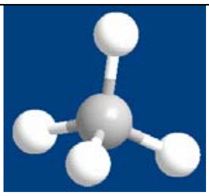
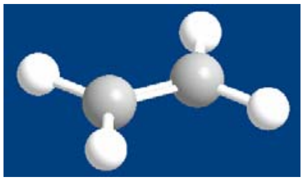
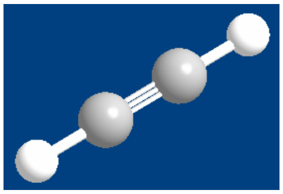
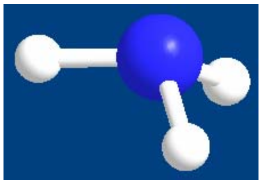
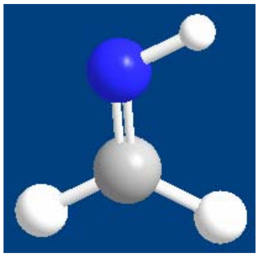
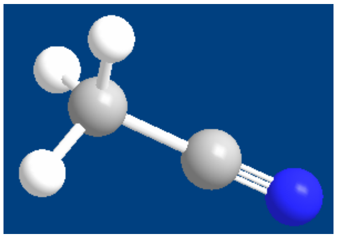
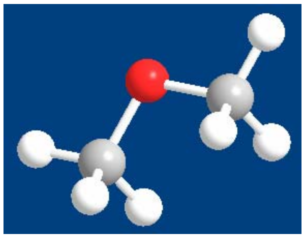
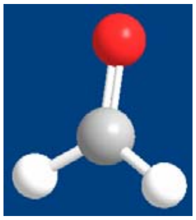
HYBRIDIZATION

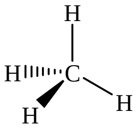
Hybridization is the mixing together of "atomic orbitals" (i.e., s-, p-) to form new, *hybridized* atomic orbitals. These new, hybridized, atomic orbitals overlap to form σ and π bonds. Carbon, oxygen and nitrogen valence atomic orbitals hybridize to form sp3, sp2 or sp hybridized orbitals. For *neutral (no formal charge)* C, O, and N atoms, the following guidelines in the table below can be used to predict the hybridization of these atoms in organic molecules.

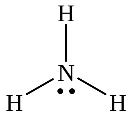
CARBON			
	Valence atomic orbitals	**Hybridized atomic orbitals**	**Bonding Pattern, geometry and bond angles in molecules**
sp3	**2s + 2px + 2py + 2pz** *All four of carbon's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new, degenerate (equal energy) orbitals are generated after hybridization. Each orbital is used to form a sigma bond*	 *(methane)* *Tetrahedral geometry(Td)* *109° bond angles* *Four σ bonds*
sp2	**$\boxed{\text{2s + 2px + 2py}}$ + 2pz** *Three of carbon's four valence orbitals mix(in box) to form three new hybridized orbitals. The unhbridized p-orbital is used for π bonding*	**sp2 + sp2 + sp2 + p** *Three new degenerate orbitals are formed after hybridization. The p orbital remains unhybridized. The sp2 orbitals are used to form σ bonds and the p orbital is used to form a π bond.*	 *(ethylene)* *Trigonal planar geometry* *120° bond angles* *Three σ bonds, one π bond*
sp	**$\boxed{\text{2s + 2px}}$ + 2py + 2pz** *Two of carbon's four valence orbitals mix(in box) to form two new hybridized orbitals. The unhbridized p-orbitals are used for π bonding*	**sp + sp + p + p** *Two new degenerate orbitals are generated after hybridization. The two p orbitals remain unhybridized. The sp orbitals are used to form σ bonds and the p orbitals are used to form π bonds.*	 *(acetylene)* *Linear geometry* *180° bond angles* *Two σ bonds, two π bonds*

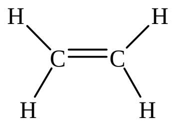
NITROGEN			
	Valence atomic orbitals	**Hybridized atomic orbitals**	**Bonding Pattern, geometry and bond angles in molecules**
sp3	**2s + 2px + 2py + 2pz** *All four of nitrogen's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new, degenerate (equal energy) orbitals form after hybridization. Three of the sp3 orbitals are used to form σ bonds and one is used for a lone pair.*	 *(ammonia)* *Trigonal pyramidal* *Bond angles: 107°* *Three σ bonds and 1 lone pair*
sp2	**2s + 2px + 2py + 2pz** *Three of nitrogen's four valence orbitals mix(in box) to form three new hybridized orbitals. The unhybridized p-orbital is used for π bonding*	**sp2 + sp2 + sp2 + p** *Three new degenerate orbitals form after hybridization. The p orbital remains unhybridized. Two of the sp2 orbitals are used to form σ bonds, one is used for a lone pair and the p orbital is used to form a π bond.*	 *(formaldamine)* *Bent geometry* *120° bond angles* *Two σ bonds, one lone pair and one π bond*
sp	**2s + 2px + 2py + 2pz** *Two of nitrogen's four valence orbitals mix(in box) to form two new hybridized orbitals. The unhybridized p-orbitals are used for π bonding*	**sp + sp + p + p** *Two new degenerate orbitals are generated after hybridization. The two p orbitals remain unhybridized. One of the sp orbitals is used to form a σ bond and the other is used for the lone pair. The two unhybridized p orbitals are used to form two π bonds.*	 *(acetonitrile)* *Linear geometry* *180° bond angles* *One σ bond, one lone pair and two π bonds*

