

Learning Guide for Chapter 1 - Atoms and Molecules

- I. Introduction to organic chemistry - p 1
- II. Review of atomic structure - p 3
 - Elementary particles
 - Periodic Table of Elements
 - Electronegativity
 - Atomic mass and isotopes
 - Ions
 - Valence electrons
- III. Review of Ionic and Covalent Bonds - p 7
 - Overview of ionic and covalent bonds
 - Lewis structures of covalent compounds
 - Polarity of covalent bonds
 - Strength of covalent bonds
 - Geometry of molecules
 - Molecules with charges
 - Resonance structures
- IV. Orbitals and Hybridization - p 17
 - Atomic orbitals
 - Molecular orbitals
 - Hybridized atomic orbitals

I. Introduction to Organic Chemistry (1-1)

What will we be studying in organic chemistry?

Why is it called organic chemistry?

What did early organic chemists think about organic compounds?

What fields of study does organic chemistry prepare you for?

What industries depend upon organic chemistry?

Why are organic compounds so important?

Why are there so many organic molecules?

How are organic compounds put together?

Here are two examples of organic compounds, to give you a preview of the kinds of things we will be working with.

This chapter will review the things you need to know about atoms, ions, and molecules in order to begin our study of organic compounds.

II. Review of Atomic Structure (1-2)

Elementary Particles

What three elementary particles make up an atom? What charge does each have?

Draw a simple picture of an atom, showing how these elementary particles are arranged.

What's in the middle of the atom?

What does the nucleus have in it?

What is around the nucleus?

Which part participates in chemical reactions? Why?

Periodic Table of Elements

What is an element? How many of them are found in nature?

What gives an atom its identity?

What is the atomic number of carbon?

How are the elements organized in the Periodic Table?

Why is the Periodic Table so useful?

Locate the following on the Periodic Table below:

metals

nonmetals

transition metals

inner transition metals

periods 1-7

alkali metals, alkaline earth metals, halogen family, noble gases

A large grid of 100 squares arranged in 10 rows and 10 columns. A mouse cursor is pointing at the square in the 5th row and 5th column.

What happens to the size of an element as you go across a period? Why?

What happens to the size of an element as you go down a family? Why?

Where will you find elements with similar chemical reactivity?

Write in the symbols of the following elements in the Periodic Table below:

Four most common elements
in organic compounds:

carbon (C)
hydrogen (H)
nitrogen (N)
oxygen (O)

Other nonmetals:

fluorine (F)	boron (B)
chlorine (Cl)	sulfur (S)
bromine (Br)	phosphorus (P)
iodine (I)	

Main group metals:

lithium (Li)
sodium (Na)
potassium (K)
magnesium (Mg)
aluminum (Al)

Transition metals:

chromium (Cr)	iron (Fe)
manganese (Mn)	silver (Ag)
mercury (Hg)	zinc (Zn)
palladium (Pd)	copper (Cu)
platinum (Pt)	osmium (Os)

Memorize the positions of these elements (except the transition metals)!
You will need to draw this table from memory.

[illegible][illegible]

What period are carbon, nitrogen, and oxygen in? What about sulfur and phosphorus?

Which element is in the same family as oxygen? Nitrogen? Boron?

Electronegativity

What is electronegativity?

Do nonmetals have high or low electronegativities? What about metals?

What is the most electronegative element?

Which is more electronegative, nitrogen or oxygen?

Which is more electronegative, nitrogen or phosphorus?

Which of these two comparisons is more important?

When considering two elements in the same period, what property is most important?

When considering two elements in the same family, what property is most important?

Atomic mass and isotopes

Which elementary particles contribute the most to the atomic mass?

What is an isotope?

What does ^{13}C mean? How else could it be written? How many protons and neutrons does it have?

How are isotopes useful in organic chemistry?

What is the weighted average of all naturally occurring isotopes of carbon?

What is the most common isotope of carbon?

Ions

What elementary particles determine the charge of an atom?

Which of these is an atom more likely to lose or gain, and why?

What happens to an atom when it loses an electron?

What happens to an atom when it gains an electron?

