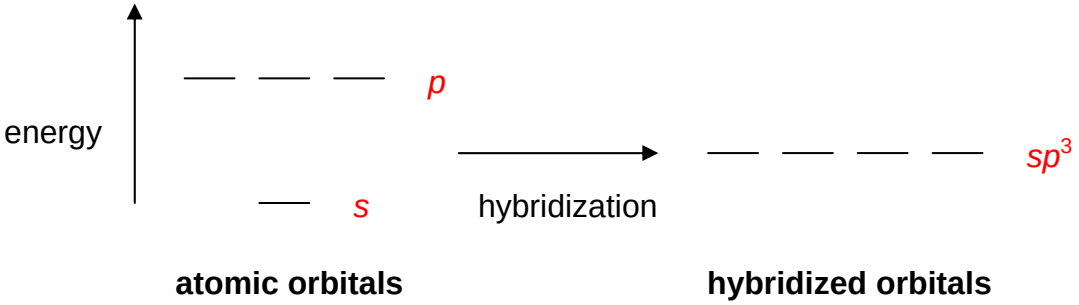
Worksheet 14 - Hybridization

When atoms bond to form molecules, they use **molecular orbitals**. These are formed through the **hybridization** of the **atomic orbitals** that we have already discussed, ***s***, ***p***, and ***d*** orbitals.

The **hybridized molecular orbitals** have different shapes and energy levels than the **atomic orbitals**. The number of molecular orbitals created by hybridization depends on the number of atomic orbitals that are mixed to form them.

In forming ***sp*^{3}** hybridized orbitals, **four** atomic orbitals are mixed, one *s* and three *p*. The energy diagram for this process is shown below. The hybridized orbitals are higher in energy than the *s* orbital, but lower in energy than the *p* orbitals.



Carbon has 4 valence electrons. Add these electrons to the atomic and molecular orbitals. This hybridization gives **tetrahedral geometry.**

With this hybridization, C will form **four equivalent σ bonds**.

Draw a similar energy diagram for ***sp*^{3}** hybridized **oxygen**.

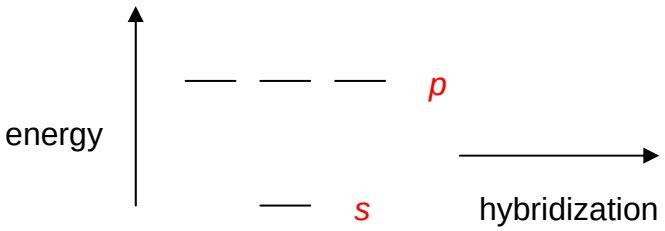
How many σ bonds will be formed?

How are the other *sp*^{3} orbitals used?

Do the same for ***sp*^{3}** hybridized **nitrogen.**

In some Lewis structures, there are only **three** equivalent bonds formed. To create three equivalent hybridized orbitals, mix **three** atomic orbitals.

Draw and name the orbitals formed in this hybridization, then add the electrons for **sulfur**. Since the hybridized orbitals are close in energy, every orbital is filled with one electron before electrons are paired.



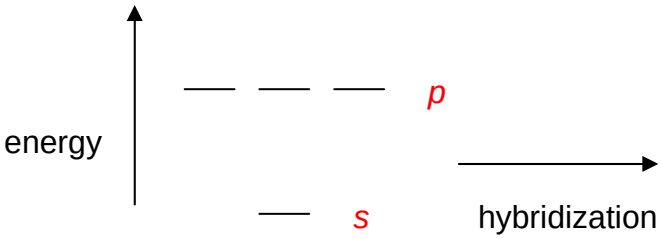
The hybridized orbitals will form _____ σ bond(s).

The unhybridized orbital will form _____ π bond(s).

There will be _____ lone pair(s).

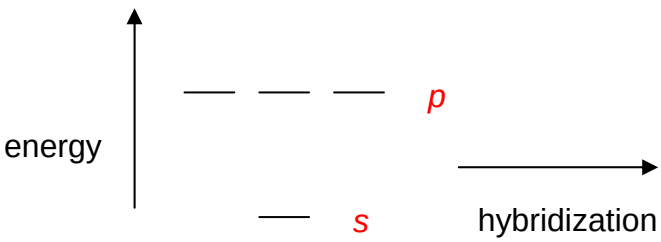
This hybridization gives **trigonal planar** geometry.

In **linear** molecules, like CO_2, the central atom has only **two** equivalent bonding orbitals. Draw the energy levels and name the orbitals formed in this hybridization.



Fill in the electrons for carbon and determine the number and typed of bonds formed.

