# 240 Chem

# Organic Chemistry -1

## Chapter 1
## Introduction

# What Is Organic Chemistry About?

- The term *organic* suggests that this branch of chemistry has something to do with *organisms*, or living things.

- It gradually became clear that most compounds in plants and animals differ in several respects from those that occur in nonliving matter, such as minerals. In particular, most compounds in living matter are made up of the same few elements: *carbon, hydrogen, oxygen, nitrogen*, and sometimes *sulfur, phosphorus*, and a few others. *Carbon* is virtually always present. This fact led to our present definition:

*Organic chemistry is the chemistry of **carbon** compounds*

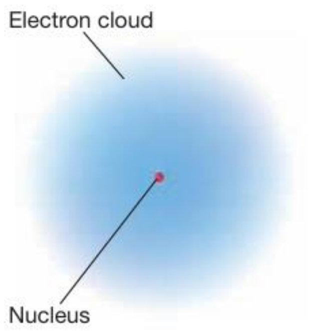
This definition broadens the scope of the subject to include not only compounds from nature but also synthetic compounds.

# Organic Chemistry in Everyday Life

- Organic chemistry touches our daily lives. We are made of and surrounded by organic compounds.
- The major constituents of living matter: proteins, carbohydrates, lipids (fats), nucleic acids (DNA and RNA), cell membranes, enzymes, hormones are organic.
- Other organic substances include the gasoline, oil, and tires for our cars; the clothing we wear; the wood for our furniture; the paper for our books; the medicines we take; and plastic containers, camera film, perfume, carpeting, and fabrics.

# How Electrons Are Arranged in Atoms

- An atom consists of a small, dense nucleus containing positively charged protons and neutral neutrons and surrounded by negatively charged electrons.
- In a neutral atom, the positive charge of the nucleus is exactly balanced by the negative charge of the electrons that surround it.
- The atomic number of an element equals the number of protons in its nucleus.
- The atomic weight is the sum of the number of protons and neutrons in its nucleus.



# How Electrons Are Arranged in Atoms

- Each orbital can contain a maximum of two electrons.
- The orbitals, which differ in shape, are designated by the letters *s*, *p*, and *d*.
- In addition, orbitals are grouped in shells designated by the numbers 1, 2, 3, and so on.
- Each shell contains different types and numbers of orbitals, corresponding to the shell number. For example, shell 1 contains only one type of orbital, designated the 1*s* orbital. Shell 2 contains two types of orbitals, 2*s* and 2*p*, and shell 3 contains three types, 3*s*, 3*p*, and 3*d*.

| | Number of orbitals of each type | | | |
|---|---|---|---|---|
| **Shell number** | ***s*** | ***p*** | ***d*** | **Total number of electrons when shell is filled** |
| 1 | 1 | 0 | 0 | 2 |
| 2 | 1 | 3 | 0 | 8 |
| 3 | 1 | 3 | 5 | 18 |

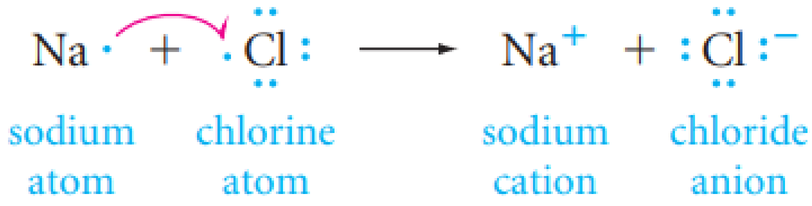
# Chemical Bonds

- Theory of chemical bonding was proposed in 1916 by Gilbert Newton Lewis.
- Lewis noticed that the inert gas helium had only two electrons surrounding its nucleus and that the next inert gas, neon, had 10 electrons, that atoms of these gases must have very stable electron arrangements.
- He further suggested that other atoms might react in such a way in order to achieve these stable arrangements. This stability could be achieved in one of two ways:
    - by complete transfer of electrons from one atom to another.
    - by sharing of electrons between atoms.

# Chemical Bonds

## Ionic Bonding

- Ionic bonds are formed by the transfer of one or more valence electrons from one atom to another.
- Because electrons are negatively charged, the atom that gives up electrons becomes positively charged, a cation. The atom that receives electrons becomes negatively charged, an anion.
- The reaction between sodium and chlorine atoms to form sodium chloride (ordinary table salt) is a typical electron-transfer reaction.




- The majority of ionic compounds are inorganic substances.

# Chemical Bonds

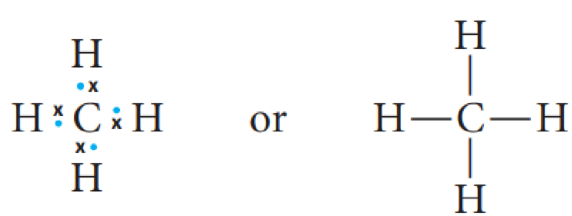
## Covalent Bonding

- Elements that are neither strongly electronegative nor strongly electropositive, or that have similar electronegativities, tend to form bonds by sharing electron pairs rather than completely transferring electrons. A covalent bond involves the mutual sharing of one or more electron pairs between atoms.
- When the two atoms are identical or have equal electronegativities, the electron pairs are shared equally.

$$H\cdot + H\cdot \longrightarrow H:H + \text{heat}$$

hydrogen atoms → hydrogen molecule

- The carbon–hydrogen bond requires special mention. Carbon and hydrogen have nearly identical electronegativities, so the C-H bond is almost purely covalent.