How many electrons would have each element have under the following conditions?

neutral:	+1 charge:	-1 charge:	+2 charge:	-2 charge:
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fluorine

calcium

Which of these ions is most likely to be formed?

Which is a cation, and which is an anion?

Valence Electrons

Draw some circles to represent the energy levels around the nucleus below. Which is the lowest energy? Which is the highest? How do the electrons fill these levels?



Which are the valence electrons? Why are they important?

How many valence electrons do each of the following elements have?

H	O	Mg	F	Al	P
---	---	----	---	----	---

Draw the Lewis dot structures for the following atoms.

C	H	N	O
B	Cl	S	Ar

III. Review of Ionic and Covalent Bonds

Overview of Ionic and Covalent Bonds

Why do atoms form chemical bonds?

What is the octet rule?

What kind of compound is KCl? How do you know? Use Lewis structures to show how it would be formed.

What kind of compound is HCl? How do you know? Use Lewis structures to show how it would be formed.

What does a line between two atoms represent?

What kind of bonds does NaOH have?

When are covalent bonds found in organic chemistry?

When are ionic bonds found in organic chemistry?

Lewis structures of covalent compounds

What steps should you follow when drawing the Lewis structure of a compound?

- 1)
- 2)
- 3)
- 4)

Draw the Lewis structure of each atom below. Then calculate the number of bonds that each atom will typically form.

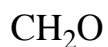
	H	C	N	O	F
valence electrons					
number of bonds					

What is the relationship between these numbers?

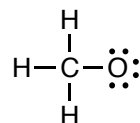
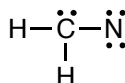
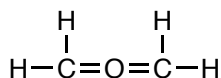
How many bonds and how many electron pairs will each of the following atoms have?

H	C	C	N	N	O	F
	C	C	N		O	

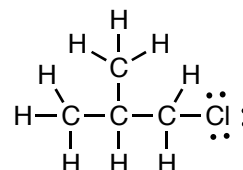
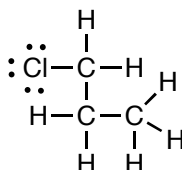
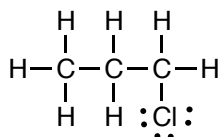
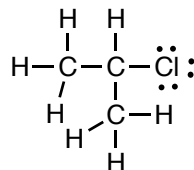
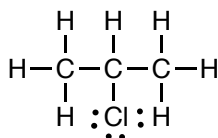
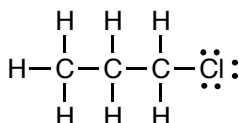
Draw a Lewis structure for the following compounds.



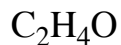
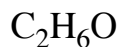
What is wrong with each of the following structures?



Which of the following structures represent different compounds, and which are just different ways to draw the same compound?



Draw two different Lewis structures for each of the following formulas.



When are covalent bonds polar? When are they nonpolar?

Which atom in a C-F bond is partially positive? Which is partially negative? Why? How can we show this?



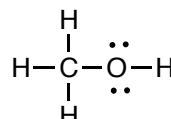
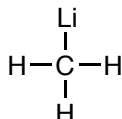
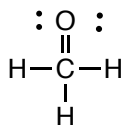
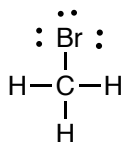
Describe the polarity of the following bonds and the partial charges on the atoms:



Which is the more polar bond? Why?



Locate and label the most important polar bond(s) in each of the following molecules.



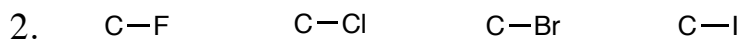
Strength of Covalent Bonds

Why is the strength of a bond important?

Predict the trend in the following sequences. Do the bonds get stronger or weaker? Why?

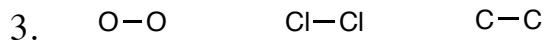


bond energy (kcal/mol)



average bond length

bond energy

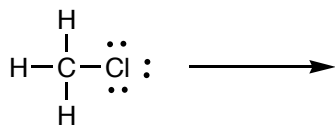
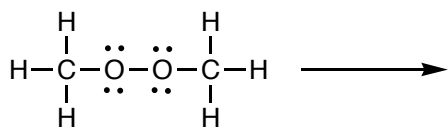


average bond length

bond energy

What is the difference between homolytic and heterolytic bond cleavage? Which is more common?

