
Introduction to Organic Chemistry

CHEM 108

Credit hrs.: (3+1)

King Saud University

College of Science, Chemistry Department

CHAPTER 1: Introduction

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Bonding, Structural Formulas, and Molecular Shapes

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Organic Chemistry: Definition

- The word **Organic** can be a biological or chemical term, in biology it means anything that is living or has lived.
- **Organic Chemistry** is unique in that it deals with vast numbers of substances, both natural and synthetic.

The clothes, the petroleum products, the paper, rubber, wood, plastics, paint, cosmetics, insecticides, and drugs

- But, from the chemical makeup of organic compounds, it was recognized that one constituent common to all was **the element carbon**.
- **Organic chemistry** is defined as *the study of carbon/hydrogen-containing compounds and their derivatives*.

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The Uniqueness of Carbon

- What is unique about the element **carbon**?
- Why does it form so many compounds?
 - *The answers lie in*
 - The **structure** of the **carbon** atom.
 - The **position** of **carbon** in the periodic table.
- These factors enable it to form strong bonds with
 - other carbon atoms
 - and with other elements (hydrogen, oxygen, nitrogen, halogens,...etc).
- Each **organic compound** has its own characteristic set of physical and chemical properties which depend on the *structure of the molecule*.

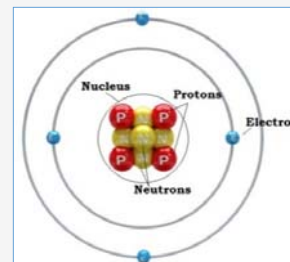
IA	IIA		Transition Elements										IIIA	IVA	VA	VIA	VIIA	Zero
H													B	C	N	O	F	Ne
Li	Be												Al	Si	P	S	Cl	Ar
Na	Mg												Ga	Ge	As	Se	Br	Kr
K	Ca												In	Sn	Sb	Te	I	Xe
Rb	Sr												Tl	Pb	Bi	Po	At	Rn
Cs	Ba																	
Fr	Ra																	

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Atomic Structure

- **Atoms** consist of three main particles: **neutrons** (have no charge), **protons** (positively charged) and **electrons** (negatively charged).

- ❖ **Neutrons** and **protons** are found in the nucleus.
- ❖ **Electrons** are distributed around the nucleus in successive *shells* (*principal energy levels*).



- **Atom** is electrically neutral.

i.e. Number of electrons = Number of protons

- **Atomic number** of an element is the number of protons.
- The **atomic weight** is approximately equal to the sum of the number of protons and the number of neutrons in the nucleus

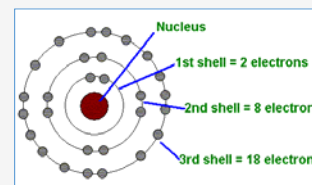
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Atomic Structure

- The **energy levels** are designated by capital letters (K, L, M, N, ..).

- The maximum capacity of a shell = $2n^2$ electrons.

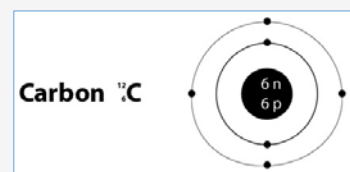
n = number of the energy level.



- For example, the element carbon (atomic number 6)

6 electrons are distributed about the nucleus as

Shell	K	L	M	N
Number of electrons	2	4	0	0



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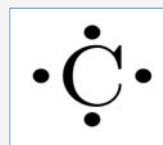
Atomic Structure

Electron-dot structures

○ **Valance Electrons** are those electrons located in the *outermost energy level (the valance shell)*.

○ **Electron-dot structures**

- The symbol of the element represents the core of the atom.
- The valance electrons are shown as dots around the symbol.



Valance Electrons are those electrons located in the *outermost energy level (the valance shell)*.

Valences of Common Elements						
Element	H·	·C·	·N·	·O·	:F:	:Cl:
Valence	1	4	3	2	1	1

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Chemical Bonding

○ In 1916 G.N. Lewis pointed out that:

The noble gases were stable elements and he ascribed their lack of reactivity to their having their valance shells filled with electrons.

