**Hybridization**

**sp³ Hybridization efficiently bonds to four atoms and lone pairs**

Mix 3 carbon $p$ + 1 carbon $s$ to get 4 equivalent $sp^3$ orbitals ($sp^3 = 1$ part $s$, 3 parts $p$)

![hybridization_diagram](image)

We now have 4 $sp^3$(C)-s(H) bonds of equal length at 109.5° apart.

**Hybridization with multiple bonds**

We need 3 orbitals to make 3 bonds

Mix 2 carbon $p$ + 1 carbon $s$ to get 3 equivalent $sp^2$ orbitals

![hybridization_diagram](image)

The remaining orbital is an unhybridized $p$ orbital

Each unpaired electron on carbon forms a bond with the other unpaired electron (this forms a $\pi$ bond)

This time, we only need 2 orbitals to make 2 bonds:

Mix 1 carbon $s$, 1 carbon $p$ to get 2 equivalent $sp$ orbitals

![hybridization_diagram](image)

The remaining orbitals are unhybridized $p$ orbitals

Each unpaired electron on carbon forms a bond with the other unpaired electron (this forms a $\pi$ bond)

Note that these orbitals ($p_x$ and $p_z$) are 90° apart.
**Example Problems**

**Guide for determining hybridization:**

1. Draw a good Lewis structure.
2. Focus on an atom and sum up: 
   \# bonded atoms + \# of lone pairs
3. This will give a sum between 2-4:

<table>
<thead>
<tr>
<th>Sum</th>
<th>Hybridization</th>
<th>Geometry</th>
<th>Bond angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>sp</td>
<td>linear</td>
<td>180°</td>
</tr>
<tr>
<td>3</td>
<td>sp(^2)</td>
<td>trigonal planar</td>
<td>120°</td>
</tr>
<tr>
<td>4</td>
<td>sp(^3)</td>
<td>tetrahedral</td>
<td>109.5°</td>
</tr>
</tbody>
</table>

Note: This is a guide not an absolute rule. Atoms will rehybridize to place lone pairs in conjugated p-orbitals if that can lower energy. 3rd row elements can access d-orbitals.

**Example Problems**

3 bonded atoms + 0 lone pairs

\[ \text{sp}^2 \text{ hybridization, 120°C} \]

2 bonded atoms + 2 lone pairs (not shown, but can be determined from a good Lewis Dot structure)

\[ \text{sp}^3 \text{ hybridization, } \sim 109.5°C \]

2 bonded atoms + 1 lone pair (*see note above)

\[ \text{sp}^2 \text{ hybridization, 120°C} \]

2 bonded atoms + 0 lone pairs

\[ \text{sp} \text{ hybridization, 180°C} \]

Challenge Problem!

*Identify the hybridization and bond angle of each atom indicated.*