How would the following bonds be likely to break in a reaction?



Geometry of Molecules

What does the geometry of a molecule tell us about it?

What principle allows us to predict molecular geometries?

Predict the geometry of an atom surrounded by the following:

4 atoms, no electron pairs –

3 atoms, no electron pairs –

2 atoms, no electron pairs –

3 atoms, 1 electron pair –

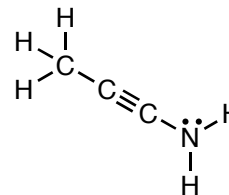
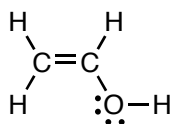
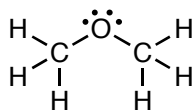
2 atoms, 1 electron pair –

2 atoms, 2 electron pairs –

Draw Lewis structures for the following compounds. Then build a model of the molecule and sketch a picture of it. What shape do the atoms surrounding the central atom make? What angle do they make with each other?

	Lewis structure	sketch of model	shape	angle
methane CH_4				
ammonia NH_3				
water H_2O				
formaldehyde CH_2O				
acetylene C_2H_2				

What is the geometry around each atom in the following compounds?



Molecules with charges

What happens when an atom in a covalent molecule loses or gains an electron?

Atoms with no charge:

Draw the Lewis structures for the following atoms. What compound would each of them form with hydrogen?

H

C

N

O

F

Atoms with a negative charge:

Draw the Lewis structures for the each of the atoms below if they gained an electron and became negatively charged. What would happen to the compounds they would make?

H

C

N

O

F

Which of the above is the most reactive? Which is the most stable? Why?

Are these molecules more or less reactive than the neutral molecules?

Atoms with a positive charge:

Draw the Lewis structures for each of the atoms below if they lost an electron and became positively charged. What would happen to the compounds they could make?

H

C

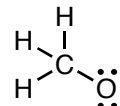
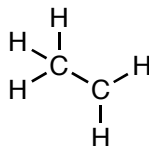
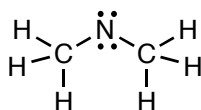
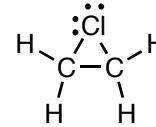
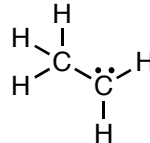
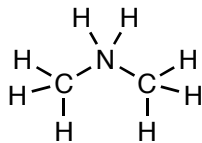
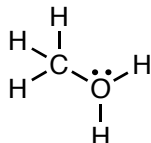
N

O

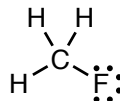
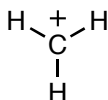
F

Which of the above are the least stable? Why?

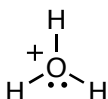
Write in the charges in each of the following compounds. Then draw in a counterion for each one.



What is the difference between the charges on these carbon atoms?



Consider hydronium ion (H_3O^+). How can the oxygen be both partially negative and still have a positive charge?

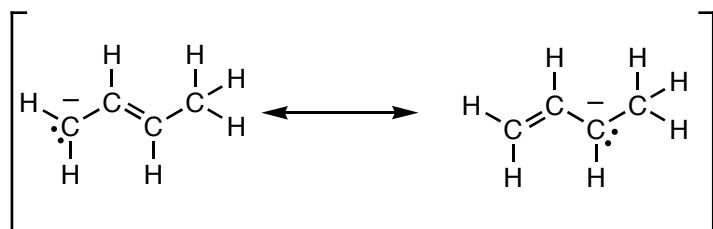


Resonance structures

When do molecules have to be represented by resonance structures?

What kinds of molecules typically exhibit this kind of behavior?

Look at the following example:



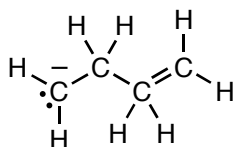
Where is the double bond?

Where is the nonbonding electron pair?

