



LECTURE 1

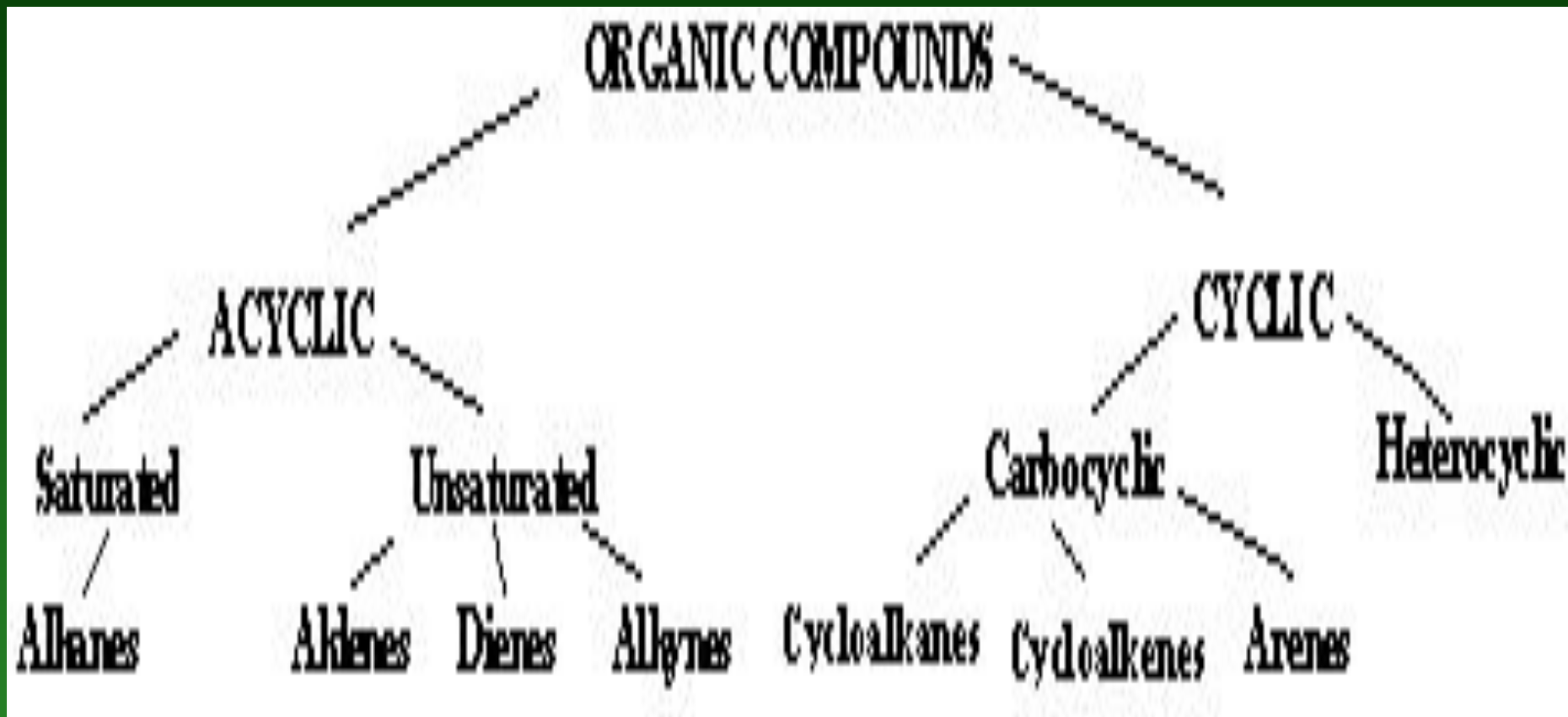
THEME: Introduction of bioorganic chemistry. Classification, structure, chemical properties of organic compounds. Properties of alcohols, aldehydes, ketons.

Lecturer: Dmukhalska Yevheniya. B.

- **Organic Chemistry** – the chemistry of the hydrocarbons and their derivatives; the chemistry of carbon compounds.
- **Bioorganic Chemistry** was study structure and properties of biomolecule. Such as: proteins, lipids, hormones, carbohydrates, vitamins, enzyme, fats, at el.

CLASSIFICATION

- **By structure of carbon chain:**



- **By functional groups:** alkanes, alkenes, alkynes, alcohols, aldehydes, ketones, carboxylic acids.

Acyclic — compounds, that don't contain any cycle in their molecules.

Saturated — compounds that contain only σ -bonds and no π - bonds (simple $-C-C-$ bonds).

Alkanes — saturated hydrocarbons that contain only $-C-C-$ and $-C-H-$ σ bonds.

Unsaturated — compounds that contain σ -bonds and π - bonds (double bonds ($-C=C-$) or triple ($-C\equiv C-$) bonds, and simple $-C-C-$ bonds).

Alkenes — unsaturated hydrocarbons that contain only one $\text{— C} = \text{C —}$ double bond ($\text{— C} = \text{C —}$).

Diene — unsaturated compounds that contain two double $\text{— C} = \text{C —}$ bonds.

Alkynes — unsaturated hydrocarbons that contain $\text{— C} \equiv \text{C —}$ triple bond ($\text{— C} \equiv \text{C —}$).

Cyclic — organic compounds that contain any cycle in its molecules.

Carbocyclic - hydrocarbons containing a cycle that consists of only Carbon atoms.

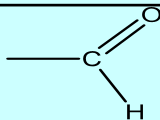
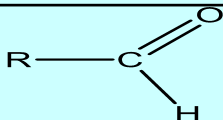
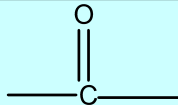
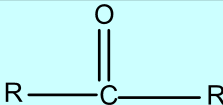
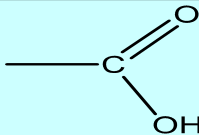
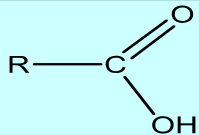
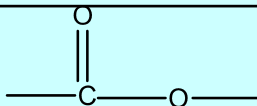
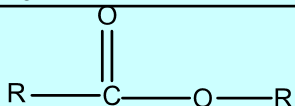
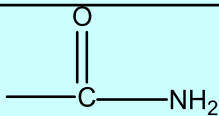
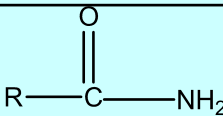
Cycloalkanes — saturated hydrocarbons containing a Carbon cycle.

Cycloalkenes — unsaturated hydrocarbons containing a Carbon cycle.

Arenes — aromatic compounds that contain benzoic kernel.

Heterocyclic - organic compounds that contain cycle between atoms of Carbon and other elements (S, O, N).

Functional group classification

Name of class of organic compounds	Functional group	General formula of class of organic compounds
Halogen carbonhydrates	—F, —Cl, —Br, —I	R—Hal
Alcohols, phenols	—OH	R—OH
Thioalcohols, thiophenols	—SH	R—SH
Ethers	—OR	R—O—R
Aldehydes		
Ketones		
Carbon acids		
Sulfoacids	$\text{—SO}_3\text{—H}$	$\text{R—SO}_3\text{—H}$
Esters		
Amides		
Nitryles	$\text{—C} \equiv \text{N}$	$\text{R—C} \equiv \text{N}$
Nitrocompounds	—NO_2	R—NO_2
Amines	—NH_2	R—NH_2

Functional Group is any part of an organic compound, which is not a carbon-hydrogen or carbon-carbon single bond.

All organic compounds concerning to the same class form homological row – it is the row of organic compounds in which each next member differ $\text{—CH}_2\text{—}$ group from previous one.

Alkanes

Methane CH_4

Ethane C_2H_6

Propane C_3H_8

Butane C_4H_{10}

Pentane C_5H_{12}

Hexane C_6H_{14}

Heptane C_7H_{16}

Octane C_8H_{18}

Nonane C_9H_{20}

Decane $\text{C}_{10}\text{H}_{22}$

Undecane $\text{C}_{11}\text{H}_{24}$

Dodecane $\text{C}_{12}\text{H}_{26}$

NOMENCLATURE

Nomenclature of organic compounds had been formed during last centuries. There are:

- Common (trivial)
- International. In order to systematize the nomenclature of organic compounds, IUPAC (**International Union of Pure and Applied Chemistry**) system of nomenclature was first introduced in 1947.

Trivial nomenclature. At first organic compounds were named by chance, for example, because the natural sources of its receiving or their properties (citric acid, formic acid). Many trivial names of organic compounds are used nowadays.

Nomenclature of organic compounds had been formed during last centuries. There are:



methane



methylethane



dimethylethane

IUPAC nomenclature:

The IUPAC system is the most rational and widely used system of nomenclature in organic chemistry. The most important feature of this system is that any molecular structure has only one name.

The **IUPAC** name of any organic compound essentially consists of three parts:

1. word root;
2. suffix;
3. prefix.

1. Word root. It is the basic unit of the name. It denotes the number of carbon atoms present in the **principal chain** (the longest possible continuous chain of carbon atoms including the functional group and the multiple bonds) of the organic molecule. For chains from one to four carbon atoms, special word roots (based upon the common names of alkanes) are used but for chains of five or more carbon atoms, Greek number roots are used as given below:

Word root	Chain length	Word root	Chain length
Meth-	C ₁	Hept(a)-	C ₇
Eth-	C ₂	Oct(a)-	C ₈
Prop-	C ₃	Non(a)-	C ₉
But(a)-	C ₄	Dec(a)-	C ₁₀
Pent(a)-	C ₅	Undec(a)-	C ₁₁
Hex(a)-	C ₆	Dodec(a)-	C ₁₂

2. Suffix. There are two types of suffixes:

a) Primary suffix. A primary suffix is always added to the word root to indicate whether the carbon chain is saturated or unsaturated.

Type of carbon chain	Primary suffix	General name
Saturated	ane	Alkane
Unsaturated with one double bond	ene	Alkene
Unsaturated with one triple bond	yne	Alkyne
Unsaturated with two double bonds	diene	Alkadiene
Unsaturated with two triple bonds	diyne	Allcadiyne

The following examples illustrate the usage of word roots and primary suffixes in naming of organic compounds:

Organic compound	Word root	Primary suffix	IUPAC name
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	But	ane	Butane
$\text{CH}_2=\text{CHCH}_3$	Prop	ene	Propene
$\text{CH}\equiv\text{CH}$	Eth	yne	Ethyne
$\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$	Buta	diene	Butadiene
$\text{CH}\equiv\text{CH}-\text{CH}\equiv\text{CH}$	Buta	diyne	Butadiyne

b) Secondary suffix. A secondary suffix is added to the primary suffix to indicate the nature of the functional groups are present in the organic compound. Secondary suffixes of some important functional groups are given below:

Class of organic compounds	Functional group	Secondary suffix
Alcohols	OH	ol
Aldehydes	CHO	al
Ketones	C=O	one
Carboxylic acids	COOH	oic acid
Acid amides	CONH ₂	amide
Acid chlorides	COCl	oyl chloride
Esters	COOR	alkyl...oate
Nitriles	CN	nitrile
Thioalcohols	SH	thiol
Amines	NH ₂	amine

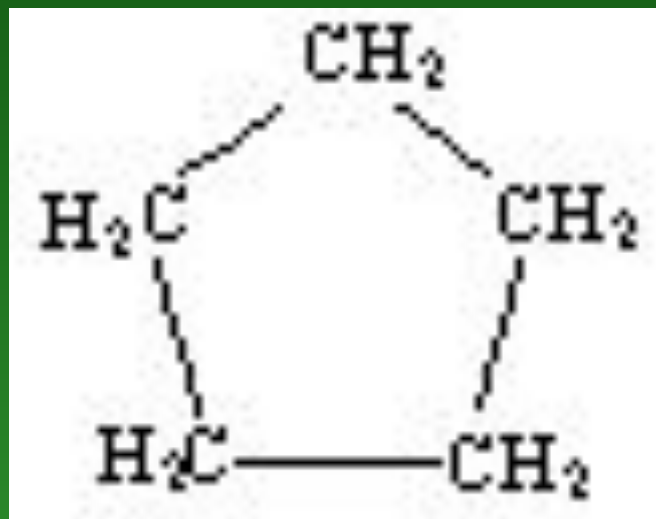
The following examples illustrate the use of word root, primary suffix and secondary suffix in naming organic compounds:

Organic compound	Word root	Primary suffix	Secondary suffix	IUPAC name
$\text{CH}_3\text{CH}_2\text{OH}$	Eth	ane	ol	Ethanol
$\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$	Prop	ane	amine	Propanamine
$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$	But	ane	oic acid	Butanoic acid
$\text{CH}_3\text{CH}_2\text{CN}$	Prop	ane	nitrile	Propanenitrile
$\text{CH}_2=\text{CHCHO}$	Prop	ene	al	Propenal
$\text{CH}\equiv\text{CHCOOH}$	Prop	yne	oic acid	Propynoic acid

3. Prefix. There are two types of prefixes:

a) Primary prefix. A primary prefix is used simply to distinguish cyclic from acyclic compounds.

For example, in case of carbocyclic compounds, (cyclic compounds containing only carbon atoms in the ring), a primary prefix, *cyclo-* is used immediately before the word root.



Cyclo
Primary prefix

pent
Word root

ane
Primary suffix

Cyclopentane
IUPAC name

If the prefix *cyclo-* is not used, it simply indicates that the compound is acyclic or with open chain.

b) Secondary prefix. In IUPAC system of nomenclature certain groups are not considered as functional groups but instead are treated as substituents, these groups are called secondary prefixes and are added order to denote the side chains or substituent groups. The secondary prefixes for some groups which are always treated as substituent groups:

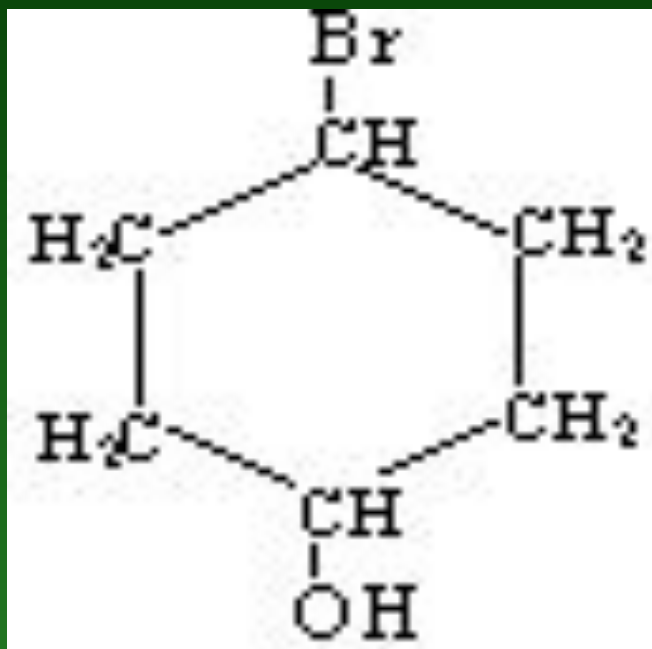
Substituent group	Secondary prefix	Substituent group	Secondary prefix
F	Fluoro	OCH_3 (OMe)	Methoxy
Cl	Chloro	OC_2H_5 (OEt)	Ethoxy
Br	Bromo	R	Alkyl
I	Iodo	CH_3	Methyl
NO_2	Nitro	C_2H_5	Ethyl
NO	Nitroso	$\text{CH}_2\text{CH}_2\text{CH}_3$ (n-Pr)	n-Propyl
$^+\text{N}\equiv\text{N}$	Diazo	$\text{CH}(\text{CH}_3)_2$ (i-Pr)	Isopropyl
OR	Alkoxy	$\text{CH}(\text{CH}_3)_3$ (t-But)	t-Butyl

- Reactivity of functional group
- Sulphonic acids > carboxylic acids > anhydrides > esters > acid chlorides > acid amides > nitriles > aldehydes > ketones > alcohols > amines > ethers > alkenes > alkynes.
- All the remaining functional groups such as halo (fluoro, chloro, bromo, iodo), nitroso ($-\text{NO}$), nitro ($-\text{NO}_2$), and alkoxy ($-\text{OR}$) are always treated as substituent groups.

The following examples illustrate the usage of word root, primary and secondary prefixes and suffixes in naming of organic compounds:

Organic compound	Secondary prefix	Word root	Primary suffix	IUPAC name
$\text{CH}_3\text{CH}_2\text{—Br}$	Bromo	eth	ane	Bromoethane
$\text{CH}_3\text{—NO}_2$	Nitro	meth	ane	nitromethane
$\text{C}_2\text{H}_5\text{—O—C}_2\text{H}_5$	Ethoxy	eth	ane	Ethoxyethane

In the case of carbocyclic compounds primary prefixes are also used. For example,



4-Bromo cyclo hex an (e) 1-ol
4-Bromocyclohexan-1-ol

Secondary	Primary	Word	Primary	Secondary
prefix	prefix	root	suffix	suffix

Complete IUPAC name of organic compound consists of the following parts:

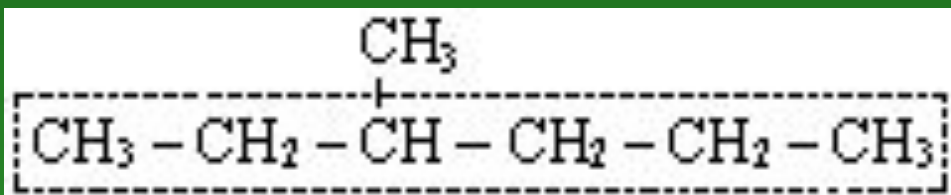
**SECONDARY PREFIX +
PRIMARY PREFIX +
WORD ROOT +
PRIMARY SUFFIX +
SECONDARY SUFFIX**

Rules for IUPAC names of complex aliphatic organic compounds.

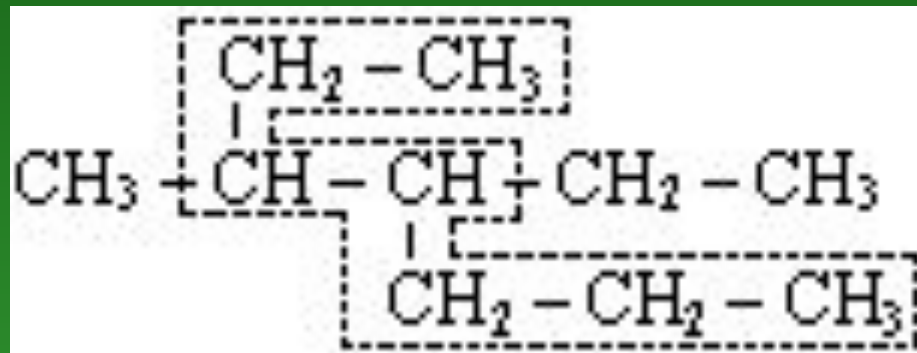
I. Rules for IUPAC nomenclature of complex saturated hydrocarbons (Alkanes)

Alkanes which contain a number of branched chains are called complex alkanes. These alkanes are usually named by the IUPAC system according to the following rules:

1. Longest chain rule. Find the longest continuous chain of Carbon atoms in the molecule. This is called the parent chain. For example:

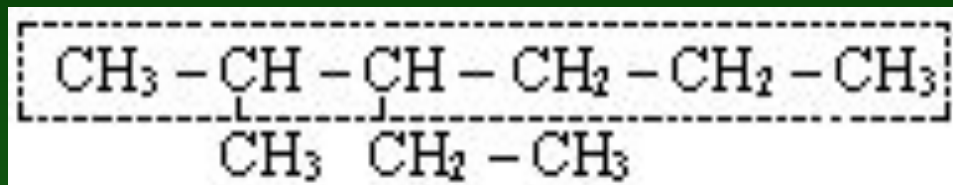


Longest chain contains 6 Carbon atoms.
Named as hexane

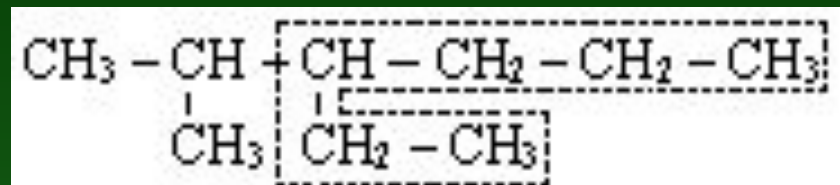


Longest chain contains 7 Carbon atoms
Named as heptane

2. Rule for larger number of side chains. If two different chains of equal lengths are possible, select the one with larger number of side chains or alkyl groups. For example,

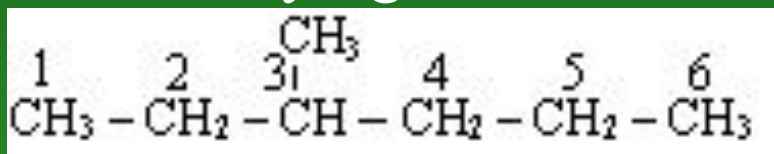


Named as hexane with two alkyl substituents (correct)

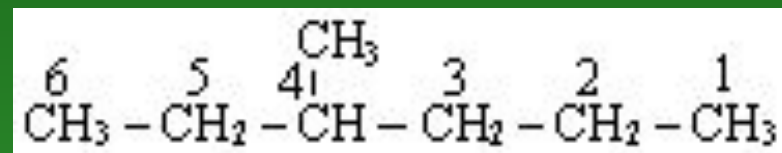


Named as hexane with one alkyl substituent (wrong)

3. Lowest number rule or lowest locant rule. Number the Carbon atoms of the parent chain as 1, 2, 3, 4, ... etc. starts from that end which gives the lowest possible number to the Carbon atom carrying the substituents.



correct



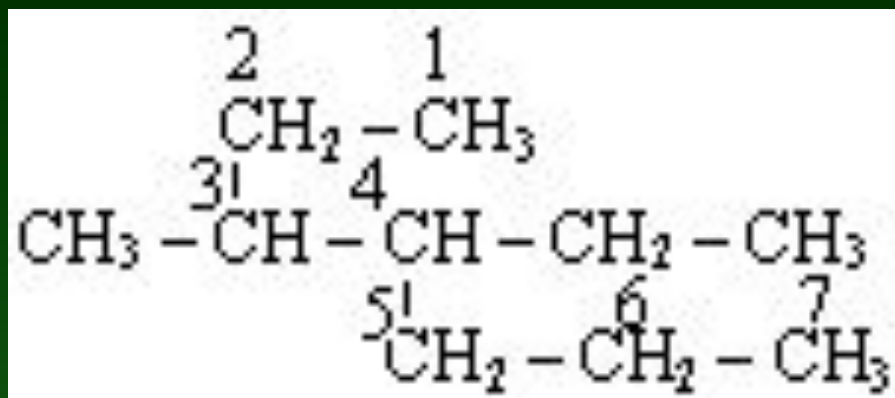
wrong

The number that indicates the position of the substituent in the parent chain is called the positional number or the locant. The correct locant for the methyl is 3.