- 2 electrons in case of helium.
- 8 electrons for the other noble gases.

○ According to Lewis,

in interacting with one another atoms can achieve a greater degree of stability

by rearrangement of the valance electrons to acquire the outer-shell structure of the closest noble gas in the periodic table.

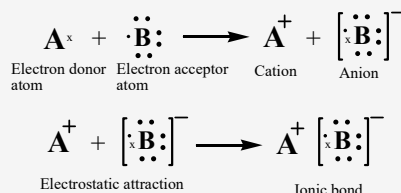
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A) Ionic Bonds

Chemical Bonding

Ionic bonds are formed by the transfer of one or more valence electrons from one atom to another.

- Elements at the left of the periodic table give up their valence electrons and become +ve charged ions (*cations*).
- Elements at the right of the periodic table gain the electrons and become -ve charged ions (*anions*).



Ionic Bond is the electrostatic force of attraction between oppositely charged ions.

- The majority of ionic compounds are *inorganic substances*.

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A) Ionic Bonds

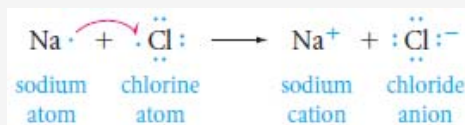
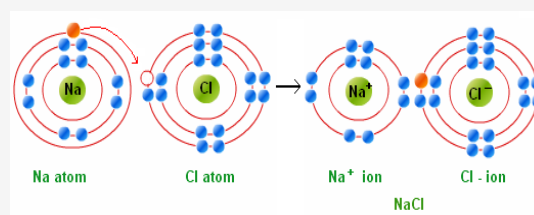
Chemical Bonding

Electronegativity Measures The Ability of An Atom To Attract Electrons

Increasing electronegativity						
H						
2.1						
Li	Be	B	C	N	O	F
1	1.5	2	2.5	3	3.5	4
Na	Mg	Al	Si	P	S	Cl
0.9	1.2	1.5	1.8	2.1	2.5	3
K						Br
0.8						2.8

Decreasing electronegativity

Example

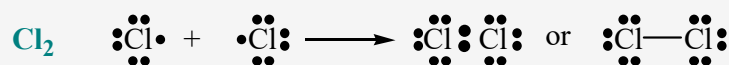
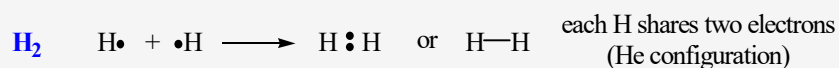


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B) Covalent Bonds

Chemical Bonding

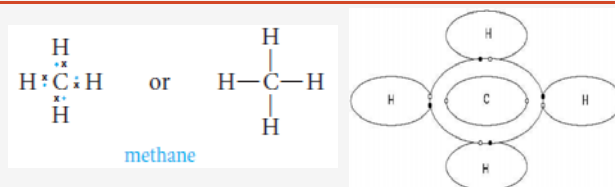
- o Elements that are close to each other in the periodic table attain the stable noble gas configuration by sharing valence electrons between them.
- o A shared electron pair between two atoms or single covalent bond, will be represented by a dash (-).
- o A covalent bond involves the mutual sharing of one or more electron pairs between atoms.
 - ❖ When the two atoms are identical or have equal electronegativities, the electron pairs are shared equally



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B) Covalent Bonds

Chemical Bonding

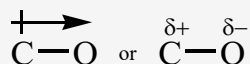


- ❖ When two unlike atoms;
the bonding electrons are no longer shared equally (shared unequally).

A Polar Covalent Bond

A bond, in which an electron pair is shared unequally.

- o The more electronegative atom assumes a partial negative charge and the less electronegative atom assumes a partial positive charge.