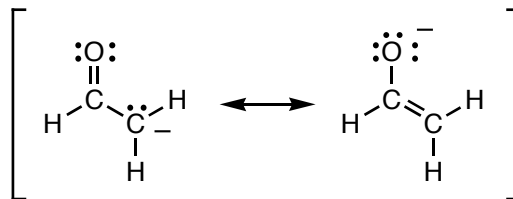
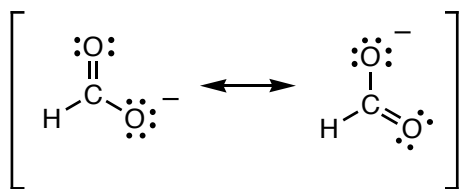
What does the compound really look like?

How can we show that these are resonance structures?

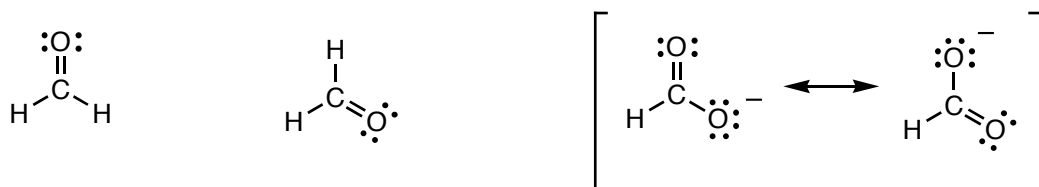
The following molecule does not have any resonance structures. Is it more or less stable than the one above?



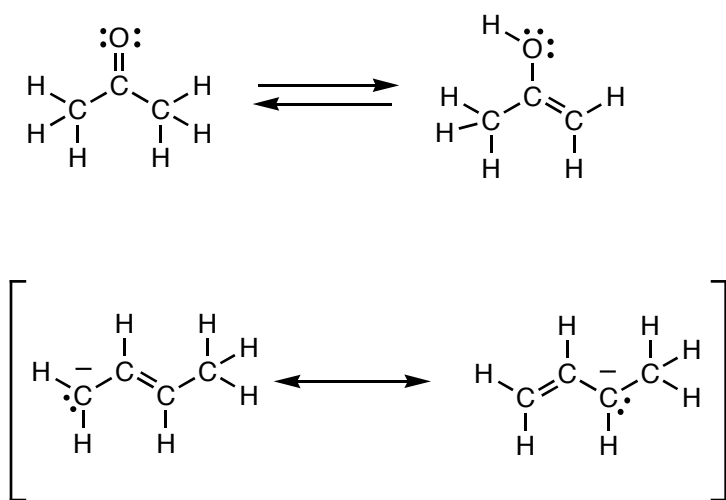
Which of the following resonance structures have equal resonance contributors, and which have unequal resonance contributors? Why?



Why are the molecules below the same, but the resonance structures different?

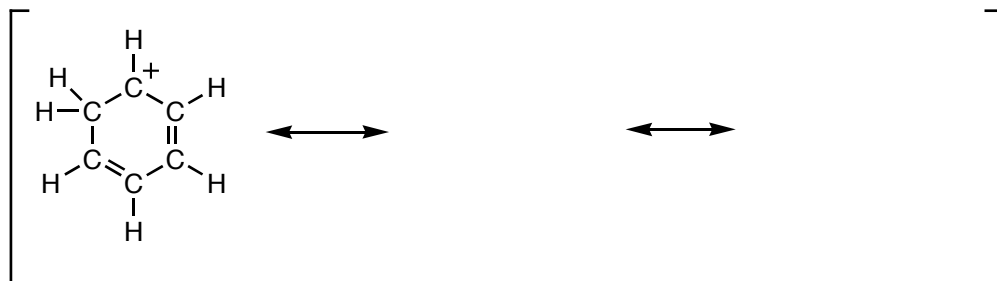


How is a resonance structure different from two molecules in equilibrium?



How can you tell which is which?

Fill in the missing resonance structures.



Why is this carbocation unusually stable?

IV. Orbitals and Hybridization

Atomic orbitals

What is an atomic orbital?

How many electrons can fit into one atomic orbital?

What are the four kinds of atomic orbitals?

How many of each type of orbital are found?