4. Lowest sum rule and lowest set of locants rule. When two or more substituents are present, two rules are generally mentioned. These are:

a) Lowest sum rule. When two or more substituents are present, the numbering of the Carbon atoms of the parent chain is done in such way that the sum of locants is the lowest. This is called the **lowest sum rule**.

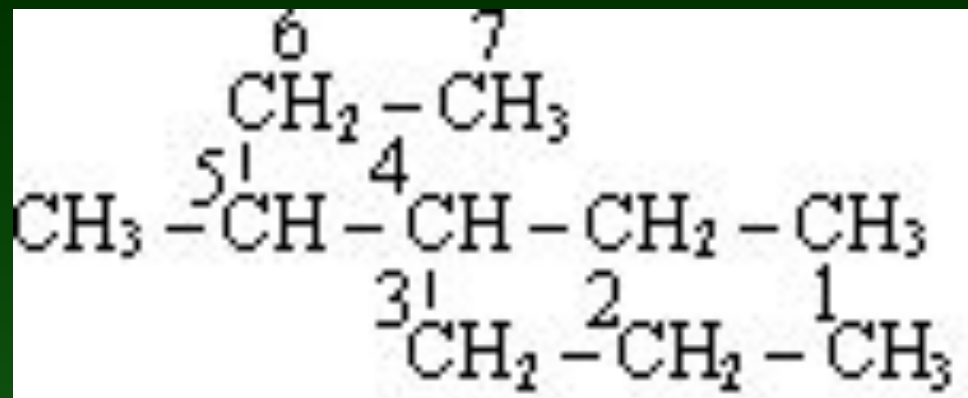
b) Lowest set of locants rule. When two or more substituents are present in the parent Carbon atom chain the lowest set of locants are numbered from all the possible directions.



correct

Sum of the locants = 3 + 4 = 7

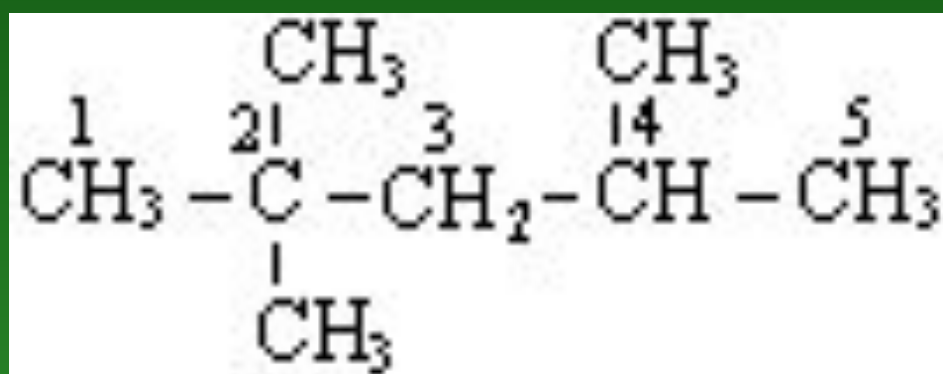
Set of locants = 3, 4



wrong

Sum of the locants = 4 + 5 = 9

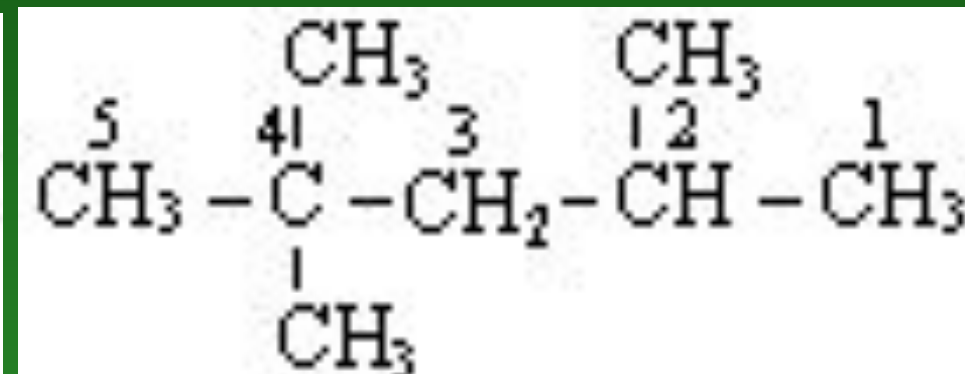
Set of locants = 4, 5



correct

Sum of the locants = 2 + 2 + 4 = 8

Set of locants = 2, 2, 4

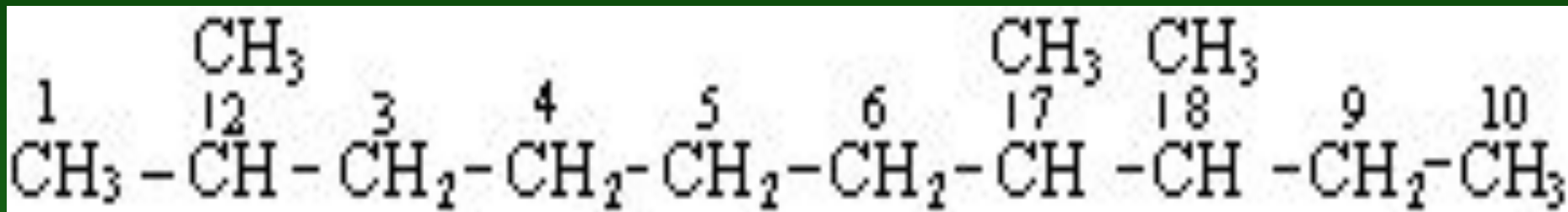


wrong

Sum of the locants = 2 + 4 + 4 = 10

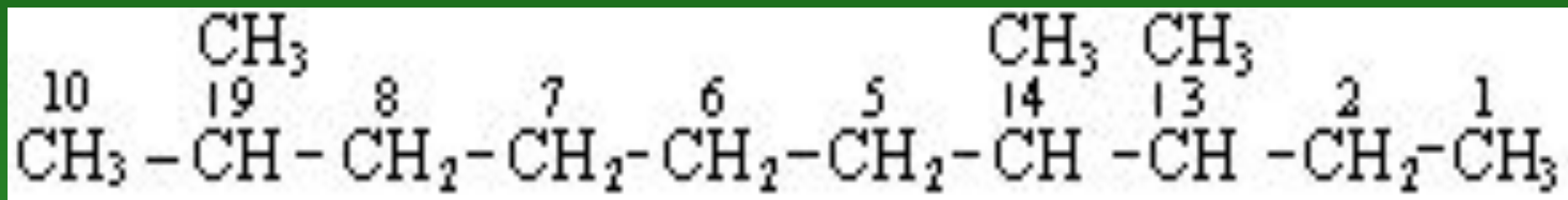
Set of locants = 2, 4, 4

But when the length of the carbon chain is long, the two rules often give different results. For example,



Correct numbering

Sum of locants = $2 + 7 + 8 = 17$ Set of locants = 2, 7, 8 (correct)



Wrong numbering

Sum of locants = $3 + 4 + 9 = 16$ Set of locants = 3, 4, 9 (wrong)

5. Name of the complex alkane. We use prefix to indicate the position of substituent on the parent chain writing the number of the Carbon atom carrying the substituent.

6. Alphabetical order of the simple substituents. When two or more simple substituents are present on the parent chain, each prefixes is arranged in alphabetical order before the name of the parent alkane.

7. Numbering of the different substituents in equivalent positions. When two different substituents are present in equivalent positions, the numbering of the parent chain is done in such a way that the substituent which comes first in the alphabetical order gets the lower number.

8. Naming of the same substituents in different positions.

When the same substituents occur more than once on the parent chain at different positions, the positional number of each substituent is separated by commas and suitable numerical prefixes such as di (for two), tri (for three), tetra (for four) etc. are attached to the name of the substituents. However, the prefixes di, tri etc. are not considered while deciding the alphabetical order of the alkyl groups.

In case the same substituent occurs twice on the same Carbon atom, its positional number is also repeated twice.

9. Naming of the complex substituent (or substituted substituent).

- a)** In the case the substituent on the parent chain is complex (i. e., it has branched chain), it is named as a substituted group by separately numbering the Carbon atom of this group attached to the parent chain as 1. The name of such a substituent is always enclosed in brackets to avoid confusion with the numbers of the parent chain.
- b)** While deciding the alphabetical order of the various substituents, the name of the complex substituent is considered to begin with the first letter of complete name.
- c)** When the names of two or more substituents are composed of identical words, priority of citation is given to that substituent which has lowest locant at the cited point of difference within the complex substituent.

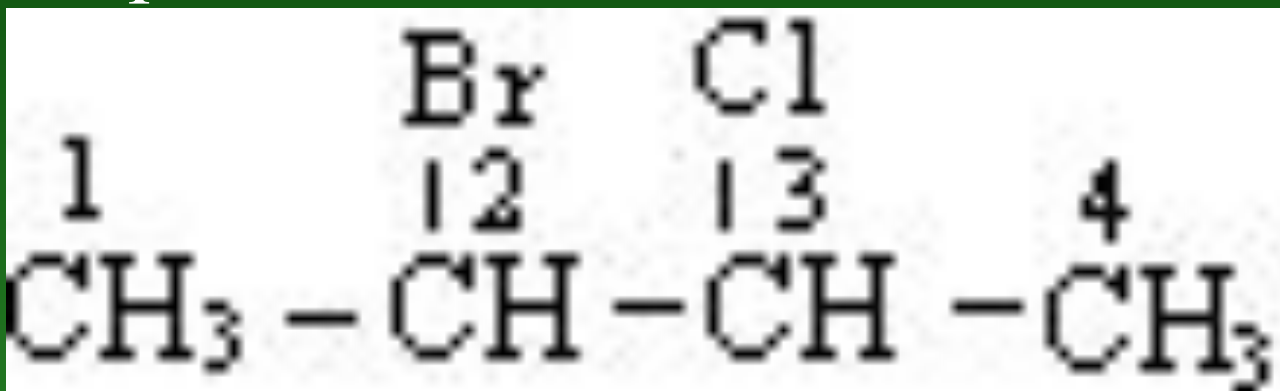
II. Rules for IUPAC nomenclature of unsaturated hydrocarbons (Alkenes and Alkynes). When naming compounds containing multiple (double and triple) bonds, the following additional rules are followed:

1. The parent chain must contain the multiple bond regardless of the fact whether it also denotes the longest continuous chain of Carbon atoms or not.
2. If both double and triple bonds are present, the numbering of the parent chain should always be done from that end which is nearer to the double or the triple bond.
3. If, however, there is a choice in numbering the double bond is always given preference over the triple bond.

III. Rules for IUPAC nomenclature of complex haloalkanes. Some important rules according to 1993 recommendations are discussed below:

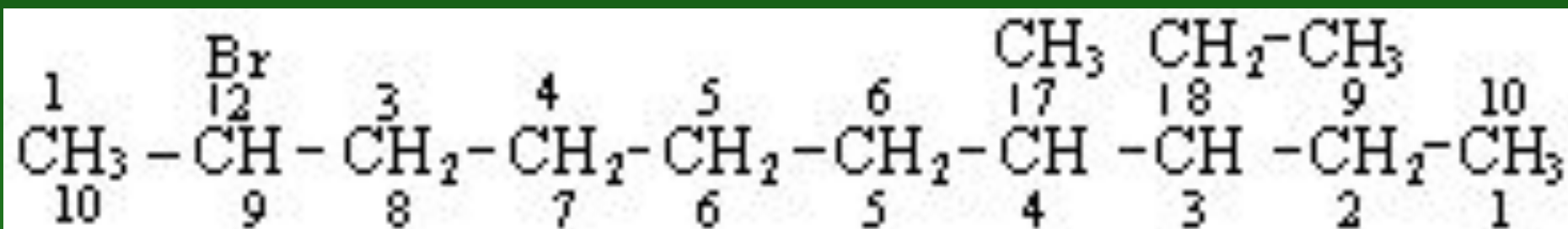
1. When there are two different substituents:

For example,



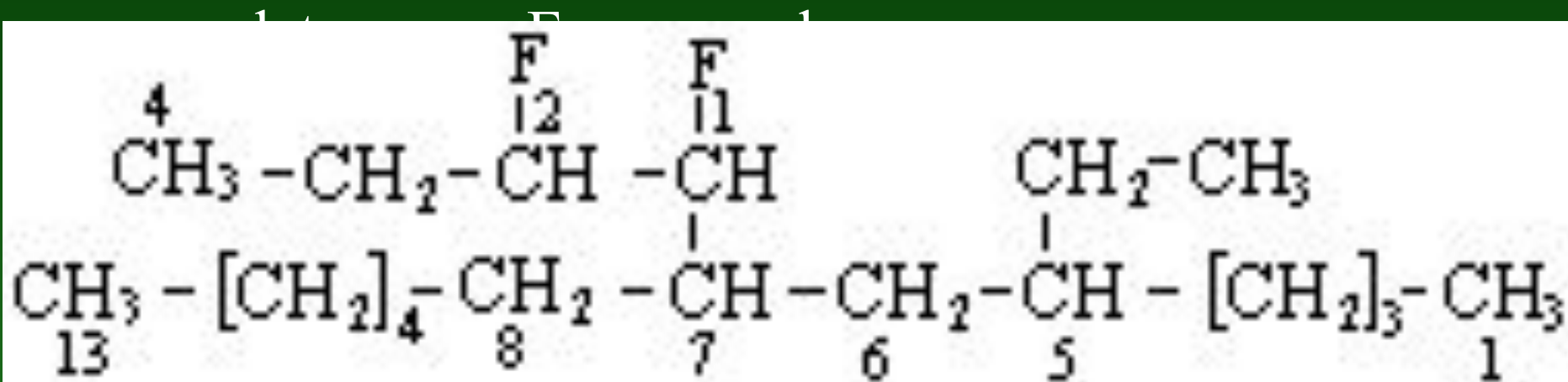
2 – Bromo – 3 – chlorobutane
(Not 2 – Chloro – 3 – bromobutane)

2. Lowest set of locants. In principle, when two or more different sets of locants are possible, that set of locants is preferred, which has the lowest term at the first point of difference even if it violates the lowest sum rule. For example: the locant set 2, 7, 8 (sum 17) is preferred over 3, 4, 9 (sum 16).

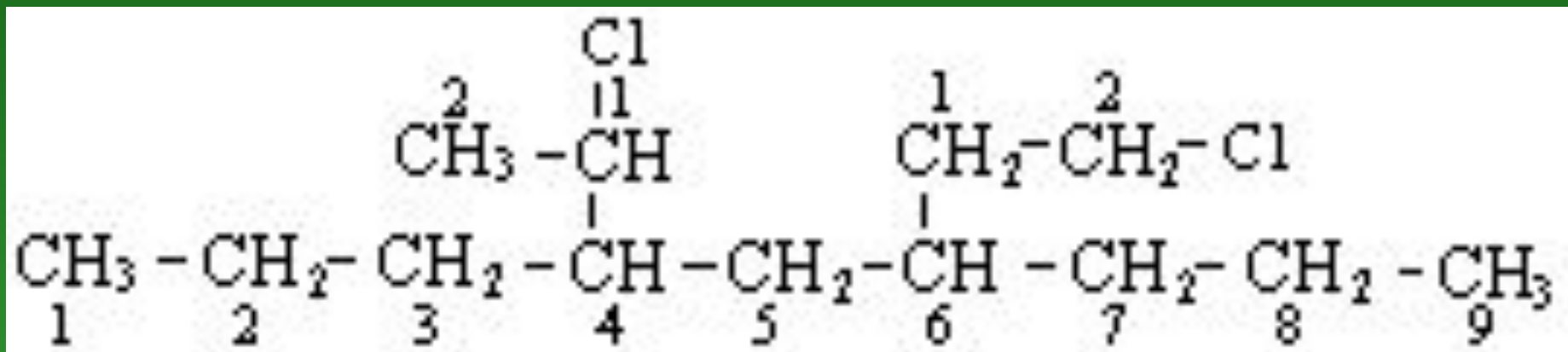


2 – Bromo – 8 – ethyl – 7 – methyldecane
 (Not 9 – Bromo – 3 – ethyl – 4 – methyldecane)

3. Name of a prefix for a substituted substituent is considered to begin with the first letter of its



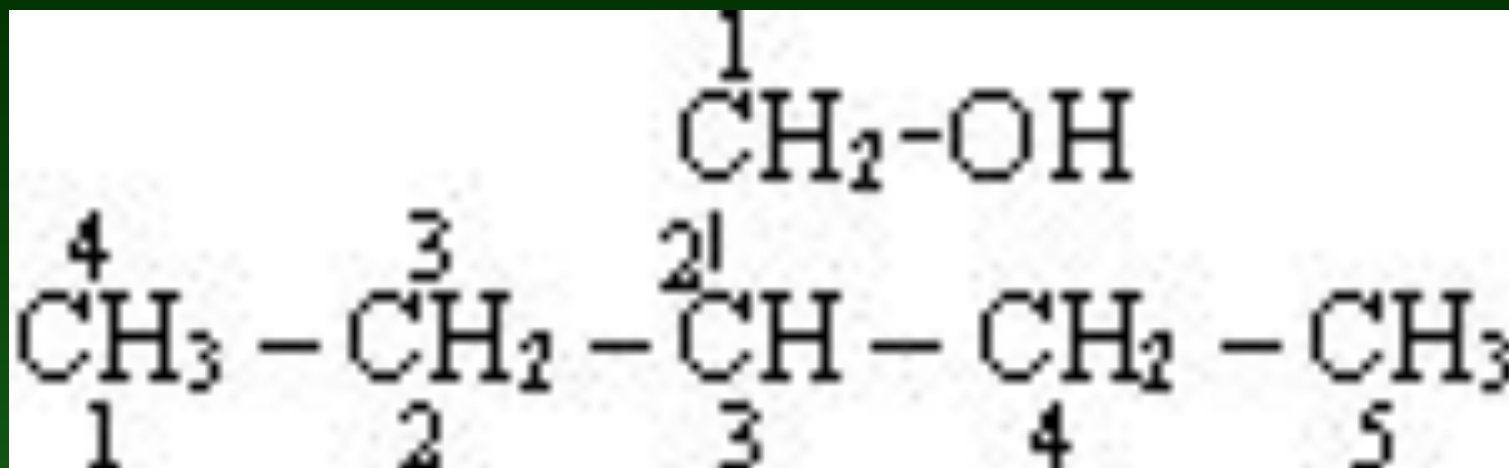
7 – (1, 2 – Difluorobutyl) – 5 – ethyltridecane



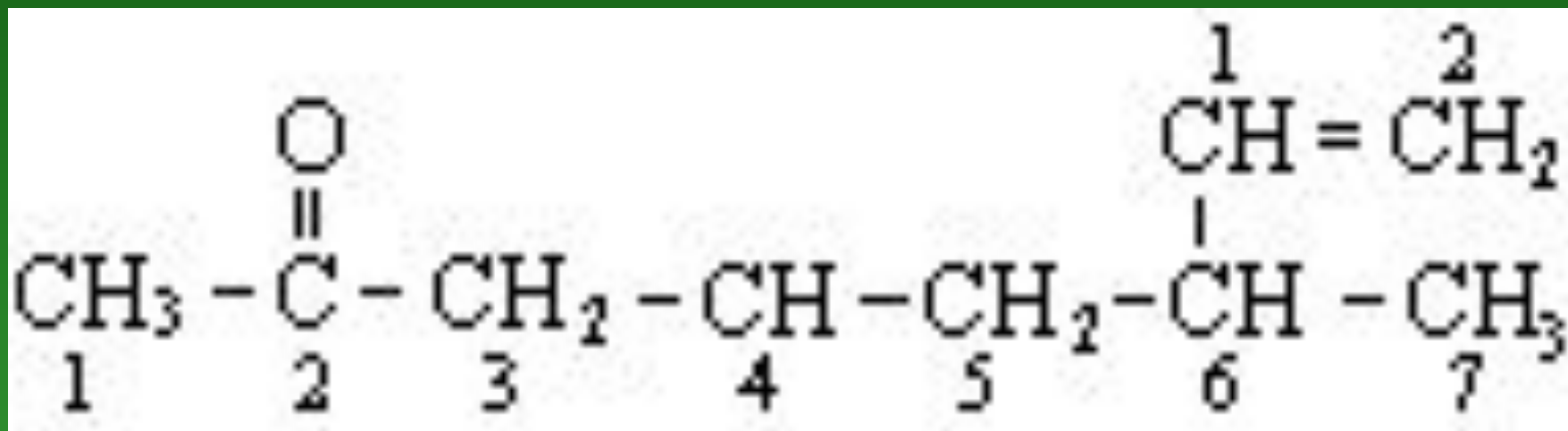
4 – (1 – Chloroethyl) – 5 – (2 – chloroethyl) nonane

IV. Rules for IUPAC nomenclature of compounds containing one functional group, multiple bonds and substituents. While naming organic compounds containing one functional group, double and triple bonds, and substituents, the following additional rules are observed.