In CO_2, determine the hybridization of the **oxygen** atoms. Complete the energy diagram for the oxygens. Draw the structure of CO_2.



In atoms with n=3 or larger, the *d* orbitals can also be hybridized. In molecules with **five** molecular orbitals, **five** atomic orbitals are mixed:

___ + ___ + ___ + ___ + ___

This will give **trigonal bipyramidal** geometry and is called ***dsp*^{3}** hybridization.

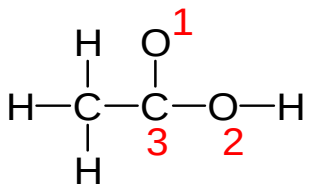
Finally, molecules with **octahedral** geometry, will have ____ molecular orbitals. This hybridization is called _____ .

Shown below is a portion of the chart from **Worksheet 13**. Fill in the **hybridization** for each of the compounds.

compound	**bonds**	**lone pairs**	**geometry**	**shape**	**hybridization**
SF_6	6	0	octahedral	octahedral	
NH_3	3	1	tetrahedral	trigonal pyramidal	
ICl_4^-	4	2	octahedral	square planar	
CF_4	4	0	tetrahedral	tetrahedral	
SO_3	3	0	trigonal planar	trigonal planar	
SF_4	4	1	trigonal bipyramidal	seesaw	
CO_2	2	0	linear	linear	
H_2O	2	2	tetrahedral	V-shaped	
NO_2^-	2	1	trigonal planar	V-shaped	

Fill in the chart below and then complete the Lewis structures for the molecules shown below and fill in those charts.

element	Lewis symbol	# bonds	# lone pairs
C			
N			
H			
O			
Halogen			

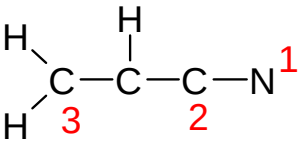


acetic acid

σ bonds ___–

π bonds _____

atom #	bond angle	hybridization
1		
2		
3		

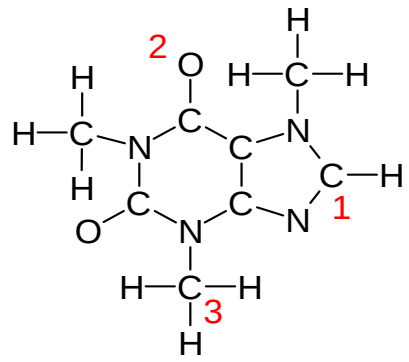


acrylonitrile

σ bonds ___–

π bonds _____

atom #	bond angle	hybridization
1		
2		
3		

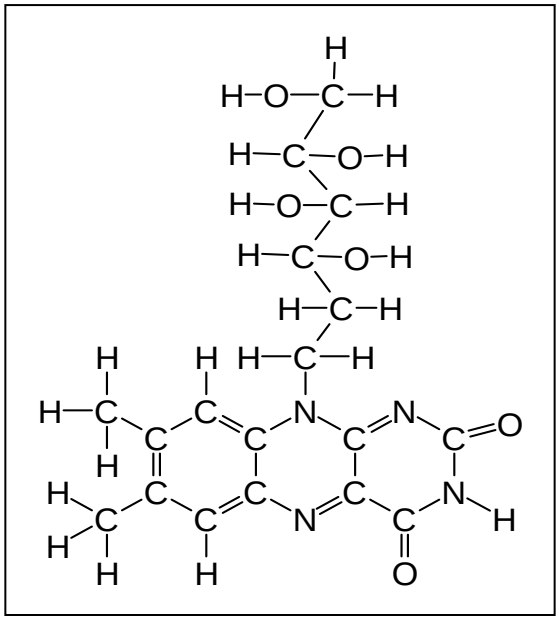


caffeine

σ bonds ___–

π bonds _____

atom #	bond angle	hybridization
1		
2		
3		



The molecule shown to the left is riboflavin (vitamin B2). Answer the following questions about its structure.

a) how many carbons are sp^3 hybridized?

sp^2 hybridized?

sp hybridized?

b) How many nitrogens are sp^3 hybridized?

sp^2 hybridized?

sp hybridized?

c) How many oxygens are sp^3 hybridized?

sp^2 hybridized?

sp hybridized?

d) How many σ bonds are there in total?

e) How many π bonds are there in total?

~~f)~~ ~~Which of the three rings are **planar**?~~

The acetate ion, $C_2H_3O_2^-$, has both oxygens bonded to the same carbon.

a) Draw the Lewis structure and all resonance forms.

b) Label the hybridization around each carbon.

c) Pick one resonance structure and label the hybridization of each oxygen.

d) How many σ and π bonds are present?

e) Which atom carries the formal negative charge?