People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

University of Ghardaia

Organic chemistry –
Courses and corrected exercises

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Table of Contents

Chemistry is divided into two branches: organic chemistry and inorganic chemistry.
Organic chemistry is the field that studies organic compounds. These compounds can be natural or synthetic.

Organic compounds are compounds that essentially contain carbon except carbon monoxide (CO), carbon dioxide (CO_2), carbonates (K_2CO_3, Na_2CO_3, $NaHCO_3$), cyanides (KCN, NaCN), disulphide (CS_2) and carbides (CaC_2) which are inorganic compounds. Organic compounds are formed by covalent bonds. They are rarely soluble in water and easily decompose by heat.

Until the 19th century, organic chemistry studied the substances produced by living beings as well as the bodies resulting from their transformations. Their synthesis seemed impossible, despite many efforts, until 1828 when Wöhler achieved the impossible: he synthesized urea. But it was around the

This Polycopie of “organic chemistry” is intended to students of the second year license of L2 Process Engineering and Materials Science (SM) semester module. Its use is obviously possible for students of biology, chemical engineering, etc...

This manual deals with the chemical functions with a very pedagogical set of concepts and methods and it draws on a series of reference books that have led to the current understanding of organic chemistry, essential knowledge for any student moving towards the scientific field

The present work is presented in four chapters. It is reinforced with examples of application in order to help the student to better assimilate the new concepts to carry out his examination.

The first chapter studies nomenclatures. Find the name of a molecule by knowing the structure or find the structure of a molecule by knowing the name.

The second chapter is devoted to the study of stereoisomerism. Isomers have strictly the same number of atoms but their physical, chemical and/or biological properties differ.

The third chapter deals with the study of some mechanisms. The study of mechanisms provides invaluable assistance in understanding and predicting reaction processes.

Each chapter is accompanied by examples and applications. Thus, the reader will have to establish a relevant link between the definitions and the corresponding applications.

Finally, the fourth chapter gives exercises along with their solutions. Through these exercises, the polycopie gives the keys to understand the different types of organic chemistry problems.

Exercises without solution are also included to push the learning further and to encourage the student to think about the problems of organic chemistry.

I used the Chem Draw (ultra 0.8) Cambridge Soft software which allows us to design the molecules and the reactions.

Chapter 1: Carbon atom and nomenclature

The carbon atom is the basis of any organic structure. **Carbon atoms** ***can*** **join** ***together to*** **form chains** ***or rings. Organic chemistry creates long and often complex molecules for which it seems very complicated to give a name or to build the molecule from its name. A few rules make it possible to quickly find the link name molecules and without ambiguity, that is to say that everyone must name the same molecule with the same name***.

I. Study of the carbon atom

I. 1 Definition:

The carbon atom: carbon gives covalent bonds with hydrogen, oxygen, nitrogen and non-metals

Organic compounds are essentially covalent compounds
Because each carbon is identical, they all have four valence electrons, so they can easily bond with other carbon atoms to form long chains or rings

I. 2 The nucleus

The nucleus, that dense central core of the atom, contains both protons and neutrons. Electrons are outside the nucleus in energy levels. Protons have a positive charge, neutrons have no charge, and electrons have a negative charge. For example, That means a carbon atom has **6 protons, 6 neutrons, and 6 electrons,** with a total positive charge of 6+

(nucleus = protons) + neutrons) and electron cloud

6 protons , 6 neutrons, and a net charge of +6

Figure 1:carbon atom nucleus

I. 3 Properties of the carbon atom

-IONIZATION ENERGIES

1 st : 11,26030 eV	4 th : 64,4939 eV
2 nd : 24,3833 eV	5 th : 392,087 eV
3 rd : 47,8878 eV	6 th : 489,99334 eV

-VARIOUS

Electronegativity (Pauling)	2.55
Massic heat	710 $J \cdot kg^{-1} \cdot K^{-1}$
Electrical conductivity	61×10^3 $S \cdot m^{-1}$
Thermal conductivity	129 $W \cdot m^{-1} \cdot K^{-1}$

-Isotopes of carbon characteristics

Isotope	N	Mass (u)	abundance	Period	**Decay mode**	Ed	radioactive reaction	**Nuclear spin**
^{12}C	6	12	99.9%		Stable with 6 neutrons			0+
^{13}C	7	13.003355	1.1%		Stable with 7 neutrons			½−
^{14}C	8	14.0003242	trace	5730 years	ray ß-	0,156	^{14}N	0+

I. 4 Electronic structure of the carbon atom

- **hybridization:** The mixing of the atomic orbitals in an atom to produce a set of hybrid orbitals.
- **hybrid orbitals:** The atomic orbitals obtained when two or more nonequivalent orbitals form the same atom combine in preparation for bond formation.

The hybrid orbitals are all the same

Carbon state	Electronic configuration	Valence number
Fundamental	6C : $1s^2$ $2s^2$ $2p^2$	02 only
excited	$1s^{2}$ $2s^{1}$ $2p_x^1$ $2p_y^1 2p_z^1$	04

I. 5 Chemical bonds

Carbon is the basic element in organic chemistry. **Covalent bond**, in chemistry, the interatomic linkage that results from the sharing of an electron pair between two atoms. The binding arises from the electrostatic attraction of their nuclei for the same electrons. A covalent bond forms when the bonded atoms have a lower total energy than that of widely separated atoms.

Types of chemical bonds

The valence shell (S.V.) of an element corresponds to the last unsaturated electron shell (S.E.). Only this valence shell is involved in the formation of chemical bonds. The valence of an element is the number of single electrons

The Atomic Orbitals are (s, p, d, f)

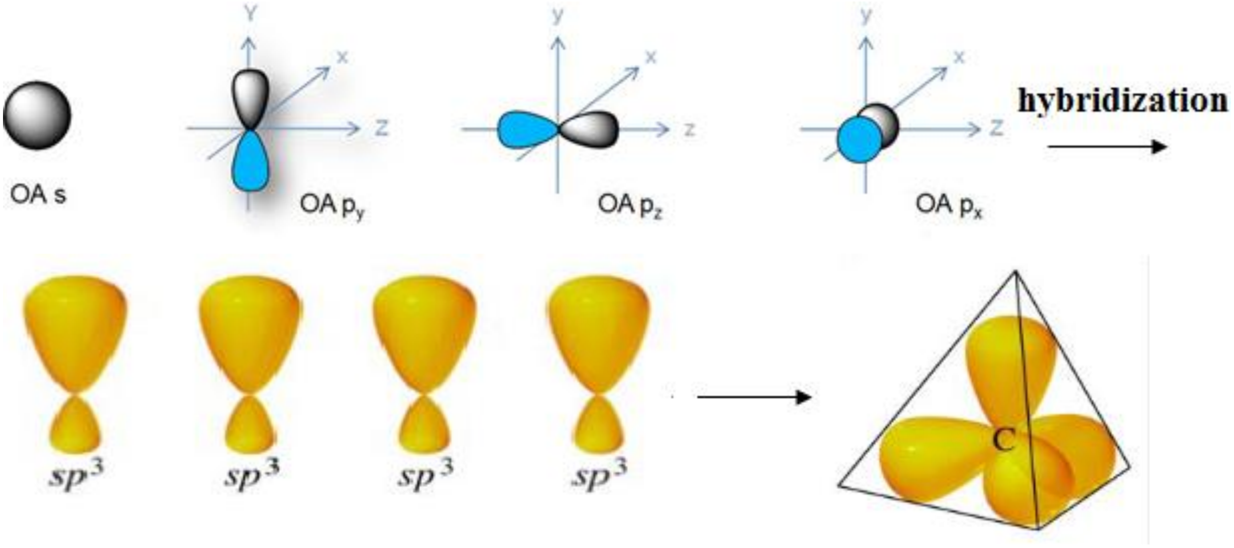
There are various types of hybridizations, we have:

1) sp3 hybridization Tetrahedral (tetragonal)

When the carbon atom is bonded to four other atoms the hybridization is said to be sp^3 type. Here 1 s orbital and 3 p orbitals in the same shell of an atom combine to form four new equivalent orbitals. The arrangement is tetrahedral with a bond angle of 109.5°.

The new orbitals formed are called **sp^3 hybrid orbitals.**

1 S orbital + 3 P orbitals → 4 sp3 hybrid orbitals



4 sp3 hybrid orbitals

Spatial layout

***Fig 2**: Representation of a carbon in the state of sp3 hybridization*

Example: carbon hybridization in the CH_4 molecule The 4 bonds are identical and indistinguishable

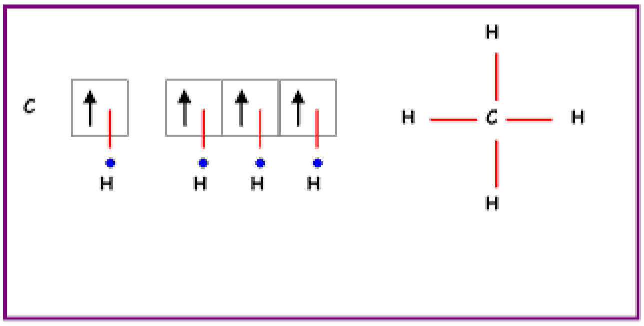


Figure 3 : formation of CH_4 according to Lewis

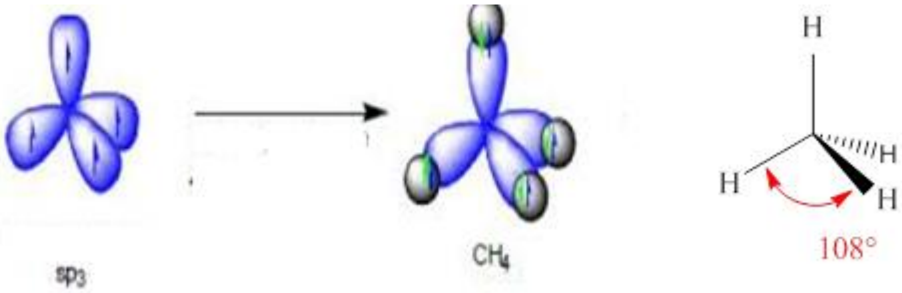
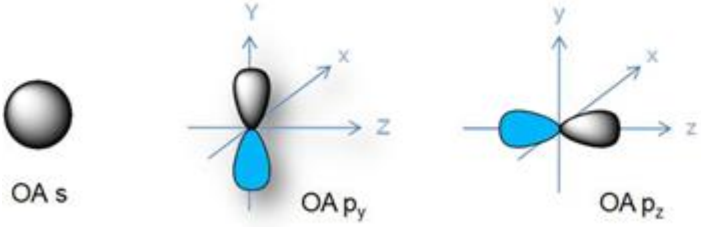


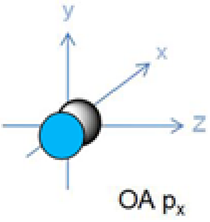
Figure 4 : *formation of the methane molecule*

2) sp2 hybridization (trigonal)

sp^2 hybridization is observed when one s and two p orbitals of the same shell of an atom mix to form 3 equivalent orbitals. The new orbitals formed are called **sp^2 hybrid orbitals.**

1 S orbital + 2 P orbitals $\longrightarrow$ 3 sp2 hybrid orbitals + 1 pure P orbital





Combination of the 2s orbital and the 2p$_x$ and 2p$_y$ orbitals of carbon

Orbital untouched By hybridization

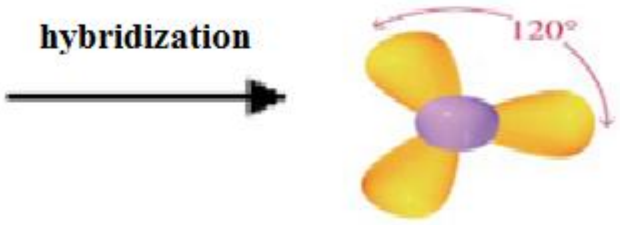
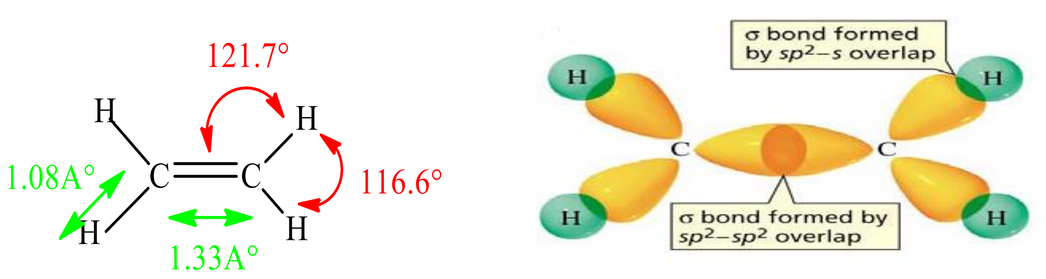


Fig 5*:Representation of a carbon in the state of sp2 hybridization*
The orbital pz is p‘ orthogonal’

The ethylene molecule associates 2 sp2 hybridized carbons.



The double bond between the 2 C

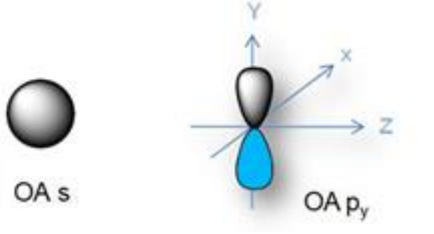
is actually 1 σ bond + 1 π bond

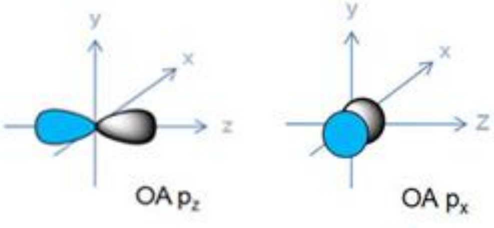
Fig 6**: formation, spatial representations and models of the ethylene molecule**

3) Sp hybridization or digonal

sp hybridization is observed when one s and one p orbital in the same main shell of an atom mix to form two new equivalent orbitals. The new orbitals formed are called **sp hybridized orbitals.** It forms linear molecules with an angle of 180°

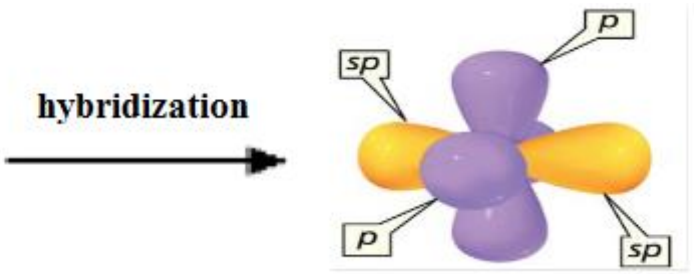
1 S orbital + 1 P orbital ⟶ 2 **sp** hybrid orbitals + 2 pure P orbitals





Combination of 2s orbital and 2px orbital

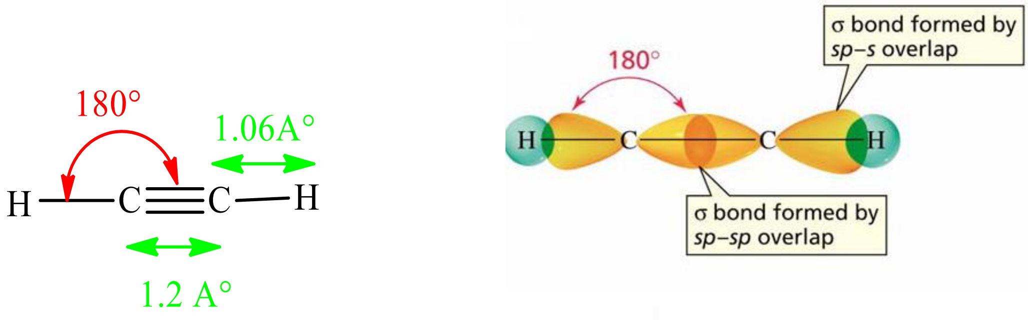
Orbitals not affected by hybridization



2 sp hybrid orbitals and 2pure orbital from 2 py , 2pz bonds

Fig 7:*Representation of a carbon in the state of sp hybridization*
The 2 orbitals py and pz are orthogonal

In this case the acetylene is the simplest, C_2H_2 . First, draw the Lewis structure:
The simplest molecule associating 2 sp hybridized carbons is that of acethylene.



The triple bond between the 2 C
1 σ bond + 2 π bonds

Fig 8: formation of the acetylene molecule

Important Points To Remember

- The different types of hybridization (sp^3, sp^2, sp) in carbon determines the structure and reactivity of carbon compounds that are formed.
- Hybridized orbitals are formed by the mixing of orbitals where electrons are mostly in an excited state.
- The different types of hybridization influence the bond strength and structure of the molecules.

II. U.I.C.P.A Nomenclature Rules

(International Union of Pure and Applied Chemistry).

Organic chemistry creates long and often complex molecules for which it seems very complicated to give a name or to build the molecule from its name

II. 1 Alkanes

a) Definition

Normal alkanes:

Alkanes are saturated (no multiple bonds) aliphatic (open carbon chain) hydrocarbons (compounds of carbon and hydrogen). Normal alkanes have an additional unbranched chain.

b) Nomenclature

Table 1: Nomenclature of the first alkanes

Semi-developed formulas	Name
CH_4	methane
CH_3-CH_3	ethane
CH_3-CH_2-CH_3	propane
CH_3-$(CH_2)_2$-CH_3	butane
CH_3-$(CH_2)_3$-CH_3	pentane
CH_3-$(CH_2)_4$-CH_3	hexane
CH_3-$(CH_2)_5$-CH_3	heptane
CH_3-$(CH_2)_6$-CH_3	octane
CH_3-$(CH_2)_7$-CH_3	nonane
CH_3-$(CH_2)_8$-CH_3	decane

II. 2 Branched alkanes

a) Definition:

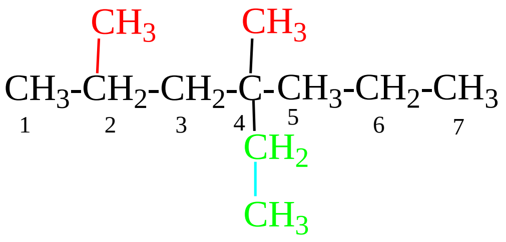
A non-cyclic alkane can be written: **C_nH_{2n+1} –;** or R-; R – is an alkyl group. An alkyl group is obtained by removing an hydrogen atom from the formula of an alkane.

b) Nomenclature

Table 2: Nomenclature of the first alkyl radicals.

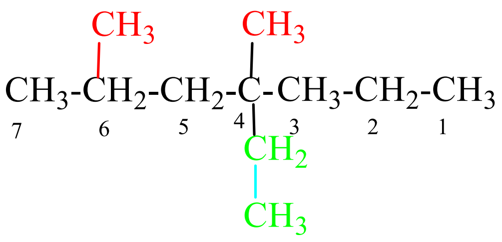
Normal side chains	
Semi-developed formulas	Name
CH_3-	methyl
CH_3-CH_2-	ethyl
CH_3-CH_2-CH_2-	propyl
CH_3-$(CH_2)_2$-CH_2-	butyl
CH_3-$(CH_2)_3$-CH_2-	pentyl
CH_3-$(CH_2)_4$-CH_2-	hexyl
CH_3-$(CH2)_5$-CH_2-	heptyl
CH_3-$(CH_2)_6$-CH_2-	octyl

- The main chains are always the longest chains.
- The main chains bear the names of the corresponding alkane
- The positions of the side chains must be indicated by indices if confusion is possible.
- Several side strings are written in alphabetical order.
  Indices: di, tri, tetra, penta, hexa, hepta, octo, nona, deca…
- The numbering of the main string begins with the end from which the greatest number of branches first appears.



$CH_3-\overset{CH_3}{CH_2}-CH_2-\underset{\underset{CH_3}{CH_2}}{\overset{CH_3}{C}}-CH_3-CH_2-CH_3$

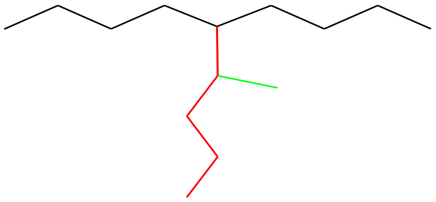
4-ethyl-2,4-dimethylheptane



$CH_3-\overset{CH_3}{CH_2}-CH_2-\underset{\underset{CH_3}{CH_2}}{\overset{CH_3}{C}}-CH_3-CH_2-CH_3$

Incorrect 4-ethyl-4,6-dimethylhepane

The nomenclature of side chains follows the same rules as that of main chains with the only exception that the carbon attached to the main chain bears the number 1



Example: 5-(1-methylbutyl) nonane

***Side groups with non-systematic nomenclature**

$(CH_3)_2CH$- isopropyl

$(CH_3)_3C$- *tert*-butyl or tertiobutyl

$CH_2=CH$- vinyl

c) Application: Write the structural formula of the following compounds:

- Dimethylpropane
- 3-ethylpentane
- 2,4-dimethylpentane
- Methylbutane

II. 3 Alkenes :

a) Definition:

Alkenes are unsaturated, non-cyclic hydrocarbons that have a carbon-carbon C=C double bond.

Their general formula: **C_nH_{2n}.**

Note: the carbon atoms of the double bond are trigonal.

b) *Nomenclature:*

The suffix **-ene** characterizes alkenes.

For straight chain alkenes, it is the same basic rules as nomenclature of alkanes apply except the **-ane** suffix is changed to **-ene**. Also, the position of double bond in the parent chain of the alkene is indicated with a number

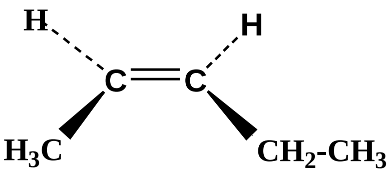
thanks to the Greek prefix indicating the number of carbon atoms followed by the suffix –**ene**.

As for alkanes, the substituent groups of the main chain are indicated

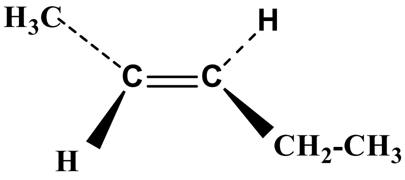
* **Z** and **E** isomerism or stereo-isomerism.

