# Organic Chemistry

## Lecture Notes on Sigma (σ) Bond and Pi (π) Bond in Hydrocarbons

### Sigma (σ) Bond

1. **Definition**:
   - A sigma bond (σ bond) is the strongest type of covalent chemical bond. It is formed by the head-on (axial) overlap of atomic orbitals.
2. **Formation**:
   - **s-s overlap**: Example: $H_2$ molecule.
   - **s-p overlap**: Example: C-H bond in methane ($CH_4$).
   - **p-p overlap**: Example: C-C bond in ethane ($C_2H_6$).
3. **Characteristics**:
   - **Strength**: Sigma bonds are generally stronger than pi bonds.
   - **Symmetry**: The electron density is symmetrically distributed around the axis connecting the two bonding nuclei.
   - **Rotation**: Free rotation around the sigma bond axis is possible, making single bonds in molecules flexible.
4. **Presence in Hydrocarbons**:
   - **Alkanes**: Only sigma bonds (single bonds) are present in alkanes. For example, in ethane ($C_2H_6$), each carbon atom forms four sigma bonds, three with hydrogen atoms and one with the other carbon atom.

### Pi (π) Bond

1. **Definition**:
   - A pi bond (π bond) is a type of covalent bond that results from the side-by-side overlap of two parallel p orbitals.
2. **Formation**:
   - **p-p overlap**: Example: C=C bond in ethene ($C_2H_4$).
3. **Characteristics**:
   - **Strength**: Pi bonds are weaker than sigma bonds.
   - **Electron Density**: The electron density in a pi bond is concentrated above and below the plane of the bonding atoms.
   - **Rotation**: Pi bonds restrict the rotation around the bond axis, giving rise to rigidity in the molecular structure.
4. **Presence in Hydrocarbons**:
   - **Alkenes**: Alkenes contain at least one double bond (one sigma bond and one pi bond). For example, in ethene ($C_2H_4$), each carbon atom is bonded to two hydrogen atoms via sigma bonds and to each other by both a sigma bond and a pi bond.
   - **Alkynes**: Alkynes contain at least one triple bond (one sigma bond and two pi bonds). For example, in ethyne ($C_2H_2$), the carbon atoms are bonded to each other by one sigma bond and two pi bonds, and each carbon is bonded to one hydrogen atom by a sigma bond.

### Comparative Overview

1. **Bond Strength**:
    - Sigma bond > Pi bond
2. **Bond Formation**:
    - Sigma bonds are formed by head-on overlapping of orbitals.
    - Pi bonds are formed by sideways overlapping of orbitals.
3. **Molecular Rotation**:
    - Sigma bonds allow free rotation around the bond axis.
    - Pi bonds restrict rotation around the bond axis, causing rigidity.
4. **Hybridization and Bonding**:
    - **Alkanes ($sp^3$ hybridization)**: All single bonds (sigma bonds).
    - **Alkenes ($sp^2$ hybridization)**: Double bonds (one sigma bond and one pi bond).
    - **Alkynes (sp hybridization)**: Triple bonds (one sigma bond and two pi bonds).

**Examples in Hydrocarbons**

1. **Ethane ($C_2H_6$)**:
    - Structure: $H_3C\text{-}CH_3$
    - Bonds: All sigma bonds (single bonds).
2. **Ethene ($C_2H_4$)**:
    - Structure: $H_2C{=}CH_2$
    - Bonds: One sigma bond and one pi bond between carbon atoms, sigma bonds between carbon and hydrogen atoms.
3. **Ethyne ($C_2H_2$)**:
    - Structure: $HC{\equiv}CH$
    - Bonds: One sigma bond and two pi bonds between carbon atoms, sigma bonds between carbon and hydrogen atoms.

**Conclusion**

Understanding the formation and properties of sigma and pi bonds is crucial in organic chemistry, as it influences the reactivity, stability, and structure of hydrocarbons. Sigma bonds provide the primary structural framework, while pi bonds contribute to the reactivity and electronic characteristics of unsaturated hydrocarbons like alkenes and alkynes.