1. Parent chain. Select the longest possible chain of Carbon atoms containing the functional group and the maximum number of multiple bonds as **parent chain**.

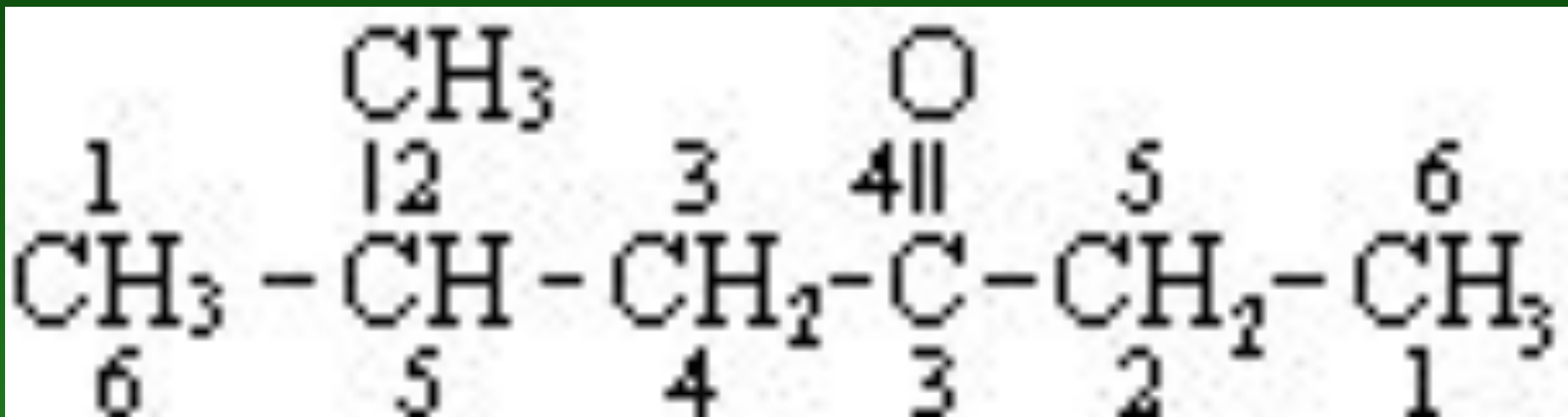


Parent chain contains four rather than five Carbon atoms.



Parent chain contains six rather than seven Carbon atoms.

2. Lowest number for the functional group. Number the parent chain in such a way that the functional group gets the lowest possible number followed by double and triple bonds even if it violates the **lowest sumrule**.

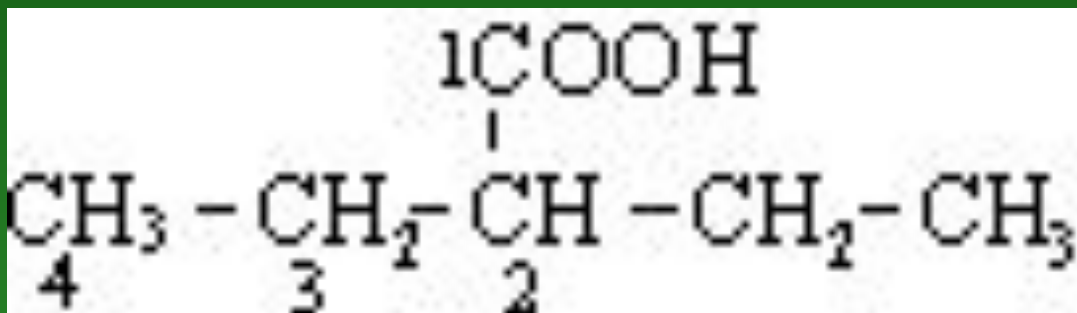


(Wrong) (> C = O group gets number 4 which is not lowest)

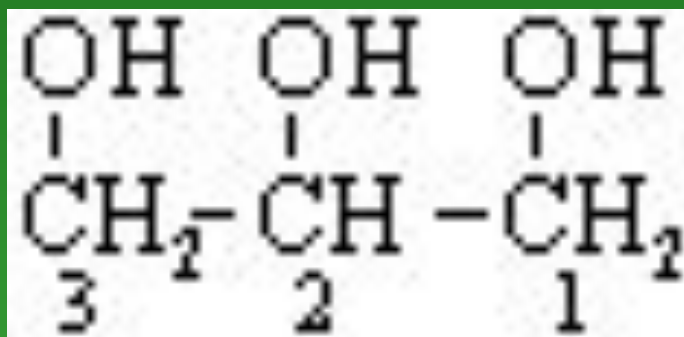
(Conect) (> C = O group gets lowest number 3)

3. Numbering of the chain terminating functional groups.

When a chain terminating functional group such as --CHO , --COOH , --COOR , --CONH_2 , --COCl , $\text{--C}\equiv\text{N}$ etc. is present, it is always given **number 1**. The locant 1 (unity) for the principal functional group is omitted when there is no ambiguity. But in this chapter, this numerical locant is always included when another numerical locant appears in the same name. For example,

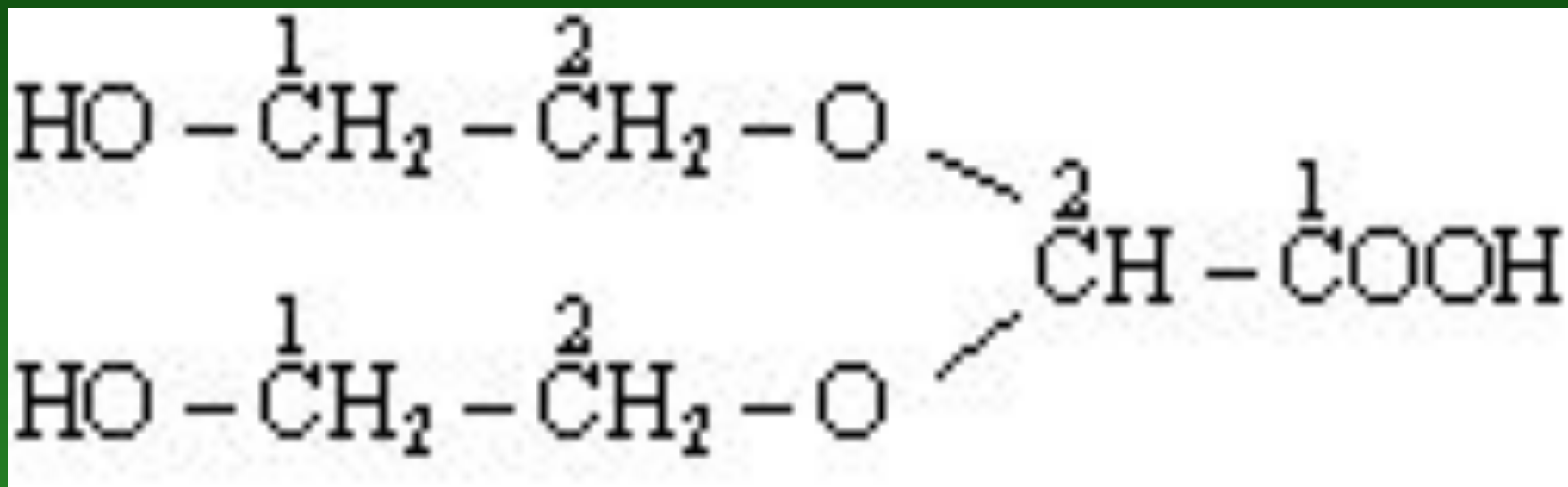


2-ethylbutan-1-oic acid



Propane-1, 2, 3-triol

If the organic molecule contains more than one similar complex substituents, then the numerical prefixes such as di, tri, tetra etc. are replaced by bis, tris, tetrakis, etc. For example,



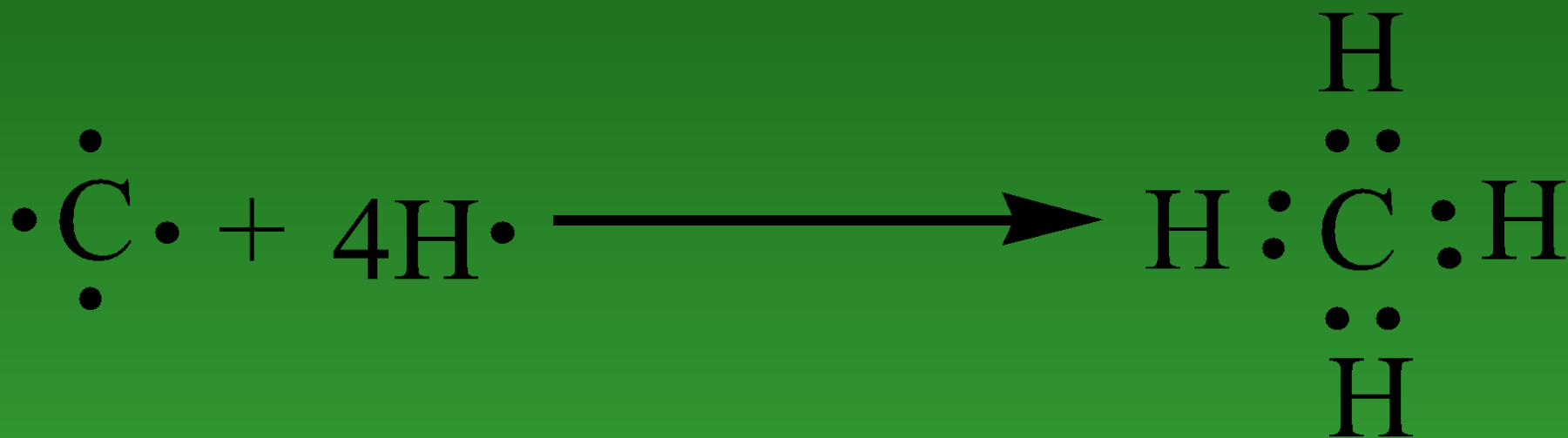
2,2-Bis(2-hydroxyethoxy)ethanoic acid

5. Types of chemical bonds and their description

In the molecule all atoms have influence on each other. The result of this influence is called electronic bonds. It compels neighboring atoms to be side by side.

There are 4 types of chemical bonds:

Covalent bond. This is the main type of bond in organic chemistry. It formed is between atoms with similar electronegativity. In this case common electronic cloud is formed.



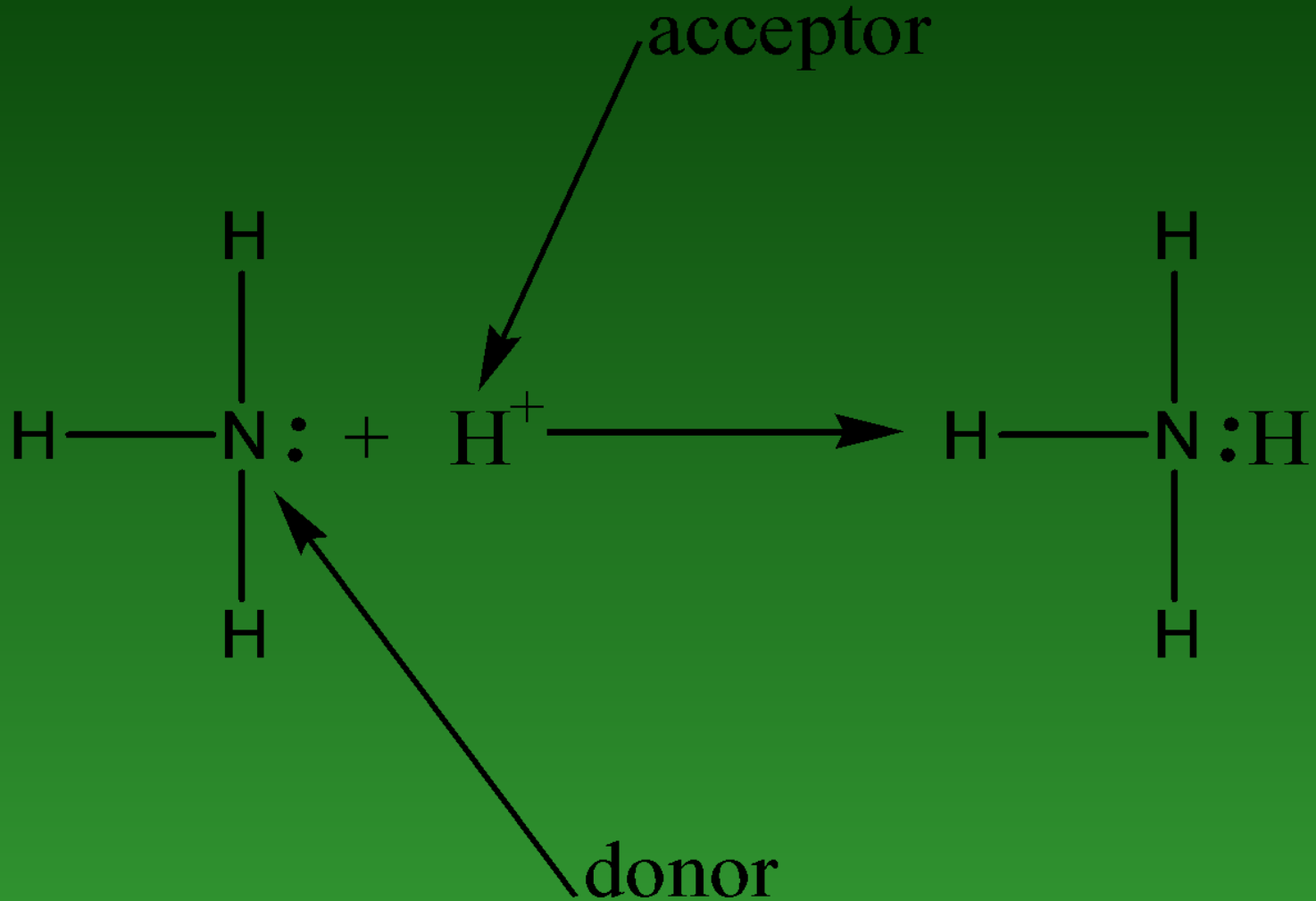
Polar bond. This is a covalent bond between 2 atoms with different electronegativity in which electron pair is not shared equally. But the difference of electronegativity is not big.



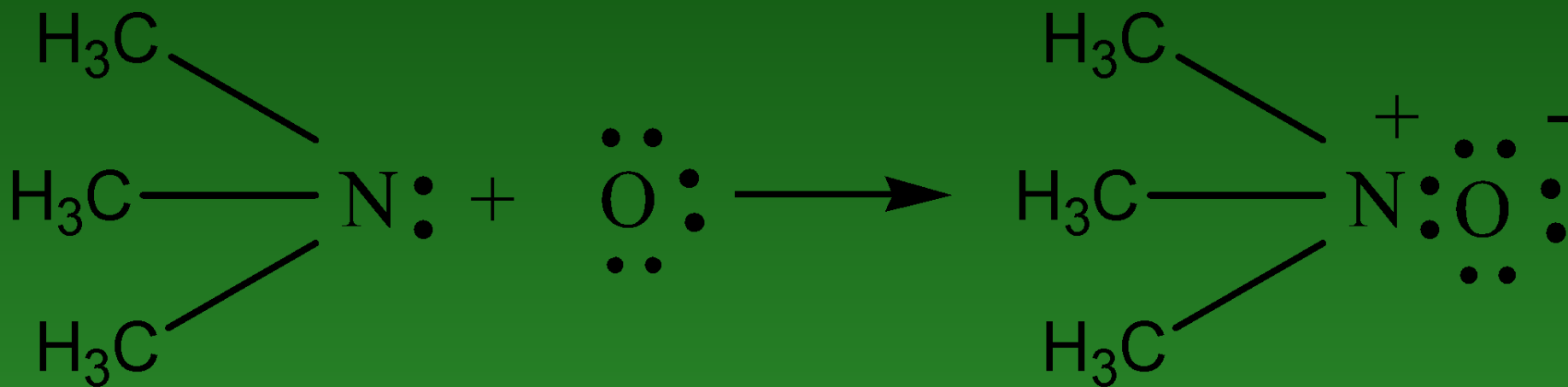
Ion bond. This is a bond between 2 atoms with different electronegativity (difference of electronegativity is very big).



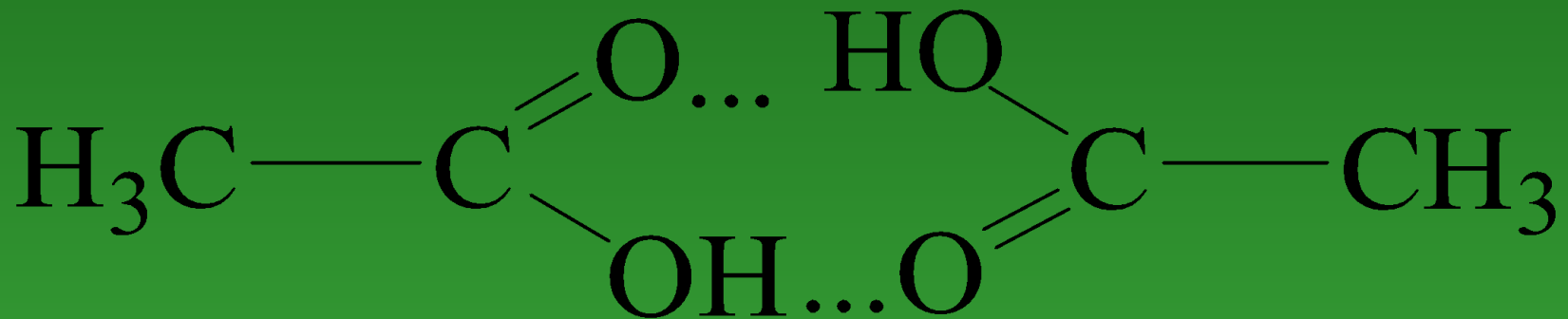
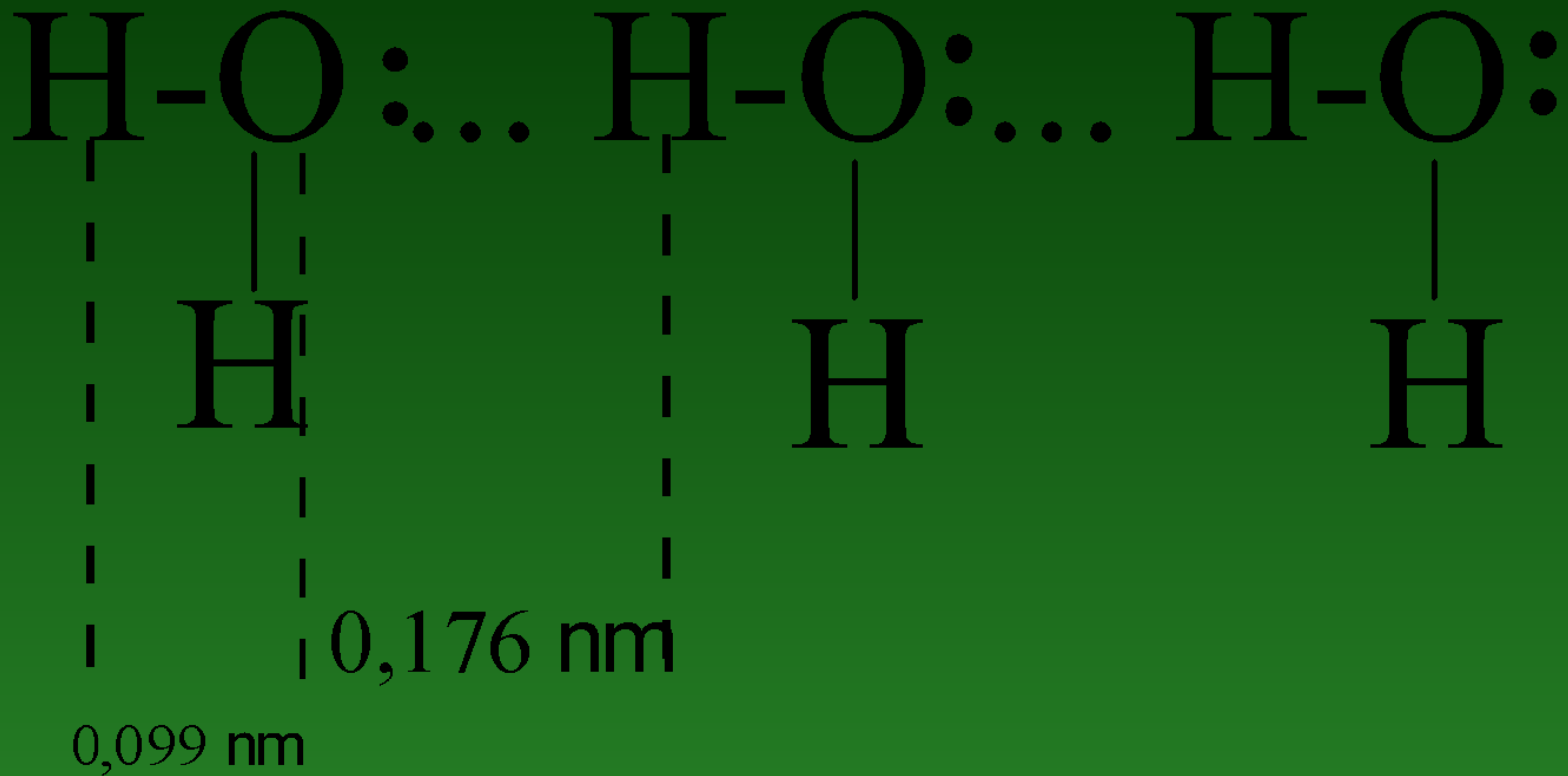
Donor-acceptor bond. This is a type of covalent bond, but it has different origin. In covalent bond a pair of electrons consists of 2 electrons from 2 atoms. But in donor-acceptor bond only one atom gives 2 electrons, but another atom accepts one electron.