Around a **C–C** single bond there is free rotation while there is no free rotation around a **C=C** double bond.-

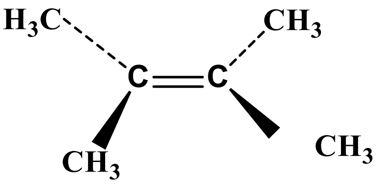
Example:



(Z) pent-2-ene



(E) pent-2-ene



2,3-dimethylbut-2-ene

c) *Application*

Write the condensed structural formula of the following compounds:

- (Z)-hex-2-ene
- 2-methylpent-2-ene
- (E)-4-methylpent-2-ene
- 2,3-dimethylbut-2-ene

- hex-2,4-diene
- 3-propylhept-1-ene

II. 4 Alkynes

a) *Definition:*

Alkynes are unsaturated, non-cyclic hydrocarbons that have a carbon-carbon C≡C trible bond.

Their general formula **C_nH_{2n-2}**

b) *Nomenclature:*

the ending "ane" of the corresponding alkanes is replaced by the ending **"yne".** For the first compound in this series H−C≡C−H, the trivial name acetylene is used instead of ethyne.

Alkynes are named **using the same** general naming **rules** for alkenes,

Example: $CH_3-C\equiv C-CH_3$ But-2-yne. The radicals are obtained by replacing the end "yne" by "ynyle".

Note: If a compound contains both types of facilities (double and triple bonds), the lowest possible indices are given to all the multiple bonds.

$H-C\equiv C-CH=CH-CH_3$ Pent-3-en-1-yne

P.S. In case of ambiguity, the lowest index is given to the double bond.

$CH\equiv C\text{-}CH=CH\text{-}CH=CH_2$ hex-1,3-diène-5-yne

c) *Application*

- Write the condensed structural formula of the following compounds,

  - pent-1-ene-4-yne
  - acetylene (not ethyne)
  - hexatriyne

II. 5 Alcohols

a) *Definition :*

Alcohol is any organic compound that has a hydroxyl group – **OH** attached to a tetragonal carbon atom.

b) *Nomenclature:*

the name for an alcohol uses the -ol suffix with the name of the parent alkane, together with a number to give the location of the hydroxyl group.

-Name the longest carbon chain that contains the carbon atom bearing the —OH group. Drop the final -e from the alkane name, and add the suffix -ol.

-Number the longest carbon chain starting at the end nearest the —OH group, and use the appropriate number, if necessary, to indicate the position of the —OH group.

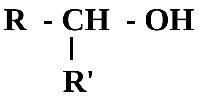
-Name the substituents, and give their numbers as for an alkane or alkene.

- We distinguish:

Primary alcohol

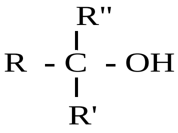
$R-CH_2OH$

Secondary alcohols



$R-CH(R')-OH$

Tertiary alcohols



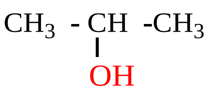
$R-C(R')(R'')-OH$

Example

Ethanol

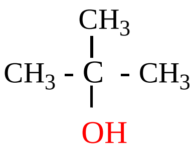
CH_3-CH_2-OH

Propan-2-ol



$CH_3-CH(OH)-CH_3$

2-methylpropan-2-ol



$CH_3-C(CH_3)(OH)-CH_3$

c) *Applications:*

Write the condensed structural formula of the following compounds: specify the class of each alcohol:

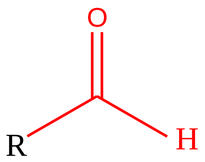
- 2,3-dimethylbutan-1-ol Alcool Primaire
- 2-methylpropan-1-ol Alcool Primaire
- 2-methylpropan-2-ol Alcool Tertiaire

- 2,3-dimethylpentan-3-ol Alcool Tertiaire
- 2-ethylbutan-1-ol
- 2-methylpropan-2-ol
- Methanol
- 2,3-dimethylbutan-1-ol

II. 6 Aldehydes

a) *Definition :*

- Aldehydes are carbonyl compounds. They have the characteristic group:



aldehydes

Note: Functional carbon is trigonal.

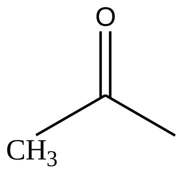
b) ***Nomenclature:*** The name of an **aldehyde** derives from that of the alkane with the same carbon skeleton, by replacing the final **e** by the ending **al**.

Functional carbon is always at the end of the chain and carries the number 1.

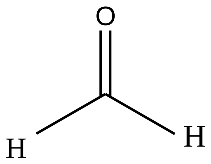
- Example : Methanal: gaseous at ordinary temperature.
- The 37% solution in water gives formaldehyde which allows the preservation of specimens and it is used in the manufacture of bakelite and formica.
- Ethanal: acetaldehyde or acetic aldehyde has an apple odor (θeb = 17°C).

It is used in the manufacture of ethanoic acid

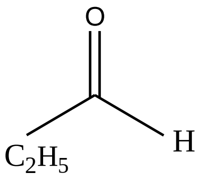
Example :



Ethanal   acetaldehyde



Methanal   formaldehyde



Propanal

c) Applications

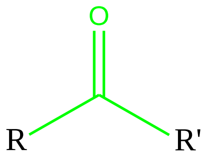
- Write the condensed structural formula of the following compounds,

- Cyclohexane carbaldehyde
- 2,3-dimethylbutanal,
- 2,2-dimethylpropanal
- pivalaldehyde

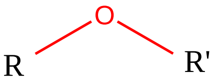
II. 7 Ketones and ether-oxides:

a) Definition:

ketones are carbonyl compounds. They have the characteristic group:



Ketone



ether-oxide

b) Nomenclature:

- The name of a **ketone** derives from that of the alkane with the same carbon skeleton, by replacing the final **e** by the **one** ending preceded by the position of the carbonyl group in the main chain.

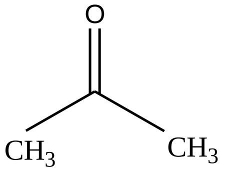
Note: The functional carbon cannot be at the end of the chain.

Acetone: propanone is used as a solvent (nail polish remover).

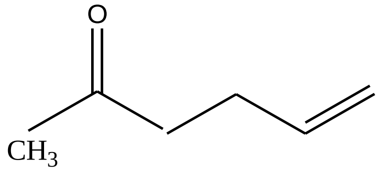
Ether(oxides):

An **ether-oxide** corresponds to the formula **R–O–R** (symmetrical ethers) or R–O–R' (mixed ethers). The name «**oxide**» is followed by that of the alkyl groups R and R' (linked to the O atom), classified in alphabetical order.

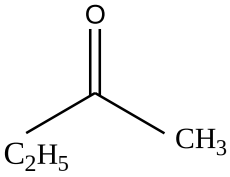
Example :



Propanone(acetone)



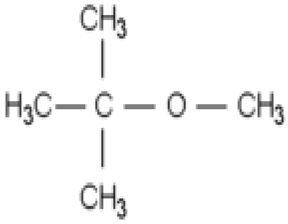
Hex-5-en-2-one



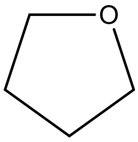
butan-2-one

CH_3-CH_2-O-CH_2-CH_3

Diethyl ether



2-methoxy-2-methylpropane



tetrahydrofuran (THF)

c) ***Applications :***

Write the condensed structural formula of the following compounds:

- 3,3-dimethylbutan-2-one
- 3-propylhexan-2-one
- Propane
- 3-methylbutan-2-one
- 2-ethoxyethanol
- Ethyleneoxide
- Methylvinylether
- Methyltert-butylether
- 4-hydroxyhexan-3-one

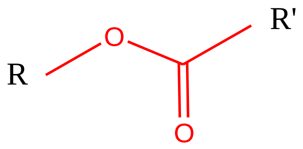
II. 8 Esters :

a) *Definition:*

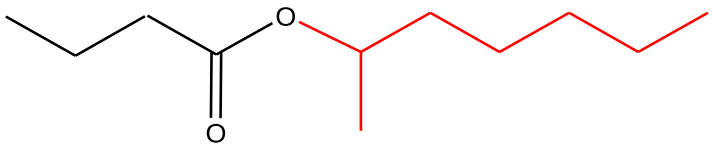
An ester is the product of the dehydration between the hydroxyl group of an organic acid and that of an alcohol.

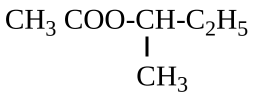
General formula $\mathbf{C_nH_{2n}O_2}$

The name of **the ester** derives from that of the alkane of the same carbon skeleton by replacing the final **e** by the ending **-oate**, and its position only at the end of the chain



- Example :





$$CH_3\,COO\text{-}\underset{\underset{CH_3}{|}}{CH}\text{-}C_2H_5$$

Methylhexyl butanoate.

1-methylpropyl ethanoate

Esters are chemical species that often have a pleasant smell (rose, jasmine, lavender, etc.). They are sometimes the source of natural fruity flavors and are very frequently synthesized for use as food flavorings.

Methyl butanoate: flavor and fragrance agents. Has a fruity type odor and an fusel type flavor

Pentylbutanoate: apricots

Ethyl butanoate: pineapple

Ethyl ethanoate: Solvent

b) Applications*:* Write the condensed structural formula of the following compounds

- Methyl cyclohexane carboxylate
- methylethanoate

II. 9 Carboxylic acids

a) Definition:

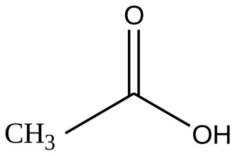
- Carboxylic acids have in common the characteristic group: **R – COOH**

- The functional carbon is trigonal and it is bonded to two oxygen atoms.

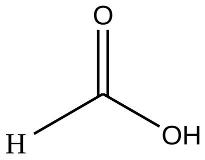
b) Nomenclature:

The name of **the carboxylic acid** derives from that of the alkane of the same carbon skeleton by replacing the final e by the **oic** ending, the whole being preceded by the word **acid**.

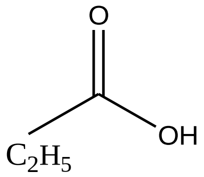
Example:



Ethanoic acid
Acetic acid



Methanic acid
Formic acid



Propanoic acid

c) ***Applications:*** Write the condensed structural formula of the following compounds

- 2,3-dimethylbutanoic acid
- 2-Methylbutanoic acid
- 2-hydroxypropanoic acid
- 6-hydroxyhexanoic acid

II. 10 Amines

a) ***Definition**:* An amine is any organic compound obtained by replacing in the ammonia molecule **NH_3**, one, two or three hydrogen atoms by one, two or three alkyl groups.

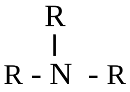
A distinction is made between primary amines, secondary amines and tertiary amines..

R – NH – R

Symmetric secondary amines

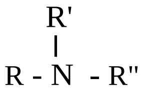
R – NH – R'

Non-symmetrical secondary animes



$$\underset{}{R-\overset{\overset{\large R}{|}}{N}-R}$$

Symmetric tertiary amines



$$R-\overset{\overset{\large R'}{|}}{N}-R''$$

Non-symmetrical tertiary animes.

b) Nomenclature:

1) Primary amines:

General formula: **R –NH $_2$** the amine is named from the name of the corresponding **R – H** alkane, with elision of the e, which is followed by the **amine** ending, specifying the position of the **NH$_2$** group.

2) *Symmetrical secondary and tertiary amines:*

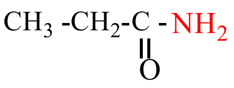
The name of the alkyl **R –**, preceded by **di** or **tri,** is followed by the **amine** ending

3) *Non-symmetrical secondary and tertiary animes:*

They are named as substitution derivatives on the nitrogen of the amine **R – NH $_2$** where **R –** is the longest group.

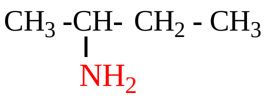
The substituent group(s) on the nitrogen are written in alphabetical order, preceded by the letter N and followed by the name of the amine **R – NH $_2$**.

- Exemple :



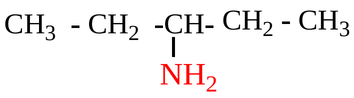
$CH_3-CH_2-\underset{\overset{\|}{O}}{C}-NH_2$

Propanamide



$CH_3-\underset{NH_2}{\underset{|}{CH}}-CH_2-CH_3$

butan-2-amine



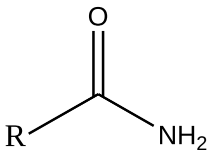
$CH_3-CH_2-\underset{NH_2}{\underset{|}{CH}}-CH_2-CH_3$

Pentan-3-amine

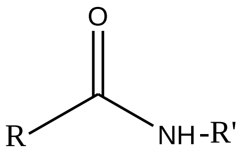
c) ***Applications**:* Write the condensed structural formula of the following compounds, then do the verification.

- *N*-ethyl-*N*-methylethanamine
- Dimethylethanamine
- *N*,*N*-dimethylmethanamine
- 3-methylbutan-2-amine
- *N*-ethyl-*N*,4,4-trimethylpentanamine

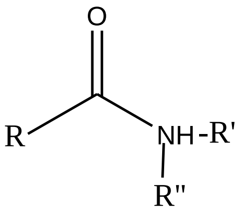
II. 11 Amides (alkanamides)



Primary amide:



Secondary amide:



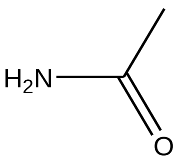
Tertiary amide:

- When there is substitution on nitrogen, the letters **N-**, **N,N-** , as in amines.

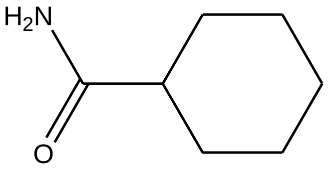
Main Group: Suffix = **-amide**

-carboxamide

Primary amide:

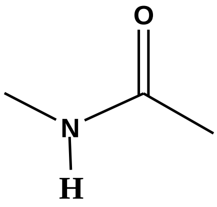


Ethanamide



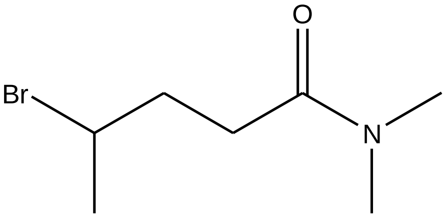
cyclohexanecarboxamide

Secondary amide:



N-methylethanamide

Tertiary amide:



4-bromo-N,N-dimethylpentanamide

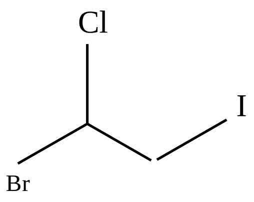
II. 12 Halogen compounds or alkyl halides.

a) Definition:

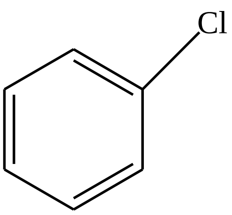
We call alkyl halides any organic compound having a halogen atom. (**Cl**, **Br**, **I**, **F**) bonded to a carbon atom by a single bond.

General formula: R-X X=Cl, Br , I, F

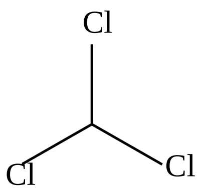
b) Nomenclature: Their name is obtained by preceding the name of the corresponding alkane with the prefix chloro, bromo, iodo or fluoro, preceded by its position index



1-bromo-1-chloro-2-Iodoethane



chlorobenzene



Trichloromethane(chloroform)

c) Applications: Write the condensed structural formula of the following compounds, then do the verification.

- 3-bromo-5-chloro-2-iodohexane
- tetrachloromethane

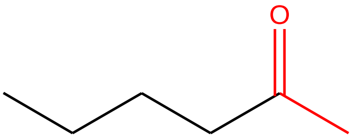
III. Determination of the name of a functionalized molecule

- Determine the main function: suffix
- Determine the basic structure: chain or cycle
- Naming Substituents
- Number
- Assemble the names of the substituents in alphabetical order.

- The different functional groups are classified in Table 3 according to the order of priority

- The highest group in Table 3 is chosen as the main group. It is designated by the corresponding suffix.

- All other groups are designated by prefixes.



hexan-2-one

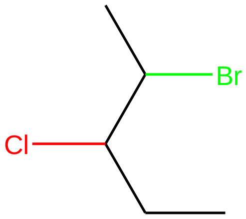
Main function: ketone, one ending.

Main chain: the one carrying the main function, 6 C hexane.

Numbering: 2

Name: hexan-2-one

P.S. Halogens never have priority, they are always designated by prefixes.



2-bromo-3-chloropentane

-F fluoro

-Cl chloro

-Br bromo

-I iodo

In the case where a compound contains two or more functions of the same valence, a conventional order of priority has been established (Table 3).

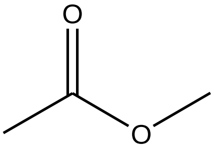
Table 3: Nomenclature of functions classified by order of priority.

Priority order	Functional Group	Suffix	Prefix
1	**Carboxylic acid**	**Alkanoic acid**	**---**
2	**ester**	**alkyl alkanoate**	**alkoxycarbonyl**
3	**acylhalide**	**---**	**---**
4	**amide**	**alkanamide**	**amido**
5	**nitrile**	**alkanenitrile**	**cyano**
6	**aldehyde**	**alkanal**	**oxo**
7	**ketone**	**alkanone**	**oxo**
8	**alcohol**	**alkanol**	**hydroxy**
9	**amine**	**alkanamine**	**amino**
10	**ether**	**---**	**alkoxy**
11	**halogen**	**---**	**fluoro, chloro,** **bromo, iodo**
12	**nitro**	**---**	**nitro**

For example, $OHC\mathbf{C}O(NH_2)$ is formyl**meth**anamide and not formylethanamide (in blue the main chain)

Application Exercises :

a) Reproduce and name the following molecules, then do the verification



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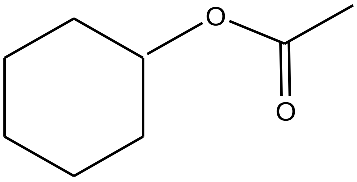

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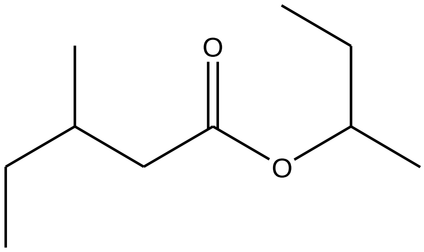

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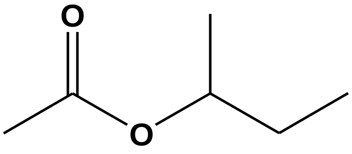

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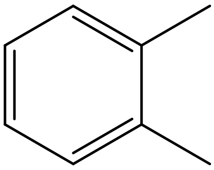

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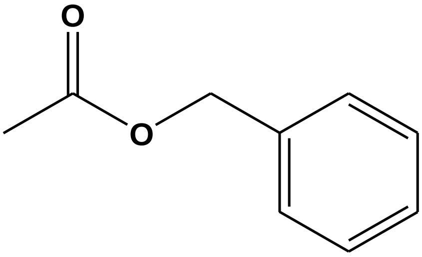

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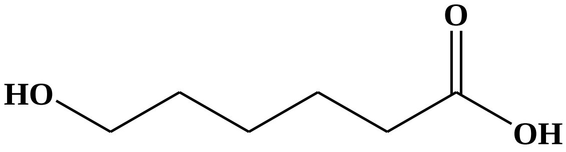

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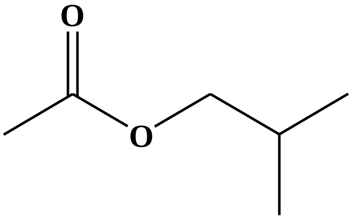

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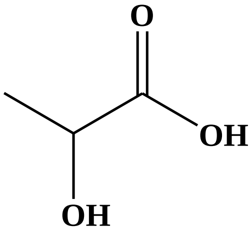
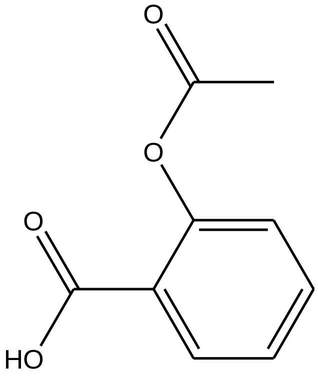


9.

b) **Aromaticcompounds :**



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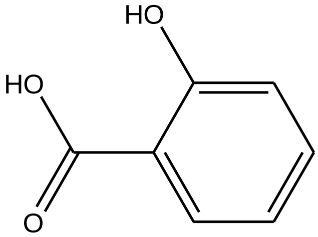

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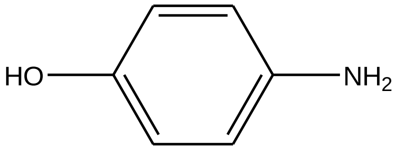

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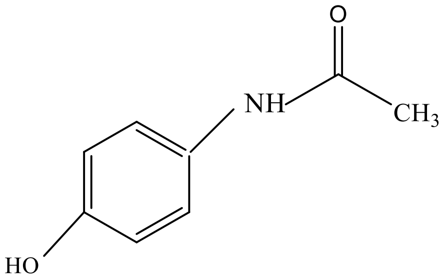

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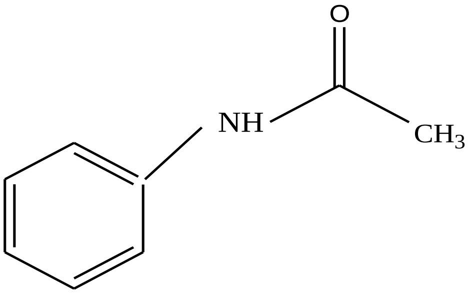

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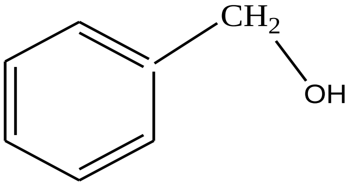


15.

c) Write the condensed structural formula of the following compounds:

16. 2-aminobutanoic acid

17.Ethanoic anhydride

18.Glycerol (trialcohol)

19. Dimethylethanamine

20.N-ethyl-N-methylethanamine

21. 3-methylbutan-2-amine

22.Phenylethanoate

23.(R)2-(methylperoxy)butan-2-ol

24.Propionamide

Chapter 2: Notions of stereo-isomerism

The phenomenon of isomerism was first noticed in the 19th century. At that time, chemists believed that the properties of a substance depended entirely on its molecular formula. However, the isomers have strictly the same number of atoms but their physical, chemical and/or biological properties differ.

I. Classification of isomers:

Isomers **are molecules** with **the** same molecular formulas**,** but different arrangements **of** atoms

Isomers are chemical species with the same molecular formula which differ by:

- The order or the nature of the bonds (constitutional isomerism),
- Or by the arrangement of atoms in space (stereoisomerism)

Two isomeric molecules have the same structural formula but they have different structural formulas. It is said that between these compounds there is a relation of isomerism. Isomer substances do not have the same physical and/or chemical properties.