What shapes do the first two orbitals have?

What orbitals are present in which in which energy levels?

Give the electron configuration for each of the following atoms:

H

C

N

O

P

Molecular orbitals

What is a molecular orbital?

Where do molecular orbitals come from?

How many electrons can fit into one molecular orbital?

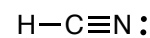
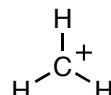
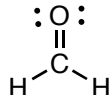
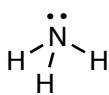
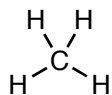
What are the two kinds of molecular orbitals?

What are the two kinds of covalent bonds?

Which bonds in a molecule are sigma bonds?

Which bonds in a molecule are pi bonds?

Label the bonds in the following molecules.

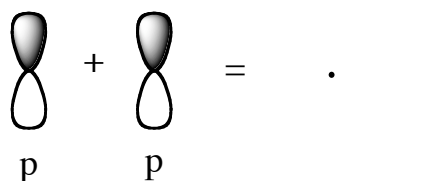
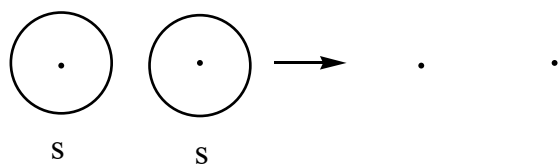


What does a sigma bonding orbital look like? What does a pi bonding orbital look like?

Why are pi bonding orbitals needed when forming a double or triple bond?

When a sigma or pi bonding orbital is formed, what other kind of orbital is also formed?

How is a sigma orbital formed from two s orbitals? How are pi orbitals formed from two p orbitals?



Why are antibonding orbitals called this?

Draw lines representing the energy of the sigma bonding, sigma antibonding, pi bonding, and antibonding orbitals in the following diagrams.



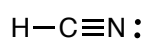
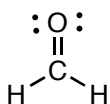
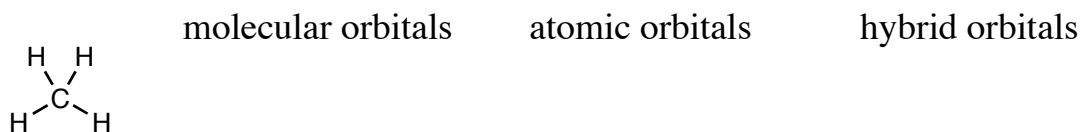
Which is more stable, an atomic orbital or a molecular bonding orbital?

Why are the antibonding orbitals usually empty?

Which is likely to be more reactive, electrons in a sigma bonding orbital or a pi bonding orbital?

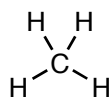
Hybridized atomic orbitals

What problem do we find when trying to form molecular orbitals for the following molecules?



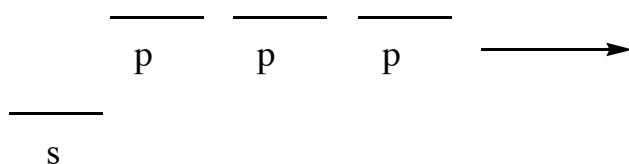
How can we solve this problem?

How many hybrid orbitals does methane need?



What hybridization will it have?

atomic orbitals



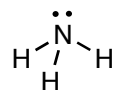
hybridized atomic orbitals

What do sp^3 orbitals look like?

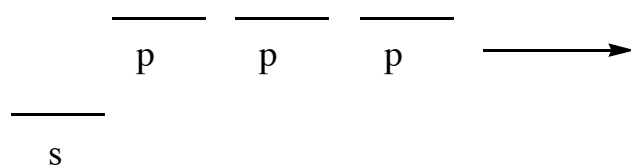
How are they oriented?

How will each of the bonds be formed?

How many hybrid orbitals does ammonia need?



What hybridization will it have?

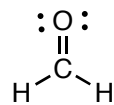


How will each of the bonds be formed?