Semipolar bond. This is a type of donor-acceptor bond, then one atom has 2 free electrons, and another atom has 6 electrons.



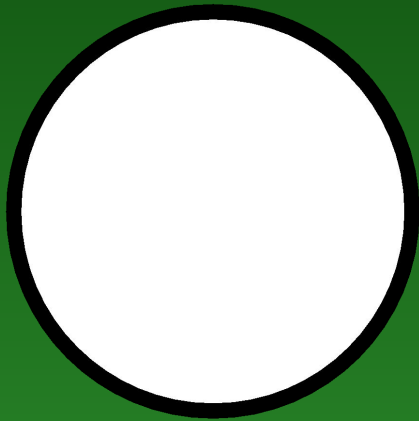
Hydrogen bond. This bond is formed between atom of H⁺ and negative atom. This bond is designated as 3 points (...).



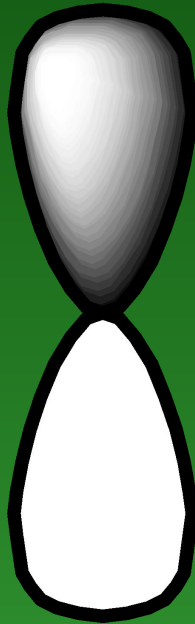
Hybridization of atom orbitals:

sp-, sp²-, sp³-

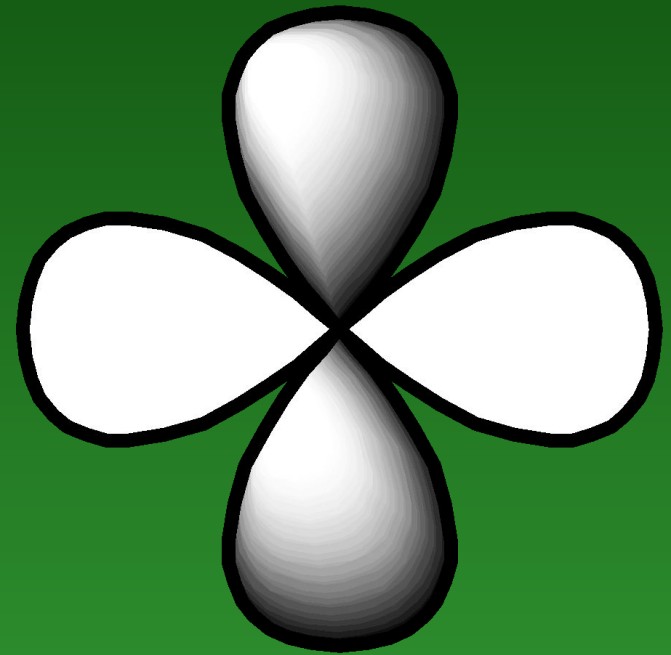
Atom orbital is the space where the atom can be. There are s-, p- and d-atom orbitals.



s-orbital



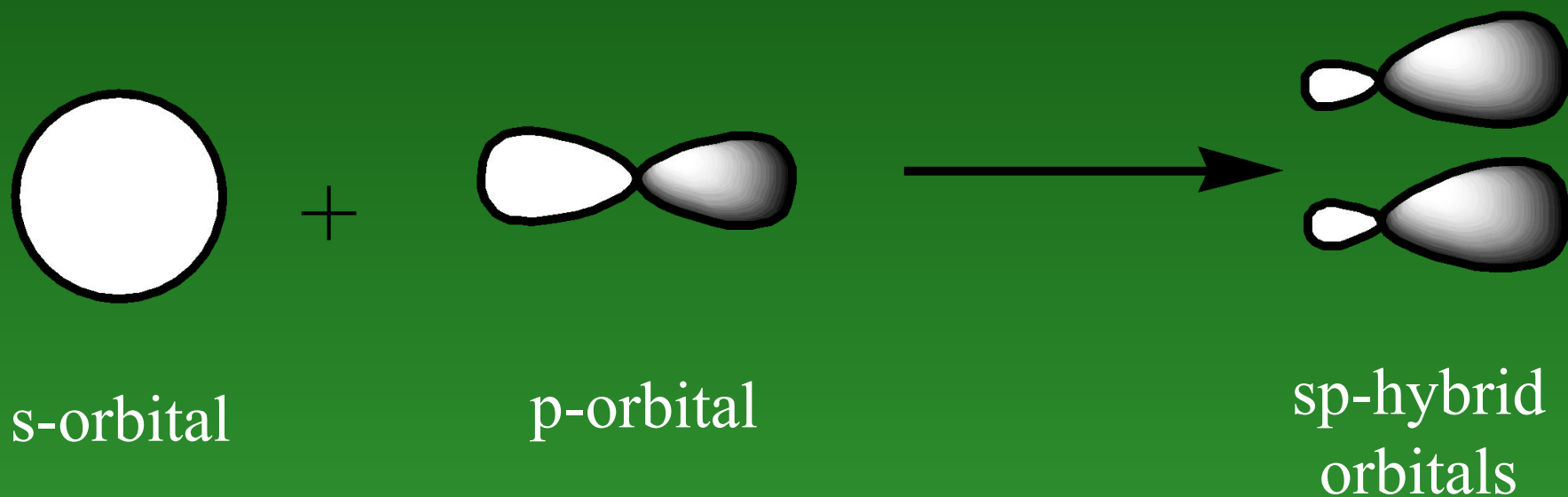
p-orbital



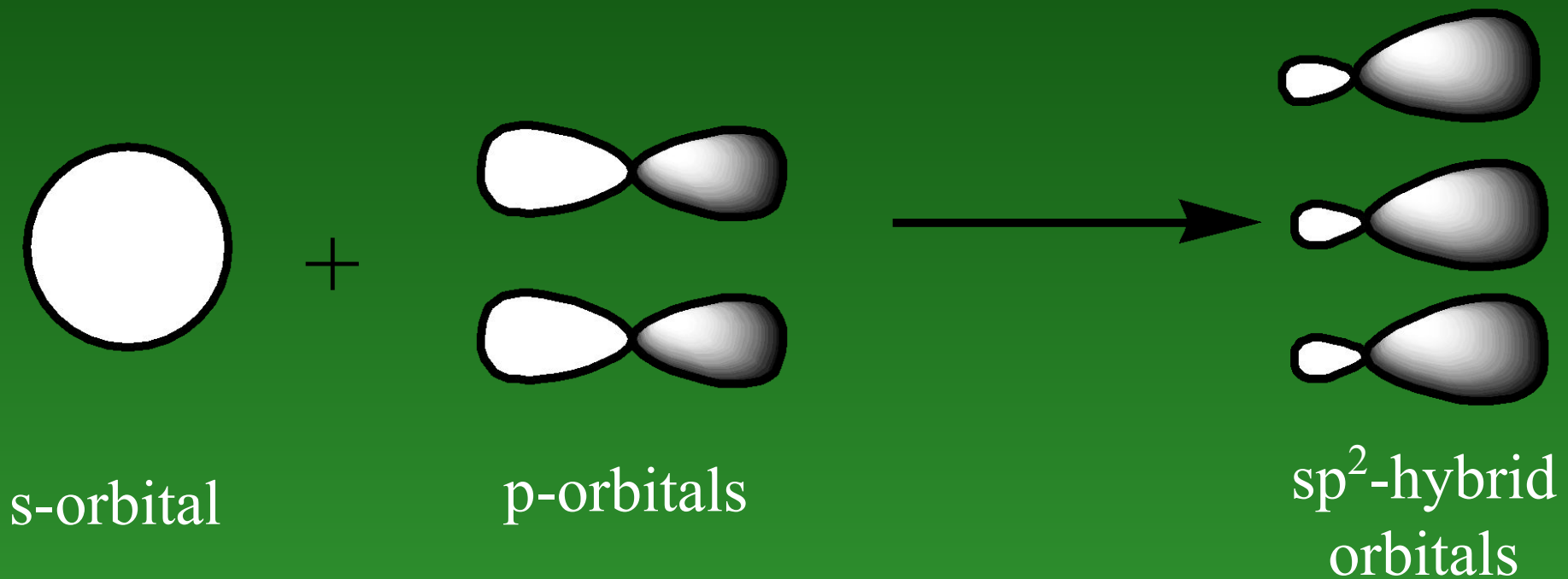
d-orbital

In organic compounds the atom of Carbon has hybrid orbitals. There are 3 main types of them:

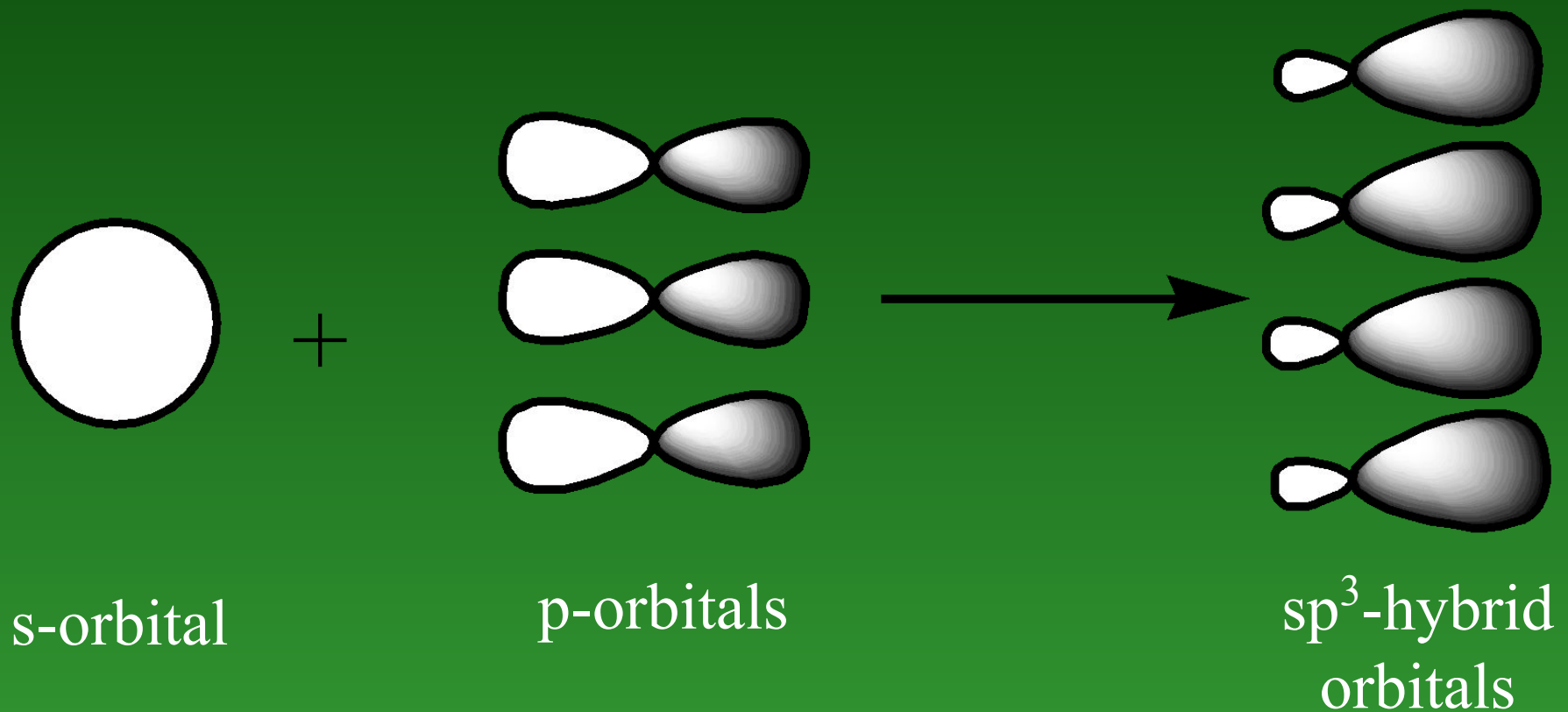
- sp-hybridization of atom orbitals. This hybridization is formed when s-orbital joined to p-orbital.



- sp^2 –hybridization of atom orbitals. This hybridization is formed when s–orbital joined to 2 p–orbitals.

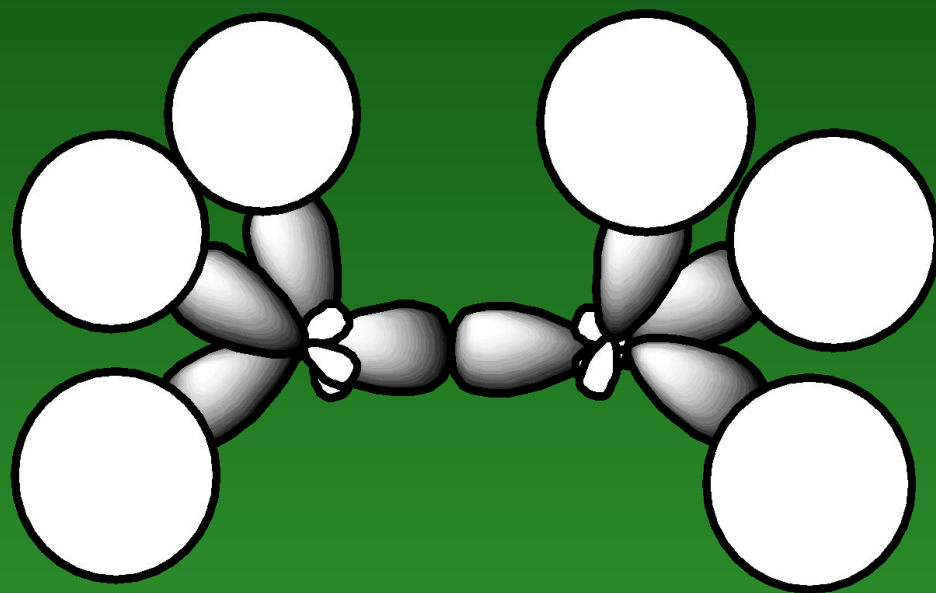
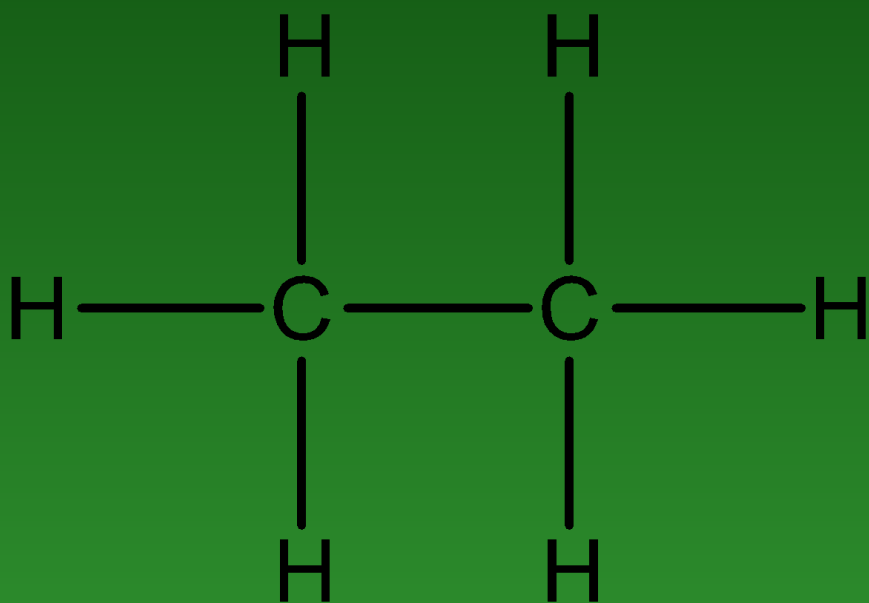


- sp^3 –hybridization of atom orbitals. This hybridization is formed when s–orbital joined to 3 p–orbitals.

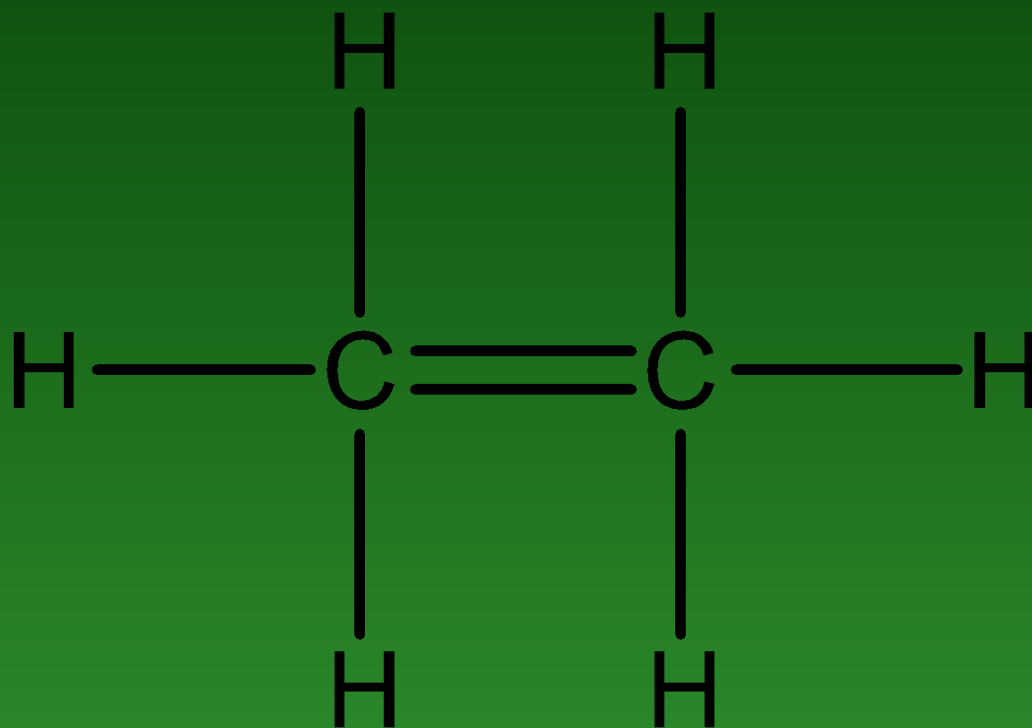


The Carbon atom forms covalent bonds in the molecule of organic compounds. There are 2 types of covalent bonds: σ - and π -bonds.

σ -bond is formed after joining of two different atomic orbitals (s- and p-orbitals) or two hybrid orbitals (sp^3 -hybrid orbitals):



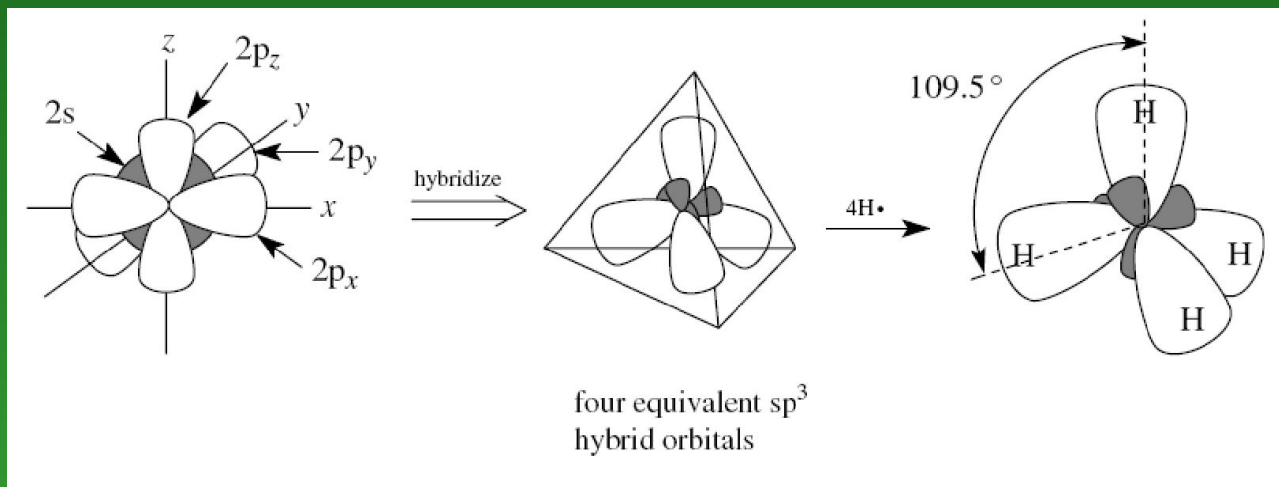
π -bond is formed after joining of two identical s- or p-orbitals.



