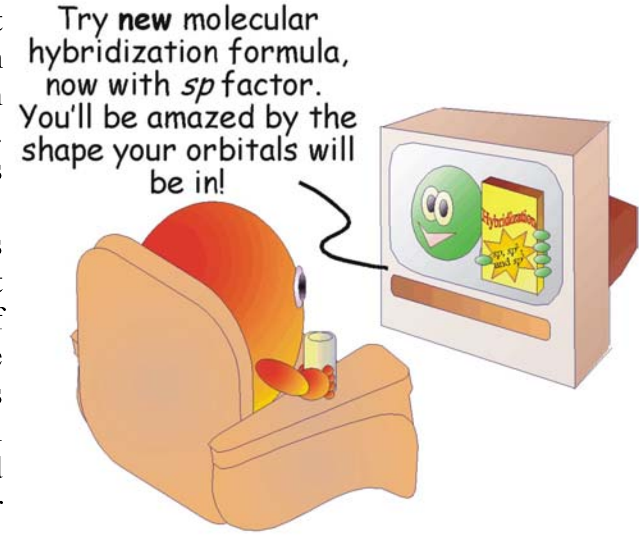
Name ________________________________

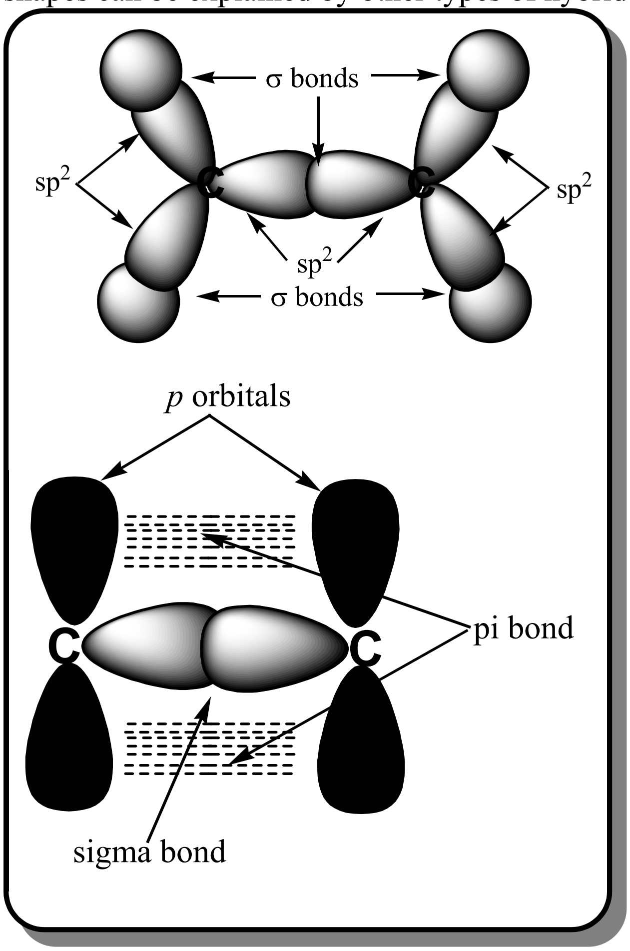
Date __________________ Period _____

Understanding Hybrid Orbitals



The native orbitals found in an atom in the free state cannot always account for the geometry of the compounds formed from the atom. Atomic orbitals that provide for minimum energy in the free state, are often different from those in a molecule. Mixing of native atomic orbitals to allow bonding to occur is known as **hybridization**.

Methane (CH_4) illustrates how hybridization explains observed molecular structure. Methane has four equivalent bonds with a tetrahedral arrangement. The valence structure of carbon ($2s^22p^2$) does not fit this structure because *s* orbitals are nondirectional, *p* orbitals are at right angles, and *s* and *p* orbitals don't form equivalent bonds. When methane forms, one *s* orbital combines with three *p* orbitals to form four equivalent sp^3 hybrid orbitals. sp^3 hybrid orbitals are tetrahedral. Other molecular shapes can be explained by other types of hybrid orbitals:



- Whenever an atom is surrounded by three effective electron pairs to form a trigonal planar molecule, a set of sp^2 hybrid orbitals is required.. Combination of one *s* orbital and two *p* orbitals to form an sp^2 hybrid gives the appropriate 120°angle. In forming the sp^2 orbital, one *p* orbital is not used, and is oriented perpendicular to the plane of the sp^2 orbitals each of the three sp^2 orbitals forms bonds by sharing a pair of electrons in an area centered on a line between the two atoms. These are called sigma (σ) bonds. The double bond is formed in the space above and below the σ bond by the *p* orbital perpendicular to the sp^2 orbitals. This is called a pi (π) bond.
- *sp* hybridization enables two effective pairs of electrons to bond at 180°. One *s* and one *p* are hybridized to form two *sp* hybrid orbitals at a 180° angle. Two *p* orbitals remain. The hybrid orbitals form sigma bonds and the *p* orbitals form pi bonds.
- dsp^3 hybridization enables a trigonal bipyrimidal arrangement for five pairs of electrons surrounding a central atom, while d^2sp^3 hybridization enables an octahedral arrangement for six pairs of electrons surrounding a central atom.

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For each of the formulas below, do the following: [a] Draw the Lewis structure; [b] state the shape (*Linear*, *Trigonal planar*, *Tetrahedral*, *Trigonal bipyramidal*, *Octahedral*, *Pyramidal*, or *Bent*); [c] identify the type of hybrid orbitals present (*sp*^{3}, *sp*^{2}, *sp*, *dsp*^{3} or *d*^{2}*sp*^{3}); and [d] indicate whether or not there are any *pi* bonds.

1. CO_2
   [a]

   [b] Shape: ____________________

   [c] Hybrid orbitals: _____________

   [d] Pi bonds ❑ Yes ❑ No

2. C_2F_4
   [a]

   [b] Shape: ____________________

   [c] Hybrid orbitals: _____________

   [d] Pi bonds ❑ Yes ❑ No

3. H_2O
   [a]

   [b] Shape: ____________________

   [c] Hybrid orbitals: _____________

   [d] Pi bonds ❑ Yes ❑ No

4. PCl_5
   [a]

   [b] Shape: ____________________

   [c] Hybrid orbitals: _____________

   [d] Pi bonds ❑ Yes ❑ No

5. C_6H_6
   [a]

   [b] Shape: ____________________

   [c] Hybrid orbitals: _____________

   [d] Pi bonds ❑ Yes ❑ No

6. XeF_4
   [a]

   [b] Shape: ____________________

   [c] Hybrid orbitals: _____________

   [d] Pi bonds ❑ Yes ❑ No