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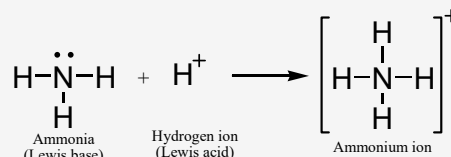
B) Covalent Bonds

Chemical Bonding

Coordinate Covalent Bond

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

- For example;



- Lewis base

The species that furnishes the electron pair to form a coordinate covalent bond.

- Lewis acid

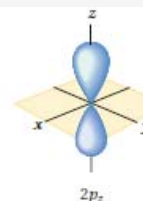
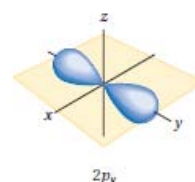
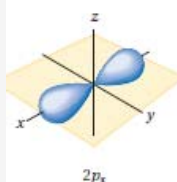
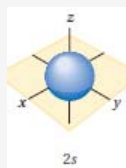
The species that accepts the electron pair to complete its valence shell.

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Atomic Orbitals

Shapes of Organic Molecules: Orbital Picture of Covalent Bonds

- An **atomic orbital** represents a specific region in space in which an electron is most likely to be found.
- **Atomic orbitals** are designated in the order in which they are filled by the letters *s*, *p*, *d*, and *f*.
- Examples: *K shell has only one 1s orbital.*
L shell has one 2s and three 2p (2p_x, 2p_y and 2p_z).
- An s_orbital is **spherically shaped** electron cloud with the atom's nucleus and its center.
- A p_orbital is a **dumbbell-shaped** electron cloud with the nucleus between the two lobes.

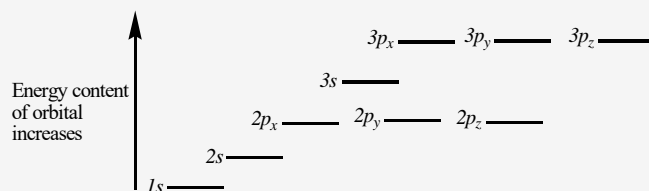


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Atomic Orbitals

Shapes of Organic Molecules: Orbital Picture of Covalent Bonds

- An energy level diagram of atomic orbitals.



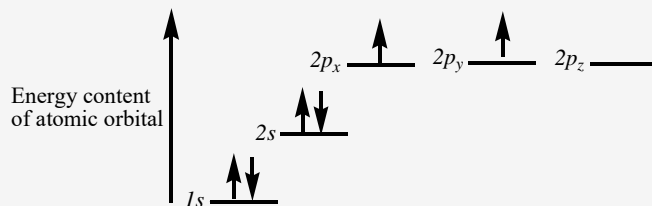
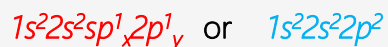
- When filling the atomic orbitals, keep in mind that
 - An atomic orbital contain no more 2 electrons.
 - Electrons fill orbitals of lower energy first.
 - No orbital is filled by 2 electrons until all the orbitals of equal energy have at least one electron.

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Atomic Orbitals

Shapes of Organic Molecules: Orbital Picture of Covalent Bonds

- The electronic configuration of carbon (atomic number 6) can be represented as



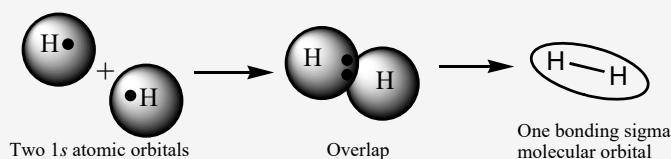
Energy level diagram for carbon.

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Molecular Orbitals

Shapes of Organic Molecules: Orbital Picture of Covalent Bonds

- A covalent bond consists of the overlap between two atomic orbitals to form a **molecular orbital**.
- Example: **Molecular orbital of H₂**

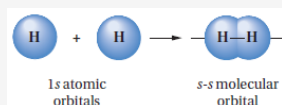


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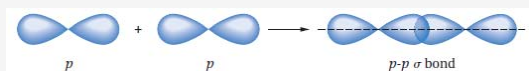
Molecular Orbitals

Shapes of Organic Molecules: Orbital Picture of Covalent Bonds

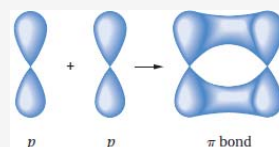
- **Sigma bonds (σ bonds)** can be formed from
 - ❖ The overlap of **two s** atomic orbitals.
 - ❖ The overlap of two an **s** atomic orbital with a **p** atomic orbital.