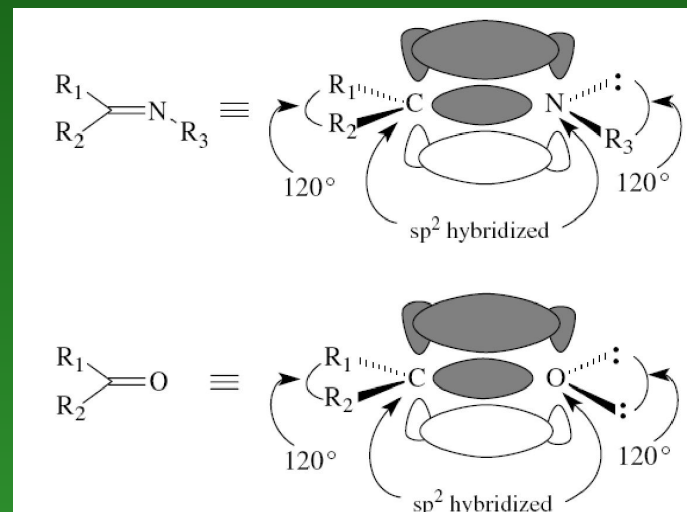
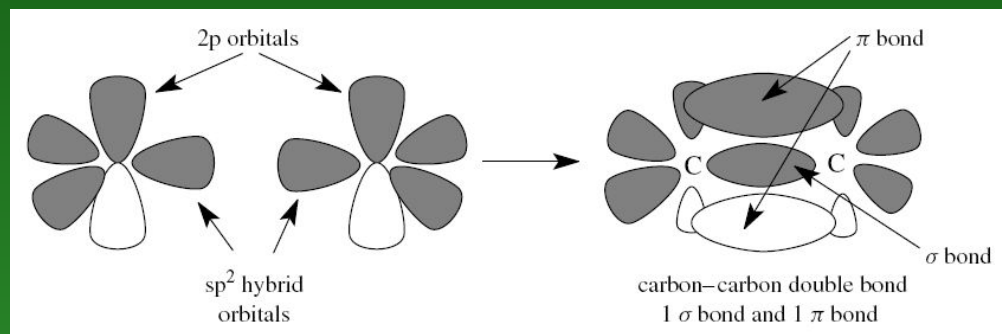
Hybrid Atomic Orbitals

Orbitals formed by mixing the wave functions of pure s and p orbitals of an atom. There are three major types of hybrid atomic orbital :

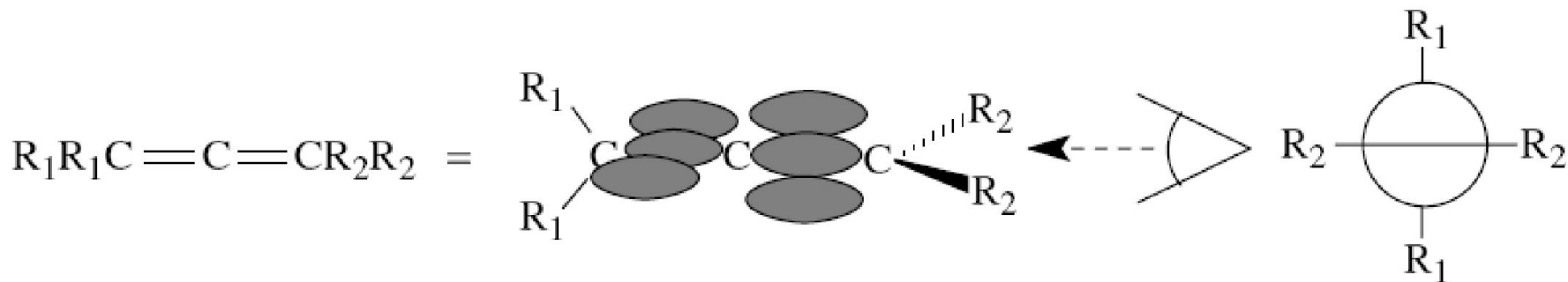
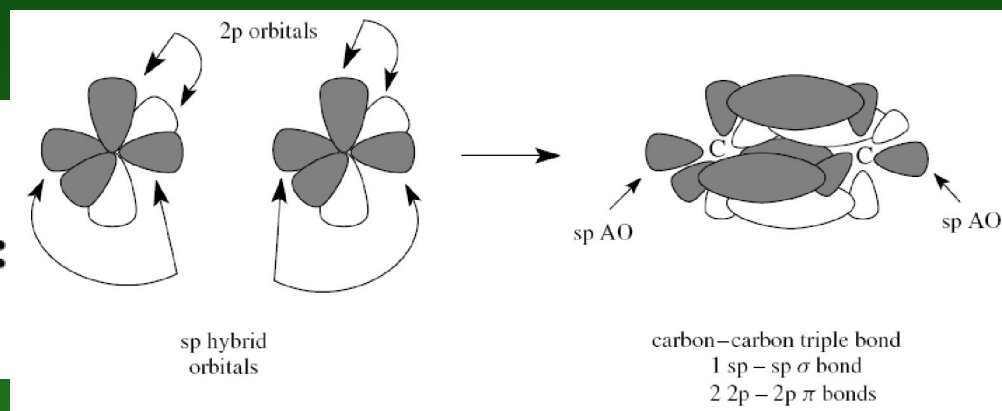
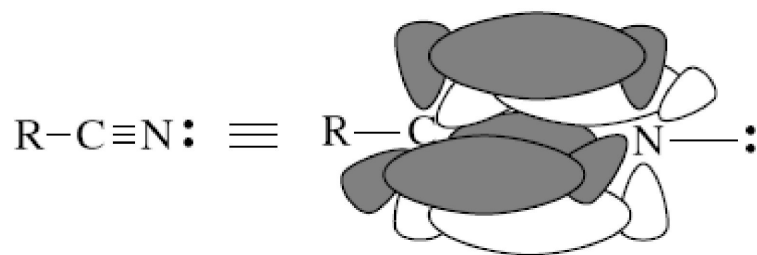
sp^3 – formed by combining the wave function of one s orbital with the wave functions of three p orbitals. Four hybrid orbitals oriented towards the vertices a tetrahedron are formed.

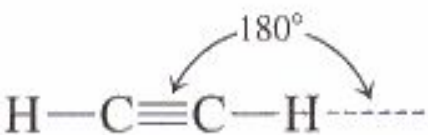


- sp^2 – formed by combining the wave function of one s orbital with the wave functions two p orbitals. Three coplanar hybrid orbitals oriented towards the vertices of an equilateral triangle are formed. Each of the three sp^2 hybrids has a shape that is much like that of an sp hybrid orbital, but the three are oriented, at 120° from each other.

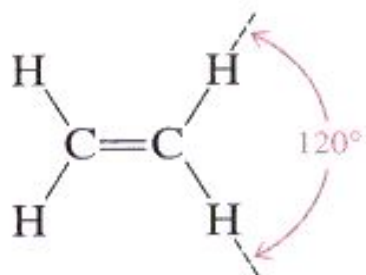


- **sp** – obtained by combining the wave function of one s orbital with the wave function of one p orbital. Two colinear hybrid orbitals oriented in opposite directions are formed. The hybrid orbitals are oriented at 180° from each other.

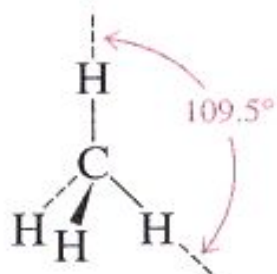




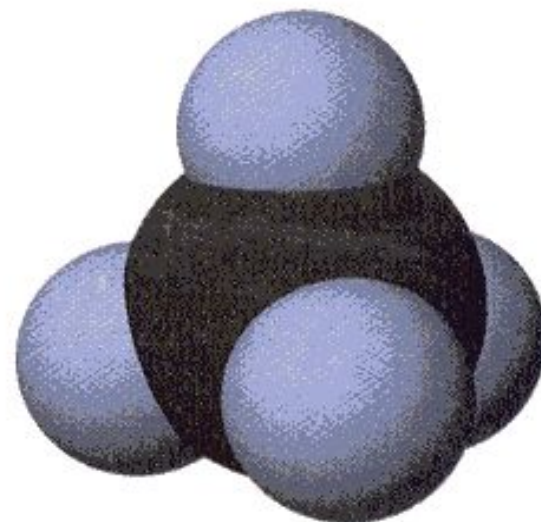
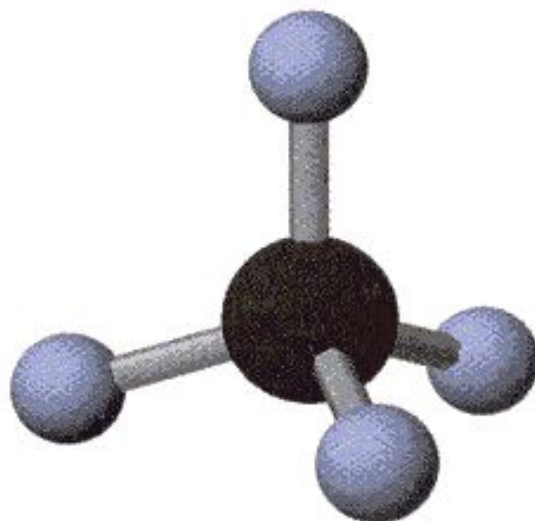
Ethyne—a linear molecule with bond angles of 180°



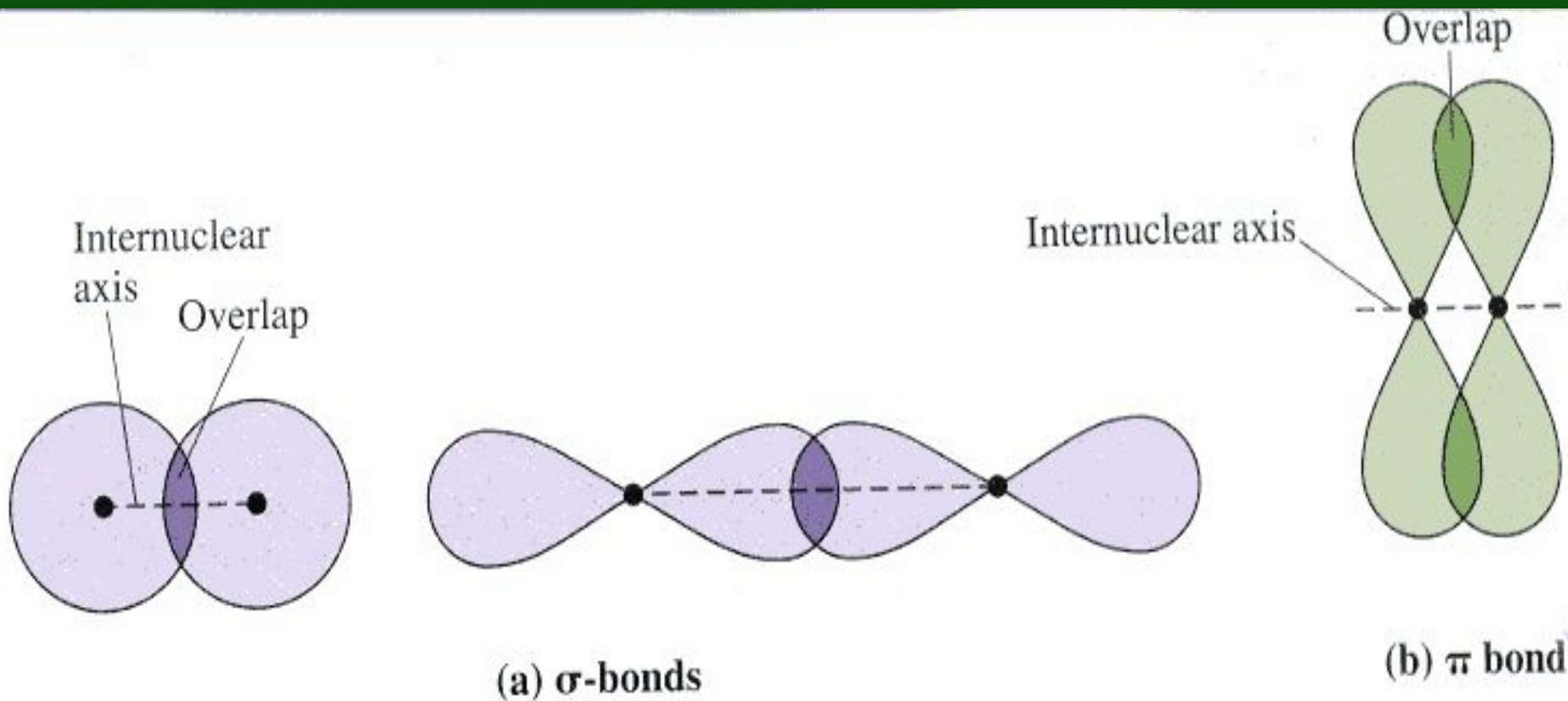
Ethene—a flat molecule with bond angles of 120°



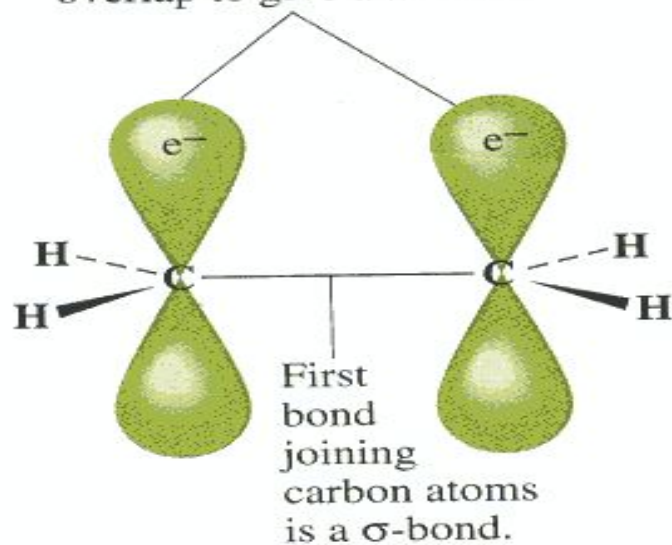
Methane—a tetrahedral molecule with bond angles of 109.5°



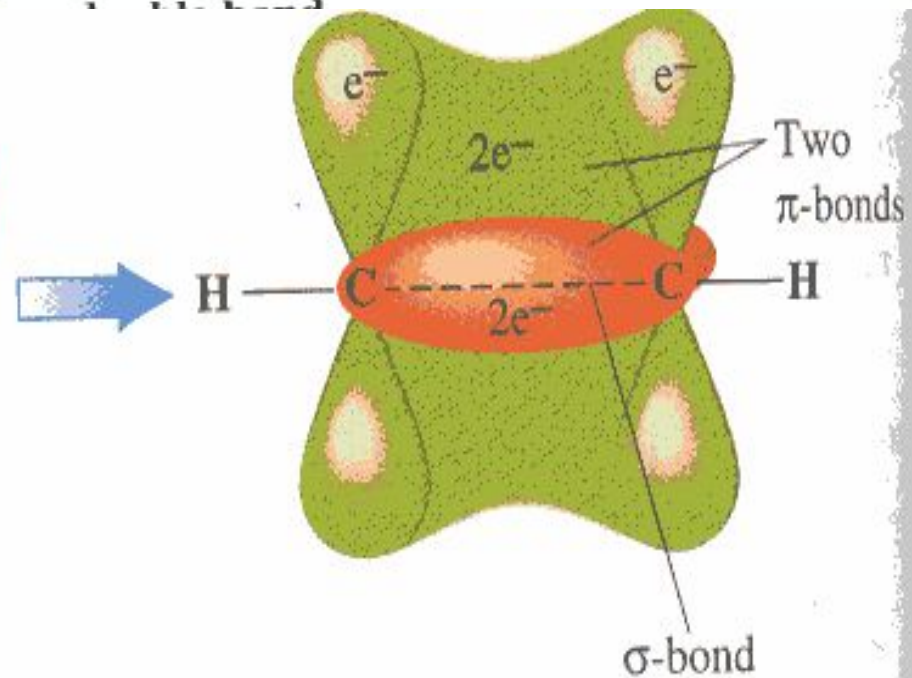
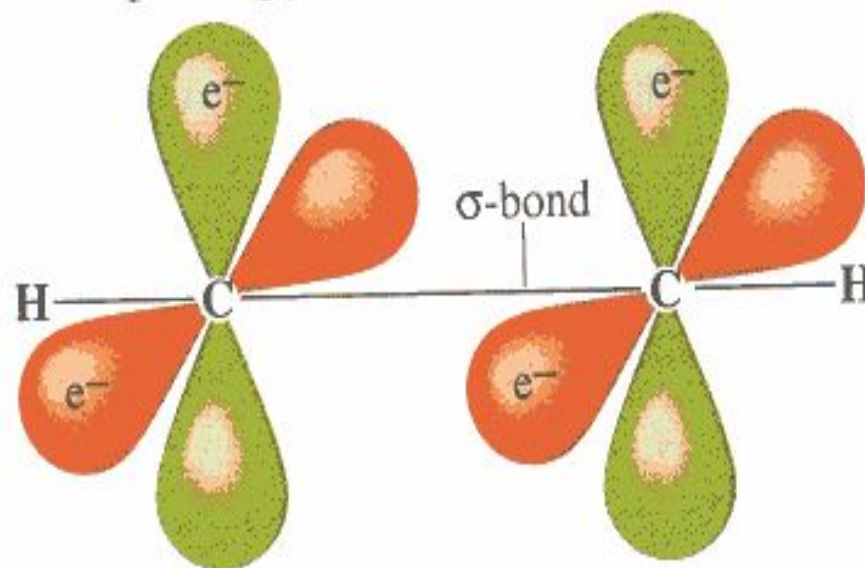
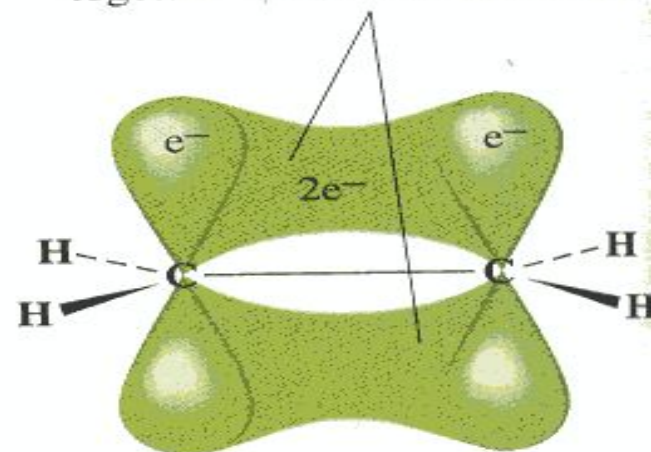
Formation bond in molecules of organic compounds

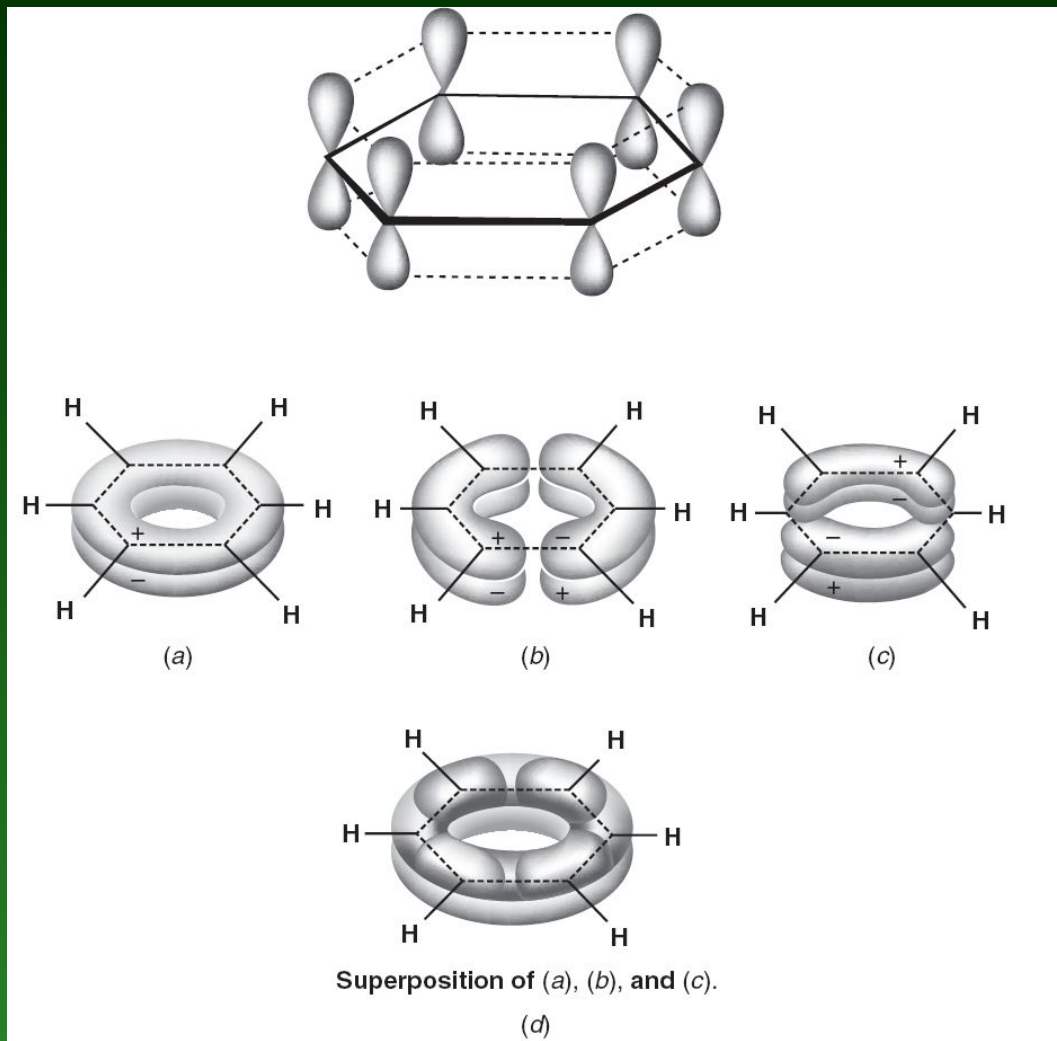


Two p orbitals, each with one e^- , overlap to give a π -bond.