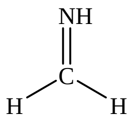
OXYGEN			
	Valence atomic orbitals	**Hybridized atomic orbitals**	**Bonding Pattern, geometry and bond angles in molecules**
sp3	**2s + 2px + 2py + 2pz** *All four of oxygen's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new orbitals form after hybridization. Two of the sp3 orbitals are used to form σ bonds and two are used for two lone pairs.*	 *(dimethylether)* *Bent* *104 ° bond angles* *Two σ bonds and 2 lone pairs*
sp2	**$\boxed{2s + 2px + 2py}$ + 2pz** *Three of oxygen's four valence orbitals mix(in box) to form three new hybridized orbitals. The unhybridized p-orbital is used for π bonding*	**sp2 + sp2 + sp2 + p** *Three new orbitals form after hybridization. The p orbital remains unhybridized. One of the sp2 orbitals are used to form σ bond, two are used for lone pairs and the p orbital is used to form a π bond.*	 *(formaldehyde)* *Linear geometry* *180 ° bond angles* *Two σ bonds, one lone pair and one π bond*

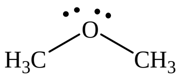
Example molecules:

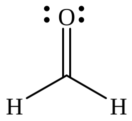








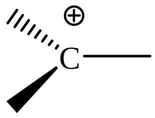
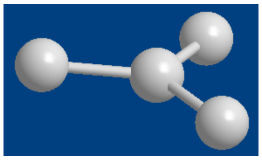
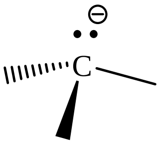
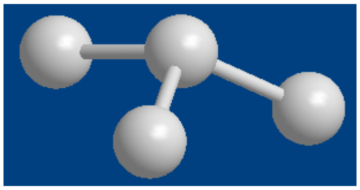




$H-C\equiv C-H$

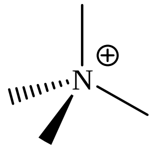
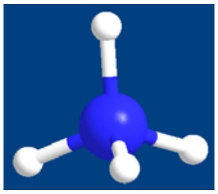
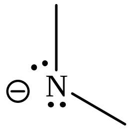
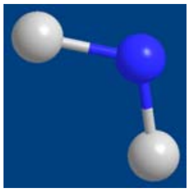
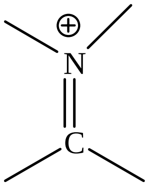
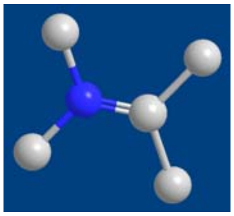
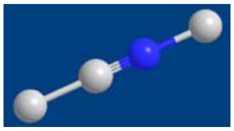
$CH_3-C\equiv N$

For charged atoms (those with formal charge), bonding patterns for specifically hybridized atoms is different. Charged atoms are encountered during chemical reactions as reaction intermediates.

CHARGED CARBON ATOMS			
	Valence atomic orbitals	**Hybridized atomic orbitals**	**Bonding Pattern, geometry and bond angles in molecules**
 *carbocation* *$1s^22s^22p^1$* **sp2**	**$\boxed{\text{2s + 2px + 2py}}$ + 2pz** *Three of carbon's valence orbitals mix to form three new hybridized orbitals. One of the p orbitals remains unhybridized*	**sp2 + sp2 + sp2 + p** *Three new, orbitals are formed after hybridization. The three sp2 orbitals are used to form σ bonds. The p orbital remains vacant (no electrons and is available to accept electrons from a nucleophile.)*	 *Trigonal planar* *120° bond angles* *Three σ bonds and 1 vacant p-orbital*
 *carbanion* *$1s^22s^22p^3$* **sp3**	**2s + 2px + 2py + 2pz** *All four of carbon's four valence orbitals mix to form four new hybridized orbitals.*	**sp3 + sp3 + sp3 + sp3** *Four new degenerate orbitals form after hybridization. Three of the sp3 orbitals are used to form σ bonds, one is used for a lone pair.*	 *Trigonal pyramidal* *107° bond angles* *Three σ bonds and one lone pair*