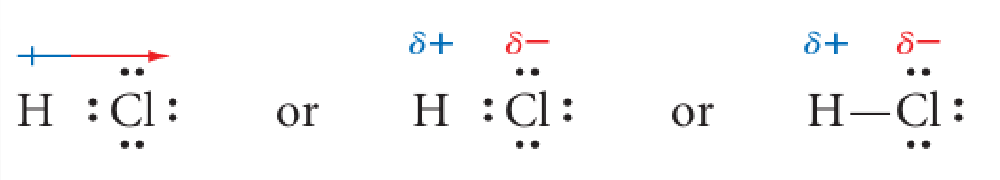



methane

# Chemical Bonds

## Polar Covalent Bonding

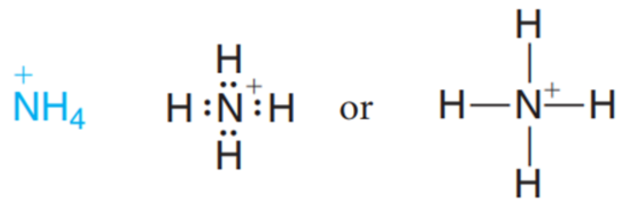
- A polar covalent bond is a covalent bond in which the electron pair is not shared equally between the two atoms.
- This bond polarization is indicated by an arrow whose head is negative and whose tail is marked with a plus sign. Alternatively, a partial charge, written as $\delta$+ or $\delta$- (read as "delta plus" or "delta minus").
- The more electronegative atom assumes a partial negative charge and the less electronegative atom assumes a partial positive charge.



# Chemical Bonds

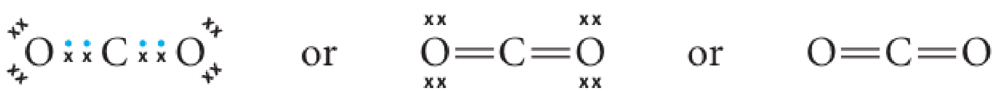
## Coordinate Covalent Bonds

- There are molecules in which one atom supplies both electrons to another atom in the formation of a covalent bond.



## Multiple Covalent Bonds

- In a double bond, two electron pairs are shared between two atoms.



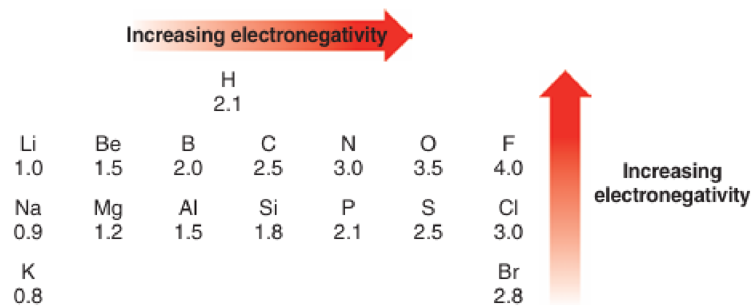
Carbon dioxide, $CO_2$

- In a triple bond, three electron pairs are shared between two atoms

hydrogen cyanide

# Bond Polarity and Dipole Moment (μ)

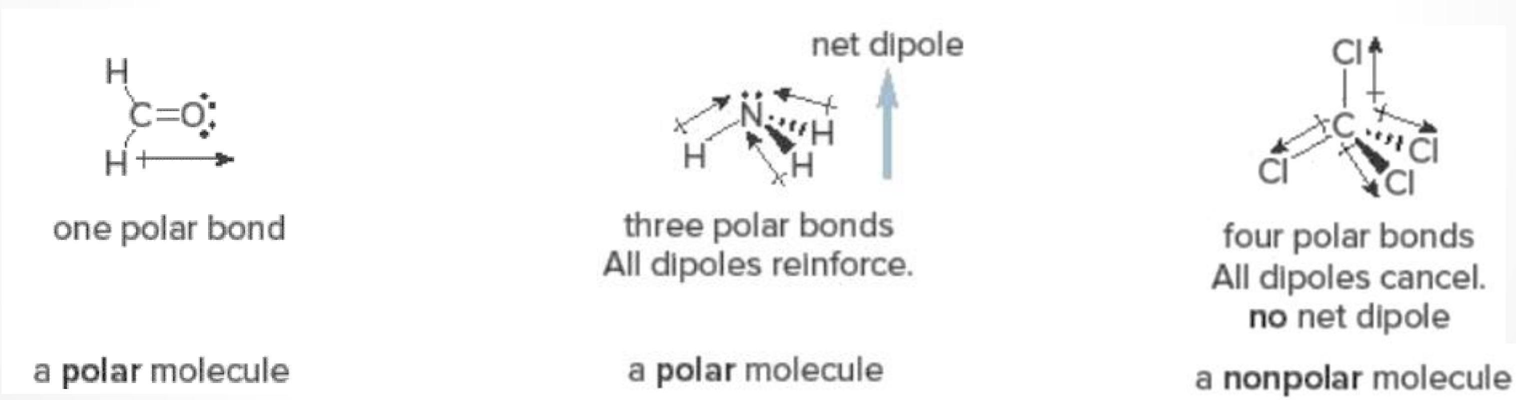
- Dipole moment depends on the inductive effect.
- Inductive effect can be defined as the permanent displacement of electrons forming a covalent bond (σ bonds ) towards the more electronegative element or group, The direction of polarity of a polar bond can be symbolized by a vector quantity $+\!\!\!\longrightarrow$.