The two overlap regions together constitute one π -bond.





The six p orbitals of benzene overlap to form three bonding orbitals, (a), (b), and (c). The three orbitals superimposed are shown in (d).

Types of bond fission or cleavage (breaking of a covalent bond).

- **Homolytic (symmetrical) fission.** If a covalent bond breaks in such a way that each atom takes away one electron of the shared pair, it is called **homolytic or symmetrical fission**.



- **Heterolytic (unsymmetrical) fission.** When a covalent bond joining two atoms A and B breaks in such a way that both the electrons of the covalent bond are taken away one of the bonded atoms, the mode of bond cleavage is called **heterolytic fission**.



- **Electrophilic** are electron loving chemical species. Their attraction for electrons is due to the presence of an electron-deficient atom in them.
- Electrophilic may be either positively charged or electrically neutral chemical species.
- Positive electrophiles: H^+ , H_3O^+ , Cl^+ , Br^+ , I^+ , NO_2^+ , NO^+ , R^+ (carbocation) etc.
- Neutral electrophiles: $\text{R}\cdot$ (free radicals), $:\text{CR}_2$ (carbenes), $:\text{NR}$ (nitrenes), BP_3 , AlC_3 , FeCl_3 , SnCl_4 .

- **Nucleophiles** are nucleus loving chemical species. Since the nucleus of any atom is positively charged, therefore, nucleophiles must be electron rich chemical species containing at least one lone pair of electrons. They may be either negatively charged or neutral chemical species:
- **Negative nucleophiles:** H^- (hydride ion), CR^- , Br^- , I^- , R^- (carbanion), OH^- , OR^- , SR^- , NH_2^- , CN^- , RCOO^- .
- **Neutral nucleophiles:** H_2O , NH_3 , RNH_2 , ROH , RSH , ROR etc.

Types of organic reactions.

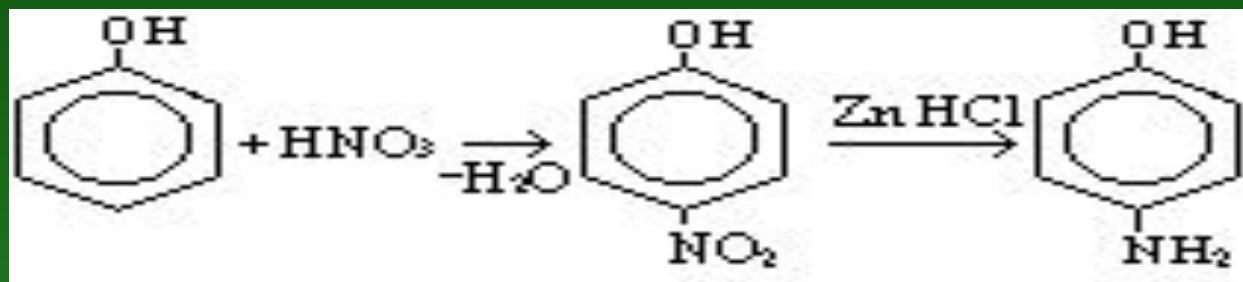
All the organic reactions can be broadly classified into the following four types:

- (a) substitution reactions,
- (b) addition reactions,
- (c) elimination reactions,
- (d) rearrangement reactions.

(i) Substitution reactions which are brought about by nucleophiles are called **nucleophilic substitution reactions**:



(ii) Substitution reactions which are brought about by electrophiles are called **electrophilic substitution reactions**:



(iii) Substitution reactions brought about by free radicals are called **free radical substitution reactions**:

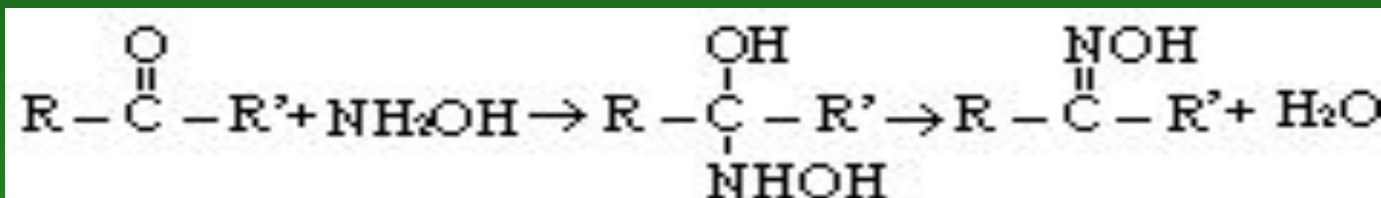


Addition reactions

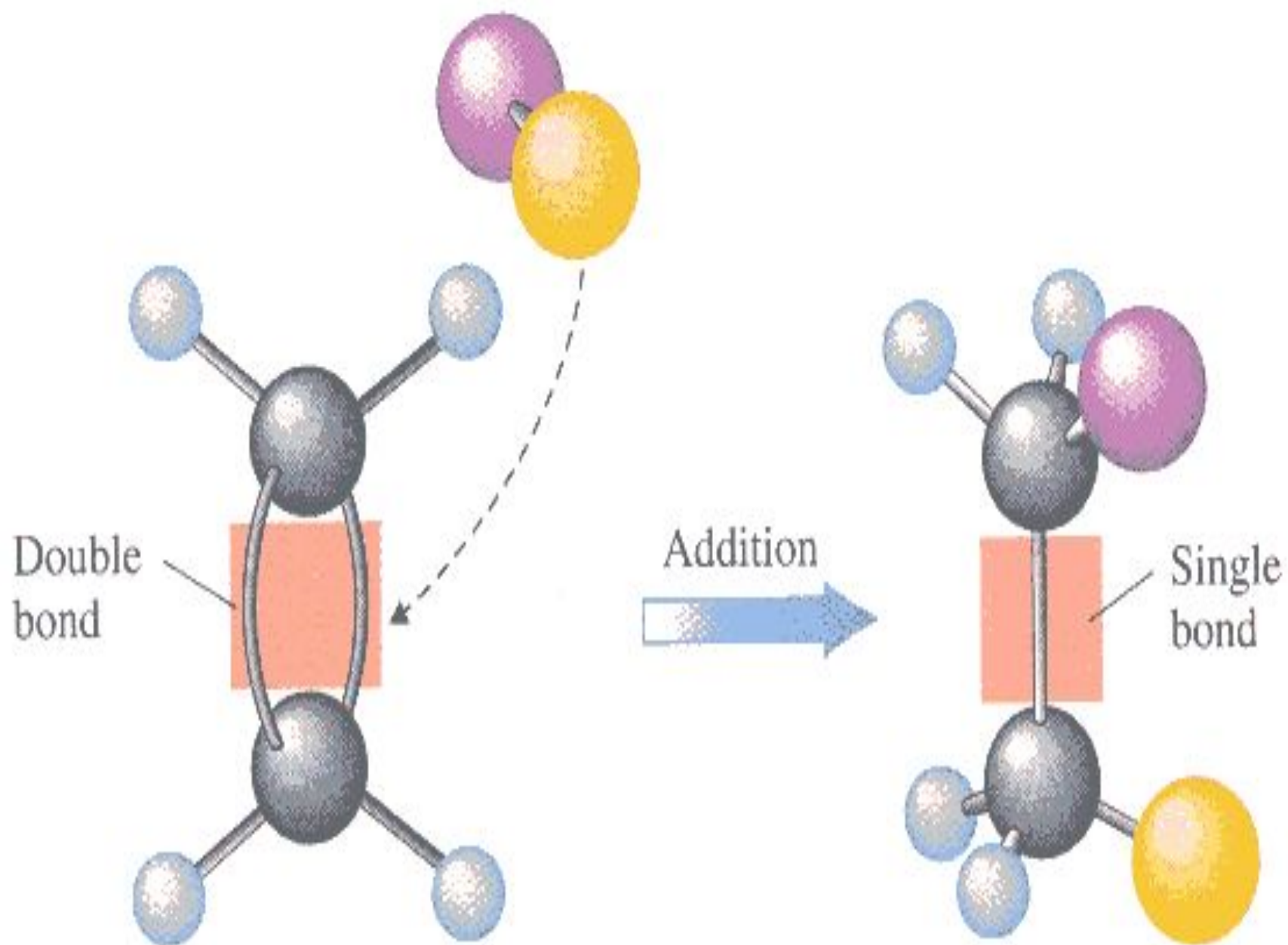
- Reactions, which involve combination between two reacting molecules to give a single molecule of the product are called addition reactions. Such reactions are typical of compounds containing multiple (double or triple) bonds.

Addition reactions are of the following three types:

- (i) Addition reactions brought about by nucleophiles are called **nucleophilic addition reactions**:



- (ii) Addition reactions brought about by electrophiles are called **electrophilic addition reactions**.
- (ii) Addition reactions brought about by free radicals are called **free radical addition reactions**.



- **Elimination reactions.** An elimination reaction is one that involves the loss of two atoms or groups of atoms from the same or adjacent atoms of a substance leading to the formation of a multiple (double or triple) bond:

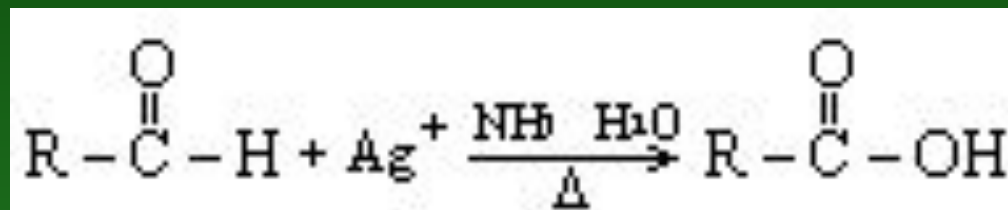


These are of two types:

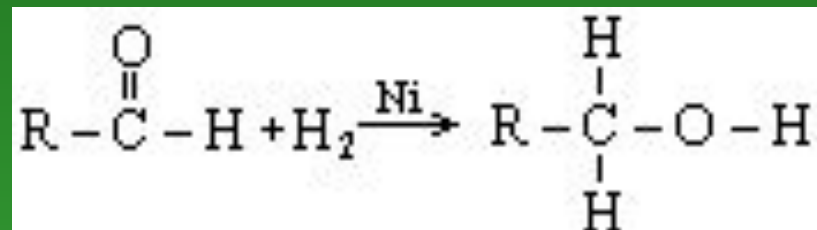
- **β -Elimination reactions.**
- **α -Elimination reactions.**

Reactions involving the migration of an atom or a group from one atom to another within the same molecule are called **rearrangement reactions**.

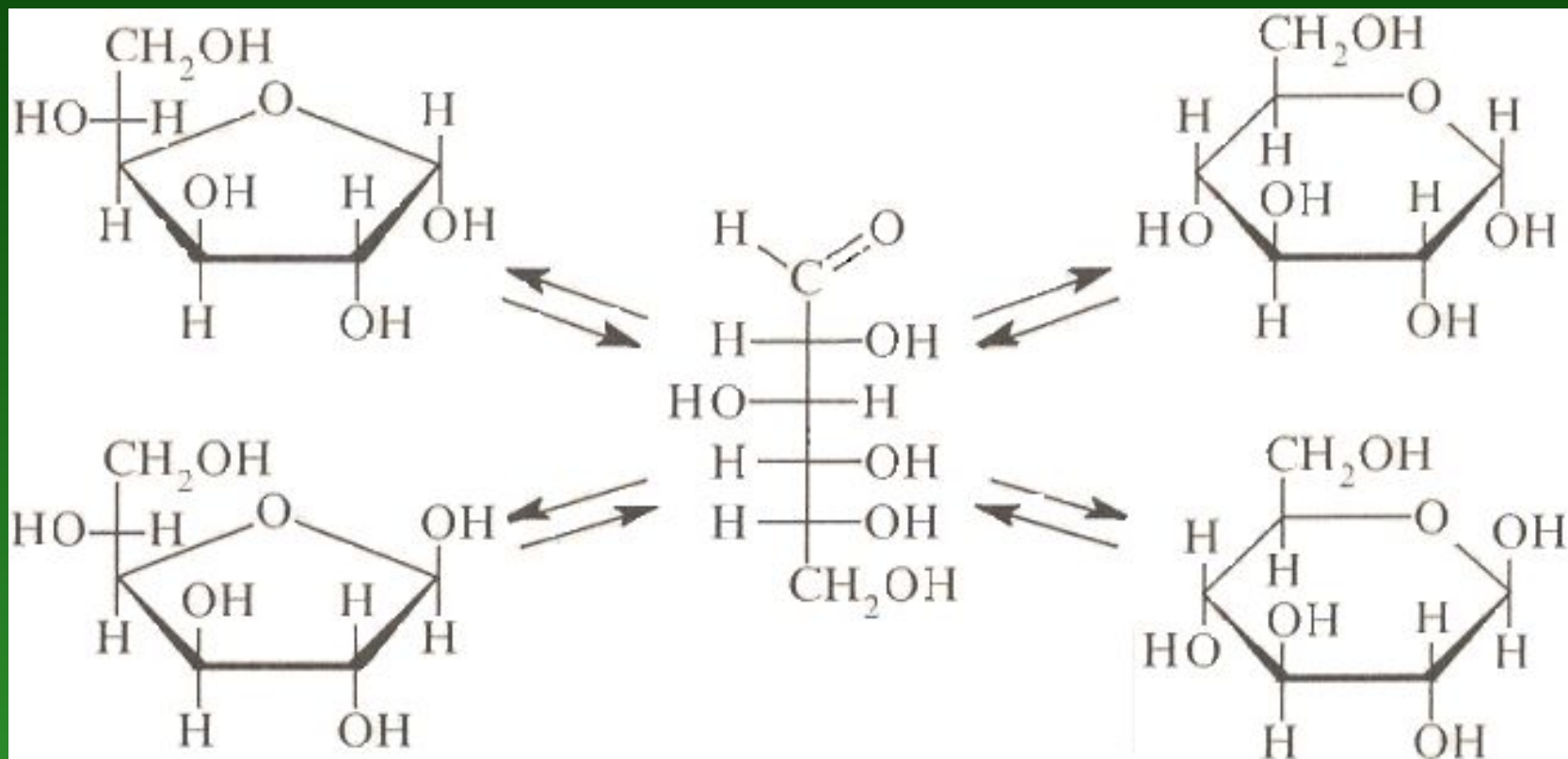
Oxidation — a net decrease in the number of π bonds to hydrogen or electropositive element, or a net increase in the number of bonds to electronegative elements. A net loss of electrons.



Reduction — a net increase in the number of σ bonds to hydrogen or electropositive element, or a net decrease in the number of bonds to electronegative elements. A net gains electrons.



Rearrangement reactions

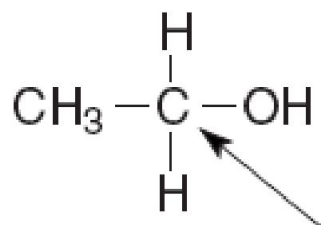


Alcohols

- **Alcohols** are a family of compounds containing a hydroxyl (OH) group bonded to an sp^3 hybridized carbon atom. The most widely known alcohol is ethanol (ethyl alcohol, CH_3CH_2OH).

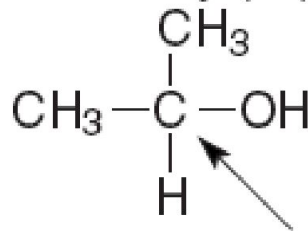
classification

Primary (1°) alcohol



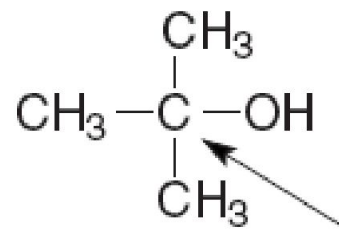
1° carbon atom

Secondary (2°) alcohol



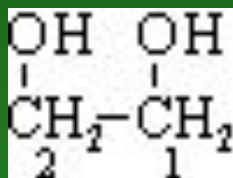
2° carbon atom

Tertiary (3°) alcohol

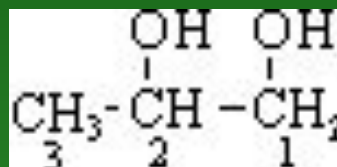


3° carbon atom

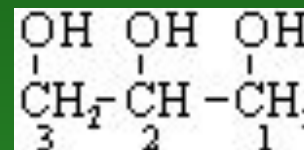
$\text{CH}_3\text{CH}_2\text{OH}$
methanol
ethanol



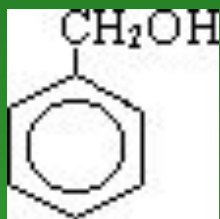
1,2-Ethenediol



1,2-propanediol



1,2,3-propanetriol

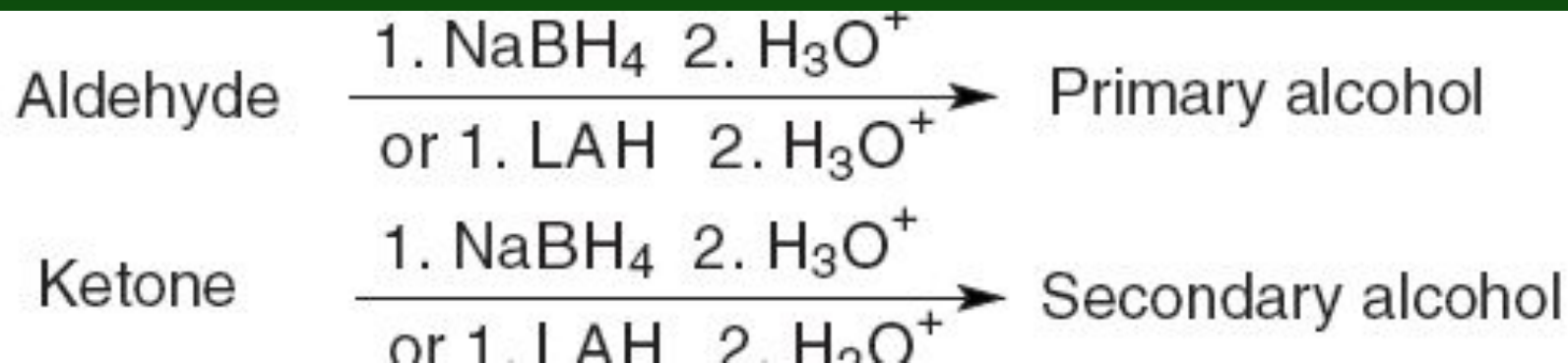


phenylmethanol (benzyl alcohol)



Propen-2-ol

Preparation of Alcohols



Reaction

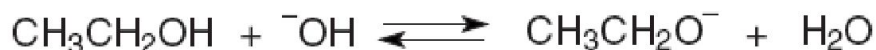
Alcohols react with active metals such as sodium and potassium,



$\text{p}K_{\text{a}} = 15.9$

$\text{p}K_{\text{a}} = 36$

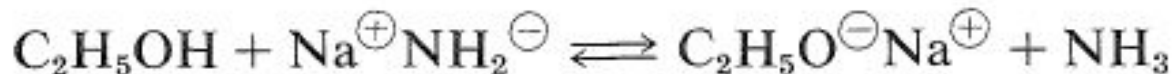
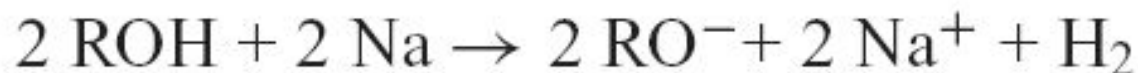
Much weaker acid