The arrangement of atoms in isomeric molecules can differ in several ways, which explains the existence of various types of isomerism.

There are two main types of isomerism relations:

- *Structural or constitutional isomerism*: two structural isomer molecules differ by the sequence order of the individual atoms, therefore by their planar structural or semi-structural formula.

- *Stereoisomerism:* two stereo-isomeric molecules have the same connections between atoms, therefore the same flat structural formula, but differ by the three-dimensional arrangement atoms.

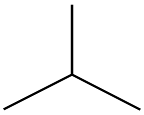
I. 1 PLANE ISOMERY or CONSTITUTIONAL ISOMERY

Constitutional isomerism: we call constitutional isomers, two molecules which have the same structural formula but have different planar structural formulas. Isomers have different physical, chemical and biological properties. There are three types of isomerism:

I. 1. 1 Skeletal or chain isomerism:

The sequence of atoms on the carbon skeleton is different: have the same molecular formula, may be different and are more or less branched to give isomers with different physical properties.

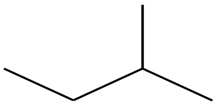
Butane, B.P = -0.5°C



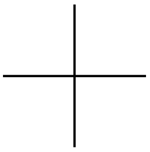
Isobutane B., P. = -10°C

It should be mentioned that the isomer which has the most branched structure will have the lowest boiling point.

Pentane, B.P = 35°C



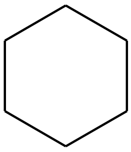
Isopentane B.P = 25°C



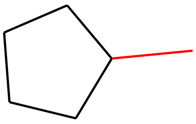
Neopentane, B.P = 9°C

Also, Skeletal isomerism lies between rings and aliphatic (acyclic) alkenes.

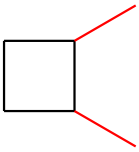
Example: C_6H_{12}, I = 1 (a double bond or a ring).



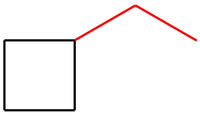
cyclohexane



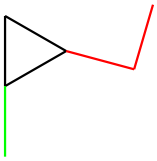
methyl cyclopentane



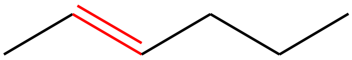
1,2-dimethylcyclobutane



1-ethylcyclobutane



1-ethyl-2-methyl
cyclopropane

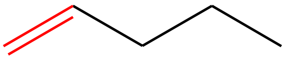


hex-2-ene

2-methylpent-2-ene

Examples: Structural Isomers

Different compounds with the same molecular formula:



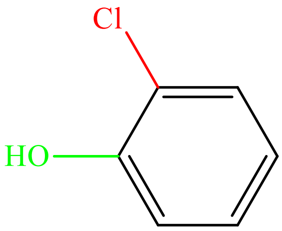
Pent-1-ene B.P = 30°C

Pent-2-ene, B. P = 37°C

I. 1. 2 Positional isomerism

Two molecules are positional isomers when they have the same carbon skeleton and differ only by the position of an atom, a group of atoms (function) or a bond multiple. Their chemical properties are usually similar, but their physical properties are different (boiling temperature, density, etc.).

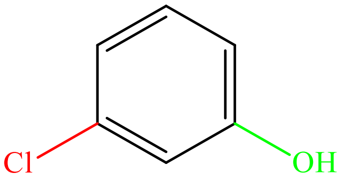
C_6H_5ClOH, I=4.



B. P = 195°C ,P.F = 9.3°C

Ortho chlorophenol

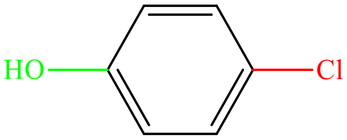
2-chlorophenol



B.P = 214°C, P.F = 33°C

meta chlorophenol

2-chlorophenol



B.P = 219°C P.F = 43.5°C

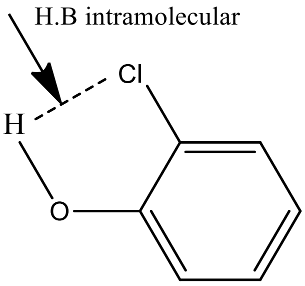
para chlorophenol

3-chlorophenol

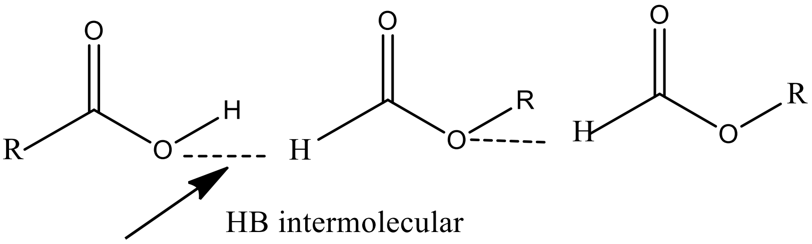
Note: Notion of hydrogen bond (B.H) It is a low energy bond, it occurs between a slightly acidic hydrogen atom and an electronegative atom with at least one free pair such as halogens (F, Cl, Br, I) and heteroatoms (N, O, S).

Hydrogen bond: can be intramolecular or intermolecular; it is represented by dotted lines.

a) **Intramolecular hydrogen bond:** is established in the same molecule. She is forming always to create a five- or six-membered ring (stable ring).

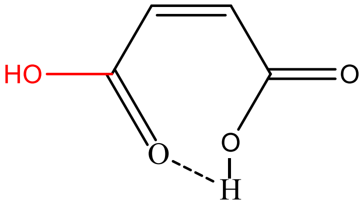


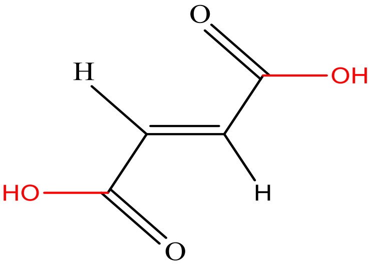
b) Intermolecular hydrogen bond: is established between two molecules.



Consequence of L.H: Hydrogen bonding can have an important influence on the physical and chemical properties of compounds. It can have effects on the melting points, boiling points, solubility, conformation and acidity of molecules.

Example:





Maleic acid, P.F = 131°C

Pka1 = 1.92, Pka2 = 6.23

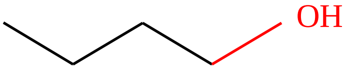
Fumaric acid, P.F = 287°C

Pka1 = 3.02, Pka2 = 4.38

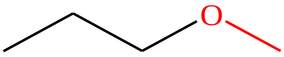
I. 1. 3 Functional isomerism:

When molecules with the same molecular formula differ by the functional group, they are said to be function isomers.

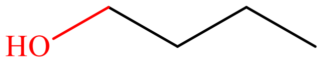
Example:



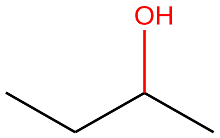
butanol



1-methoxypropane



Butan-1-ol B.P = 117.7°C



butan-2-ol B. P = 98°C

I. 1. 4 Cyclanic isomery:

Cyclanes are a family of saturated cyclic hydrocarbons.

The general formula of alkanes being **CnH2n+2** that of cyclanes will be **C_nH_{2n}.**

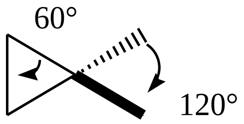
Cyclization leads to the loss of 2 H and allows the ring to be closed by a σ > C-C bond.

The general formula is therefore analogous to that of the alkenes.

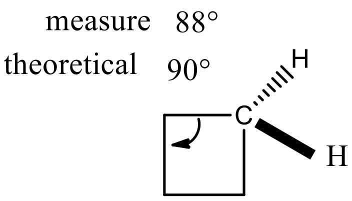
Only the cycle in C3 is plane.

The cycles in C4 and C5 are approximately planar.

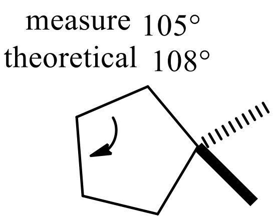
Cycles at C ≥ 6 are not planar.



Cyclopropane

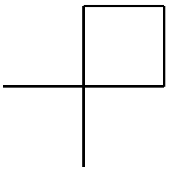


Cyclobutane

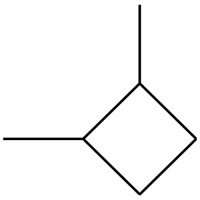


cyclopentane

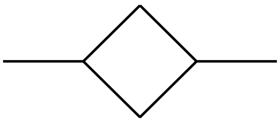
Dimethyl Cyclobutane Isomers C_6H_{12}



1,1-dimethylcyclobutane



1,2-dimethylcyclobutane



1,3-dimethylcyclobutane

I. 2 Stereoisomery:

three-dimensional arrangement of atoms (groups) in space

The study of stereo-isomerism is of major importance in organic chemistry. Indeed, two molecules A and B which appear similar when we only see their planar semi-developed formula, can have totally different chemical reactivities or biological activities depending on the arrangement of the atoms in space.

Stereoisomers: Two molecules with the same constitution but different stereochemistry. All stereoisomers are either configurational isomers or conformational isomers

I. 2. 1 Geometry isomerism:

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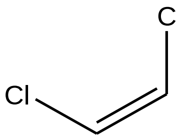
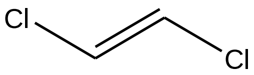
I. 2. 1. 1 Configurational or configurational isomers : are stereoisomers that cannot be converted into one another by rotating the molecule around a single bond. These are therefore different molecules that can be isolated.

Example: 1,2-dichloroethene



(*Z*)-1,2-dichloroethene
First configuration

T boiling = 47°C



(E)-1,2-dichloroethene
Second configuration

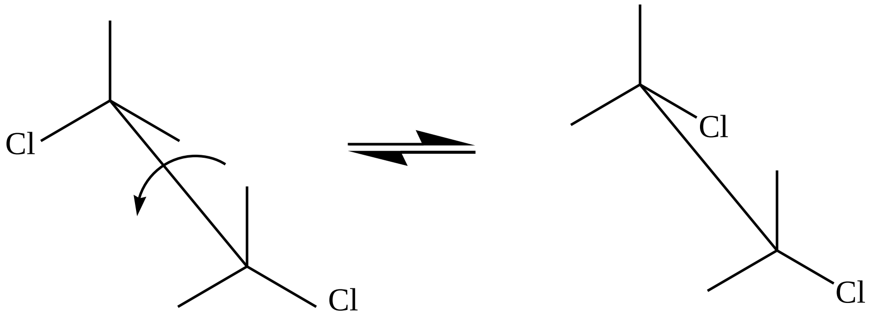
T boiling = 60°C

Stereoisomers separable by distillation

The transition from one configuration to another requires the breaking of a bond and then its formation again. In the example above it is the π bond between the two carbons.

I. 2. 1. 2 Conformational or conformal isomers : is a form of stereoisomerism where interconversions of isomers are possible by rotations referring to single bonds

Ex : 1,2-dichloroethane



First configuration Second configuration

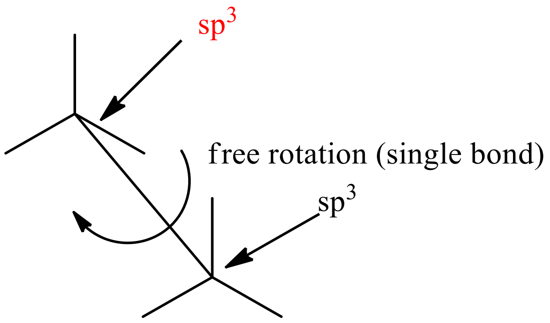
conforming isolatable, T boiling = 83°C

The transition from one conformation to another is by simple rotation and without breaking bonds.

There are two types of configurational isomers: diastereisomers and *enantiomers*. Enantiomers are non-superposable mirror images.

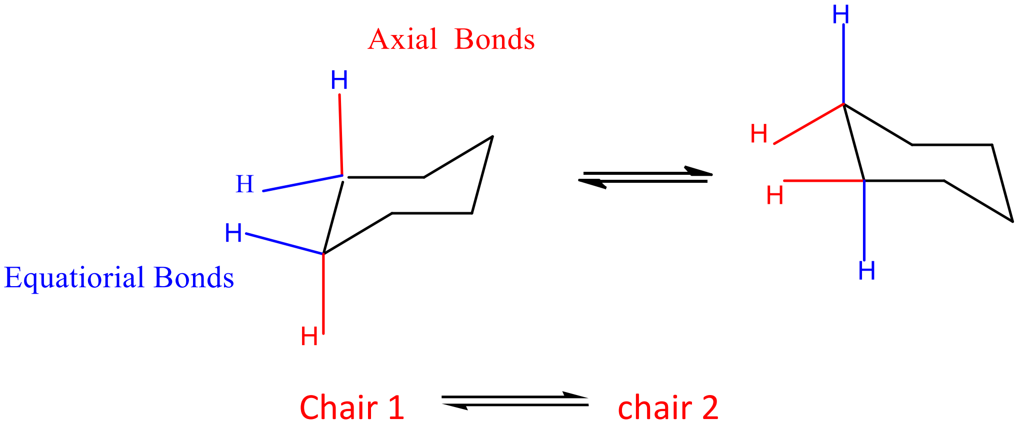
II. Conventional representation of organic molecules

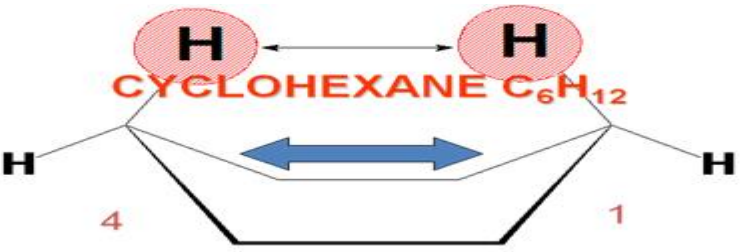
II. 1 Perspective representation (or cavalier perspective):



The perspective representation is mainly used for cyclic molecules.

Cyclohexane C_6H_{12}





The passage from “chair 1” to “chair 2” is done by an unstable intermediate conformer:

the “boat” shape for which all the H are in the “eclipsed” position.

The strong repulsion of H in position 1 - 4 makes this conformer unstable

$$\text{boat} \rightleftharpoons \text{chair}$$

$$\Delta G = -\,23\ \text{kJmol}^{-1}$$

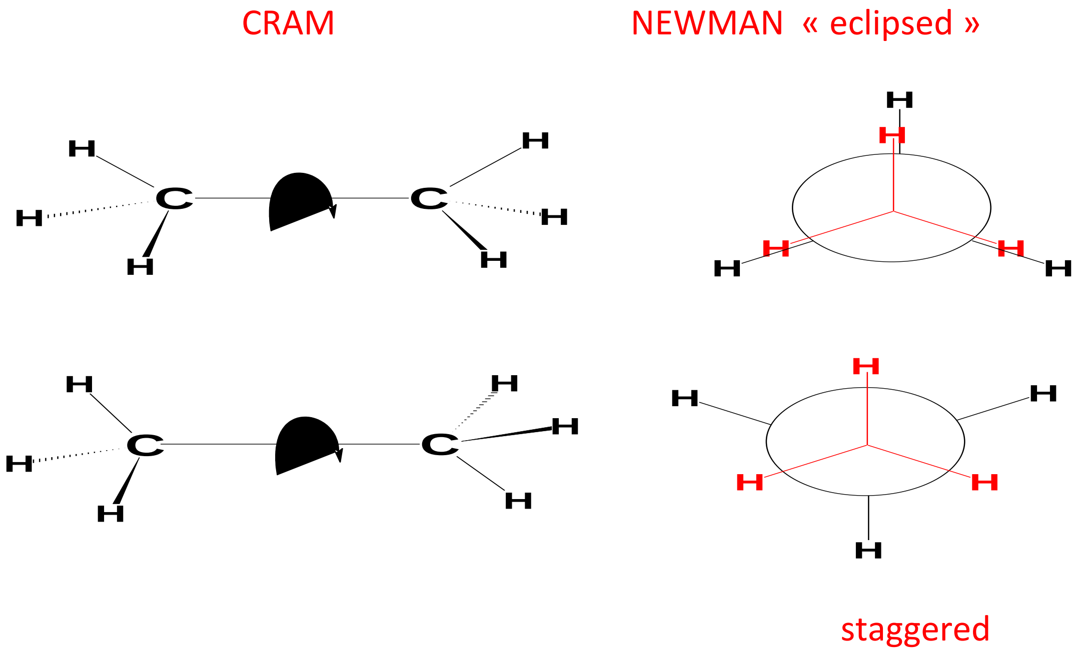
II. 2 Projective representation or Cram convention:

It consists in representing a connection by convention:

II. 3 Newman projection:

In Newman's representation, the molecule is viewed along the axis of a C-C single bond between two neighboring carbon atoms. The bonds resulting from the two atoms are projected on a plane perpendicular to the axis of the studied bond:

Representation of Ethane



''''''IIII paper back binding

◀ binding in the foreground of the paper

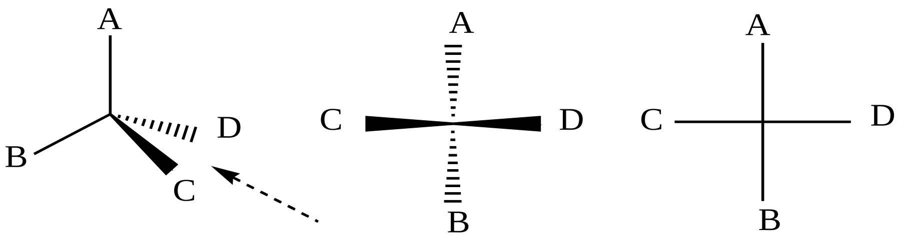
_____ binding in the plane of the paper

The Newman Projection of an organic compound makes it possible to study its different conformations (one passes from one conformal to another by rotation around a single C-C bond).

II. 4 Fisher projection:

In Fischer projection, bonds are represented by solid vertical and horizontal lines, according to the following conventions:

- The vertical lines represent the links behind the plane of the figure.
- The horizontal lines represent the connections in front of the plane of the figure.
- The longest carbon chain is placed vertically and numbered from top to bottom.
- The link with the lowest index (most often associated with the most oxidized carbon) is placed at the top.



- Stereoisomers can be configuration isomers or conformation isomers:

III. Enantiomerism

III. 1 Chirality

A chiral molecule is a type of molecule that has a non-superposable mirror image.

III. 1. 1 Definition of enantiomers

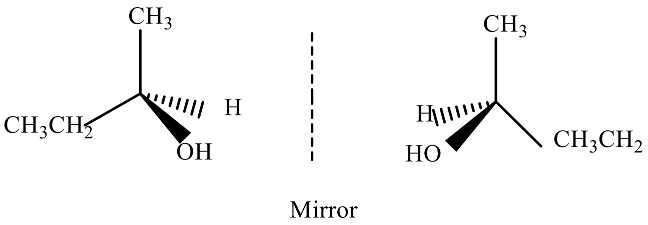
Enantiomers are non-superposable mirror images. Almost all of the physical and chemical properties of a pair of enantiomers are identical (melting point, boiling point, solubility etc.).

III. 1. 2 Chiral center definition:

A chiral center is defined as an atom in a molecule that is bonded to four different chemical species, allowing for optical isomerism. It is a stereocenter that holds a set of atoms (ligands) in space such that the structure may not be superimposed on its mirror image.

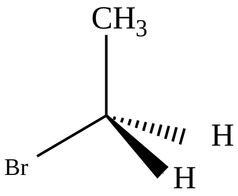
The central carbon in butan-2-ol is a chiral carbon**.**

REMINDER: Any tetrahedral atom sp^{3}that bears four different substituents can be a **chirality center**.



A molecule that cannot be superimposed on its mirror image, i.e. a molecule that has one enantiomer, is said to be chiral.

Thus, each of the two isomers of butan-2-ol described above is a chiral molecule.



Bromoethane is an achiral molecule (not chiral) because it is superimposable (identical) to its image in a mirror

How to know if a molecule is chiral without drawing its image in a mirror?

- If a molecule has, in one of its conformations, a plane or a center of symetry, then it is achiral.

For the above **bromoethane**, the plane of the sheet is plane of symmetry. Indeed, bromine, carbon and methyl are in this plane, therefore reflect themselves and the two hydrogens are images of each other with respect to this plane.
There is a plane of symmetry so this molecule is not chiral.

III. 1. 3 Optical isomerism.

Asymmetric atoms nevertheless play an essential role in the existence of stereoisomers. R/S system of nomenclature is **a naming system used for assigning absolute configuration to chiral molecules**.

III. 2 Optical activity:

Enantiomers have identical chemical and physical properties and are indistinguishable from each other except for the direction of rotation of the plane of polarized light. They are described as optically active.

- Right (dextrorotatory) → designated as + or **d**

  dextrorotatory (d): rotates light to the right (clockwise)

- Left (levorotatory) → designated as – or **l**

  levororotatory (l): rotates light to the left (counterclockwise)

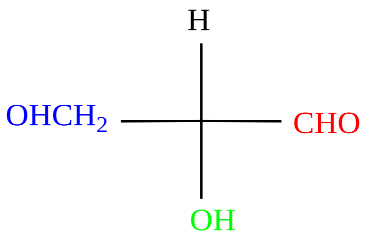
  a: angle (# of degrees) plane polarized light is rotated by an optically active sample

- A racemic mixture is optically inactive because it contains the two enantiomers in equimolar quantity and has zero optical rotation. The "racemic" is noted (±) $\alpha = 0$.

  The molecule is called **levorotatory or levorotary**, from the Latin *laevus*, meaning “left”, and is designated by the prefixes **(-)**, or ***l***– from *laevo*-.