- ❖ The **end-on overlap** of **two p** atomic orbitals.



- **pi bonds (π bonds)** can be formed from
 - ❖ The **side-side overlap** between **two p** atomic orbitals.

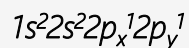


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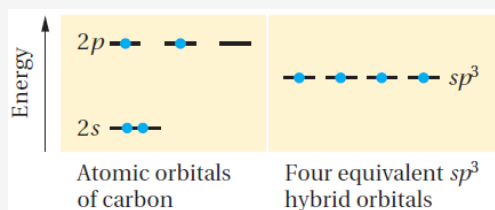
Carbon sp^3 Hybrid Orbitals

Hybridization

- The electronic configuration of the isolated or ground-state carbon



Equivalent to $:\dot{\text{C}}:$



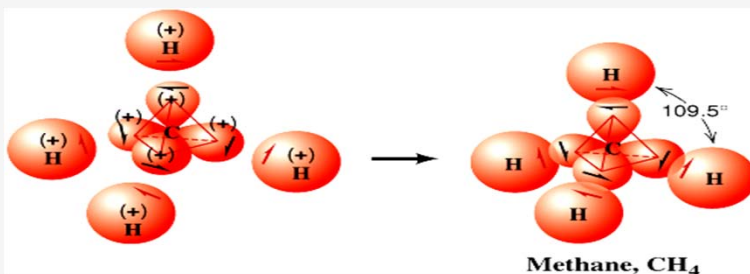
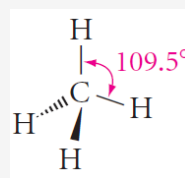
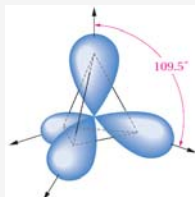
- Mix or combine the four atomic orbitals of the valence shell to form four identical hybrid orbitals, each containing one valence electron.
- In this model, the hybrid orbitals are called sp^3 hybrid orbitals because each one has one part s character and three parts p character
- Each sp^3 orbital has the same energy: less than that of the $2p$ orbitals but greater than that of the $2s$ orbital.

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Carbon sp^3 Hybrid Orbitals

Hybridization

- Regular tetrahedron with all H-C-H bond angles of 109.5° .

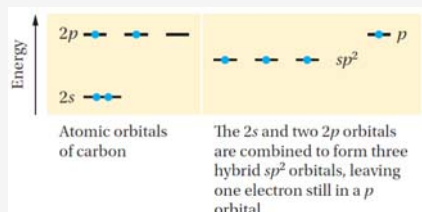


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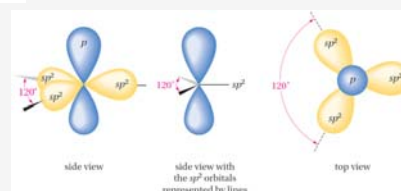
Carbon sp^2 Hybrid Orbitals

Hybridization

- Combine only three of the orbitals, to make three equivalent sp^2 -hybridized orbitals (called sp^2 because they are formed by combining one s and two p orbitals)



- Three valence electrons are placed in the three sp^2 orbitals. The fourth valence electron is placed in the remaining $2p$ orbital, whose axis is perpendicular to the plane formed by the three sp^2 hybrid orbitals



