice versa.

None of the perspectives of these pairs of atoms is consistent when viewed from the either side. All of these are drawn incorrectly.
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As much as possible, draw a sequence of sp\(^3\) atoms in a zig-zag shape. Besides there being a logical “energetic” reason for drawing a structure this way, it is easier to draw and see on a piece of paper. The zig-zag bonds in the plane of the paper all use simple lines and there will be a wedged and dashed line coming off each sp\(^3\) atom. At alternate positions they will be pointing up, when the chain is up, and then down, when the chain is down. Keep in mind the point of view restrictions shown above.

2D condensed formula 2D Lewis structure Zig-Zag connections

CH\(_3\)CH\(_2\)CH\(_2\)CH\(_2\)CH\(_3\)

Zig-Zag connections, with wedges and dashes

CH\(_3\)CH\(_2\)OCH\(_2\)CH\(_3\)

CH\(_3\)OCH\(_2\)CH\(_2\)NH\(_2\)

CH\(_3\)CH\(_2\)NHCH\(_3\)

It’s easy to switch in an sp\(^3\) heteroatom in place of an sp\(^3\) carbon atom. All we need to do is place a lone pair at the end of one of the hybrid orbitals in place of an atom (all hydrogen atoms here).
Branches off of the zig-zag chain are generally difficult to draw. Anything that moves off the plane of the paper makes the 3D drawing more difficult. We will try to minimize drawing 3D structures with these features.

Here are two examples, showing all three possible hybridization states in one molecule, and some heteroatoms thrown in to boot.

A difficult 3D Lewis structure to draw. Whatever you draw on the paper is a good approximation of what is in your head. Errors on the page imply errors in your mind. Be careful and precise in what you write down.
Lecture 4
Summary of 3D shapes for carbon, nitrogen, oxygen and fluorine

Carbon: Four ways to draw carbon in organic chemistry.

Nitrogen: Four ways to draw nitrogen in organic chemistry.

Oxygen: Three ways to draw oxygen in organic chemistry.

Fluorine: Two ways to draw fluorine in organic chemistry.
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Problem 4 – First, convert the condensed line formulas of the following hydrocarbons into 2D Lewis structures. Next, draw 3D structures for each of the 2D structures.

Condensed line formulas

a. \( H_2CCCH_2 \)  
b. \( CH_2CHCH_3 \)  
c. \( H_3CCCH \)  
d. \( CH_2CCH_2 \)  
e. \( CH_2CHCHCH_2 \)

f. \( H_2CCCHCH_3 \)  
g. \( CH_3CCCH_2CH_2CH_3 \)  
h. \( H_2CCCCH_2 \)  
i. \( C_6H_5CCCHCH_2 \)  
j. \( CH_3CCCCCH_3 \)

Problem 5 – This problem is very similar to the above problem, except heteroatoms (N, O and F) are substituted in for some of the carbon atoms and some structures have formal charge.

Condensed line formulas

a. \( CH_2CHCHO \)  
b. \( HCCCO_2H \)  
c. \( H_3CCH_2CN \)  
d. \( CH_3NHCH_2CH_3 \)  
e. \( CH_3CCCCCH_3 \)

f. \( CH_3CH_2COCH_3 \)  
g. \( CH_3CHCHCH_2OH \)  
h. \( CH_2CHN_3 \)  
i. \( OHCC_6H_4CN \)  
j. \( CH_3CHN_2 \)

k. \( CH_2CHC_6H_4CCCO_2CH_3 \)  
l. \( CICH_2CH_2CONHCH_3 \)  
m. \( O_2NCHCHCCCH_3 \)  
n. \( CH_3C_5NH_4 \)

six atom ring  
six atom heterocyclic ring