- Dipole moment (μ) defined to be the amount of charge separation ( $+\delta$ and $-\delta$ ) multiplied by the bond length.
- The bond polarity is measured by its dipole moment (μ).

# Bond Polarity and Dipole Moment (μ)

- A bond with the electrons shared equally between two atoms is called a nonpolar bond.
- A bond with the electrons shared unequally between two different elements is called a polar bond.



# Valence

- The valence of an element is simply the number of bonds that an atom of the element can form.
- The number is usually equal to the number of electrons needed to fill the valence shell.
- Notice the difference between the number of valence electrons and the valence. Oxygen, for example, has six valence electrons but a valence of only 2. The sum of the two numbers is equal to the number of electrons in the filled shell.
- The valences apply whether the bonds are single, double, or triple. For example, carbon has four bonds in each of the structures we have written so far: *methane, tetrachloromethane, ethane, ethene, ethyne, carbon dioxide*, and so on.

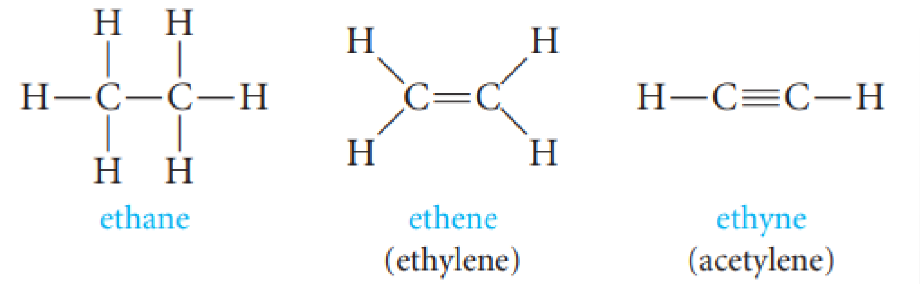
## Valences of Common Elements

| Element | H· | ·C· | ·N: | ·O: | :F: | :Cl: |
|---|---|---|---|---|---|---|
| Valence | 1 | 4 | 3 | 2 | 1 | 1 |

# The Uniqueness of Carbon:

$$^{12}_{6}C$$

- It has 6 electrons in its outer shell arranges $1s^2 2s^2 sp^2$
- The unique property of carbon atoms that is, the property that makes it possible for millions of organic compounds to exist is their ability to share electrons not only with different elements but also with other carbon atoms.
- Carbon atoms can be connected to one another by double bonds or triple bonds, as well as by single bonds. Thus, there are three hydrocarbons (compounds with just carbon and hydrogen atoms) that have two carbon atoms per molecule: *ethane*, *ethene*, and *ethyne*.