$\text{p}K_{\text{a}} = 15.9$

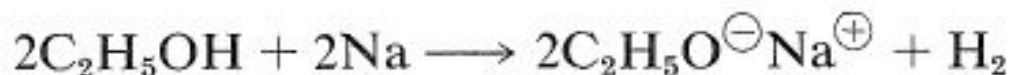
$\text{p}K_{\text{a}} = 15.7$

Slightly weaker acid

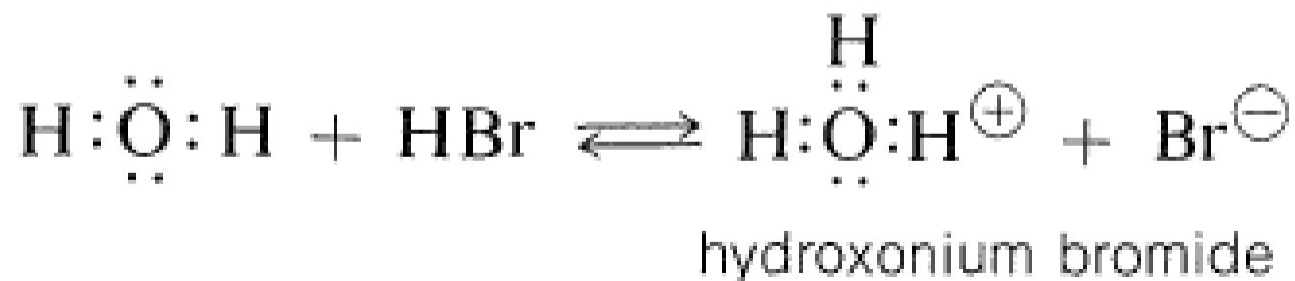
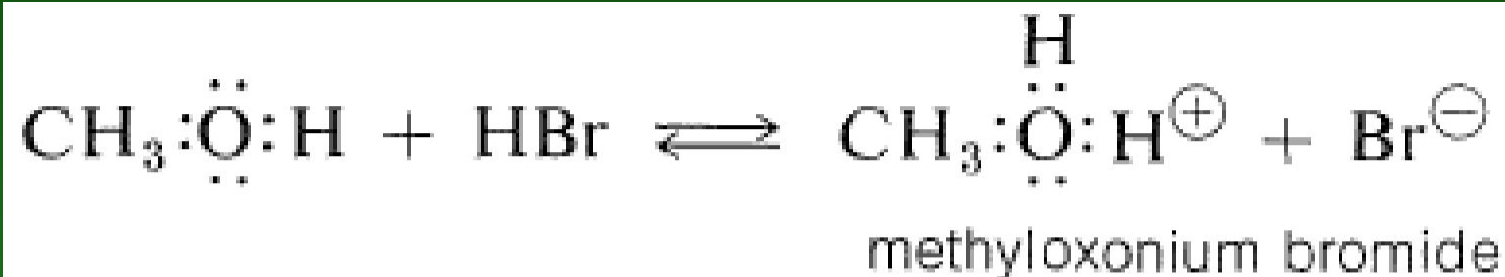


sodium amide
(sodamide)

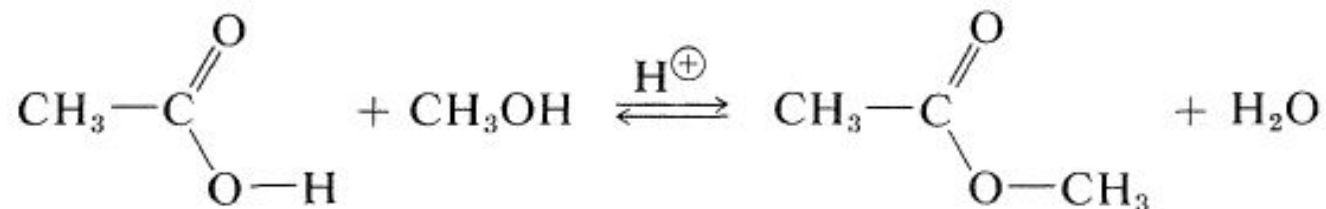
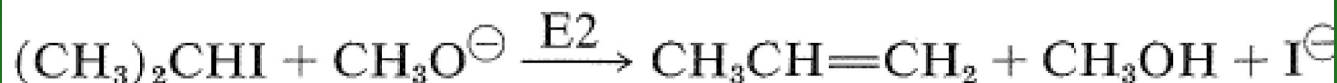
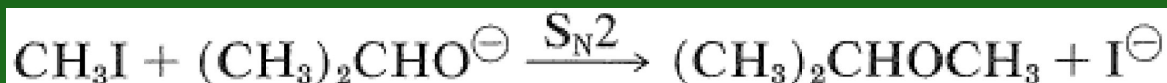
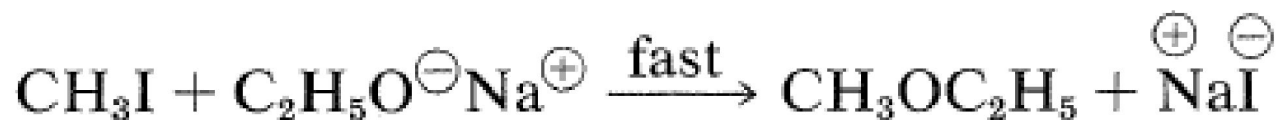
sodium ethoxide

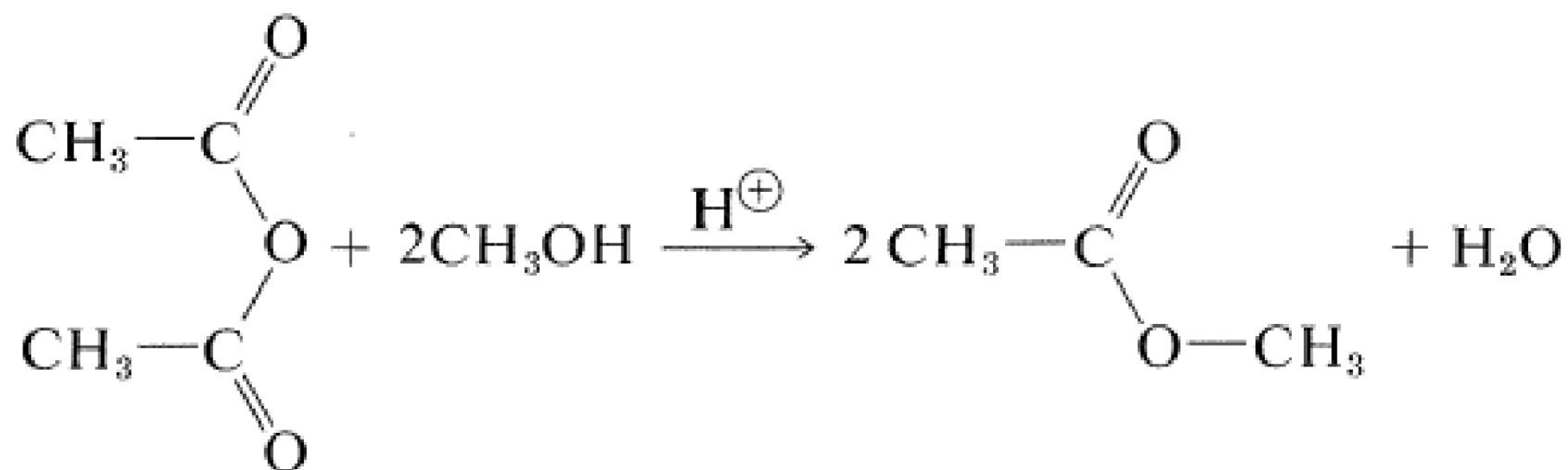
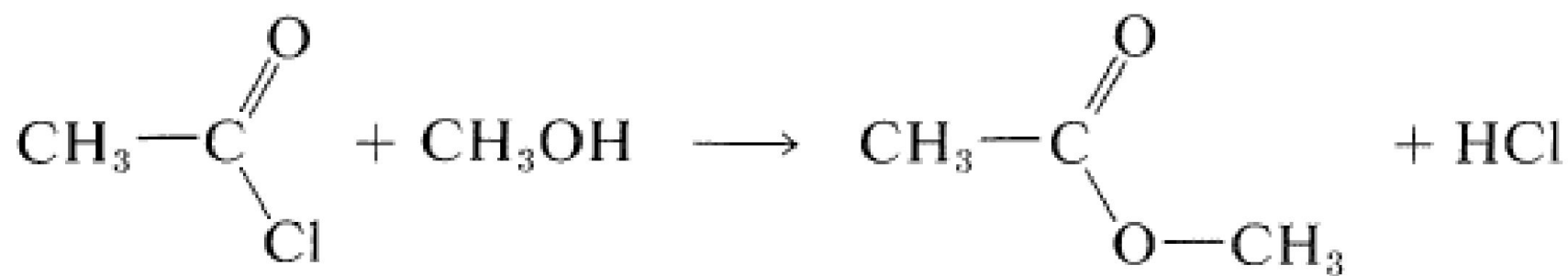


Basic Properties

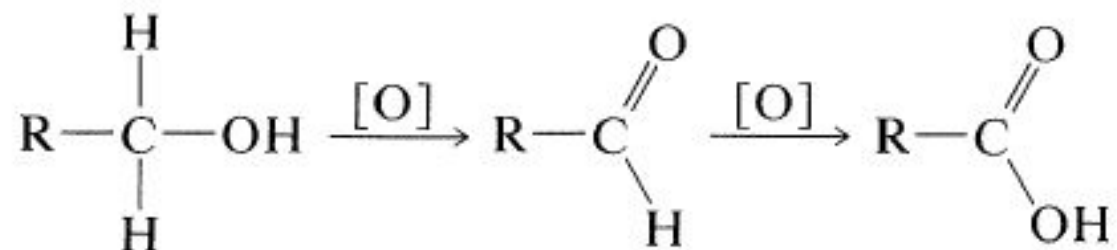


Nucleophilic Properties

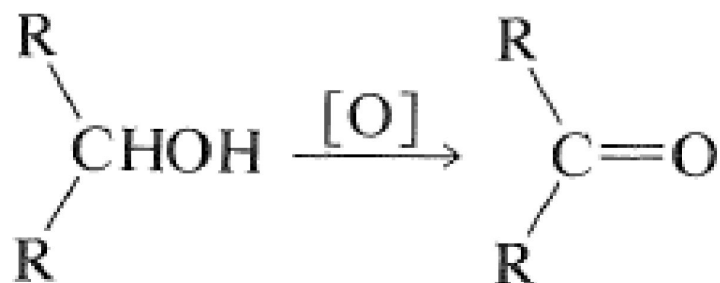




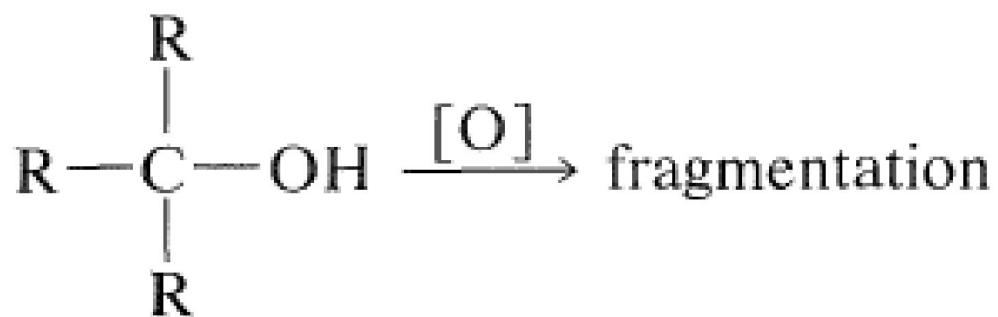
primary alcohols



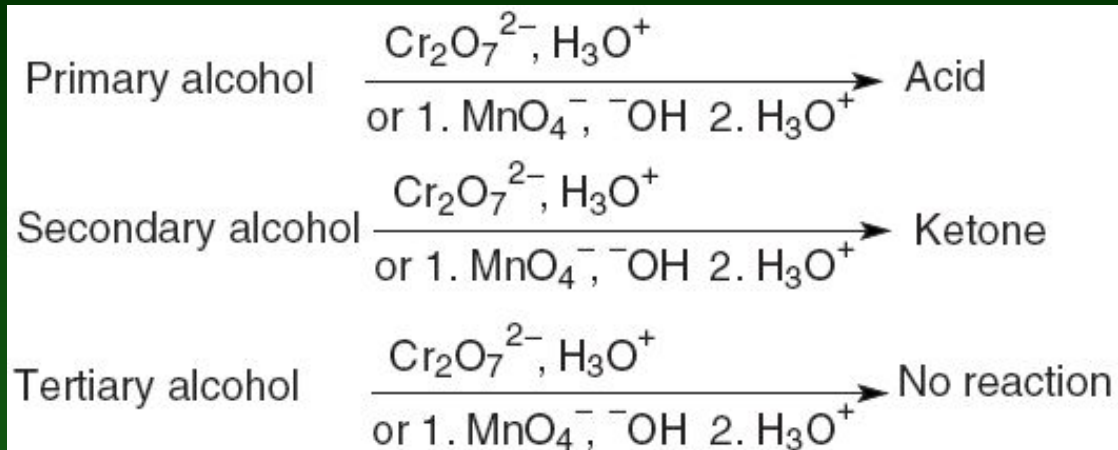
secondary alcohols



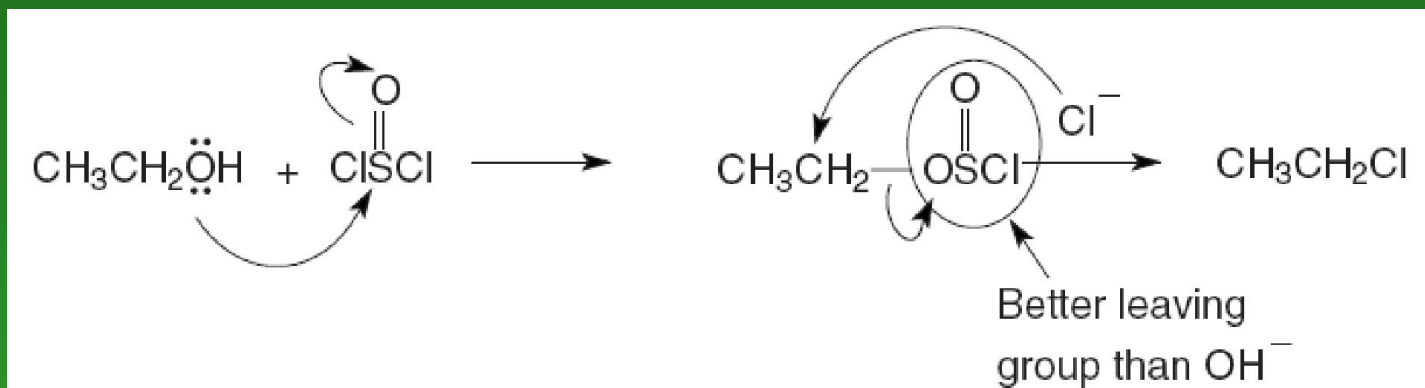
tertiary alcohols



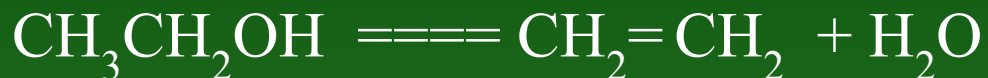
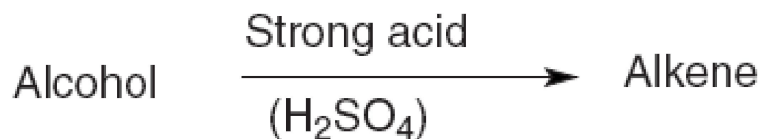
- Oxidation reactions.



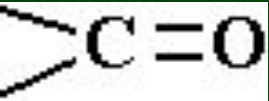
- Conversion of Alcohols to Alkyl Halides



Dehydration Reactions

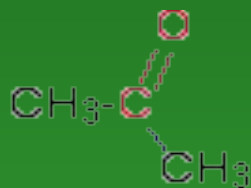
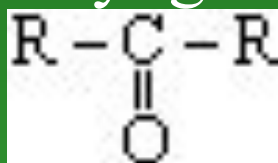


Carbonyl compounds

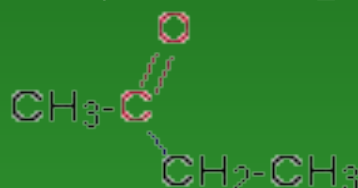
- compounds which contain a *carbonyl group* - a carbon-oxygen double bond 
- Aldehyde** - a carbonyl compound containing two hydrogen atoms or hydrogen and alkyl group.



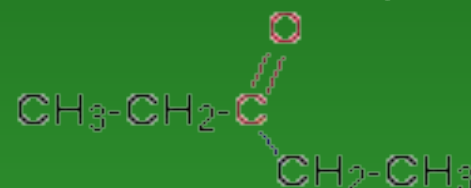
- Ketene** - a carbonyl compound containing a pair of cumulative double bonds of which one is the carbonyl group, or **ketone** is a carbonyl compound containing two alkyl groups.



propanone

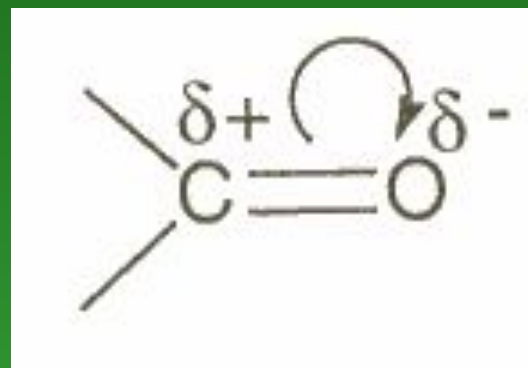
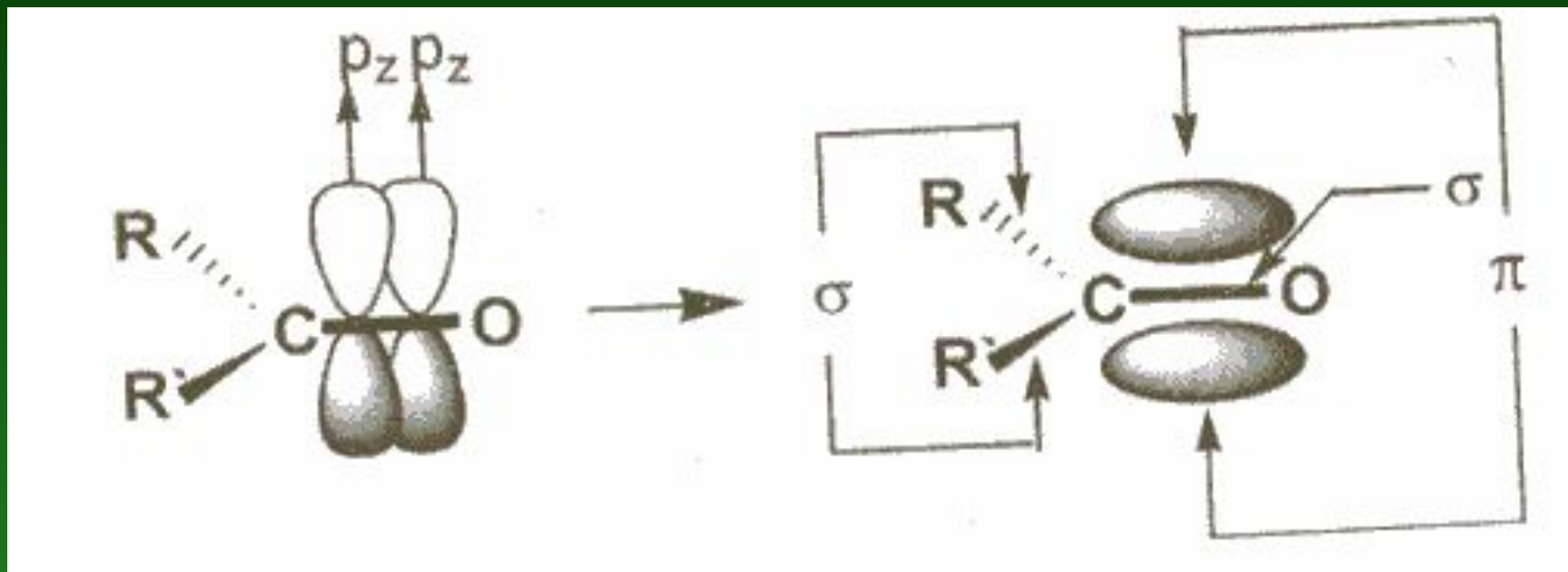


butanone

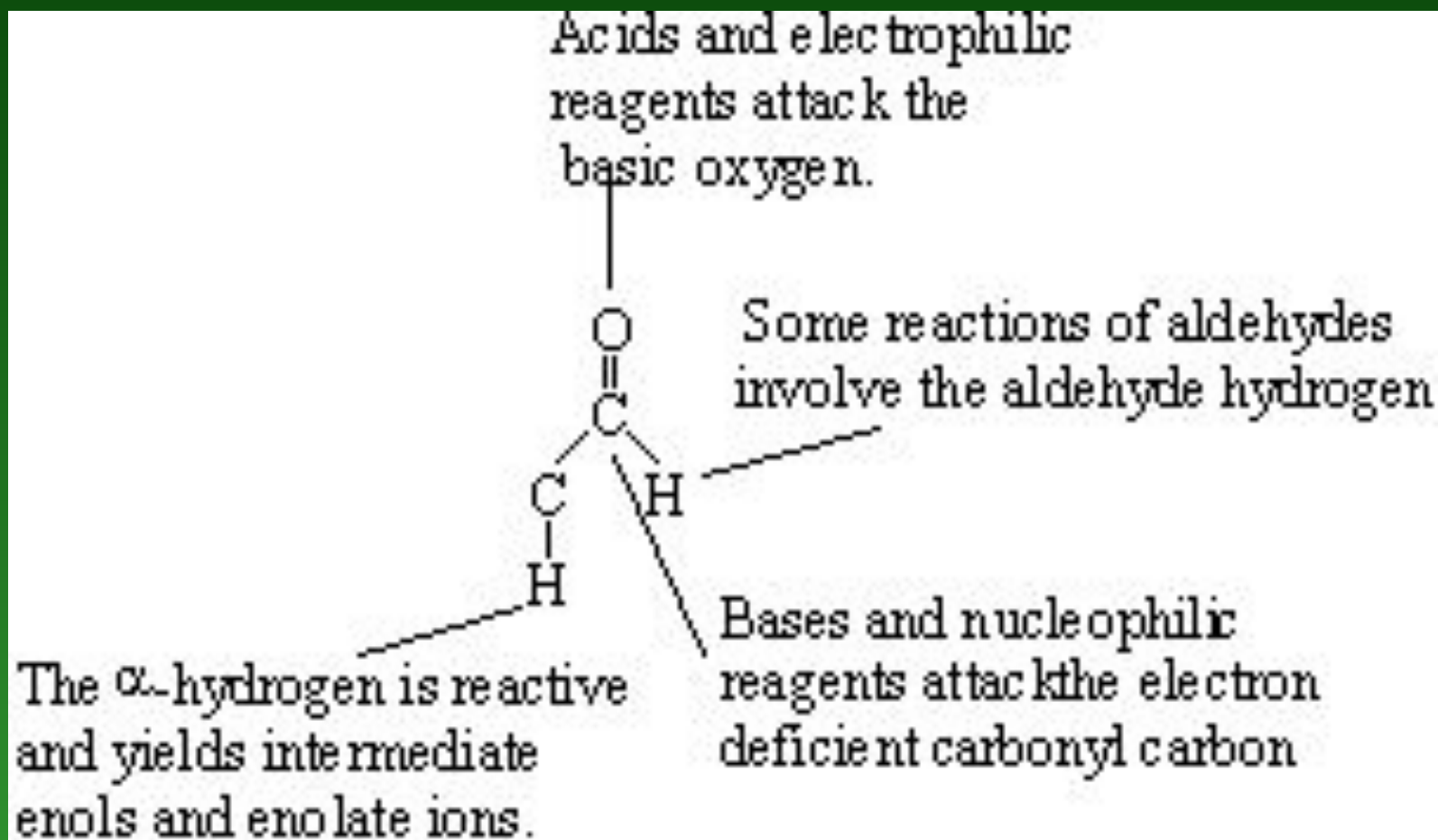


pentan-3-one

Structure of carbonyl group

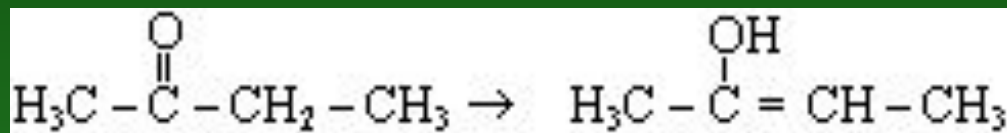
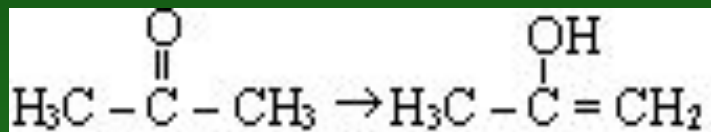


