CHEM1611 Worksheet 5: Introduction to Carbon Chemistry

Model 1: Bonding in Organic Molecules

Here is a partial periodic table. The shaded elements are the focus of organic chemistry. The number above each column indicates the **number of covalent bonds that an element in that column will typically make**.

1	2	0	0	0	0	0	0	0	0	0	0	3	4	3	2	1	0
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Sr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe

Figure 1. Partial Periodic Table

Critical thinking questions

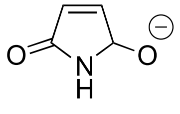
1. How many bonds does carbon typically make? Draw a molecule composed of only C and H with exactly two C atoms and some number of H atoms in which both C and H are making their typical number of bonds.

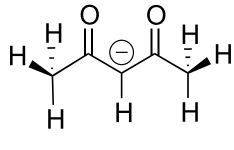
2. Nitrogen typically forms three bonds. Given that each bond involves two electrons, and nitrogen obeys the octet rule, how many valence electrons are unaccounted for?

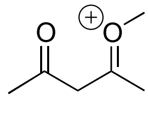
3. Free electrons, like bonding electrons, take up space. How does this lone pair of electrons affect the shape of a molecule like NH_3? (Try to draw it in 3-D.)

Sometimes atoms will form more or less than their typical number of bonds. In these cases the atoms are said to carry a formal charge (either + or -).

4. Here are a few examples. How does the typical number of bonds formed and the actual number of bonds formed relate to the formal charge? Can you write this as a formula*?

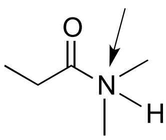


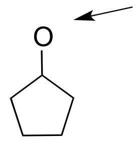


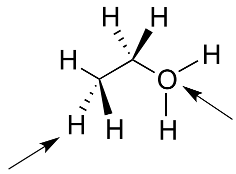


* This formula works well for heteroatoms (atoms other than C and H) but care must be taken when determining the formal charge on C, as we will see next week.

5. Determine the formal charges on the atoms indicated below.







Remember: formal charges must ALLWAYS be indicated when you are drawing molecular structures.

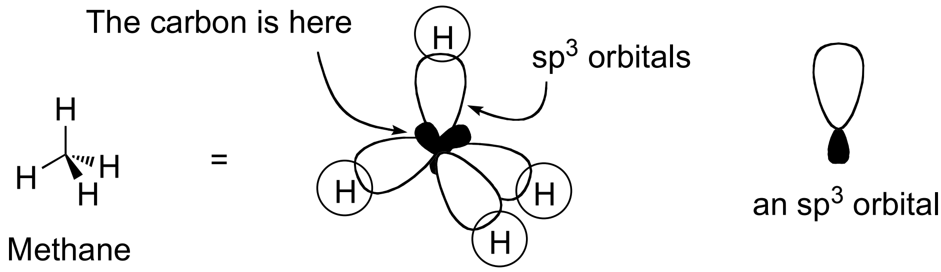
Model 2: Hybridization

There's an apparent paradox in the bonding of carbon:

a) The valence electrons of a carbon atom sit in atomic orbitals that are different in energy (what are they?)
b) The tetrahedral carbon in methane has four identical bonds to H's

So it seems like the electrons are different, but the bonds are the same..?

We resolve this by saying that the carbon orbitals (and the electrons in them) *mix* to form new orbitals. So the 2s and the three 2p orbitals can mix together to form four orbitals that are all the same. These overlap with the hydrogen 1s orbitals to form four identical bonds. This kind of orbital mixing, to produce hybrid orbitals, is known as ***hybridization***.



Critical thinking questions

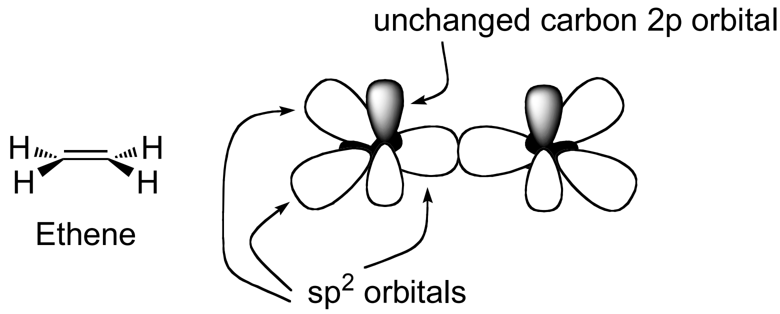
1. Is it obvious why these orbitals are called *sp*^{3} orbitals?

Carbon is also able to use its 2*s* orbital and *two* of its *p* orbitals to form new orbitals.

2. How many new, mixed orbitals would result from this? How would these orbitals arrange themselves around carbon?

3. What might you call these orbitals?

An example of this kind of mixing is found in ethene:



4. Note that a *p* orbital is left over. Are there electrons in this *p* orbital? The adjacent carbon is also in the same situation, so can these *p* orbitals combine?

5. Is this kind of bond (π-bond) stronger or weaker than the σ-bond formed by the overlap of the sp^2 hybridized orbitals? Why?

6. How many bonds are there between the two carbons of ethene? Can you relate this to the stick structure above?

Model 3: Naming Organic Molecules

Critical thinking questions

1. You find a bottle in the lab labeled dimethylpentane. This name is ambiguous, so draw (using stick notation) all the possible structures consistent with this name.

2. You should have drawn 4 structures in Q3. Pick one of these and try to give it an unambiguous name.

Convention has it that compounds are numbered from the end nearest the functional group that provides the root of the name (the alkene in 1-butene, the alcohol of 1-butanol). Where there are no such functional groups, numbering of the parent chain starts from the end nearest a branch.

3. Is your answer to Question 2 consistent with this convention? If not, try to name it again.

4. Name the other molecules in your answer to Question 1.

Learning to name organic molecules is a bit like learning a foreign language. There is no substitute for practice!

Key to success: practice further by completing this week's tutorial homework