# Formula and Diagrams

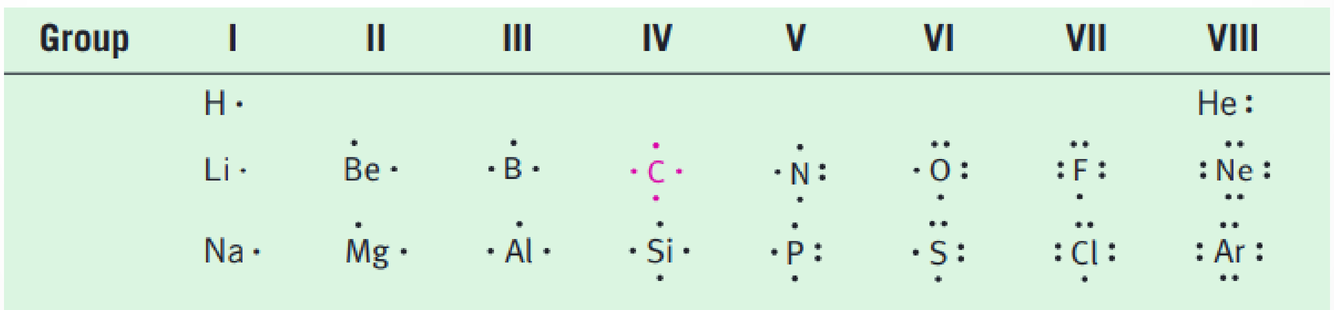
## Molecular Formula

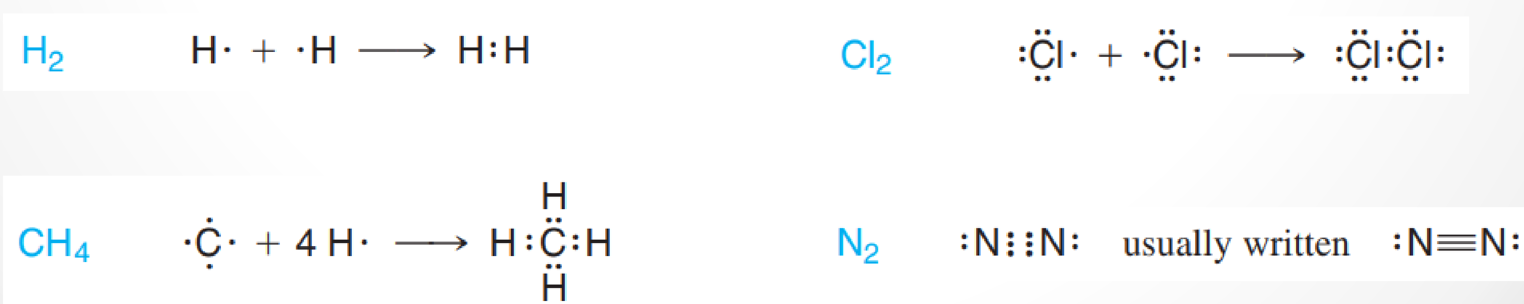
The molecular formula of a substance gives the number of different atoms present.

For example, $C_2H_6O$.

## Electron-dot Formula (Lewis structure)

Electron valance as electron dots.

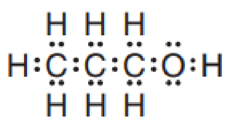


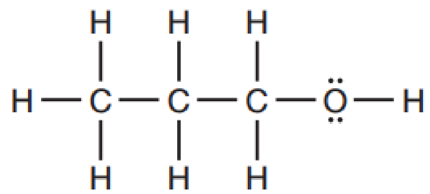
# Formula and Diagrams

## structural formula

The structural formula indicates how those atoms are arranged, it can be expressed by several ways.



Dot formula

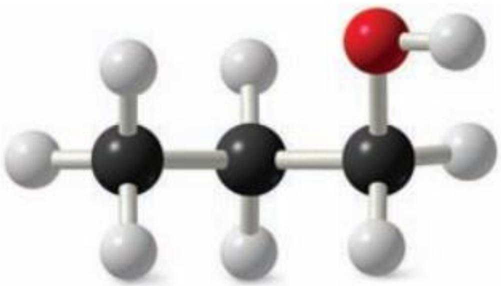


Dash formula

$CH_3CH_2CH_2\ddot{O}H$

Condensed formula

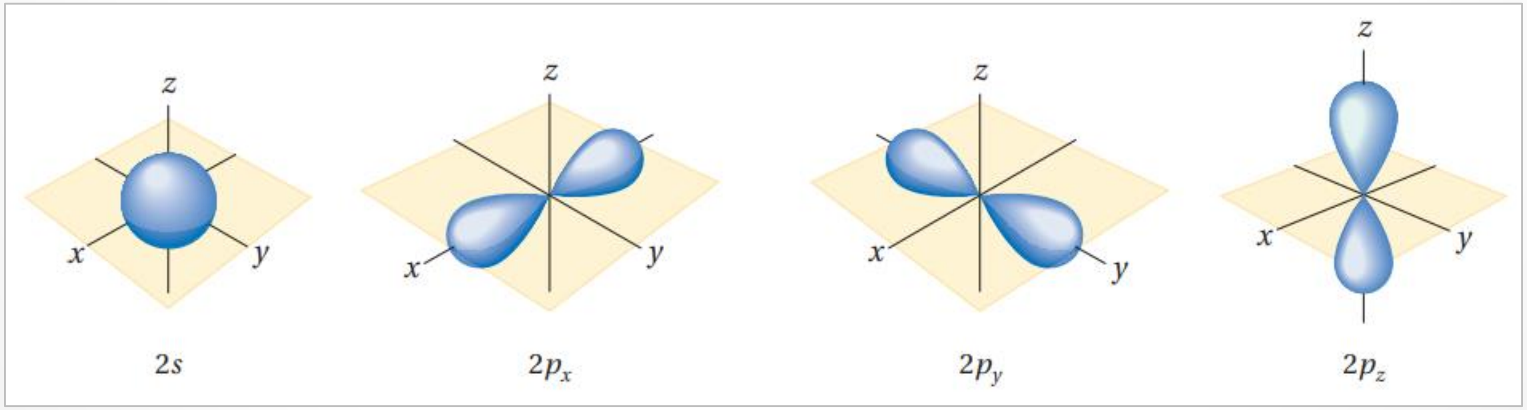
Bond-line formula



Ball-and-stick model

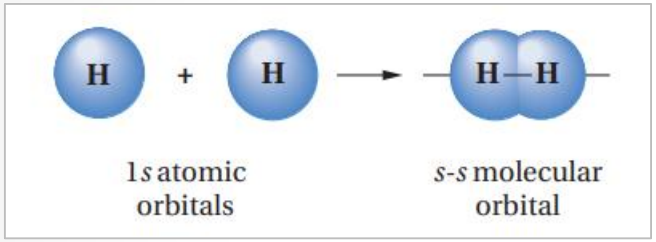
# Atomic Orbitals and their Shapes

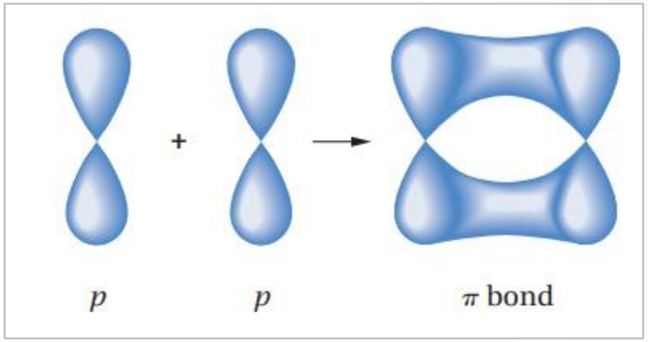
- The electrons that fill an *s* orbital confine their movement to a spherical region of space around the nucleus.
- The three *p* orbitals are dumbbell shaped and mutually perpendicular, oriented along the three coordinate axes, *x*, *y*, and *z*.