Example: $HOCH_2$-CH(OH)-CHO

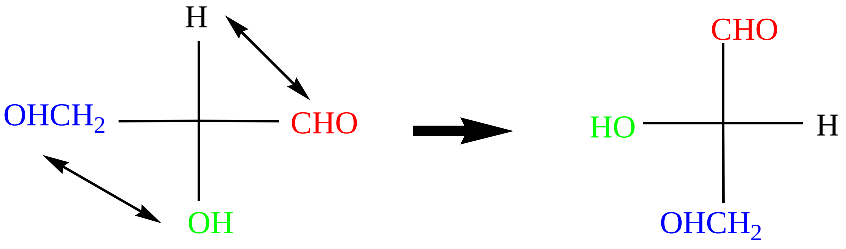
Consider this Fischer representation:



We swap between them:

- ➢ OH and CH_2 OH (least oxidized function at the bottom)

- H and CHO (most oxidized chain at the top)



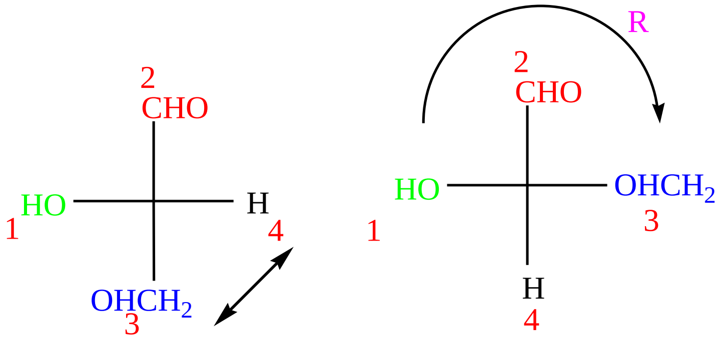
The isomer obtained is L-glyceraldehyde.

It can be levorotatory L (-) or dextrorotatory L(+).

There is nothing to predict the direction of the rotary power

What is the C* configuration?

We classify the substituents and we swap H and CH_2OH.



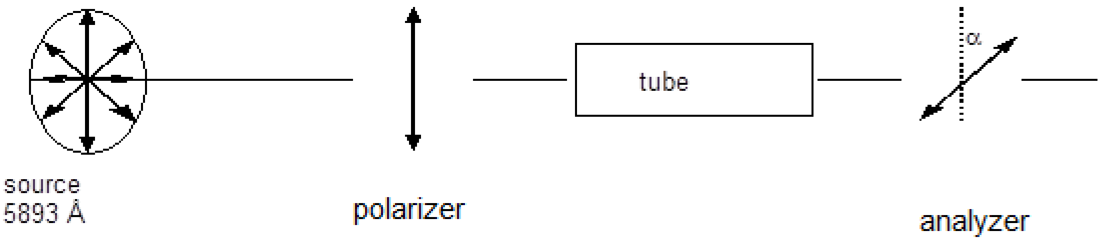
We find a carbon (R) but only inverts the configuration so the C* is (S).

CONCLUSION: L glyceraldehyde is (S) Experience shows that it is L (-).

III. 2. 1 Description of the phenomenon

When an optically active substance is crossed by a beam of polarized light, it causes a rotation of the plane of polarization of this light by an angle α which can be measured experimentally using a polarimeter. Polarization rotation of rectilinearly polarized light was observed by Jean-Baptiste Biot (1817).

The polarimeter is a device that uses so-called polarized light (light that only evolves in one plane, called the plane of polarization).



The polarimeter is a device that uses so-called polarized light (light that only evolves in one plane, called the plane of polarization). It consists of a tank of length l, filled of a solution of one enantiomer at concentration C:

III. 2. 2 Properties of enantiomers

a) Physical: Enantiomers have identical physical properties but they rotate the plane of polarization of light by an equal angle but in the opposite direction.

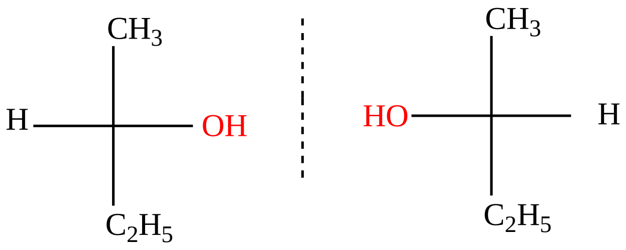
b) Chemical: The enantiomers have identical chemical properties except for the reactants which are optically active. In the case of such a reagent, the reaction rates will differ for the attack of the two enantiomers by this reagent.

(+)-glucose is active in the fermentation process while (-)-glucose is inactive

III. 2. 3 Geometric criteria of optical activity:

A substance that rotates the plane of polarization is said to be optically active. Any optically active substance is chiral, not superimposable on its image in a plane mirror

Hence the general condition stated by Pasteur in 1850; for a compound to be optically active it is necessary and sufficient that its molecule is not superimposable on its image in a plane memory



Enantiomers

*** Case of a molecule comprising an asymmetric atom**

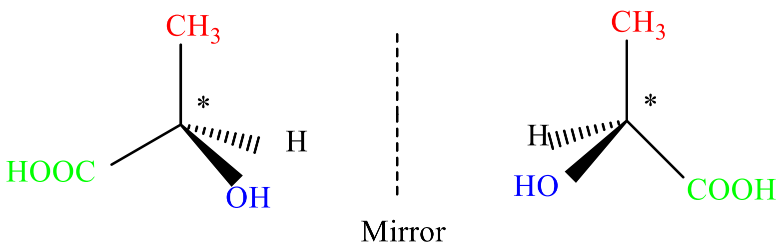
Definition: an atom is said to be asymmetric when it is tetrahedral and bound to four different atoms or groups of atoms.

By “groups of different atoms”, we mean:

- either groups composed of different atoms (different basic formulas);
- either structural isomeric groups;
- or diastereoisomeric groups.

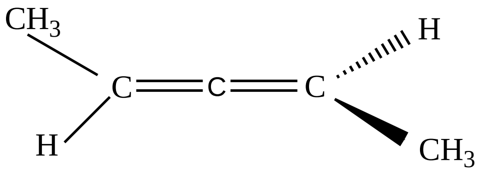
Example

Carbon atom n° 2 of 2-hydroxypropanoic acid is bonded to a hydrogen atom H, a methyl group CH_3, an amino group OH and a carboxylic group COOH. It is therefore asymmetric



III. 2. 4 Chirality in the absence of a chiral center

Chirality can also occur in the **absence of a chiral center**, due to the lack of free rotation around a double or a single bond, as in the case of: allene derivatives, organic compounds in which there are **two cumulative double bonds**, namely, two double bonds localized on the same carbon atom;



allene

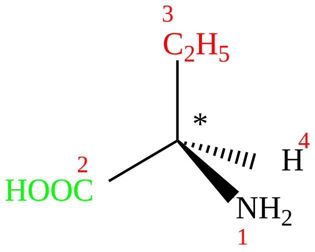
IV. Sequential rules of Cahn, Ingold and Prelog

The rules of Cahn Ingold and Prelog (CIP rules) make it possible to classify substituents (or groups) according to a well-established order of priority.

For example, one can rank in order of CIP priority the four substituents of an asymmetric carbon atom, i.e. the four groups of atoms bonded to this carbon.

Rule: Rank the level 1 atoms of each substituent by decreasing atomic number. This ordering defines the ordering of the groups. (The level 1 atom of a substituent is the atom directly linked to the carbone asymetric.)

Example : 2-aminobutanoic acid.



When two atoms are identical at level 1, we develop by writing for each the three atoms of level 2. This defines three branches of development on each atom.

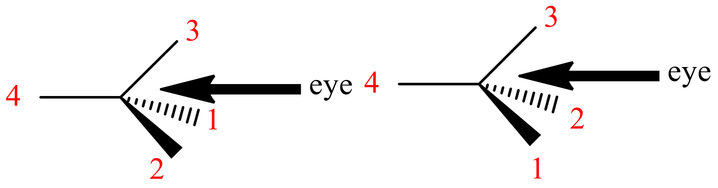
IV.1 Determination of the stereochemical descriptor R or S of an atom asymmetric (we also speak of stereodescriptor):

1. The four substituents are ranked in order of priority using the rules of Cahn, Ingold and Prelog; the priority substituent carries the number 1, the last in the order of priority number 4.

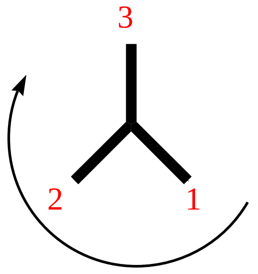
2. We look at the molecule in the axis of the C* bond − substituent n°4, the asymmetrical carbon being in the foreground and the substituent n°4 being directed towards the back.

The three substituents then present themselves:

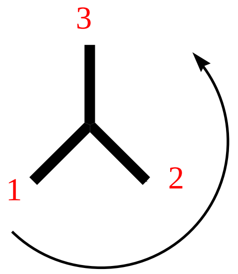
- Either in the dextrorse direction (we go from 1 to 2 and to 3 as if we were turning a steering wheel to the right): the carbon then bears the descriptor R (from the Latin rectus “right”).
- Either in the sinistrorse direction (we go from 1 to 2 and to 3 as if we were turning a steering wheel to the left): the carbon is then assigned the descriptor S (from the Latin sinister “left”).



The eye sees



Configuration R

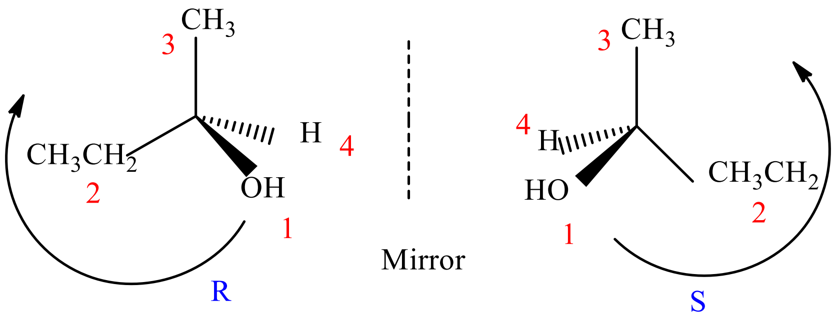


configuration S

Of course, the mirror image of an atom with descriptor R is an atom with descriptor S and vice versa. It is said that there are two absolute configurations around an asymmetric atom.

Example:

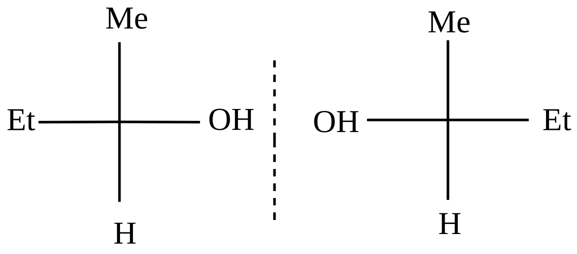
$CH_3CH(OH)\ CH_2\ CH_3$



(R)-butan-2-ol (S)-butan- 2-ol

Enantiomers

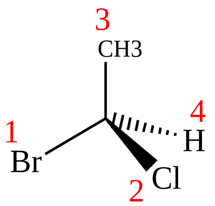
By placing the substituent 4 down, the FISCHER representation is as follows:



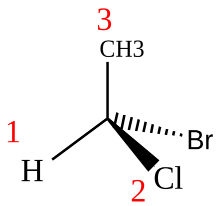
A permutation of two substituents reverses the configuration

- Two permutations keep the configuration
- The most oxidized substituent is at the top
- The longest carbon chain is at the bottom (or the least oxidized)

Example :



(*S*)-1-bromo-1-chloroethane



(*R)*-1-bromo-1-chloroethane

V.Diastereoisomerism

Diastereoisomers are configuration stereoisomers that are not mirror images of each other. Diastereoisomers, unlike enantiomers, do not have the same physico-chemical properties; they can therefore be more easily separated by distillation, recrystallization or chromatography.

Diastereoisomerism may be due either to :

- Presence of a double bond.
- Existence of several asymmetric carbons.

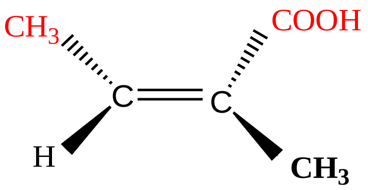
Geometric isomerism of ethylenics:

The presence of a C=C (ethylenic), C=N (imine…) or N=N (diazonium) double bond prevents the rotation of the two atoms with respect to each other. Therefore, if each of these two atoms carries 2 different groups, there can exist two distinct configurations called geometric stereoisomers or Z/E type diastereoisomers.

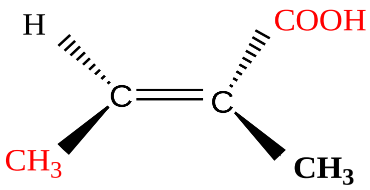
V. 1 Nomenclature Z/E

Isomer E (from Entgegen) : the higher priority groups are on opposite sides of the double bond.
Isomer Z (from the German Zusammen): the higher priority groups are on the same side of the double bond.

Example :



(Z) 2-methyl butanoicacid

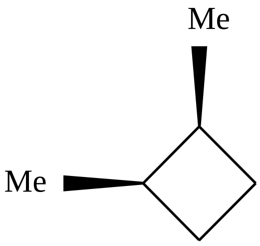


(E) 2-methyl butanoicacid

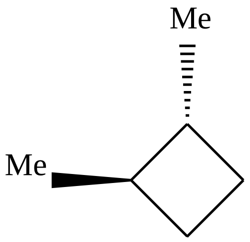
V. 2 Cis/Trans cyclanic isomerism:

Cis-trans diastereoisomerism is used in cyclic compounds that bear two identical R substituents. It is based on the relative position of the two substituents:

- If the 2 substituents are on the same side of a plane defined by the cycle; it is the "Cis" isomer.
- If the 2 substituents are on either side of the ring plane; it is the " Trans isomer



(cis)-1,2-dimethylcyclobutane



(trans)-1,2-dimethylcyclobutane

*Compounds with Multiple Chiral Centers

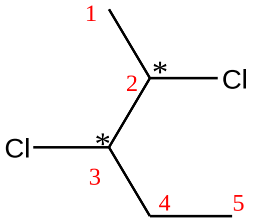
Diastereoisomerism is due to the presence of 2 (or more) C* in a molecule. Such molecules are frequent in nature and in particular in natural compounds: sugars, amino acids, etc.

A molecule containing more than one asymmetric carbon is not necessarily chiral. For a given structure, there is only one image molecule in a mirror; other possible structures are diastereoisomers.

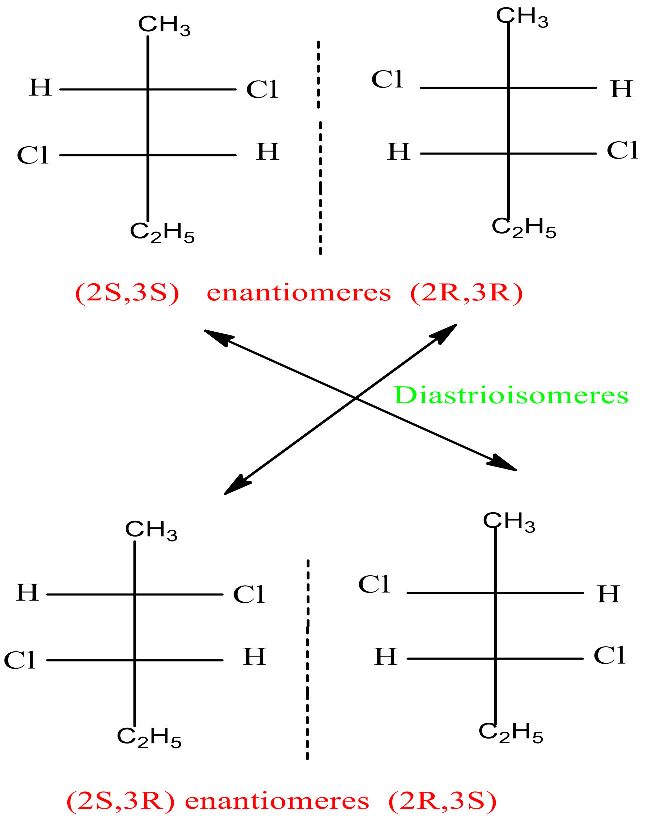
1st case: asymmetric atoms do not have their three identical substituents
* there are 4 stereo-isomers.

Examples : Molecules with two stereocenters Diastereoisomers C*

$CH_3CHClCHClCH_2CH_3$How many stereoisomers does it have?



2,3-dichloropentane



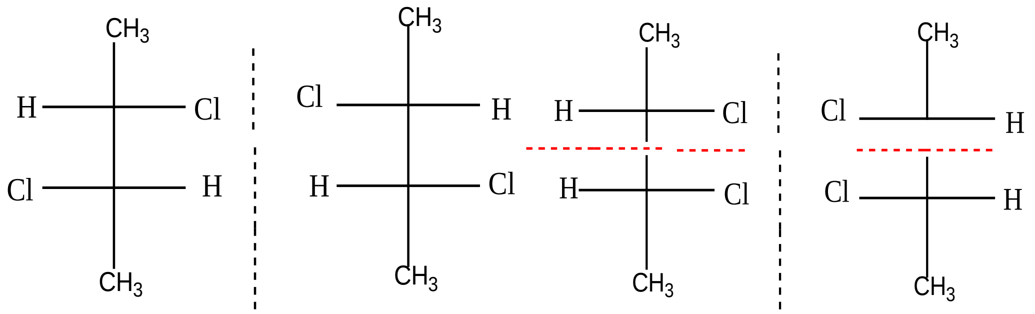
The number of stereoisomers that can exist is equal to 2n where n is the number of asymmetric carbons, therefore 4 stereoisomers

*Some molecules have chiral carbons, but are however superimposable on their image in a mirror.

Let's look at 2,3-dichlorobutane. Does it exist in four isomeric forms?

$CH_3CHClCHClCH_3$

there are two C* ... 2^n ?



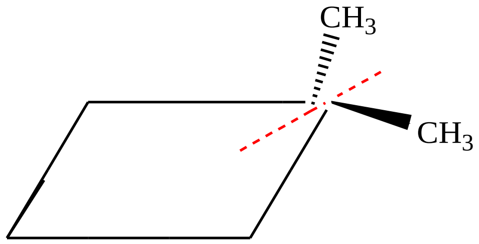
(2S,3S) enantiomeres (2R,3R) (2S,3R)? meso compound

Having a center of symmetry or a plane of symmetry implies that a molecule can always be superimposed on its image in a mirror (2S, 3R)

Two of these **stereoisomers** are **enantiomers** and the third is an achiral diastereomer, **called** a meso compound. Meso compounds are achiral (optically inactive) ...

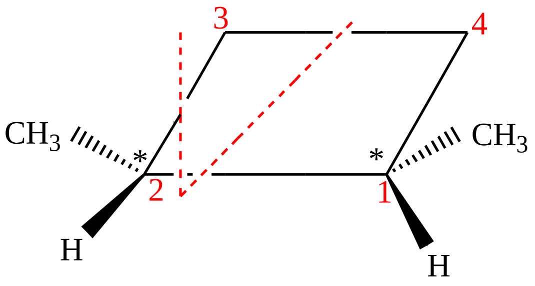
2,3-dichlorobutane exists as 3 isomers.

Exapmle: 1,1-dimethyl cyclobutane



no optical isomerism: plane of symmetry and no C*

1,2-dimethyl cyclobutane (cis)

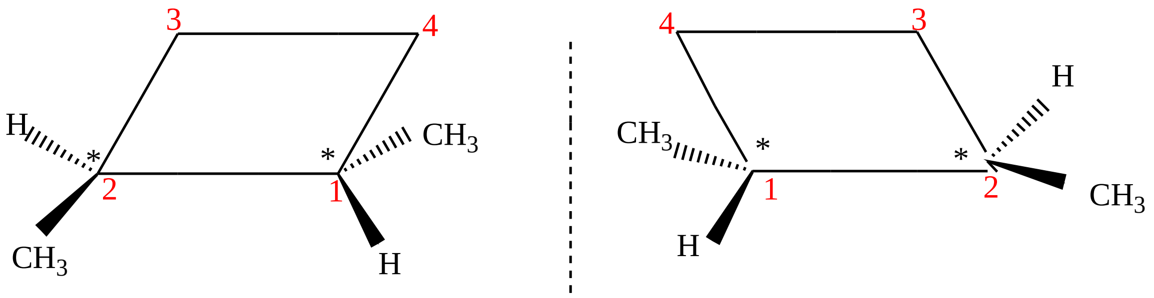


2 C* : C(1) is R; C(2) is S , there is a plane of symmetry

Lismore R-S is unique. It is “inactive by nature” It is the “meso” isomer

*The trans isomer of 1,2-dimethy cyclobutane does not have a plane of symmetry. It is therefore optically active

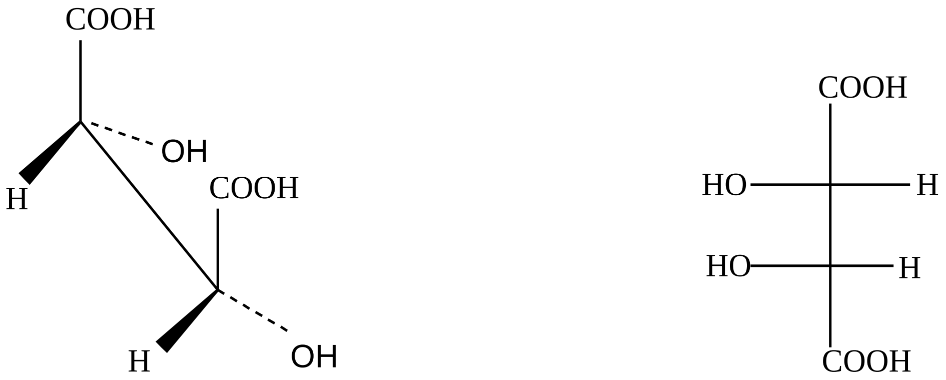
R-R S-S



1,2-dimethyl cyclobutane (trans)

GENERAL RULE:

In a molecule which has 2 chiral carbons, the "meso" isomer, inactive by nature due to the plane of symmetry, is always of the R-S type.



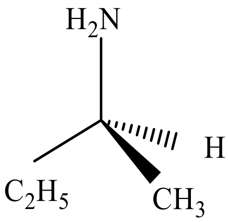
tartaric acid « meso »

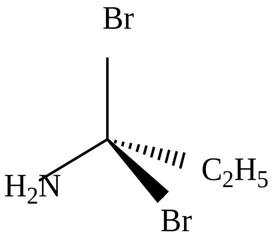
Meso compounds, even if they have asymmetric carbons, do not act on polarized light. These are therefore compounds that have a plane of symmetry.