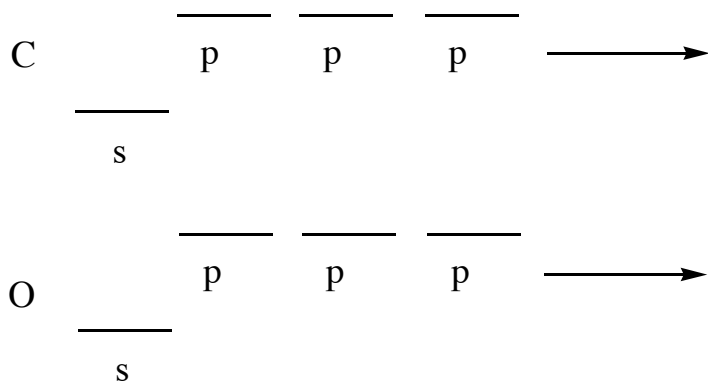
Where will the lone pair go?

How do we know it doesn't stay in a p orbital?

How many hybrid orbitals does formaldehyde need?



What hybridization will they have?



What do sp^2 orbitals look like?

How are they oriented?

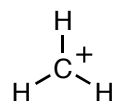
How will the C-H bonds be formed?

How will the C-O sigma bond be formed?

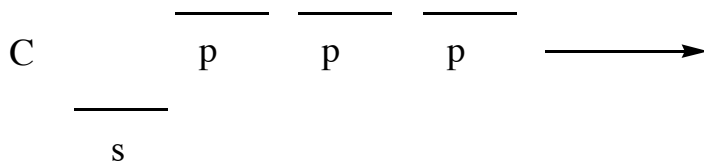
How will the C-O pi bond be formed?

Where will the two lone pairs go?

How many hybrid orbitals does a methyl cation need?



What hybridization will they have?



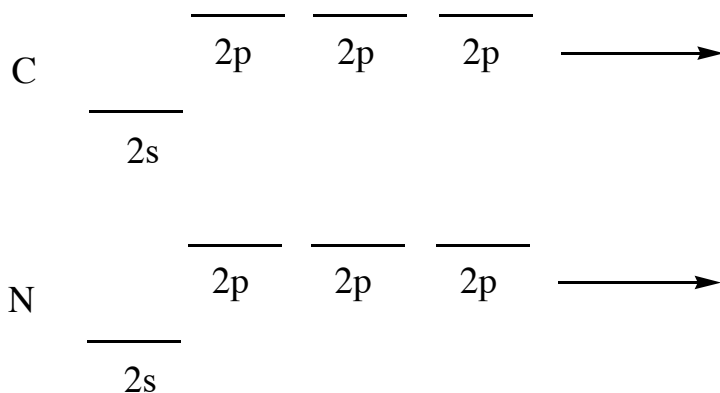
How will the C-H bonds be formed?

Where is the positive charge?

Why is the empty orbital a p orbital?

How many hybrid orbitals does hydrogen cyanide need? $\text{H}-\text{C}\equiv\text{N}:$

What hybridization will they have?



What do sp orbitals look like?

How are they oriented?

How will the C-H bond be formed?

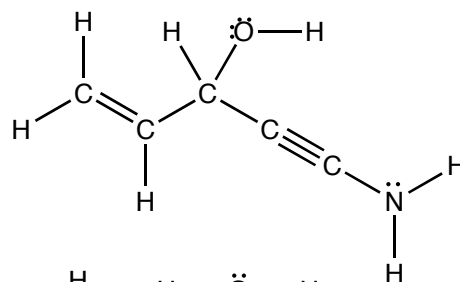
How will the C-N sigma bond be formed?

How will the two C-N pi bonds be formed?

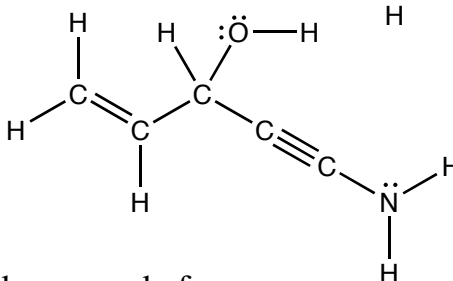
Where is that nonbonding electron pair?

Putting it all together:

Label all bonds as sigma or pi bonds.



Label the hybridization of each atom.



Label the atomic orbitals that each bond was made from.