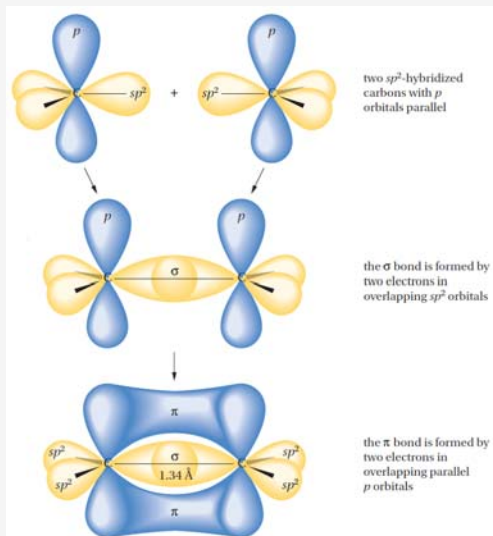
- A trigonal carbon with bond angles of 120° .

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Carbon sp^2 Hybrid Orbitals

Hybridization

Schematic formation of a carbon-carbon double bond. Two sp^2 carbons form a sigma (σ) bond (end-on overlap of two sp^2 orbitals) and a pi (π) bond (lateral overlap of two properly aligned p orbitals).

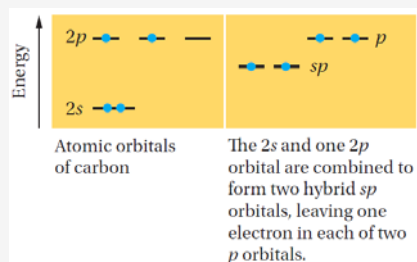


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Carbon sp Hybrid Orbitals

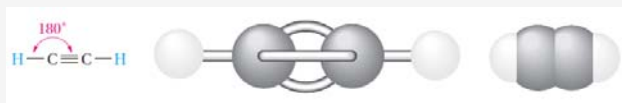
Hybridization

- The carbon atom of an acetylene is connected to only *two* other atoms. Therefore, we combine the $2s$ orbital with only one $2p$ orbital to make two sp -hybrid orbitals



- The angle between the two hybrid orbitals is 180°

- Linear

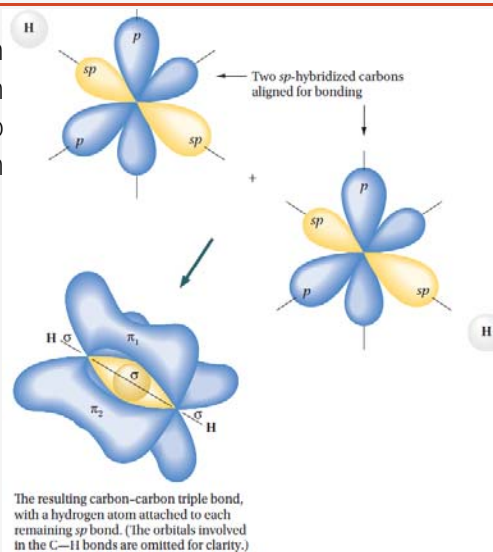


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Carbon sp Hybrid Orbitals

Hybridization

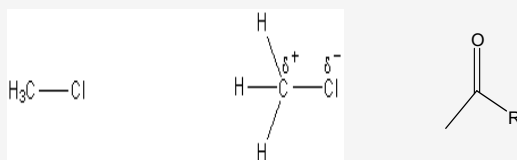
A triple bond consists of the end-on overlap of two sp -hybrid orbitals to form a σ bond and the lateral overlap of two sets of parallel-oriented p orbitals to form two mutually perpendicular π bonds.



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Inductive Effect

- Inductive effect can be defined as *the permanent displacement of electrons forming a covalent bond (sigma σ bonds) towards the more electronegative element or group.*
- The inductive effect is represented by the symbol, the arrow pointing towards the more electronegative element or group of elements.
 - (+ I) effect if the substituent electron-donating
 - (- I) effect if the substituent electron-withdrawing