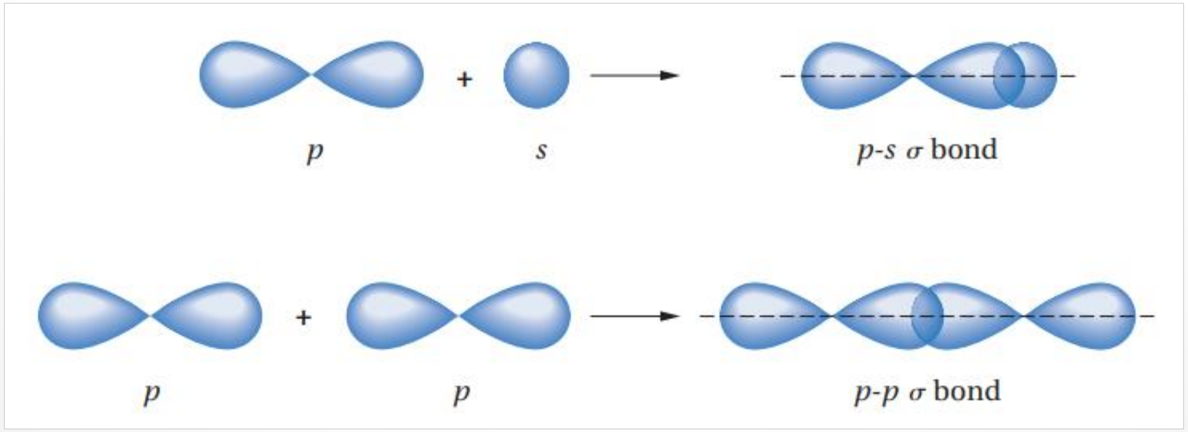


# Molecular Orbital

- A molecular orbital is formed when two atomic orbitals overlap to generate a bond.
- A molecular orbital is the space occupied by electrons in a molecule.