REACTION OF ALDEHYDES AND KETONES

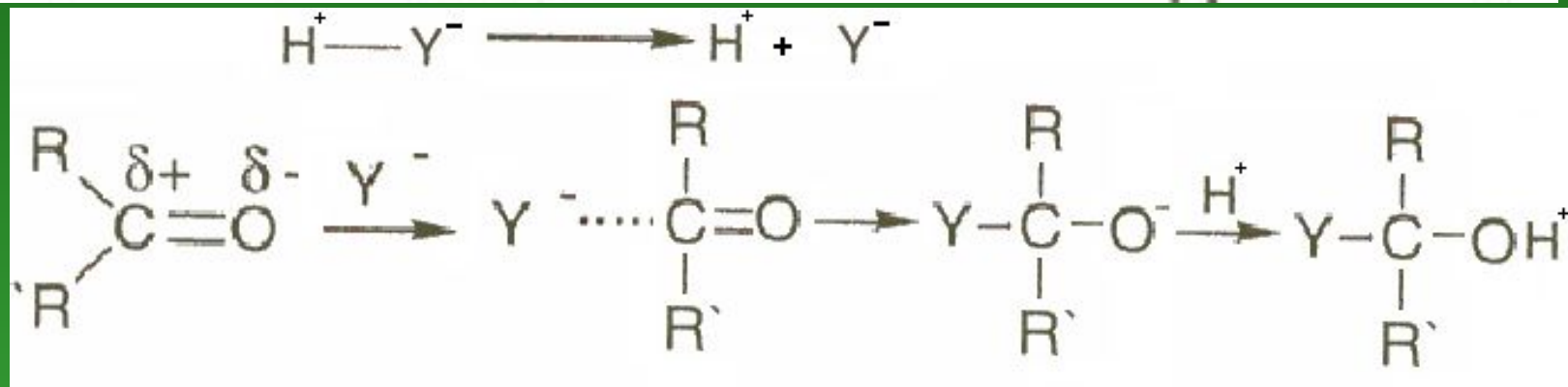
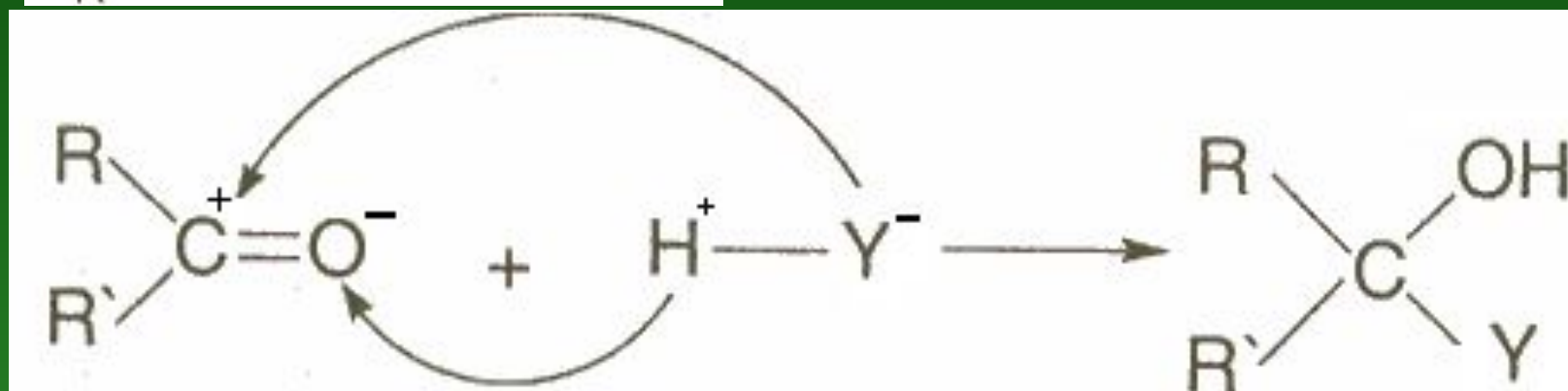
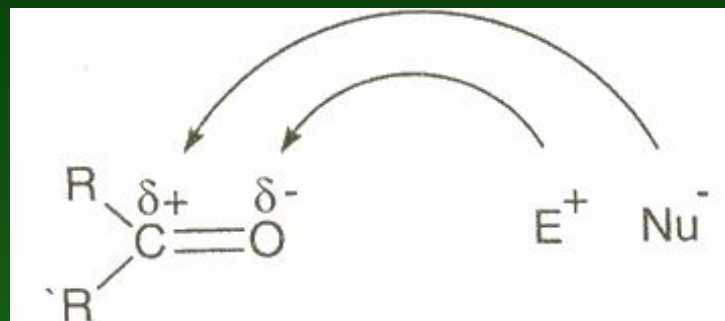


Keto – enol equilibrium.

- Aldehydes and ketones exist in solution as an equilibrium mixture of two isomeric forms, the keto form and the enol (from -ene + -ol, unsaturated alcohol) form.

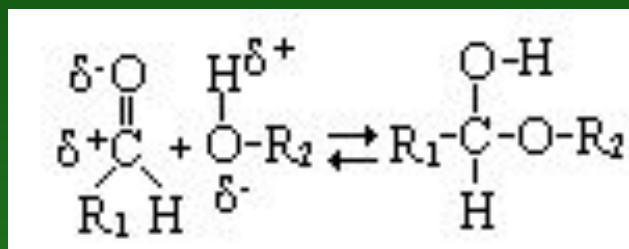


Nucleophilic addition reaction of Aldehydes and Ketones.

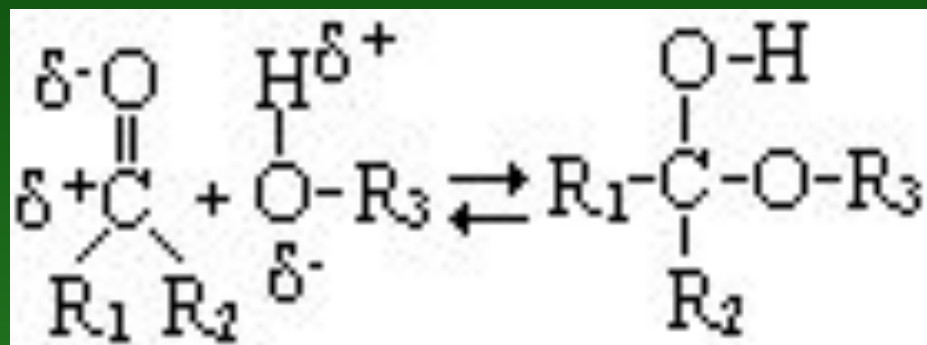


Hemiacetals and Hemiketals.

- The product of the addition of one molecule of an alcohol to an aldehyde is called a hemiacetal. Similarly, the addition of one molecule of alcohol to a ketone produces a hemiketal.



- aldehyde alcohol hemiacetal

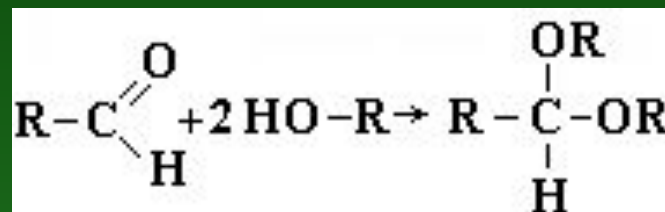


- ketone alcohol hemiketal

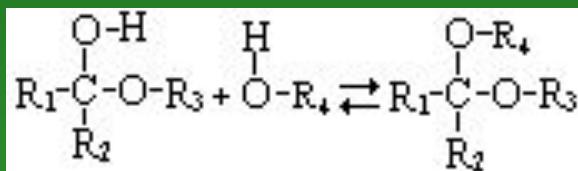
Acetals and Ketals.

- If a small amount of acid catalyst is added to a hemiacetal reaction mixture, then the hemiacetal reacts with a second alcohol molecule to form an **acetal**.

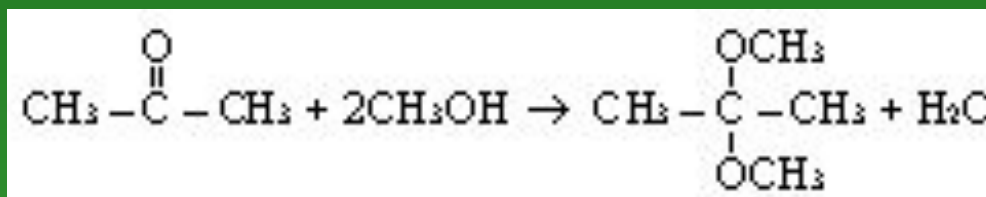
acetal

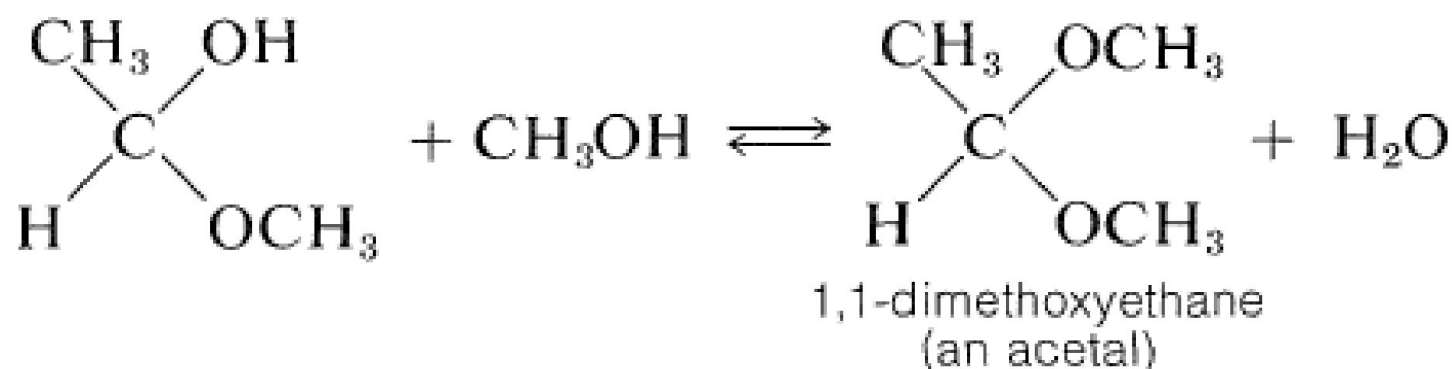
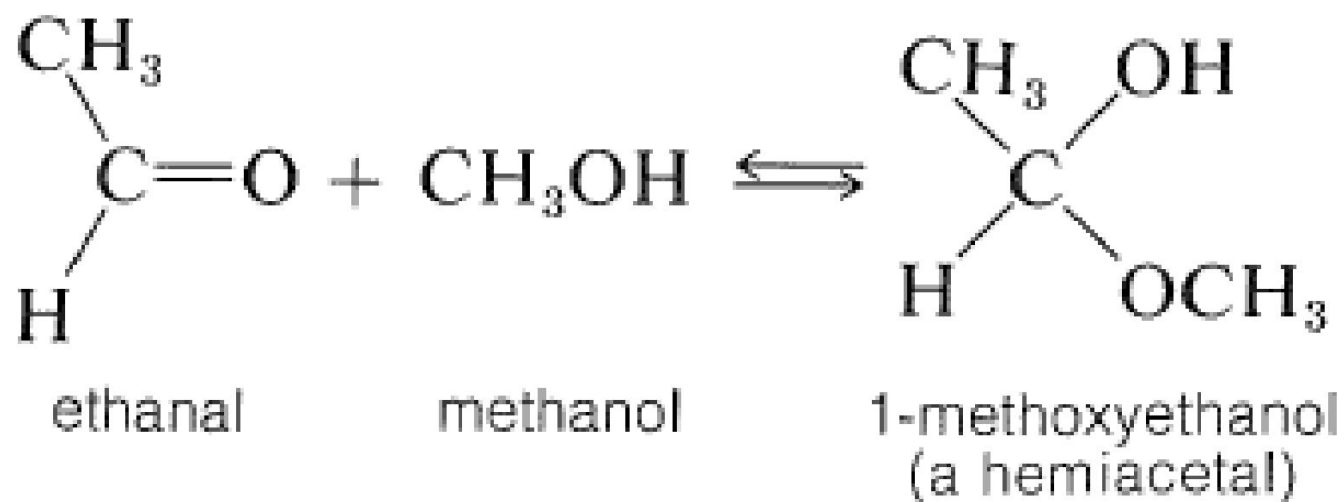


Similarly, in the presence of an acid catalyst, the reaction of a second alcohol molecule with a hemiketal produces a *ketal*.

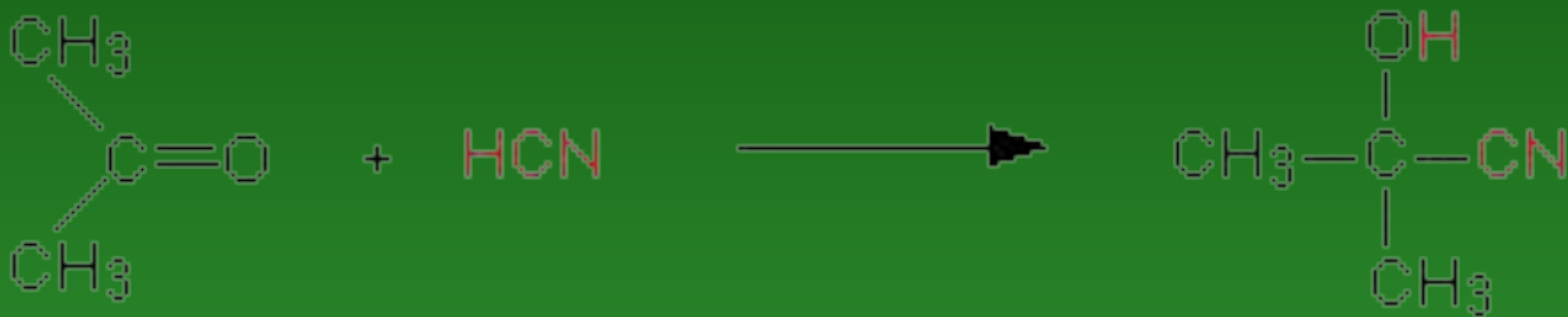


ketal



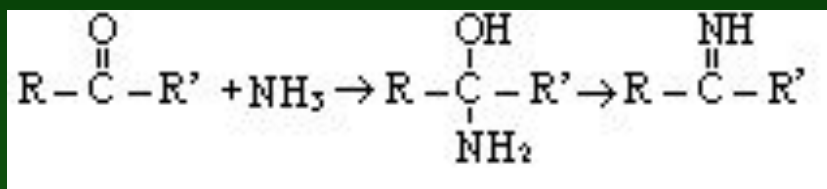


Addition of hydrogen cyanide to aldehydes and ketones

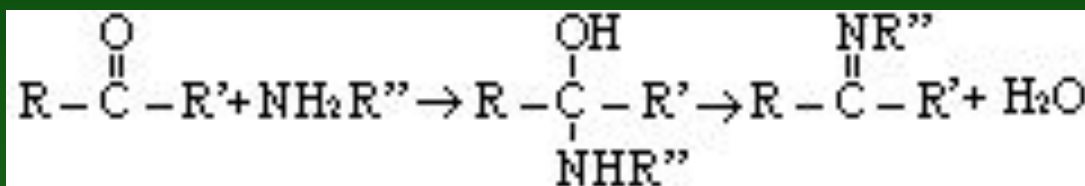


Reaction with the ammonia and its derivatives (addition-elimination reactions)

• Ammonia

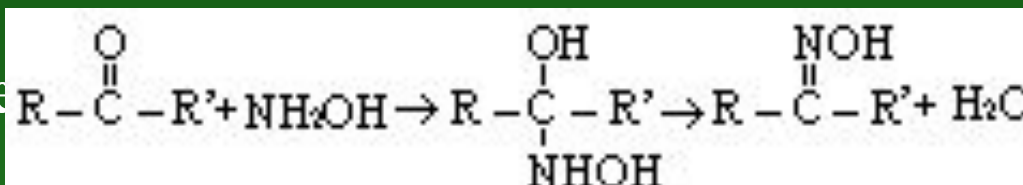


• Amines



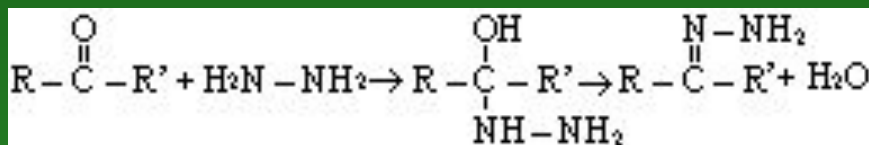
imine

Hydroxylamine



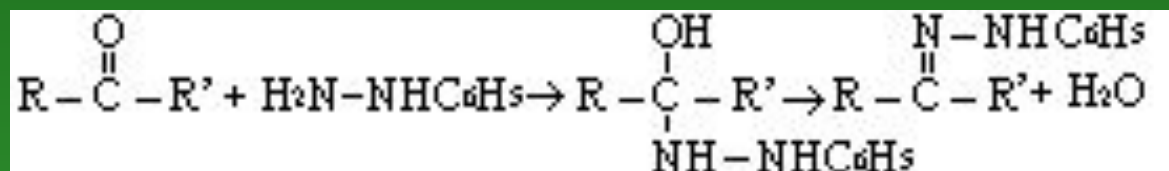
oxyme

Hydrazine



hydrazone

Derivative of hydrazine



alkyl- or arylhydrazone.

Oxidation of Aldehydes and Ketones.

a) Using Tollens' reagent (the silver mirror test)

Tollens' reagent contains the diamminesilver(I) ion, $[\text{Ag}(\text{NH}_3)_2]^+$.



- **Using Fehling's solution or Benedict's solution:**

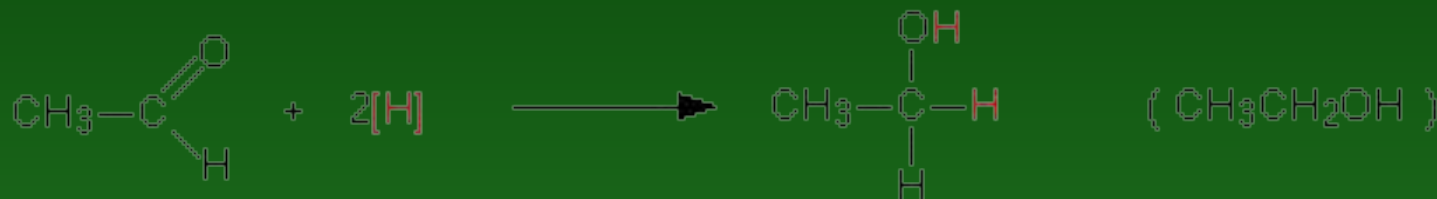
- **Fehling's solution** contains copper (II) ions complexed with tartrate ions in sodium hydroxide solution.

- **Benedict's solution** contains copper (II) ions complexed with citrate ions in sodium carbonate solution.



The reduction of an aldehyde and a ketone

- In general terms, reduction of an aldehyde leads to a *primary alcohol*.



- Reduction of a ketone leads to a *secondary alcohol*.



A close-up photograph of a flower with yellow and white petals and green variegation. The text "Thanks you for attention!" is overlaid in blue.

Thanks you for attention!