Chapter 9
Covalent Bonding: Orbitals

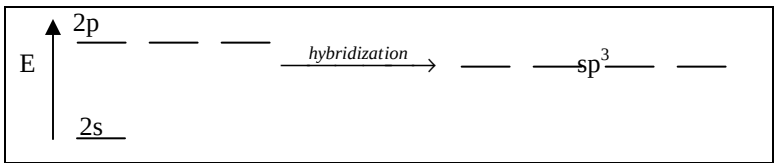
9.1 Hybridization and the Localized Electron Model

Orbital Bartending

a.) sp^3 Hybridization (4 effective pairs, 4 sigma (σ) bonds)

Consider the carbon atom in the CH_4 molecule. It would appear that the carbon atom would use the 2s and 2p orbitals to overlap with hydrogen's 1s orbital. This would lead to believe that there are bonds of unequal energy. However, experimental evidence shows that the 4 C—H bonds in methane are all equivalent. Hybridization: The mixing of atomic orbitals to form a "blend" of four equal orbital.

1 $2s^1$ + 3 $2p^3$ = 4 identical sp^3 orbitals. ($1/4^{th}$ s, sphere, and $3/4^{th}$ p, dumbbell, in character)



Orbitals are conserved. The four orbitals have a tetrahedral arrangement with 109.5° bond angles.
Demonstrate with 1s= chocolate and 3p = white milk blended together.
This can be used to explain the bonding in NH_3, H_2O, and other tetrahedral molecules where lone pair of electrons are in hybrid orbitals.

b.) sp^2 Hybridization (3 effective pairs, 3 sigma (σ) and I pi (π) bond)

Consider C_2H_4, ethylene.
The carbon atom is Trigonal planar with 120° bond angles. The carbon atom uses 1s and 2 p orbitals which hybridize to form 3 sp^2 hybrid orbitals. The pure native p is perpendicular to the plane of the bonding atoms. The C—C bond has a head to head overlap of the sp^2 hybrid orbitals called a (σ)*sigma* bond (free rotation). Each C-H bond is formed from overlap of the C's sp^2 with H's s orbital. Each C atom has one pure p orbital perpendicular to the plane. These overlap side by side which is called (π) pi bonding (energy barrier of rotation). All double bonds have one sigma and one pi bond.
Demonstrate with 1s= chocolate and 2p= white milk blended together.

c.) sp Hybridization (2 effective pairs, 2 sigma (σ) and 2 pi (π) bonds)

Consider C_2H_2, acetylene.
The carbon atom is linear and uses 1s and 1 p orbital hybridized to form 2 sp hybrid orbital. The remaining 2 p orbitals are native and are 90° perpendicular to the plane. The energy and characteristic is half s (sphere) and half p (dumbbell) accounting for the very short bond length. The head to head overlap of the sp hybrid orbital is one sigma bond and the side to side overlap of the pure p orbitals are pi bonds. Short distance and strong bond strength.
Demonstrate with 1s=chocolate and 1p= white milk blended together.

d.) dsp^3 Hybridization (5 effective pairs, 5 sigma (σ) bonds)

Consider PCl_5.
P has a trigonal bipyramidal shape. P uses 1 s, 3 p, and 1 d orbital to hybridize into 5 dsp^3 hybrid orbitals with equatorial angles of 120° and axial bond angles of 90°.

e.) d^2sp^3 Hybridization (6 effective pairs, 6 sigma (σ) bonds)

Consider SF_6.
This requires an octahedron arrangement using 1s, 3p, and 2 d orbitals to form d^2sp^3 hybrid orbitals. Bond angles of equatorial 120º and axial of 90º.

Summary:

1.) Draw Lewis structure.
2.) Determine arrangement with VSEPR theory.
3.) Specify the hybrid orbitals being used.

In Class Examples: For each draw Lewis structure, predict structure and expected hybrid orbitals and number of sigma and pi bonds.

CO_2	linear	sp 2σ , 2π
CO_3^{2-}	Trigonal planar	sp^2 3σ , 1π
TeF_4	See saw	dsp^3 5σ
XeO_4	tetrahedral	sp^3 4σ
N_2	Linear	sp 1σ , 2π

P. 418, #28 and 32 In class

Homework Practice: P.418 #25, 26, 27, 29, 30, 33, 34, 54, 56, 57, 58, 60, 71