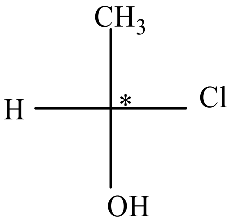
Application Exercices :

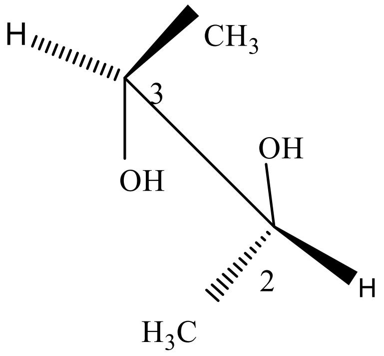
Exercice1 :

1. Are the following molecules chiral and determine the absolute R\S configuration of the C*(s)? to justify









2. 2,3,4-trihydroxybutanals CHOCH(OH) CH(OH) CH_2OH How many stereoisomers does it have? Give the Fischer representation of these diastereoisomers? Specify R or S

Exercise 2:

Rank the following substituents in order of priority:

$-(CH_3)_3$; -OH ; -CHO ; $-CH_2OH$; $-NH_2$; $-CH_2Cl$; -COOH ; $-OCH_3$.

Exercice 3 :

1- Represent according to FISCHER, NEWMANN and in Projective (CRAM) the molecule of D-erythrosisCH_2OH—CHOH—CHOH—CH=O

2- Give the structural formula (in the representation of your choice) of the following compounds: R-1-2-dichloropropane, S-2-chloropropanoic, 2-S 3-R dichloro-2,3-butanoic, R-1-2 epoxybutane, tartaric acid R-R.

3-Write in FISCHER projection the (-) (2R, 3R) 2-Benzyloxy 1,3,4-Butanetriol of linear formula: CH_2OH-$CHOH$-$CH(O$-CH_2-$\Phi)$-CH_2OH

Chapter 3 : Major reactions in organic chemistry

Chapter 3 : Major reactions in organic chemistry

The study of reaction mechanisms represents an effort to rationalize organic chemistry which makes it possible to predict the results of a chemical reaction in advance.

We now know the geometry of isolated molecules as well as their electronic organization. The problem that arises for us is to know how molecules placed in the presence of each other can react to generate new molecules.

Thus, if we mix the molecules of two compounds A and B, we can ask ourselves:
-if A and B can react on each other?
- if they react under certain conditions, which compounds C and D are generated?
-A and B give C et D, what is the "path" should be followed by the chemical system, or in other words, according to what "mechanism" does the reaction take place?
- Are there intermediate compounds likely to form during the transformation?

The answers to all asked questions will allow us to describe the "mechanism" of the reaction, that is to say, all the steps taken by the chemical systems to go from the initial state to the final state.

The study of the mechanism accounts for all the electronic, geometric, energetic and kinetic modifications of the evolving system.

Overall, a chemical reaction can be considered under three essential aspects:

- The electronic aspect: rupture and formation of bonds.
- The geometric or steric aspect: change in the configurations of the molecules.
- The energetic and kinetic aspect: variation in the energy of molecules and rate of transformation of the chemical system.

Knowledge of the course of reactions at the molecular scale makes it possible to explain and predict them.

If we consider a reaction as a whole, that is to say only the starting and finishing compounds, we can classify the reactions into four groups:

The different types of chemical reaction:

- Substitution reaction (saturated or aromatic molecules)
- Addition reaction (unsaturated molecules)
- Elimination reaction
- transposition reaction

I. Electronic aspects of chemical reactions

An “electronic effect” results from the asymmetrical distribution of charges in a molecule or an ion.

There are essentially two electronic effects:

- The donor (+I) or attractor (-I) inducing effect
- The mesomeric donor (+M) or attractor (-M) effect

I. 1 inductive effect:

This is the consequence of the differences in electronegativity between the atoms of a molecule:

$$^{+\delta}A \longrightarrow B^{-\delta}$$

B is more electronegative than A: molecule AB is a dipole.

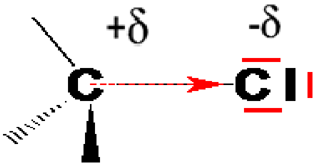
A is donor inducer (+I)

B is attractor inductor (-I)

The inductive effect is transmitted by the σ bonds. It pays off quickly when you move away from the donor or attractor group.

a) Attractor -I inducing effect:

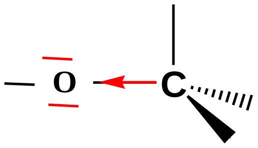
In an organic molecule any atom more electronegative than carbon is – I

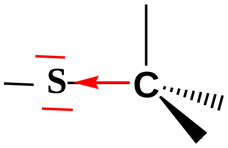


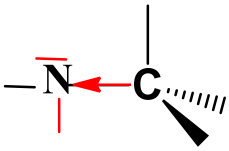
Cl has 3 doublets n

Therefore increasing **electronegativity** order is I < **Br < Cl** < **F**.

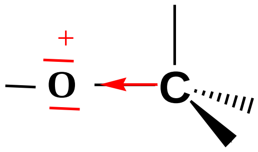
Examples:



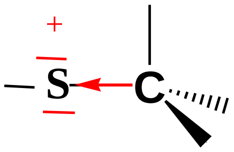




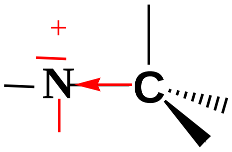
Positive IONS:



Xonium

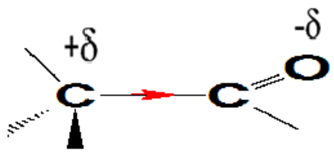


sulfonium

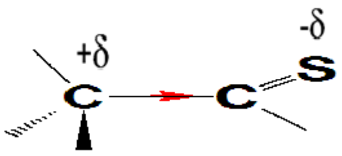


ammonium

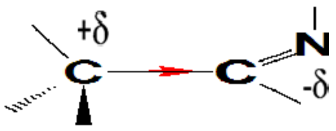
(carbons sp2 and sp)



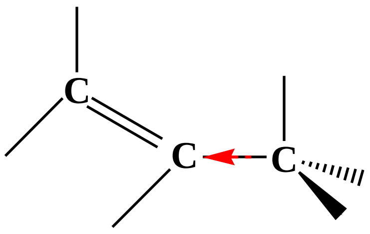
Carbonyle derivative



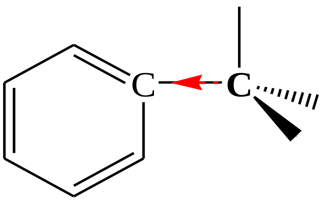
thiocarbonyle derivative



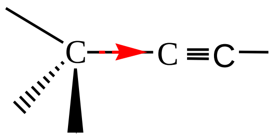
imine



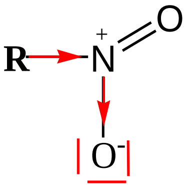
ethylenic



Aromatic



acetylenic

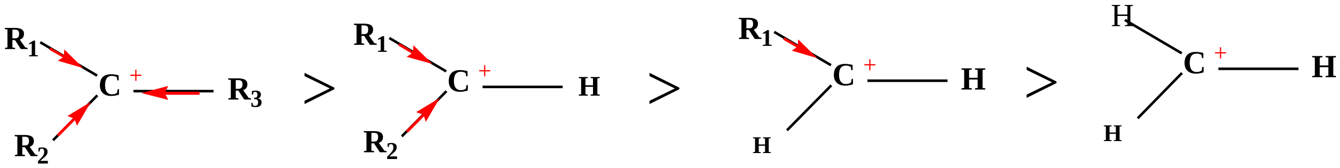


Nitro derivative: N has a + charge and attracts the doublet of the C-N S bond. One of the O atoms is (-I) the effects (I) are additive.

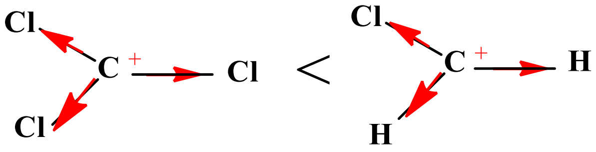
b) Effect stabilization (+I):

The inductive donor effect of the alkyl group compensates for the positive charge of the carbocation and stabilizes it

Decreasing stability



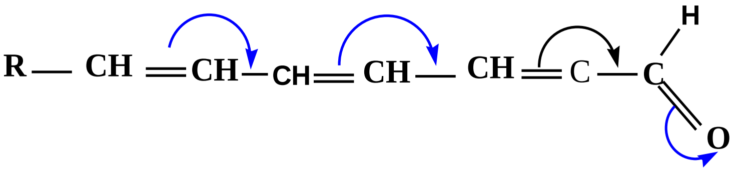
On the other hand, the inductive attractor effect destabilizes the carbocation by increasing its positive charge.



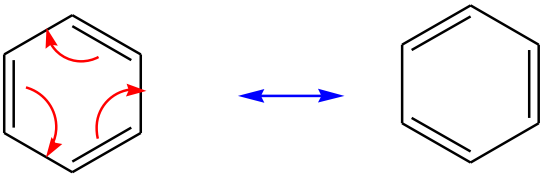
II. 2 The mesomeric effect :

The mesomeric effect results from the delocalization of π

electrons. It propagates without weakening along a chain of conjugated carbons



Example of Benzene C_6H_6:

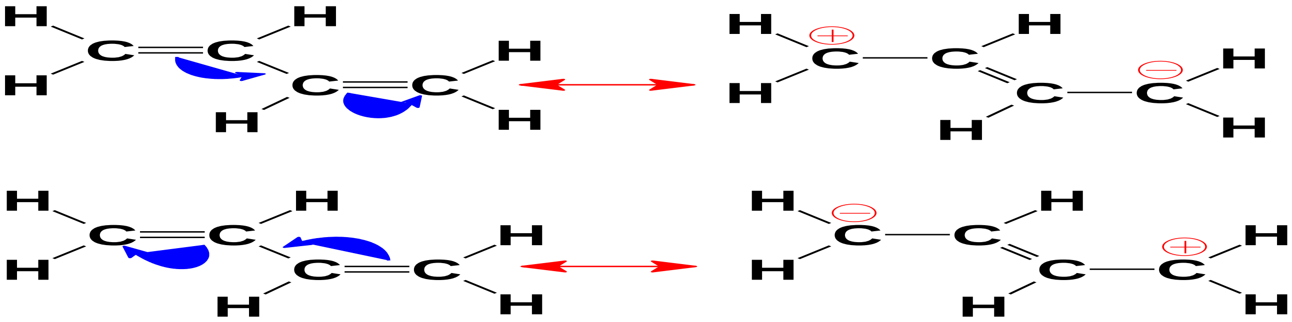


limit form 1 limit form 2

The best representation delocalizes the 6 π electrons on the 6 carbon atoms.

The arbitrary location of the p electrons along 3 double bonds gives two "boundary forms" which introduce differences between the C-C bonds which do not exist. The arrows indicate the displacement of 2 electrons.

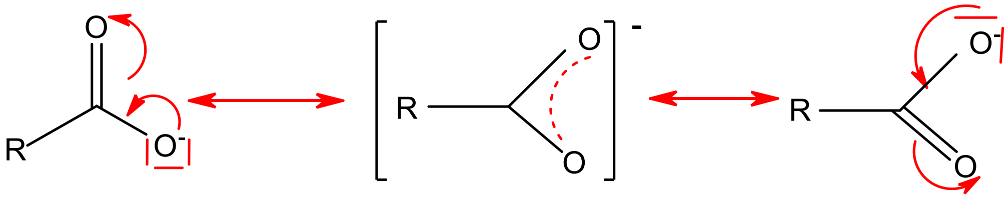
The same phenomenon is observed for butadiene:



But the resonance energy is lower:

$E_R = 14.7\ kJmol^{-1}$

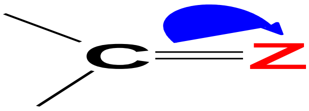
***Mesomeric stabilization of the carboxylate ion R-COO$^-$**



The two limiting forms are identical: the conjugate base R-COO$^-$ is better stabilized than the acid R-COOH which easily yields an H+ This explains the fairly strong dissociation of carboxylic acids compared to other acid-base systems: alcohols, phenols…

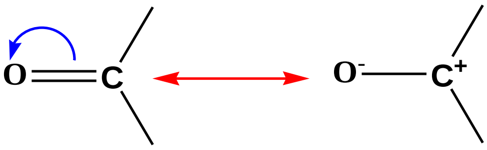
a) The Mesomeric -M Attractor Effect:

It can be summarized by the diagram:

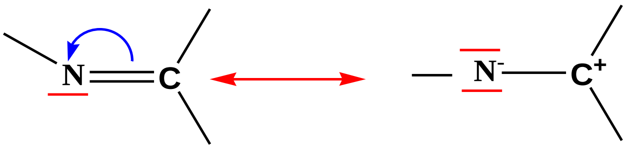


Z = O, N, S, …

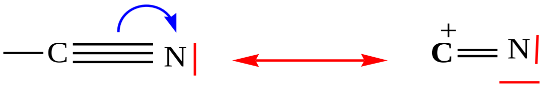
Example:



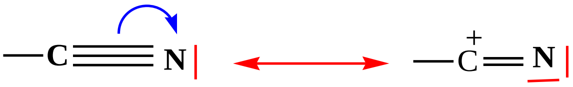
carbonyle



imine :

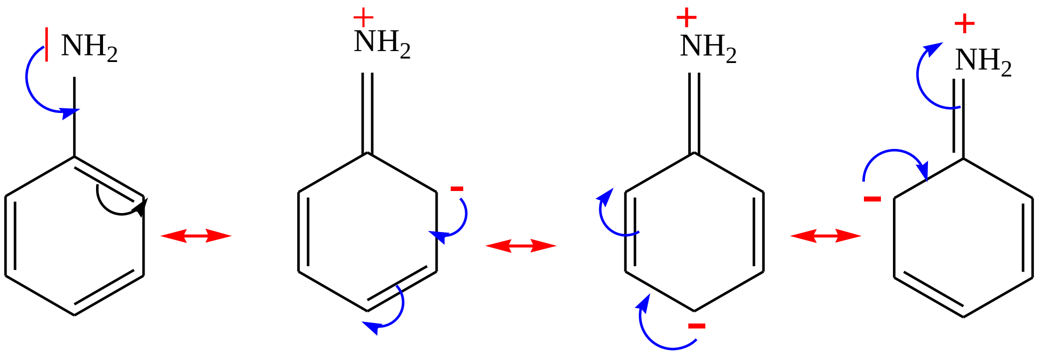


nitrile

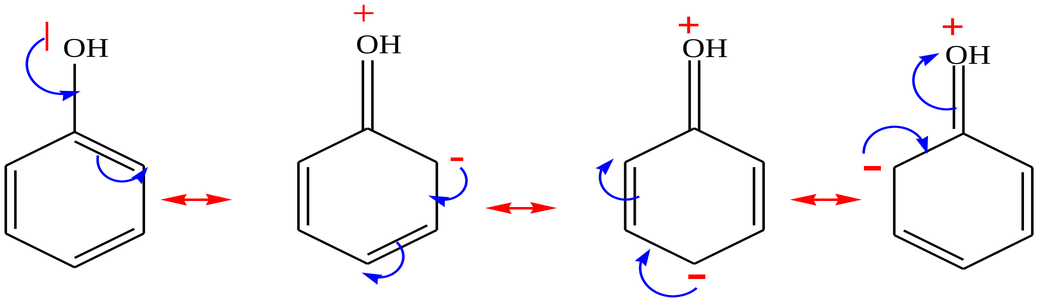


b) The +M effect in aromatic series:

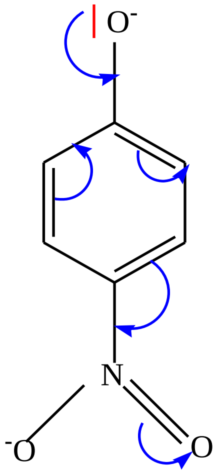
amino-benzene (aniline)

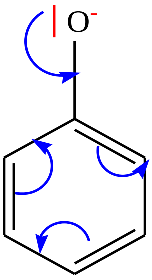


Phenol



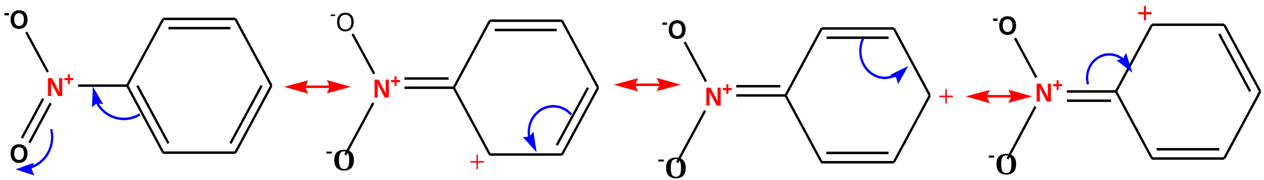
phenate ion





NO_2 is (-M) and (-I)

c) The -M effect in the aromatic series:



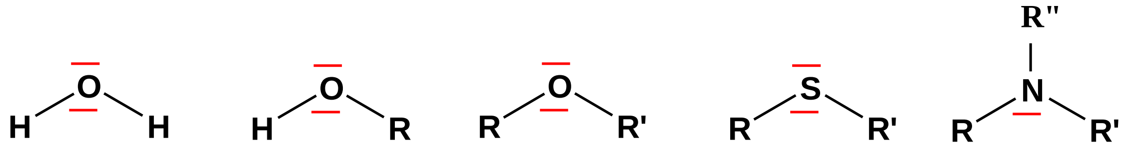
Nitrobenzene

II. The reaction in organic chemistry:

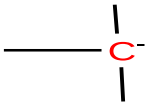
Three types of reactions in our case:

I. 1 Nucleophilic and electrophilic reagents:

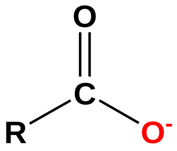
Nucleophiles: A nucleophile has one or more n-doublets or is an anion.



OH^- RO^- X^- $^-C\equiv N$



H^-



Electrophile: An electrophile has an electron void. It is a cation or a neutral molecule.

$$Nu^- + -\overset{|}{\underset{|}{C}}-X \longrightarrow Nu-\overset{|}{\underset{|}{C}}- + X$$

Nucleophile **Substrat** **products**

a) Nucleophilic substitution (SN1)

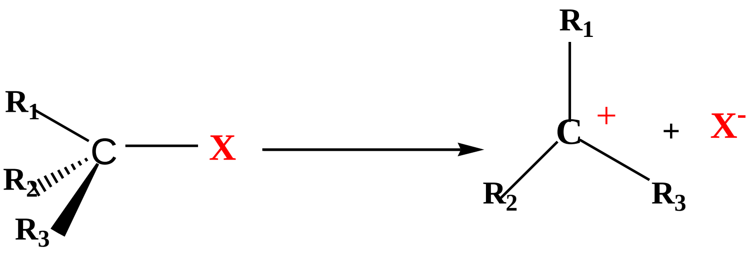
We observe experimentally.

- The reaction is first order with respect to the substrate concentration

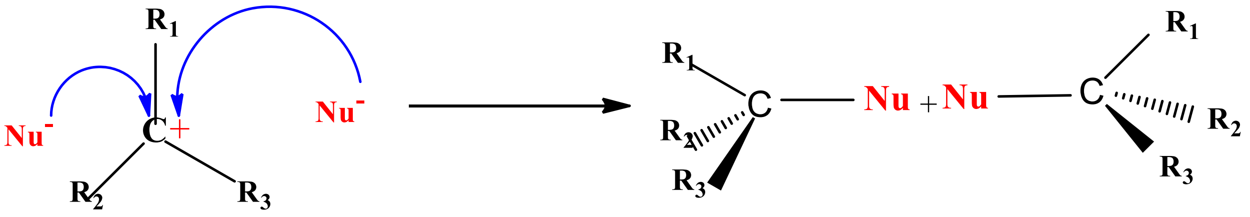
  SN1 reactions are unimolecular: the rate of this reaction depends only on the concentration of one reactant V = k $[Nu]^0$ $[Substrate]^1$.
- The slow step of the reaction which depends only on the substrate is independent of the nucleophile Nu.
- The C – X bond of the substrate is easily ionized.
- Its rupture gives a carbocation intermediate and an X^- ion. (slow step)
- In the second step the nucleophile attacks the carbocation (fast step) to give the substation product

b) SN_1 mechanism stereochemistry:

1st step: **Slow step**



2nd step: Speed step



“racemic mixture

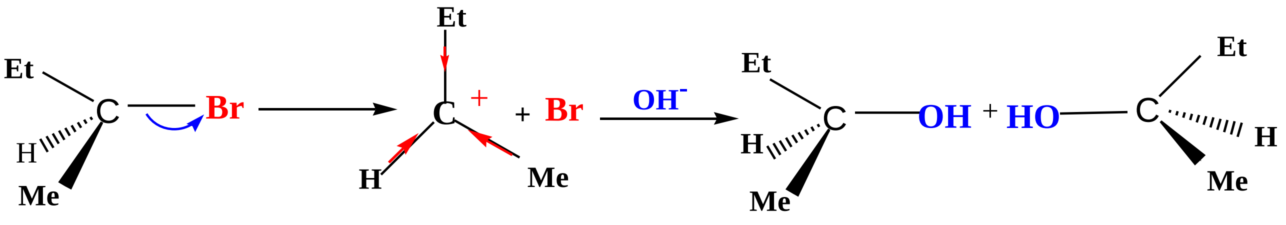
Reaction mechanism: Importantly, the carbocation being formed, the nucleophile can attack either face of the flat carbocation

The SN1 mechanism is favored when the carbocation is stabilized by +I or +M.