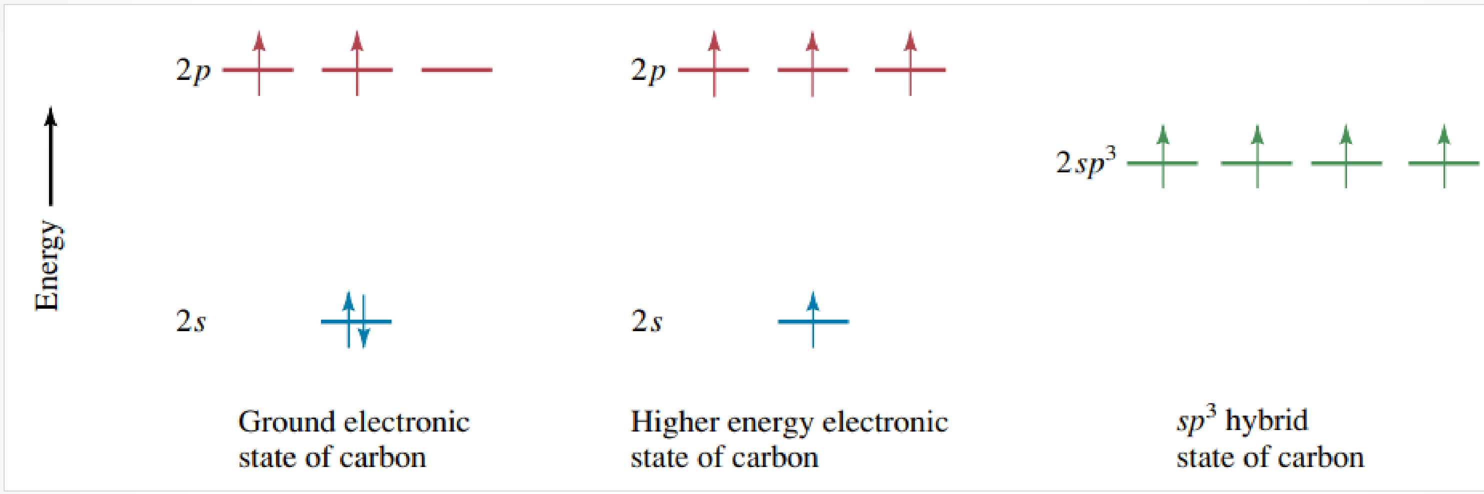


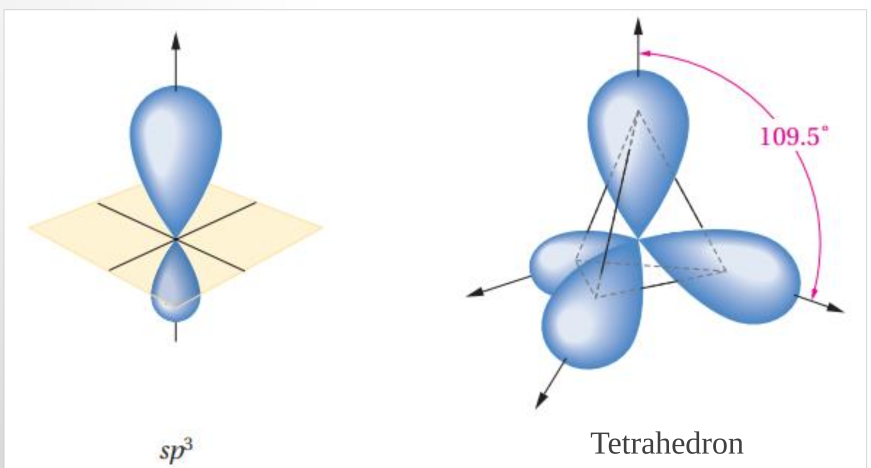



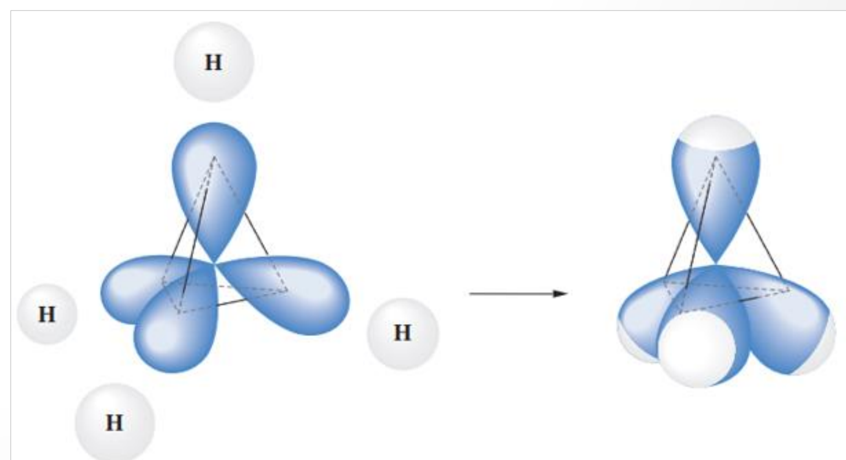



# Carbon $sp^3$ Hybrid Orbitals (Alkane )

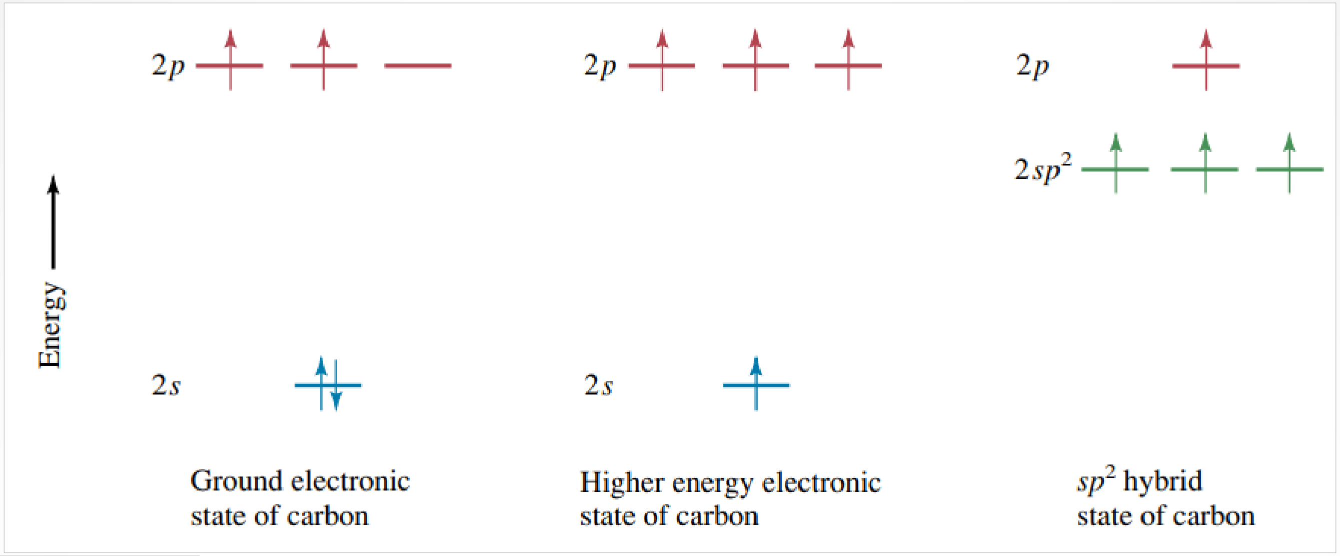
- Carbon with an electron configuration of $1s^22s^2ap_x{}^12p_y{}^1$ has only two half-filled orbitals, so how can it have bonds to four hydrogens ?