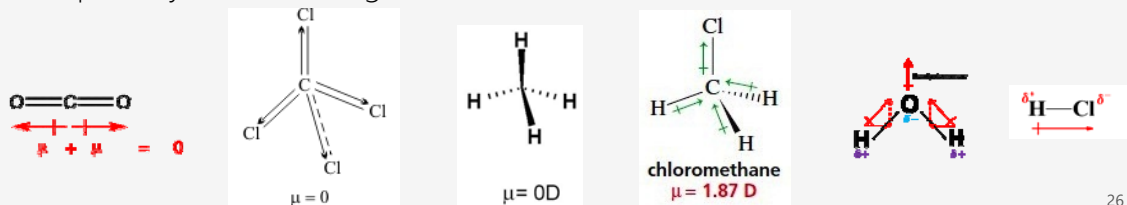
Electron-donating substituents (+I): $-\text{CH}_3$, $-\text{C}_2\text{H}_5$, $-\text{NH}_2$, OH , OCH_3 ,

Electron-withdrawing substituents (-I): $-\text{NO}_2$, $-\text{CN}$, $-\text{SO}_3\text{H}$, COOH , COOR ,

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Bond Polarity and Dipole Moment (μ)

- Dipole moment (depends on the inductive effect).
- A bond with the electrons shared equally between two atoms is called a **nonpolar bond** like in $\text{Cl}-\text{Cl}$ and $\text{C}-\text{C}$ bond in ethane.
- A bond with the electrons shared unequally between two different elements is called a **polar bond**.
- The **bond polarity** is measured by its dipole moment (μ).
- Dipole moment (μ) defined to be the amount of charge separation ($+\delta$ and $-\delta$) multiplied by the bond length.



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Functional Groups

It is a reactive portion of an organic molecule, an atom, or a group of atoms that confers on the whole molecule its characteristic properties.

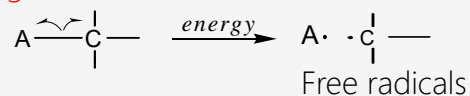
Class	General	Functional group	Specific
Alkane	RH	C - C (single bond)	H ₂ C - CH ₂
Alkene	R - CH = CH ₂	C = C (double)	H ₂ C = CH ₂
Alkyne	R - C ≡ C H	C ≡ C (triple)	H C ≡ C H
Alkyl halide	RX	-X (X = F, Cl, Br, I)	H ₂ C - Cl
Alcohol	R - OH	-OH	H ₂ C - OH
Ether	R - O - R'	- C - O - C -	H ₃ C - O - CH ₃
Aldehyde	R - $\overset{\text{O}}{\parallel}$ - H	$\overset{\text{O}}{\parallel}$ - H	H - $\overset{\text{O}}{\parallel}$ - H, H ₃ C - $\overset{\text{O}}{\parallel}$ - H
Ketone	R - $\overset{\text{O}}{\parallel}$ - R	- $\overset{\text{O}}{\parallel}$ - C -	H ₃ C - $\overset{\text{O}}{\parallel}$ - C - H ₃
Carboxylic acid	R - $\overset{\text{O}}{\parallel}$ - O - H	$\overset{\text{O}}{\parallel}$ - O - H	H - $\overset{\text{O}}{\parallel}$ - O - H, H ₃ C - $\overset{\text{O}}{\parallel}$ - O - H
Ester	R - $\overset{\text{O}}{\parallel}$ - O - R	$\overset{\text{O}}{\parallel}$ - O - R	H - $\overset{\text{O}}{\parallel}$ - O - CH ₃
Amine	R - NH ₂	- C - NH ₂	H ₃ C - NH ₂

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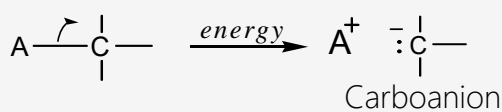
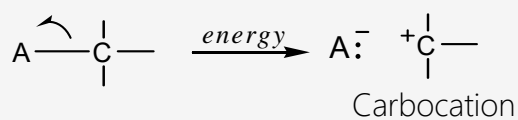
Notations for bond breaking and bond making

o A covalent bond can be broken in either two ways,

- Homolytic cleavage.



- Heterolytic cleavage.



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