Carbocations are most stable when there are more atoms to distribute

Carbocation stability: 3º > 2º >> 1º

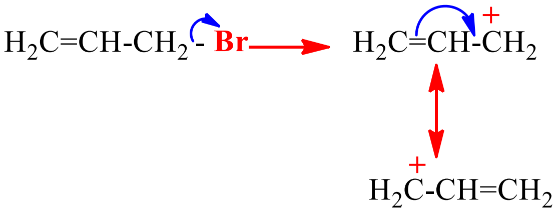
Example: The initial substrate is chiral: **2-bromo-butane (S)**:



50% S 50% R

Optically inactive "racemic" mixture

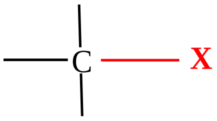
Obtaining two stereoisomeric products (R) and (S) in equal proportion (racemic) demonstrates:



$$H_2\overset{+}{C}\text{-}CH{=}CH_2 \xrightarrow{H_2O} H_2C{=}CH\text{-}CH_2\text{-}OH$$

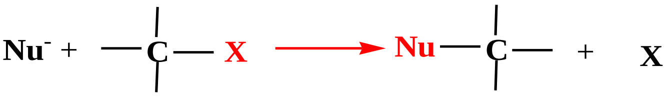
Alcohol allylic

The influence of the leaving group:



The lower the energy of the C-X bond, the more easily the carbocation is formed:

c) SN2 Mechanism:

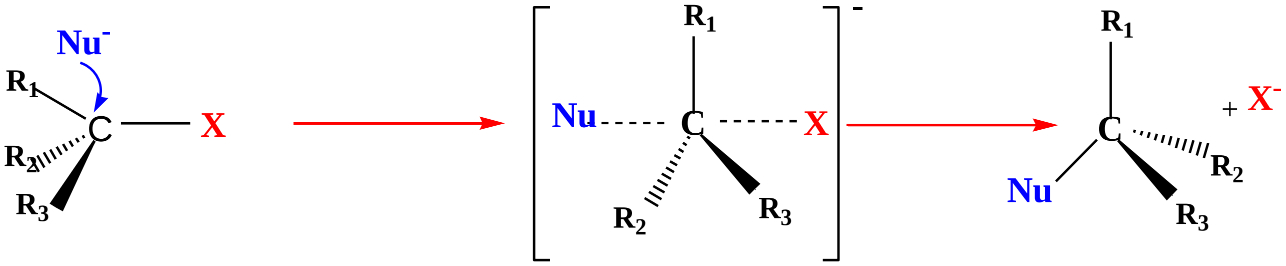


nucleophile + substrat products

We can deduct:

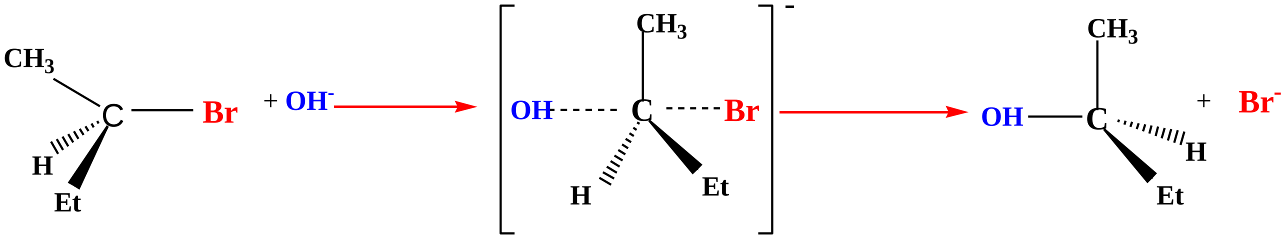
- The reaction is Bimolecular first order whose rate depends on the concentrations of two of its reactants substrate and the nucleophile.
- The kinetic order of the reaction is 2 We observe experimentally
  $V = k [Nu]^1 [Substrate]^1$
- The step is unique: it is a one-step concerted process
- The transition state (activated complex):
- Inversion of the configuration (walden inversion)

d) Stereochemistry of SN2 Mechanism:



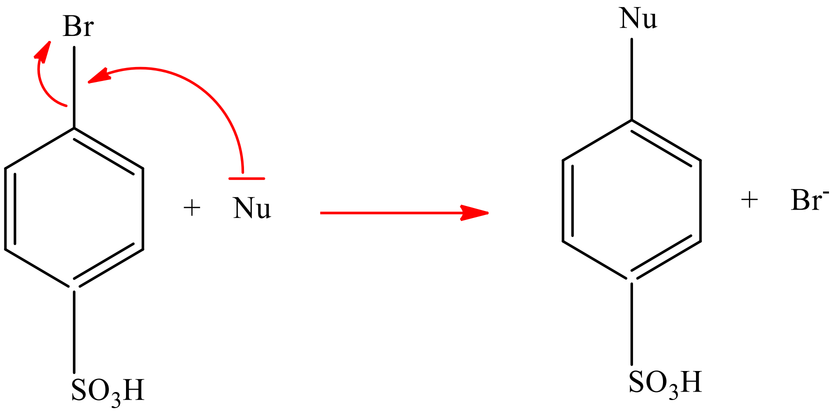
dorsal attack of the nucleophile leading to an inversion of configuration 2 molecules of reactant intervene in this mechanism in a single elementary act: bimolecular reaction SN$_2$

Example: 2-bromo-butane (R)



Butan-2-ol (S)

e) Nucleophilic substitution (SN) On an sp^2 carbon: in the aromatic series (S N_{ar})



The sulfonic group is (-M)

In this reaction , a nucleophile Nu attacks an electron-poor aromatic molecule, resulting in the substitution of a leaving group

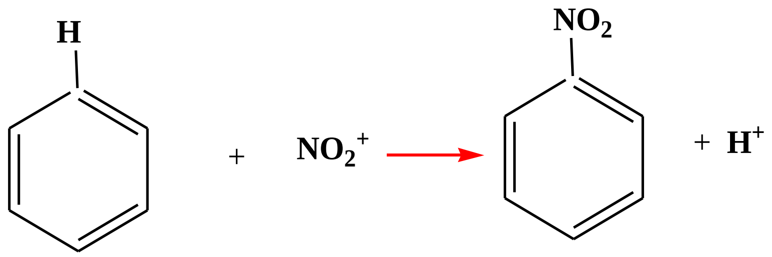
-The rate -determing step is aromatique ring by the nucleophile, witch disrupts aromaticity

-Electron-withdrawing groups on the aromatic ring help to stabilize the negative charge of the intermediate

-Because loss of the leaving group is not the rate-determining step,

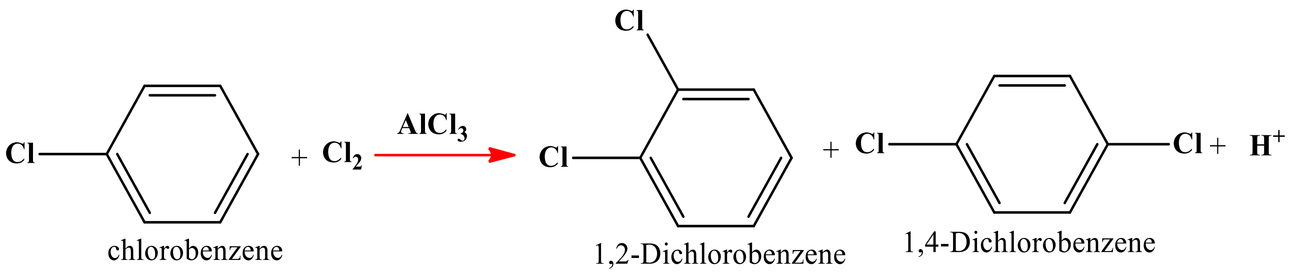
I. 2 Electrophilic substitution (ES)

It occurs most often in the aromatic series:



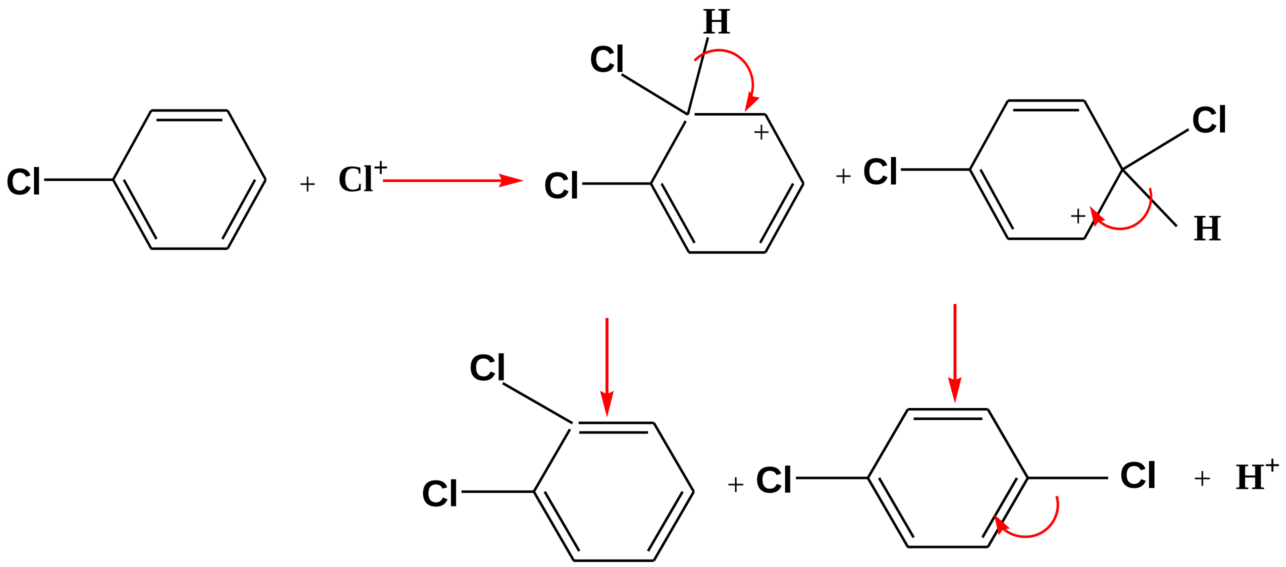
For any electrophilic substitution reaction, we need to identify: the electrophile reagent and the nature of the substitutions.

In this case, 4 steps take place:



$$Cl_2 + AlCl_3 \longrightarrow AlCl_4^- + Cl^+$$

Cl is an electron donor; it orients in Ortho and para

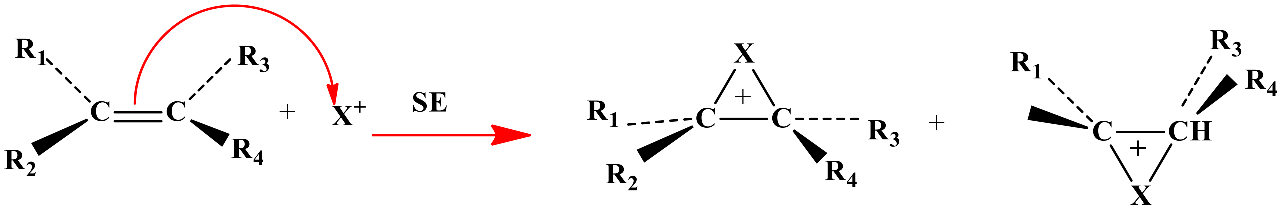


$$H^+ + AlCl_4^- \longrightarrow AlCl_3 + HCl$$

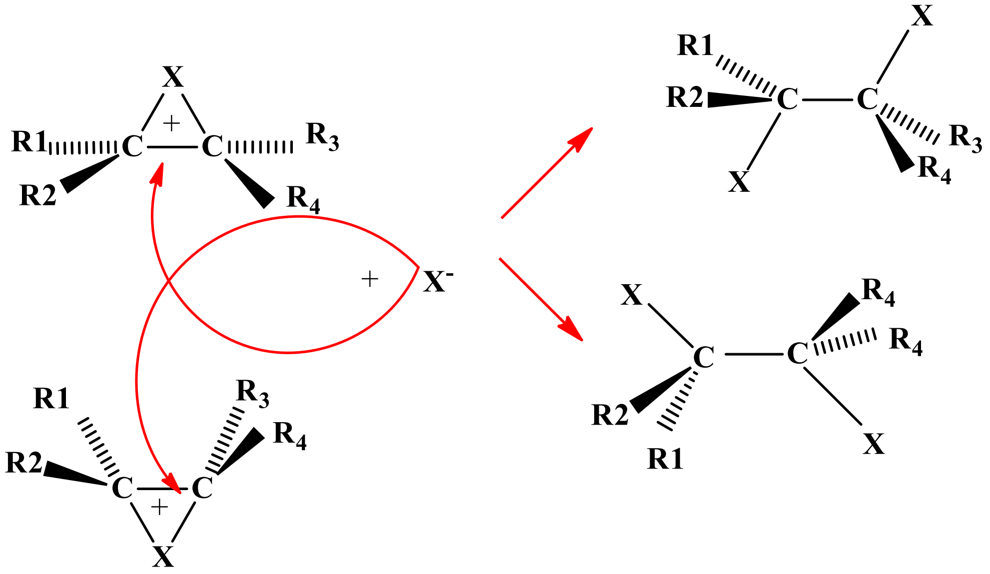
a) Double bond addition reaction:

- Molecule of type X_2 (Cl_2, Br_2, I_2)

Addition of X_2 on R_1-CR_2=CR_3-R_4. Here contains the electrophile X^+, which forms two enantiomeric bridged ions:

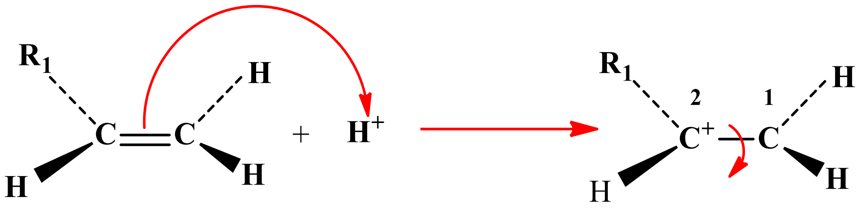


The subsequent attacked by X^- is made on the side opposite to X^+. The latter then settles definitively on the least substituted C. We have trans-addition or anti-addition either:

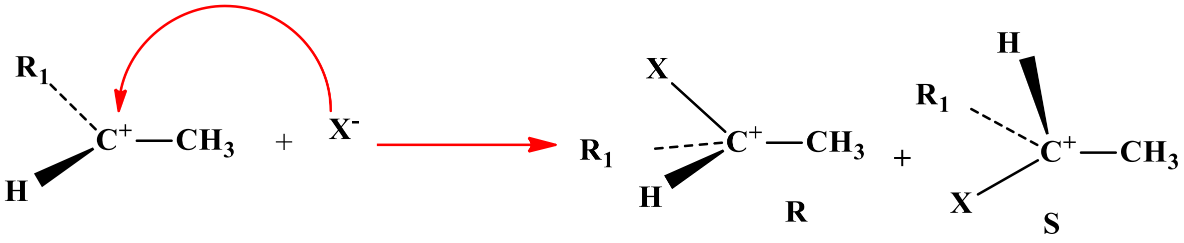


-Molecule of type HX:

Addition of HX on R_1-CH=CH_2: it is an electrophilic addition, with application of the Markovnikov rule; the H+ electrophile binds to the doubly bonded carbon to give the most stable carbocation:

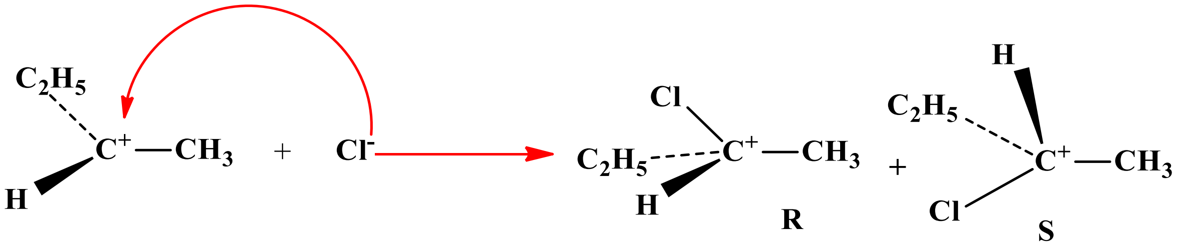


The free rotation author of the C_1-C_2 bond not being prevented, the definitive fixation of the nucleophile X- can be done in 2 different ways generating a C* 2R or 2S. Because of the equiprobability, we obtain a racemic mixture either.



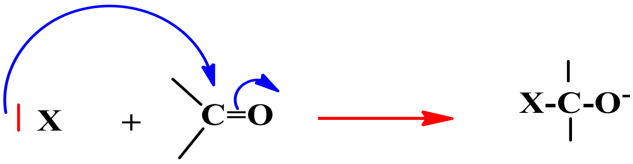
Example

Addition of HCl on C_2H_5-CH=CH_2



Mix of d'enantiomers 2 -Chloro butane R and S

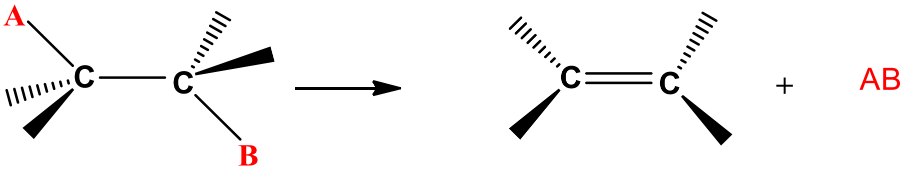
b) Nucleophile addition (NA): frequent on a carbonyl:



The reaction is initiated by the nucleophile X^-

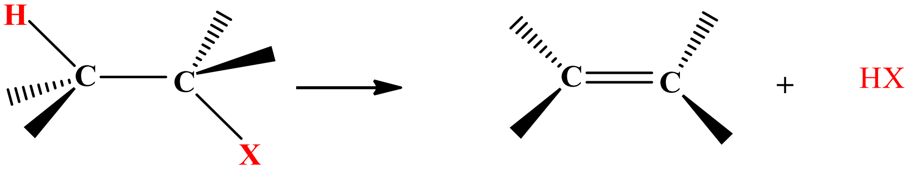
I. 3 Elimination reaction:

It is the reverse of the electrophilic addition reaction



The elimination is always done between two atoms carried by two adjacent C

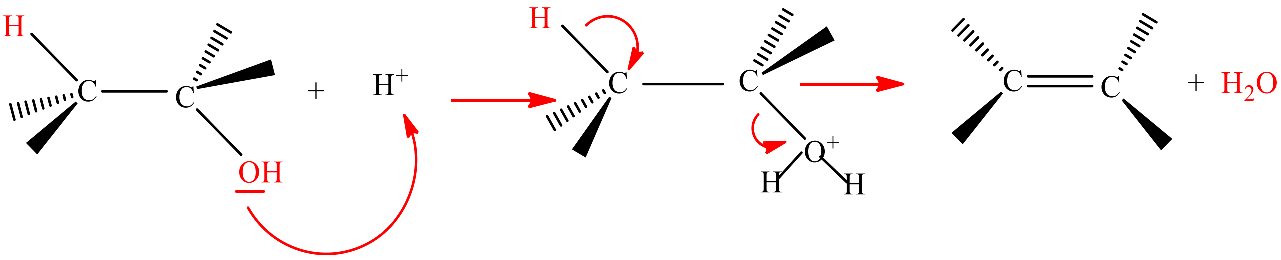
*If X= OH



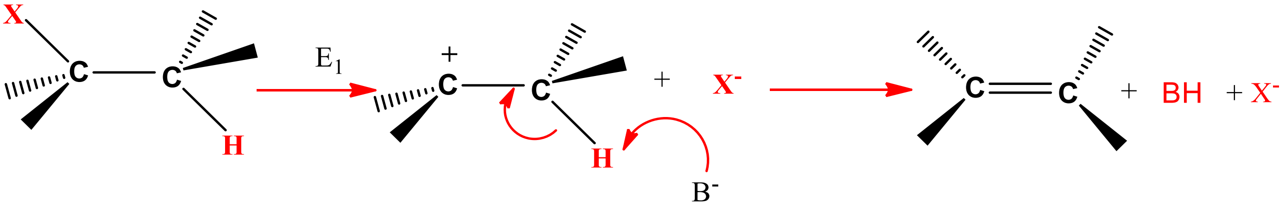
The medium must be acidic (ex: H_2SO_4 + ΔKT) we went through a

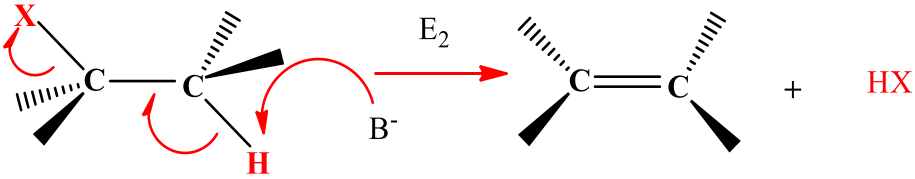
stable carbocation → order 1

unstable carbocation → order 2 (trans elimination)



*If X= Cl, Br (strong basic medium + ΔKT)



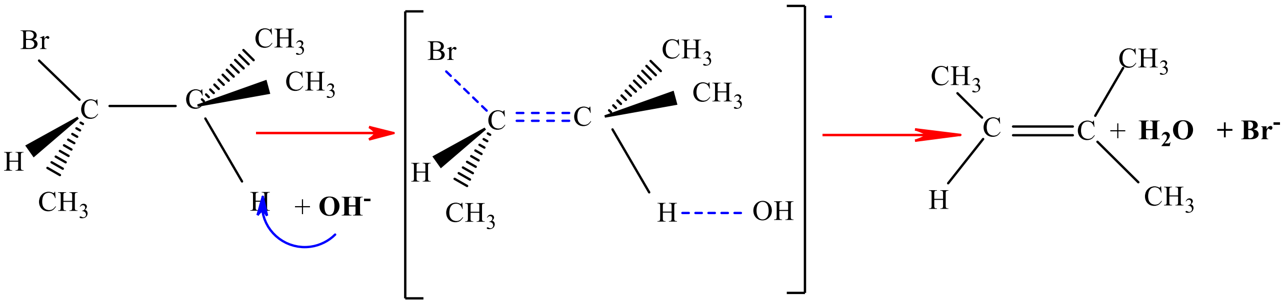


The majority product in the elimination is the most hydrogen alkene substitute (the least hydrogen). An E2 type elimination reaction generally competes with an SN2 reaction. It leads to one or more alkenes according to the saytzeff rule. Development of the mechanism that leads to the majority product (most substitute alkene).

Example :

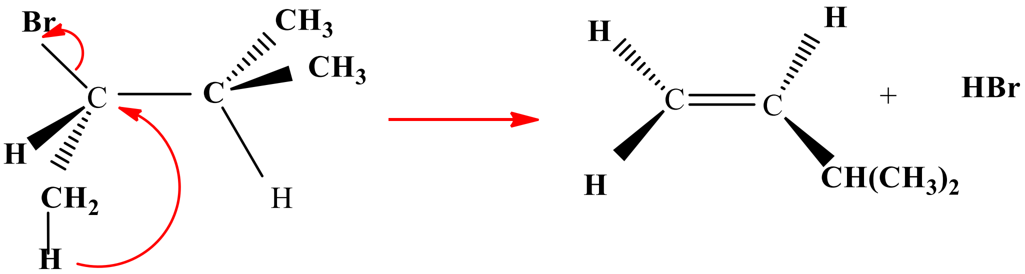
The compound R-Br adopts, from the start of the reaction, a conformation such that the C-Br and CH bonds are anti-parallel (or anti-periplanar conformation for the halogen and the hydrogen atom eliminated)

The biomolecular mechanism takes place in one step:



The conformation of the transition state where the halogen and the hydrogen are in trans of each other, ensures a minimum of electrostatic potential energy. In this state, all the bonds are formed or broken simultaneously.