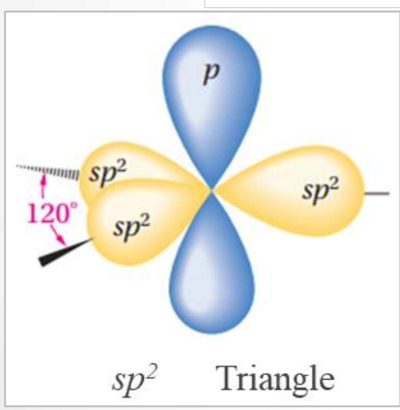


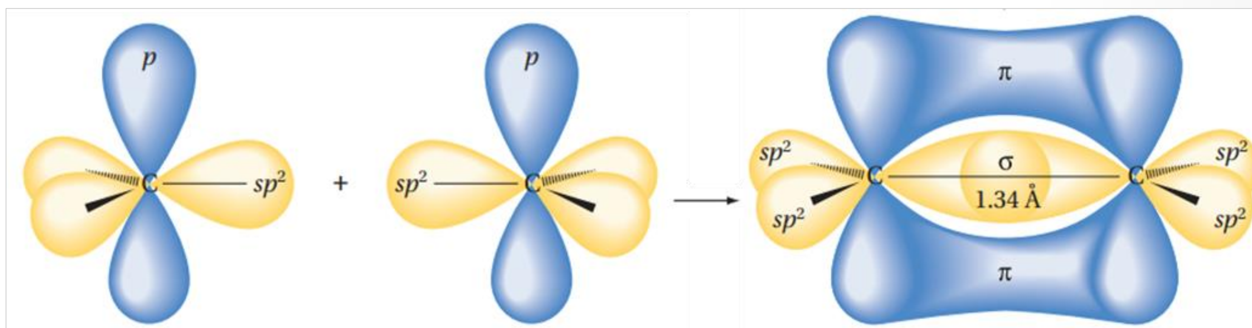



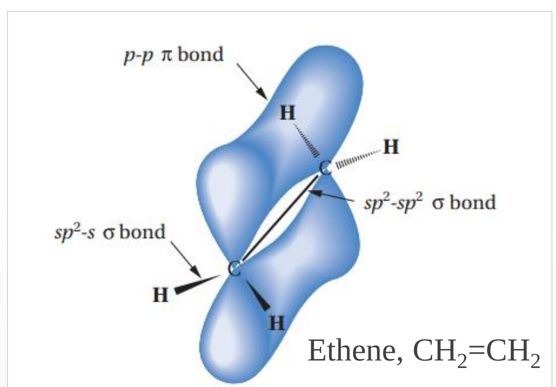



# Carbon $sp^2$ Hybrid Orbitals (Alkene )

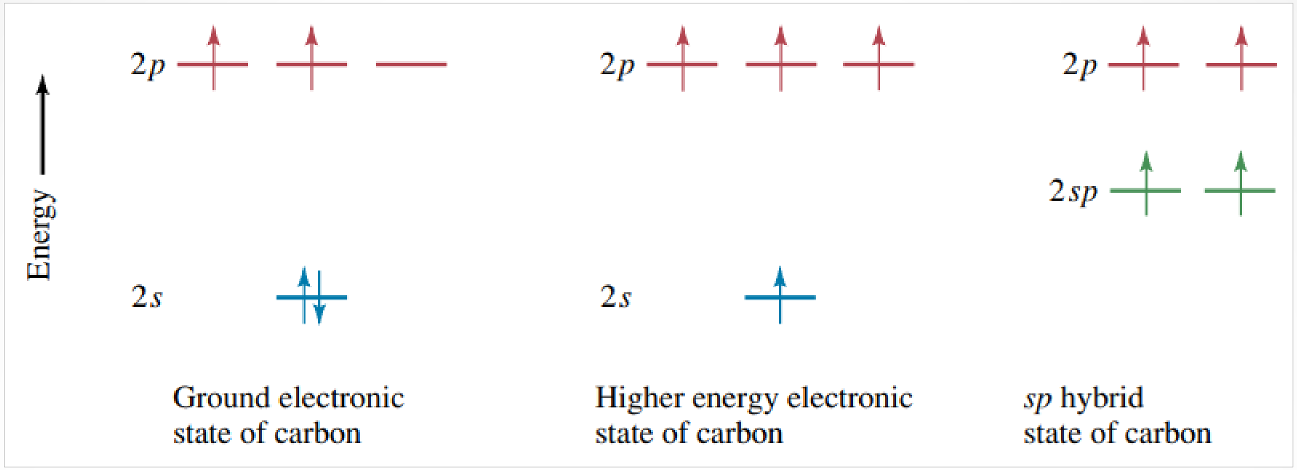


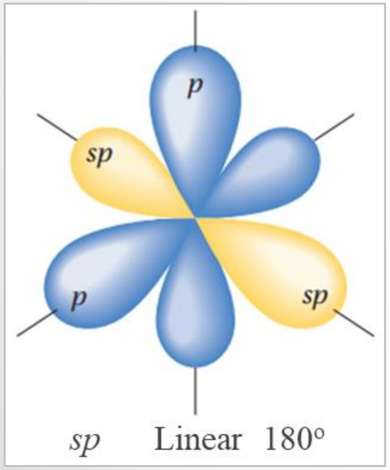



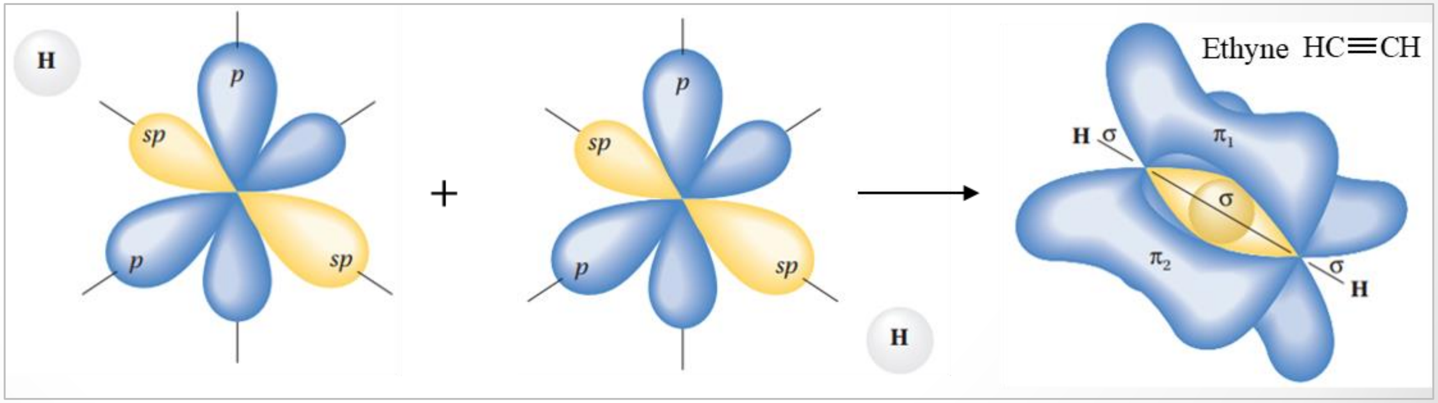



# Carbon *sp* Hybrid Orbitals (Alkyne )

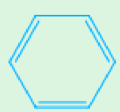
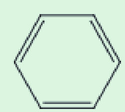


# Functional Groups

Functional groups: special groups of reactive atoms that carry out chemical reactions in many organic compounds.

| | Structure | Class of compound | Specific example | Common name of the specific example |
|---|---|---|---|---|
| *A. Functional groups that are a part of the molecular framework* | —C—C— | alkane | $CH_3—CH_3$ | ethane, a component of natural gas |
| | C=C | alkene | $CH_2=CH_2$ | ethylene, used to make polyethylene |
| | —C≡C— | alkyne | HC≡CH | acetylene, used in welding |
| |  | arene |  | benzene, raw material for polystyrene and phenol |

| | Structure | Class of compound | Specific example | Common name of the specific example |
|---|---|---|---|---|
| *B. Functional groups containing oxygen* | | | | |
| *1. With carbon–oxygen single bonds* | —C—OH | alcohol | $CH_3CH_2OH$ | ethyl alcohol, found in beer, wines, and liquors |
| | —C—O—C— | ether | $CH_3CH_2OCH_2CH_3$ | diethyl ether, once a common anesthetic |
| *2. With carbon–oxygen double bonds** | —C(=O)—H | aldehyde | $CH_2{=}O$ | formaldehyde, used to preserve biological specimens |