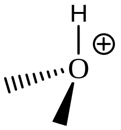
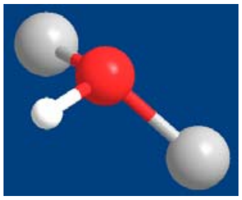
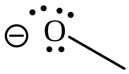
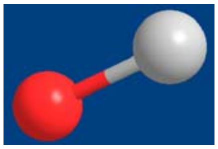
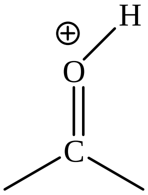
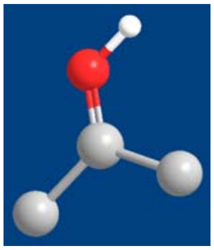
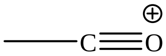
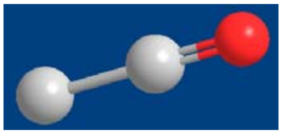
CHARGED NITROGEN ATOMS

Nitrogen atoms may take on a positive charge or a negative charge in a reactive state. Positively charged N atoms are most commonly encountered when the nitrogen atom uses its lone pair to accept a proton (H) in an acid-base reaction. Negatively charged nitrogen atoms are much less common but may be generated during chemical reactions.

	Valence atomic orbitals	**Hybridized atomic orbitals**	**Bonding Pattern, geometry and bond angles in molecules**
 **sp3**	**2s + 2px + 2py + 2pz** *All four of nitrogen's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new, degenerate (equal energy) orbitals form after hybridization. All four of the sp3 orbitals are used to form σ bonds.*	 *Tetrahedral* *Bond angles: 109 °* *Four σ bonds*
 **sp3**	**2s + 2px + 2py + 2pz** *All four of nitrogen's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new, degenerate (equal energy) orbitals form after hybridization. Two the sp3 orbitals are used to form σ bonds and two are used for two lone pairs.*	 *Bent geometry* *104 ° bond angles* *Two σ bonds ; 2 lone pairs*
 **sp2**	$\boxed{\text{2s + 2px + 2py}}$ **+ 2pz** *Three of nitrogen's four valence orbitals mix(in box) to form three new hybridized orbitals. The unhybridized p-orbital is used for π bonding*	**sp2 + sp2 + sp2 + p** *Three new degenerate orbitals form after hybridization. The p orbital is unhybridized. Three of the sp2 orbitals are used to form σ bonds, and the p orbital is used to form a π bond.*	 *Trigonal planar* *120 ° bond angles* *Three σ bonds; one π bond*
 $-C\equiv\overset{\oplus}{N}-$ **sp**	$\boxed{\text{2s + 2px}}$ **+ 2py + 2pz** *Two of nitrogen's four valence orbitals mix(in box) to form two new hybridized orbitals. The unhybridized p-orbitals are used for π bonding*	**sp + sp + p + p** *Two new degenerate orbitals are generated after hybridization. The two p orbitals remain unhybridized. The sp orbitals are used to form σ bonds. The two unhybridized p orbitals are used to form two π bonds.*	 *Linear* *180 ° bond angles* *Two σ bonds; two π bonds*

CHARGED OXYGEN ATOMS

Oxygen atoms may take on a positive charge or a negative charge in a reactive state. Positively charged O atoms (oxonium ion) are most commonly encountered when the oxygen atom uses one of its lone pairs to accept a proton (H) in an acid-catalyzed reaction. Negatively charged oxygen atoms (hydroxides or alkoxides) are formed under basic conditions.

	Valence atomic orbitals	**Hybridized atomic orbitals**	**Bonding Pattern, geometry and bond angles in molecules**
 **sp3**	**2s + 2px + 2py + 2pz** *All four of oxygen's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new, sp3 orbitals form after hybridization. Three of the sp3 orbitals are used for σ bonds and one for a lone pair*	 *Trigonal pyramidal* *Bond angles: 107°* *Three σ bonds; one lone pair*
 **sp3**	**2s + 2px + 2py + 2pz** *All four of oxygen's valence orbitals mix to form four new hybridized orbitals*	**sp3 + sp3 + sp3 + sp3** *Four new, sp3 orbitals form after hybridization. Three of the sp3 orbitals are used for lone pairs and one for a σ bond.*	 *One σ bond ; 3 lone pairs*
 **sp2**	**$\boxed{\text{2s + 2px + 2py}}$ + 2pz** *Three of oxygen's four valence orbitals mix(in box) to form three new hybridized orbitals. The unhybridized p-orbital is used for π bonding*	**sp2 + sp2 + sp2 + p** *Three new sp2 orbitals form after hybridization. The p orbital is unhybridized. Two of the sp2 orbitals are used to form σ bonds, one is for a lone pair and the p orbital for a π bond.*	 *Bent* *Two σ bonds; one lone pair; one π bond*
 **sp**	**$\boxed{\text{2s + 2px}}$ + 2py + 2pz** *Two of oxygen's four valence orbitals mix(in box) to form two new hybridized orbitals. The unhybridized p-orbitals are used for π bonding*	**sp + sp + p + p** *Two new sp orbitals are generated after hybridization. The two p orbitals remain unhybridized. The sp orbitals are used for one σ bond and one lone pair. The two unhybridized p orbitals are used to form two π bonds.*	 *Linear* *One σ bonds; one lone pair; two π bonds*