E2 elimination is concerted trans-elimination. the product is 2-methyl bute-2-ne the other alkene formed is 3-methyl butene



Chapter 3 : Major reactions in organic chemistry

I. 4 Exercises on Reaction Mechanisms

Exercise 1 :

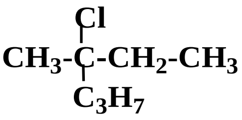
Give the limiting forms of the following molecules and ions:

-Fluorobenzene, 4-nitrophenol, benzoic acid N,N-dimethylethenamine

Exercise 2 :

1. Substitution nucleophiles

*the following compound **A:**



$$CH_3-\overset{\overset{Cl}{|}}{\underset{\underset{C_3H_7}{|}}{C}}-CH_2-CH_3$$

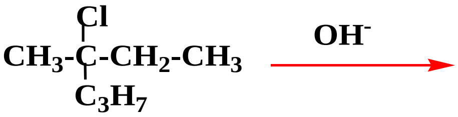
A

1) Name it.

2) A is subject to the action of the base OH^-.

What type of reaction takes place?

3) Describe it completely by identifying all the compounds and reaction intermediates likely to form.



$$CH_3-\overset{\overset{Cl}{|}}{\underset{\underset{C_3H_7}{|}}{C}}-CH_2-CH_3 \xrightarrow{OH^-}$$

2. Substitution electrophile

1) Give the formulas and names of the products obtained by:3

-paranitrotoluene monochlorination

-sulfonation of metanitrobenzaldehyde

- nitration of orthoaminoacetophenone

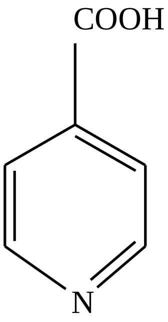
2) Complete the following reactions by failing the mechanism:

$C_6H_5Cl \xrightarrow{HNO_3/H_2SO_4} (A)$

$(A) + C_2H_5Cl \xrightarrow{AlCl_3} (B)$

What products are obtained (from the alkylation of benzene followed by nitration)?

3) Consider the following compound A:



A

-Name it.

-Give the mesomeric forms of this acid.

- The chlorine reacts with the previous acid. What products do you get if the reaction stops at monochlorination?

3. Addition electrophiles

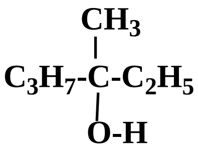
Explain the mechanism of the following reactions by naming the compounds:

Addition of HCl on $C_3H_7\text{-}CH{=}CH_2$

Addition of I_2 on $C_2H_5\text{-}CH{=}CHCH_3$ (E)

4. Elimination Reaction

A is subjected to dehydration in an acid environment.



$$\begin{array}{c} CH_3 \\ | \\ C_3H_7\text{-}C\text{-}C_2H_5 \\ | \\ O\text{-}H \end{array}$$

Two compounds B and C are formed with a third, less abundant D.

Write the different reactions taking place and name all the products formed.

Chapter 4: Topics of synthesis And solution of the exercises

Topics of synthesis 1

Exercise 1:

$CH_3CHBrCHCBrCHO$: How many stereoisomers does it have? Give the fischer representation of these diastereoisomers.Specify R or S.

Using a clear diagram, highlight the specific characters of the SN1 and SN2 reactions.

- Suppose that OH- can only give rise to substitution reactions under the experimental conditions, complete the following reaction schemes by assigning SN by 1 or 2:
- $OH^- + CH_3\text{-}CH(CH_3)\text{-}CH_2Cl \xrightarrow{SN}$
- $OH^- + C_2H_5\text{-}C\ (CH_3)_2\text{-}Cl \xrightarrow{SN}$
- $OH^- + C_2H_5\text{-}CH\ (CH_3)\ \text{–}Cl \xrightarrow{SN}$

Exercise 2:

Complete the following reactions:

1) $CH_3\text{-}MgI + C_2H_5CN \xrightarrow{H_2O} (A)$

$(A) + (CH_3)_2CH\text{-}MgCl \longrightarrow (B)$

$(B) + CH_3\text{-}CH_2\text{-}COOH \longrightarrow (C) + H_2O$

2)2- methyl 2-butene +H2O $\xrightarrow{H_2SO_4}$ (D)

$(D) \xrightarrow{\text{Alumina}} (E) + H_2O$

$(E) + HCl \longrightarrow (F) \xrightarrow{NH_3} (G) + HCl$

3)1-bromopropane + KCN $\longrightarrow$ (H) + KBr

$(H) \xrightarrow[H_2O]{C_2H_5MgI\ (I)} \xrightarrow{CH_3NH_2} (J) + H_2O$

Exercise 3:

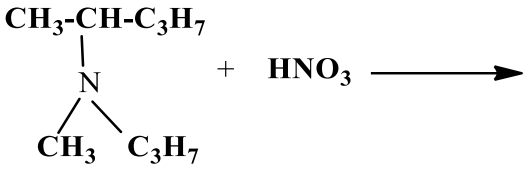
$C_6H_5Cl \xrightarrow{HNO_3}$

H_2SO_4

$Cl_2 + H_2SO_4$cc+benzene + aluminum chloride $\longrightarrow$

$C_2H_5\text{-}CHO + C_2H_5\text{-}CHO \longrightarrow$ develop the mechanism

$CH_3\text{-}CH(CH_3)\text{-}COOH + NH_2\text{-}C_2H_5 \xrightarrow{\Delta}$



$$CH_3\text{-}CH(N(CH_3)(C_3H_7))\text{-}C_3H_7 + HNO_3 \longrightarrow$$

Exercise 4:

- The ozonolysis of an alkene (C) gives two compounds (D) and (E) and hydrogen peroxide H_2O_2.- Methyl magnesium chloride reacts with (D) to give, after hydrolysis, the product (F): $CH_3CH_2C(OH)CH_3\text{-}CH_2CH_3$.

- Compound (E) of molecular formula $C_5H_{10}O$ reduces Fehling's liquor and is optically active.

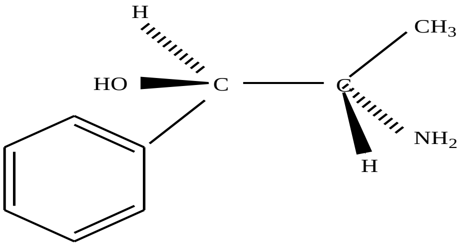
Detail the sequence of reactions to identify (C), (D) and (E). Name all the compounds.

Topics of synthesis 2

Exercise 1:

Nucleophilic substitution

1. Norephedrine A is an alkaloid with the following formula:



A

1) Give its nomenclature.

2) Determine the R\S absolute configuration of the asymmetric(s) carbon(s).

3) Resume norephedrine A in fischer projection.

4) In the presence of sodium acetylidenorephedrine gives the following representation:

$$\mathbf{A} + \mathbf{H}-C\equiv C^{-} \longrightarrow \mathbf{B} + OH^{-}$$

-Detail the mechanism of this reaction.

-Draw the spatial representation of the stereoismere (s) of the resulting compound B.

2. One mole of acetate (CH_3COO^-) reacts with one mole of 2,2-dimethyl,3-iodopentane R. The reaction is of order 1 with respect to acetate and of order 1 with respect to 2,2-dimethyl,3-iodopentane R also leads to the product C_7H_{14} following an elimination reaction.

1) Describe the mechanism of the reaction.

2) Give the Z\E configuration of the different stereoisomers likely to form.

Exercise 2:

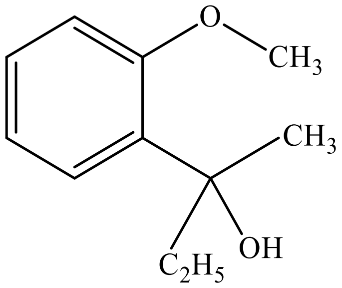
A nucleophilic substitution reaction makes it possible to prepare 2-ethyl2-methyl pentanetrile from 3-chloro-2-methyl hexane.

1) Write the balance equation of this reaction SN.
2) Explain the mechanism by specifying which SN reaction is involved.

Exercise3:

Nucleophilic substitution

Consider the following compound B



The action of HBr on compound B gives two types of reactions:

- B + HBr $\longrightarrow$ N + N' + H_2O
  racemic

- B + HBr $\longrightarrow$ M + M' + H_2O + HBr
  Majority

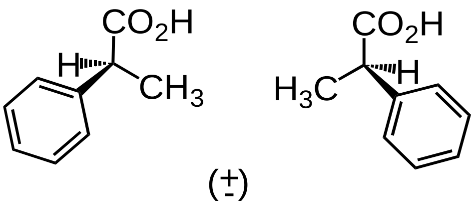
Detail the two mechanisms and name the products formed. Why is M in the majority?

Additional Exercises

Exercise1:

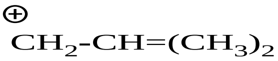
1. An alkane has a molecular mass equal to 72. It has only one monochlorinated derivative. What is its structural formula?

- Specify R or S. These molecules are they aptically?

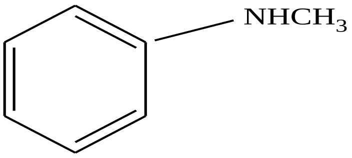


2. Write the mesomeric forms of the following compounds:

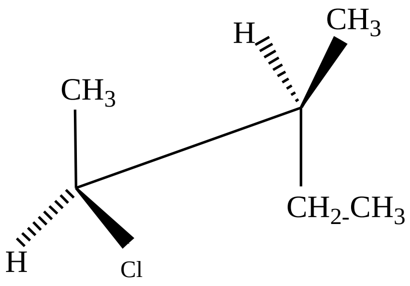
$(CH_3)_2N\text{-}CH=CH\text{-}CH_3$



$\overset{\oplus}{C}H_2\text{-}CH=(CH_3)_2$

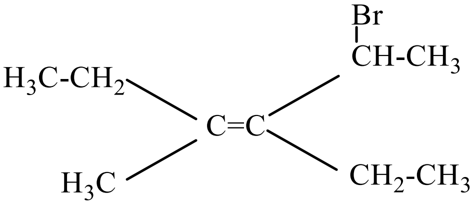


3. The following molecule is given:



- Give the fischer representation of this molecule.
- Give the Newman projection of the molecule.
- Determine the absolute configuration of the C*(S).
- Give a diastereoisomer of this molecule.

4. Consider the following molecule:



- Name it.
- Is this molecule optically active? explain why?
- In how many configurations does it exist?

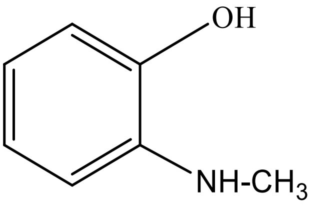
Exercise 2:

1. Under certain conditions the following compound gives two products: The kinetics is biomolecular.

CH_3-CH_2-CH (CH_3)-CH_2-Cl $\longrightarrow$ CH_3-CH_2-CH(CH_3)-CH_2-OH + CH_3-CH_2-C(CH_3)=CH_2

Explain the two reactions involved.

2. N-methyl 2-aminocyclohexanol can be prepared by hydrogenation of N-methyl 2- amino phenol
(F)



(F)

Starting from a molecule of (F), what compounds are obtained by the action of a molecule of chlorine in the presence of aluminum chloride? Give the mechanism.

Exercise 3:

Can isopropylmagnesium chloride react with the following molecules?

Write the reactions if any:

1)water4) ammonia

2) 2-bromobutane   5)2-cyanopropane

3) 1- propanol   6)hydrochloric acid

Exercise 4:

1.A pure organic product is obtained when 1-bromo-propane reacts with one equivalent of sodium cyanide in aqueous ethanol. What is this product?

*$BrCH_2CH_2CH_3 + NaCN \longrightarrow$

-Write the balance equation of this SN reaction.

Explain the mechanism by specifying which SN reaction is involved.

2.$CH_3Br + HO^- \longrightarrow$

$$V = k[CH_3Br][HO^-]$$

the determining step is bimolecular.

3. 3-chloro-3-ethylpentane + NaOH

Exercise 5:

Can isopropyl magnesium chloride react with the following molecules?

Write the reactions if any:

1)water   4) ammonia

2) 2-bromobutane   5) 2-cyanopropane

3) 1- propanol   6) hydrochloric acid

Exercise 6:

How can 2-bromo pentane be prepared from:

1/ pent-1-yne   3/ 1-bromopentane

2/$CH_3CH_2CH_2CH_2CH_2OH$ 4/1,2-dibromopentane

Exercise 7:

a) A nucleophilic substitution reaction makes it possible to prepare 2-ethyl, 2-methyl pentane nitrile from 3-chloro3-methylhexane.

1-Write the balance equation of this SN reaction.

2-Explain the mechanism by specifying which SN reaction is involved.

b) Count the following reactions:

$CH_3\text{-}CH{=}CH_2 + HCl \xrightarrow{\quad} (A)$

$(A) + C_6H_6AlCl_3 \xrightarrow{\quad} (B)$

$(B) + Cl_2 \xrightarrow{AlCl_3} (C) + (C')$

$(B) + Cl_2 \xrightarrow{UV} (D) + (D)$

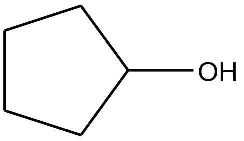
$(B) \xrightarrow{KMnO_4\ cc} (E)$

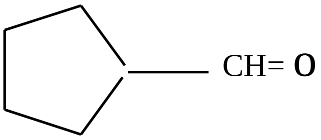
$(E) \xrightarrow{HNO_3/H_2SO_4} (F)$

Exercise 8:

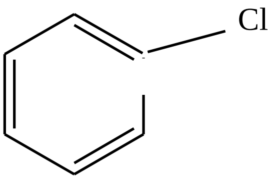
Find a sequence of reactions, as short as possible, allowing the following transformations to be carried out.

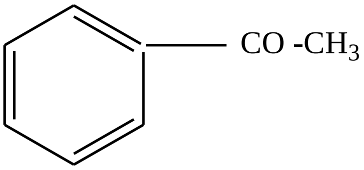
1-



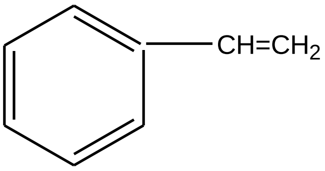


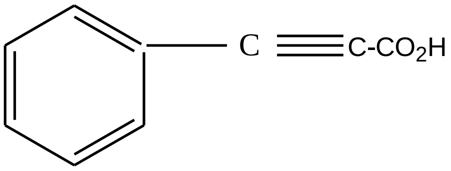
2-



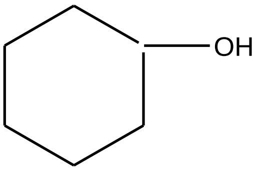


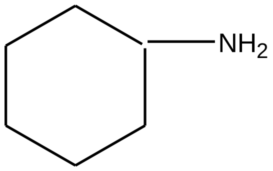
3-



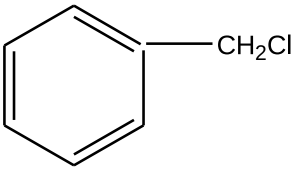


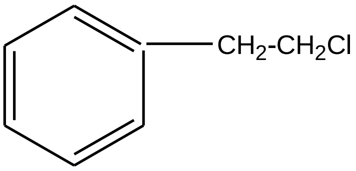
4-



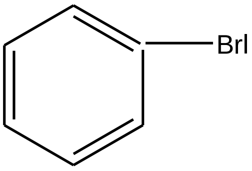


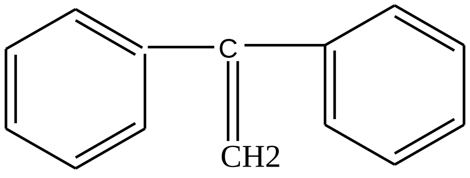
5-





6-





7- Ph-CH_3

Ph-CH_2D

8- Propéne

Hexane

Solution of application exercises and topics of synthesis

Chapter 1: Nomenclature

a)

1.
methyl ethanoate

2.
cyclohexylethanoate

3.
Methylpropyl 3-methylpentanoate

4.
1-methylpropyl ethanoate

5.
O-xylene

6.
benzylacetate (ester)

7.
1-Methylpropyl ethanoate

8.
Isobutyl acetate

9.
Lacticacid2-hydroxypropanoic acid

b) Aromatic Compounds

10.

Acetylsalicylic acid
(aspirin)

2-(acetyoxy)benzoic) acid

11.
Salicylicacid

12.

Paraminophenol

4-aminophenol

13.

N-(4-hydroxyphenyl)

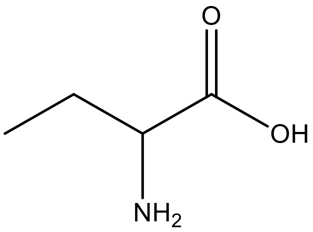
ethanamide (Paracetamol)

14.
N-Phenylethanamide
(amide)

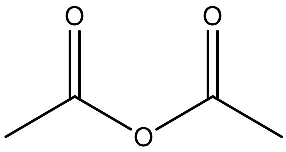
15.

Phenylmethanol (alcohol)

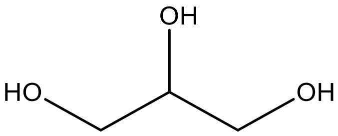
c)The structural formula of the following compounds:



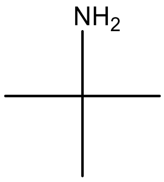
16.
2-aminobutanoic acid



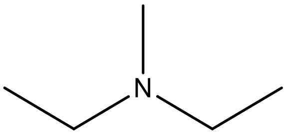
17.
Ethanoic anhydride



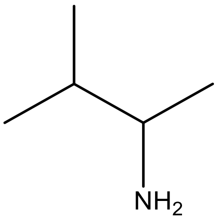
18.
Glycerol (trialcohol)



19.
Dimethylethanamine



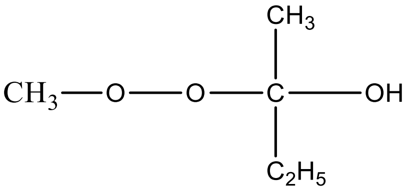
20.
N-ethyl-N-methylethanamine



21.
3-methylbutan-2-amine

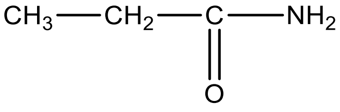
$CH_3COOC_6H_5$

22.
Phenyl ethanoate



$CH_3-O-O-\overset{CH_3}{\underset{C_2H_5}{C}}-OH$

23.
(R)2-(methylperoxy)butan-2-ol



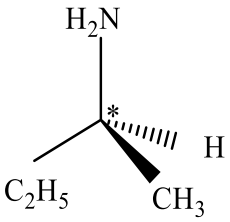
$CH_3-CH_2-\underset{\underset{O}{\|}}{C}-NH_2$

24.
Propionamide

Chapter 2: Isomers

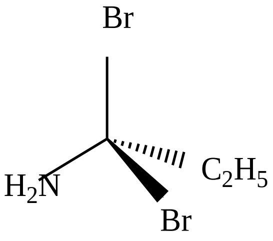
Exercise 1:

1.



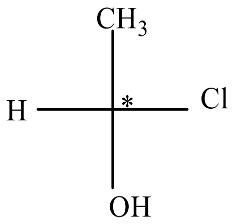
chiral

2S-configuration



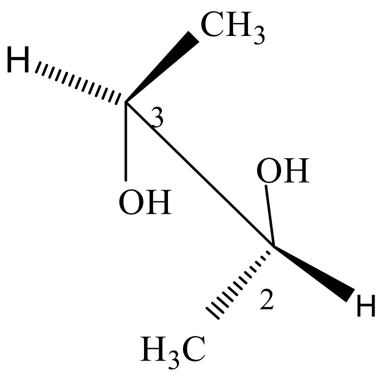
not chiral

not C*



chiral

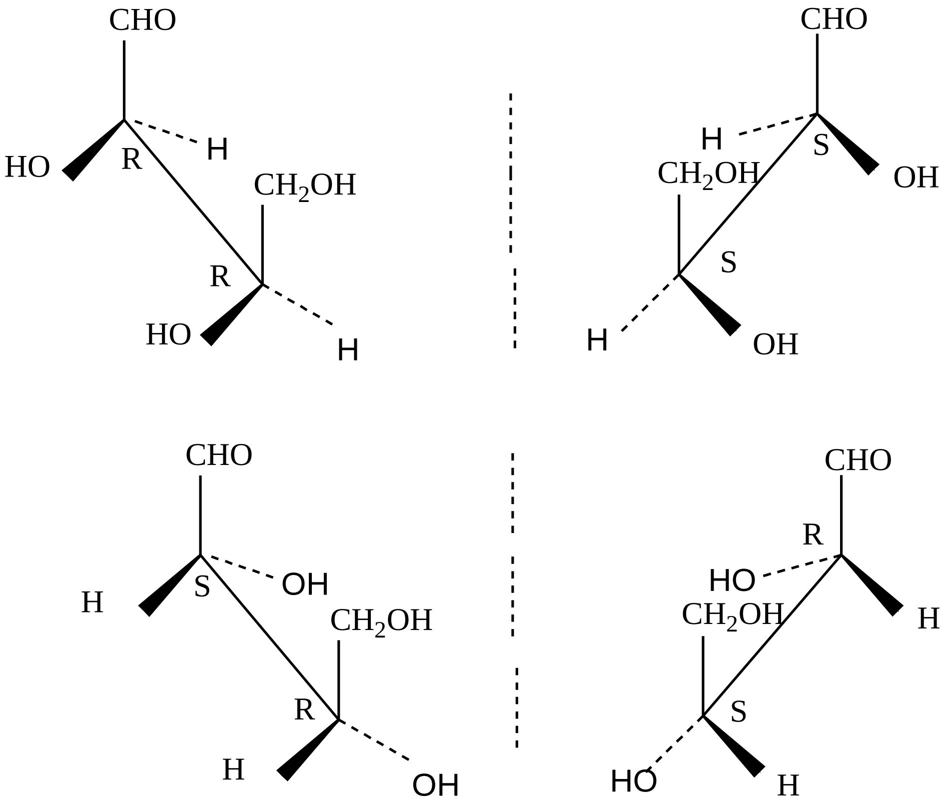
S



chiral

2R,3S

2. 2,3,4-trihydroxybutanal CH- CH(OH)- CH(OH)- CH_2OH in Projective (CRAM)



Enantiomers

The number of stereoisomers that can exist is equal to 2^n, where n is the number of asymmetric carbon. So, 4 stereoisomers

Exercise 2:

The rule of Cahn, Ingold and Prelog makes it possible to classify the following groups in order of decreasing priority:

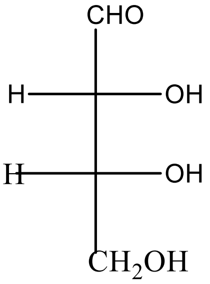
$-OCH_3$;-OH ; $-NH_2$;$-CH_2Cl$;-COOH ;-CHO ;$-CH_2OH$;$-(CH_3)_3$

Exercice 3:

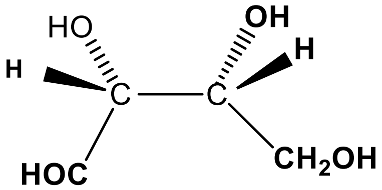
1.D-Erythrose molecule is a 4-carbon sugar D and erythro

Linear formula $O=CH-CH(OH)-CH(OH)-CH_2OH$ like all n-carbon sugars, it has an aldehyde function, followed by (n-2) secondary alcohol functions and terminated by a primary alcohol function.