| | —C—C(=O)—C— | ketone | $CH_3C(=O)CH_3$ | acetone, a solvent for varnish and rubber cement |
| *3. With single and double carbon–oxygen bonds* | —C(=O)—OH | carboxylic acid | $CH_3C(=O)—OH$ | acetic acid, a component of vinegar |
| | —C(=O)—O—C— | ester | $CH_3C(=O)—OCH_2CH_3$ | ethyl acetate, a solvent for nail polish and model airplane glue |

| | Structure | Class of compound | Specific example | Common name of the specific example |
|---|---|---|---|---|
| *C. Functional groups containing nitrogen*** | $-\overset{\mid}{\underset{\mid}{C}}-NH_2$ | primary amine | $CH_3CH_2NH_2$ | ethylamine, smells like ammonia |
| | $-C\equiv N$ | nitrile | $CH_2{=}CH-C\equiv N$ | acrylonitrile, raw material for making Orlon |
| *D. Functional group with oxygen and nitrogen* | $-\overset{O}{\overset{\Vert}{C}}-NH_2$ | primary amide | $H-\overset{O}{\overset{\Vert}{C}}-NH_2$ | formamide, a softener for paper |
| *E. Functional group with halogen* | $-X$ | alkyl or aryl halide | $CH_3Cl$ | methyl chloride, refrigerant and local anesthetic |
| *F. Functional groups containing sulfur*† | $-\overset{\mid}{\underset{\mid}{C}}-SH$ | thiol (also called mercaptan) | $CH_3SH$ | methanethiol, has the odor of rotten cabbage |
| | $-\overset{\mid}{\underset{\mid}{C}}-S-\overset{\mid}{\underset{\mid}{C}}-$ | thioether (also called sulfide) | $(CH_2{=}CHCH_2)_2S$ | diallyl sulfide, has the odor of garlic |