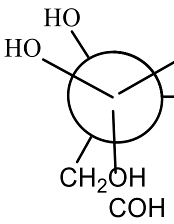
The erythro structure (of which this sugar is the reference) implies that on a Fischer view the two secondary OHs are on the same side. The descriptor D implies that the OH of the asymmetric C of highest index, here C*3, is seen on the right. The formula according to Fischer istherefore the following:



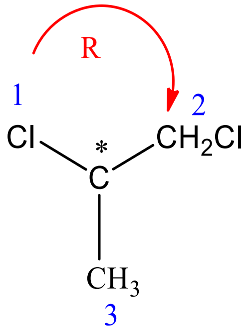
The projective form can be deduced from it, or established from the data. Several answers are possible given the angles of view and the different possible conformations. Here is the view for an observer placed according to the following scheme.



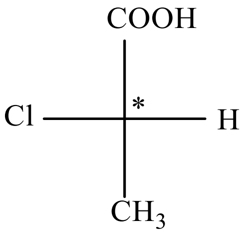
Give the following eclipsed NEWMAN representation



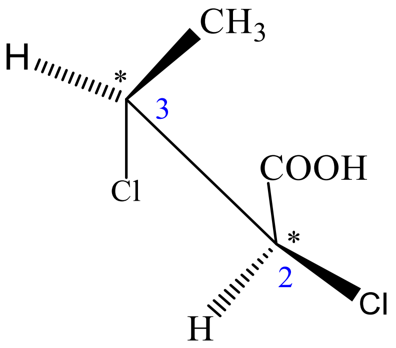
2.



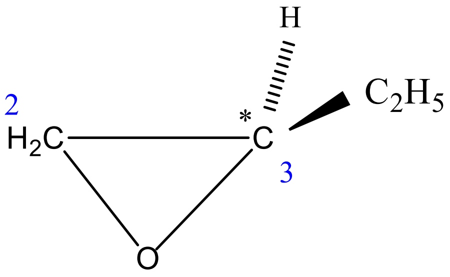
(R)-1,2dichloropropane



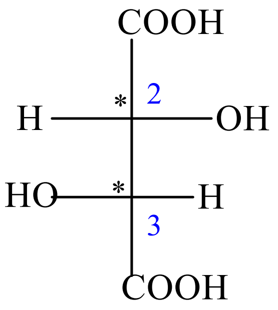
(S)-2-chloropropanoic



(2S,3R)dichloro-2,3-butanoic



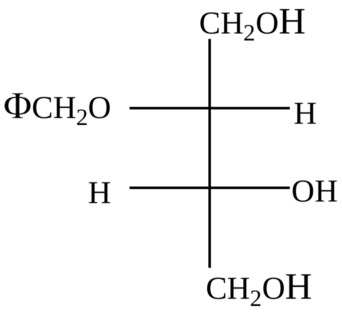
(R)1-2 epoxybutane



(2R,3R) tartaric acid

3. Formula of: (-) (2R, 3R) 2-Benzyloxy 1,3,4-Butanetriol of linear formula: CH_2OH-CHOH-CH(O-CH_2-C_6H_5)-CH_2OH

The greatest difficulty is not to get the index wrong, the C2 carries the substituentbenzyloxy

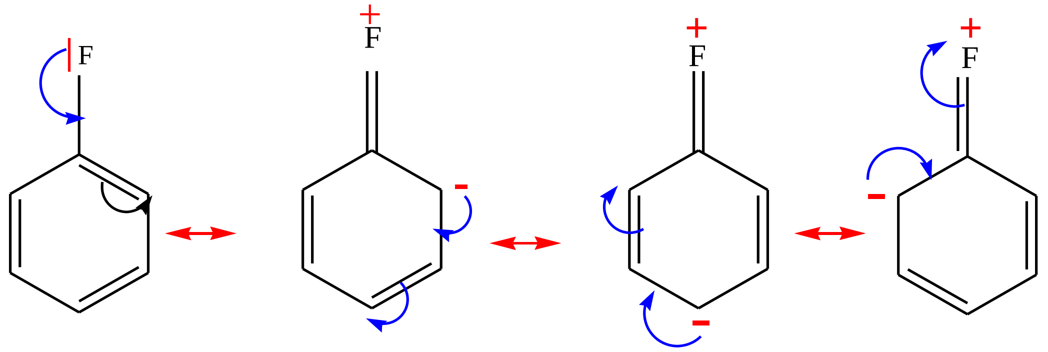


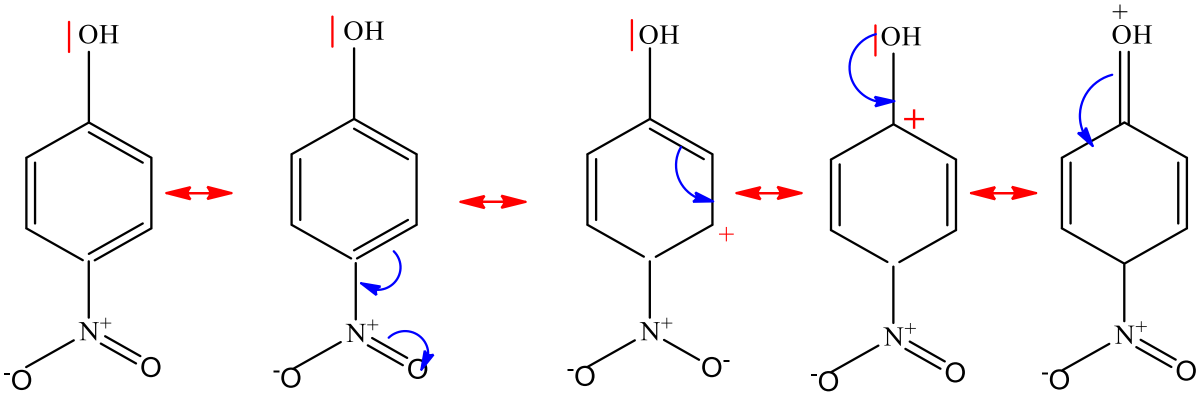
Chapter 3: Reaction Mechanisms

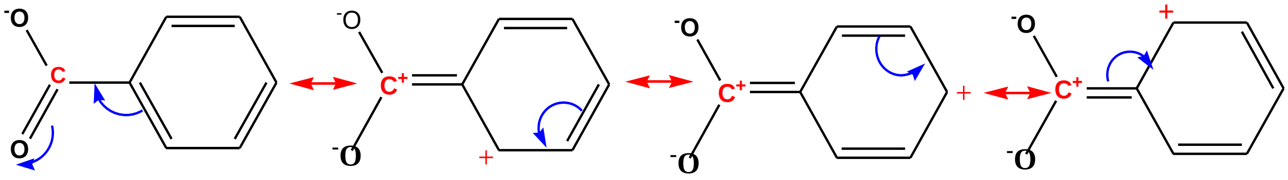
Exercise 1:

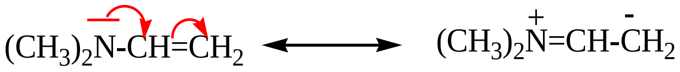
The limiting forms of the following molecules and ions:

-Fluorobenzene, 4-nitrophenol, Benzoic acid, N,N-dimethylethanamine









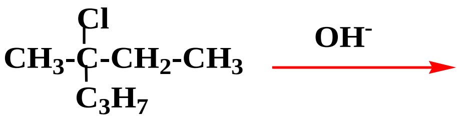
$$(CH_3)_2\overline{N}\text{-}CH{=}CH_2 \longleftrightarrow (CH_3)_2\overset{+}{N}{=}CH\text{-}\overset{-}{C}H_2$$

Exercise 2 :

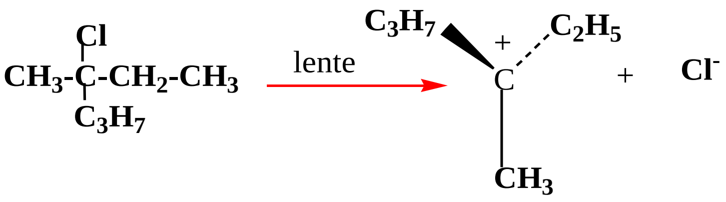
Nucleophilic substitution

3-chloro,3-methylhexane

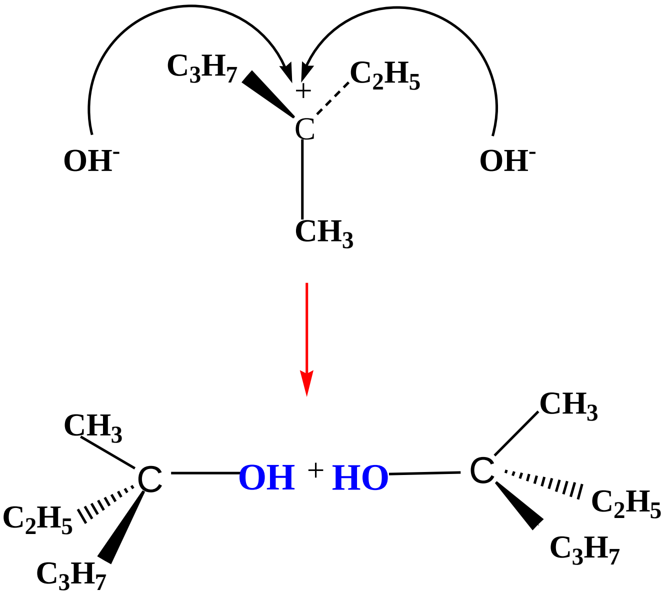
The carbon, site of the nucleophilic attack, is tertiary. The formation of a stable carbocation is therefore favored. SN1 there fore takes place



$$CH_3\text{-}\underset{C_3H_7}{\overset{Cl}{C}}\text{-}CH_2\text{-}CH_3 \xrightarrow{OH^-}$$



Tertiary planar carbocation

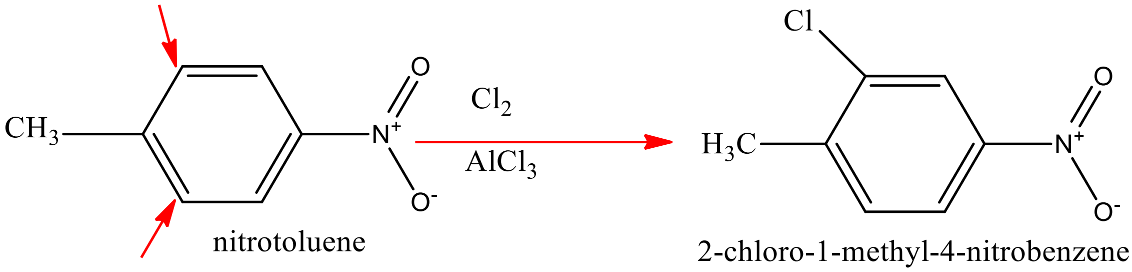


3-methyl hexan-3-ol **R and S Racemic Mixture**

Electrophilic substitution

a) The formulas and names of the products obtained by:

1.monochlorination of paranitrotoluene

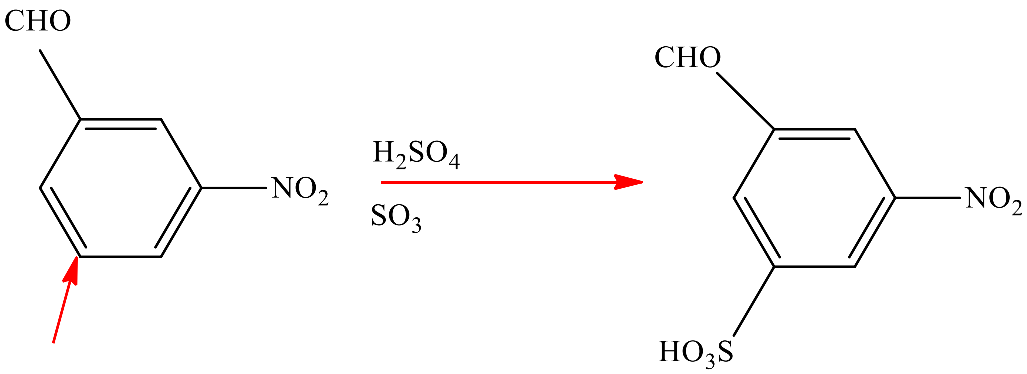


nitrotoluene

2-chloro-1-methyl-4-nitrobenzene

Each arrow represents the orientation imposed by the substituents already in place

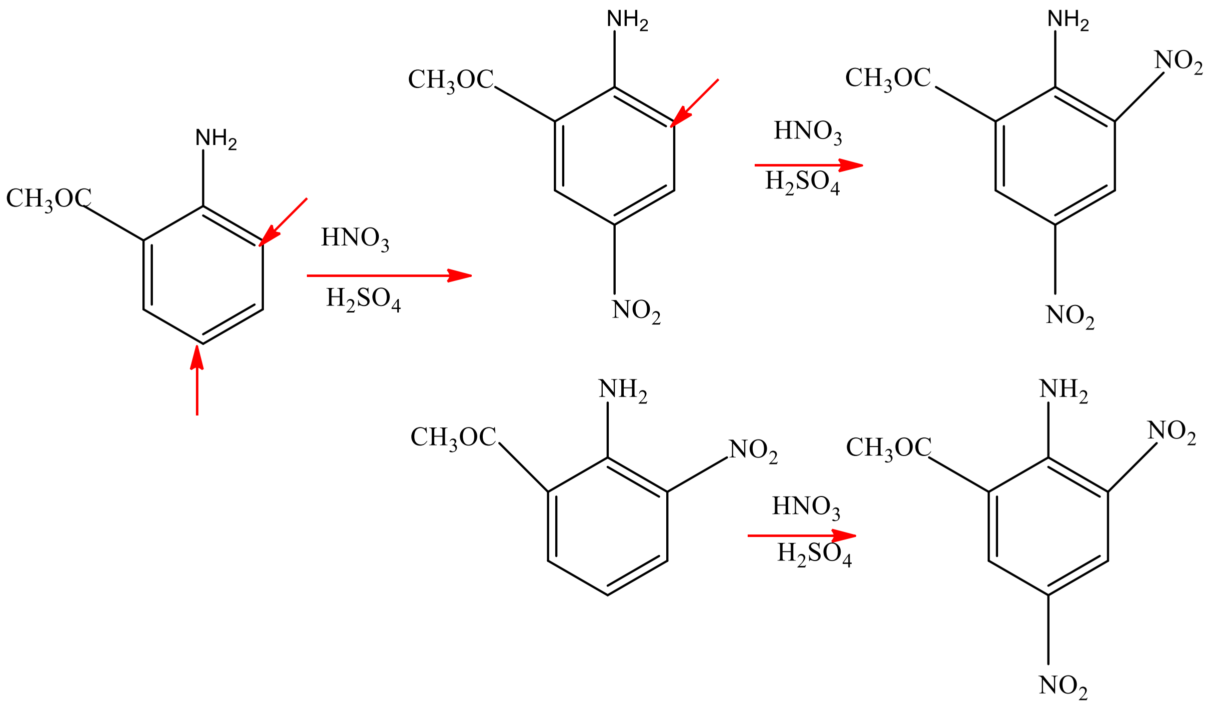
2.sulfonation of meta nitrobenzaldehyde



5-Nitro-3-oxo-benzenesulfonic acid

The reaction stops at monosulfonation

3-nitration of orthoaminoacetophenone



1-amino, 2,4-dinitro acetophenone

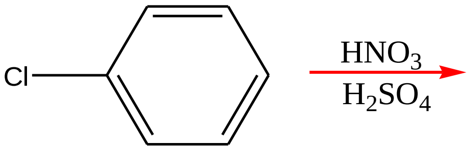
b)

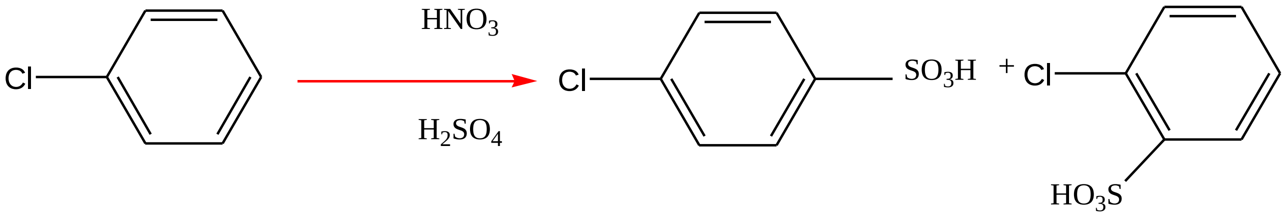
$C_6H_5Cl \xrightarrow{HNO_3/H_2SO_4}$ (A)

(A) + $C_2H_5Cl \xrightarrow{AlCl_3}$ (B)

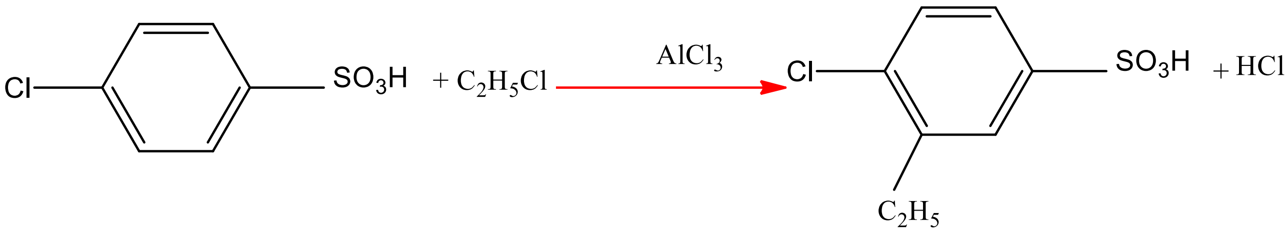
Are the products obtained by (alkylation of benzene followed by nitration)?

b) The following reactions:

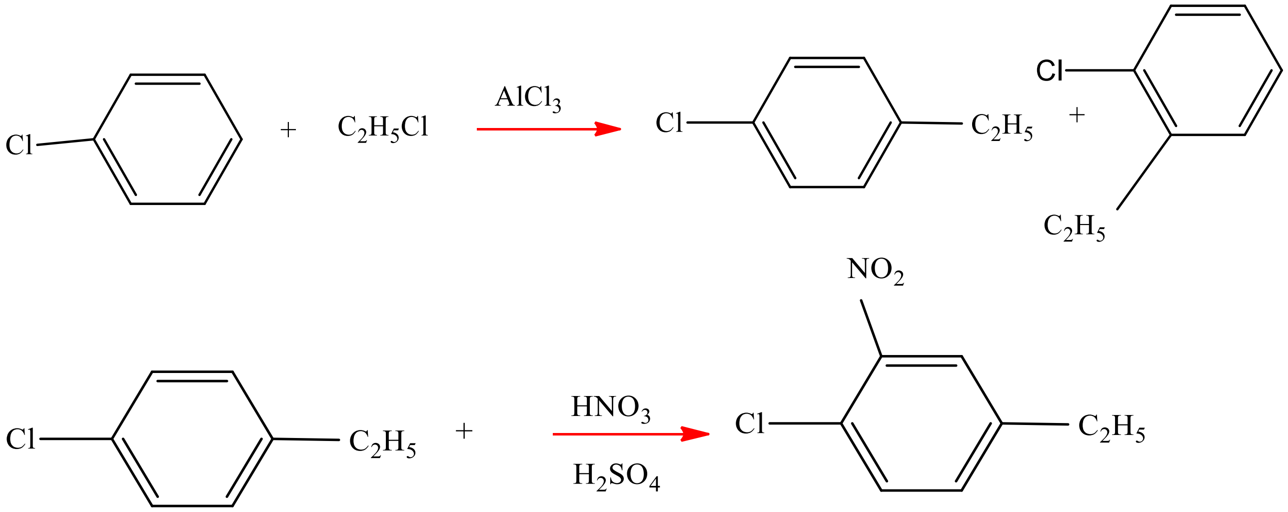




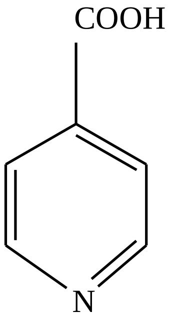
A



Alkylation of benzene followed by nitration

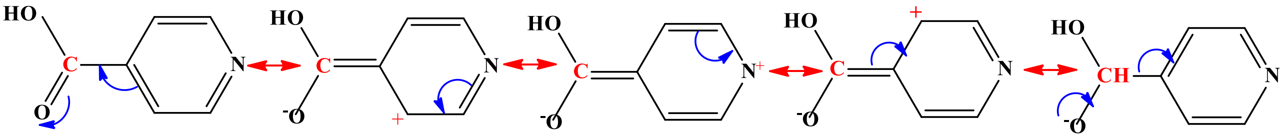


c) Consider the following compound A:

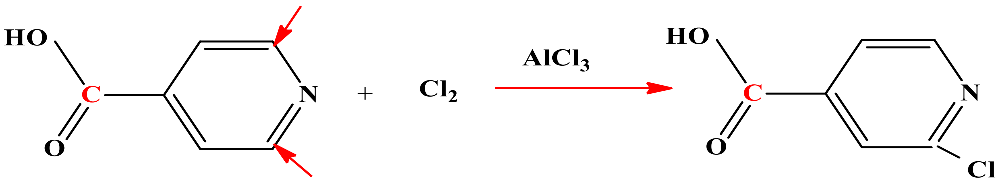


Name: isonicotinic acid

Mesomeric form of isonicotinic acid:



The writing of limit forms highlights the centers of attack by an electrophilic reagent; only -COOH meta positions will be taken.



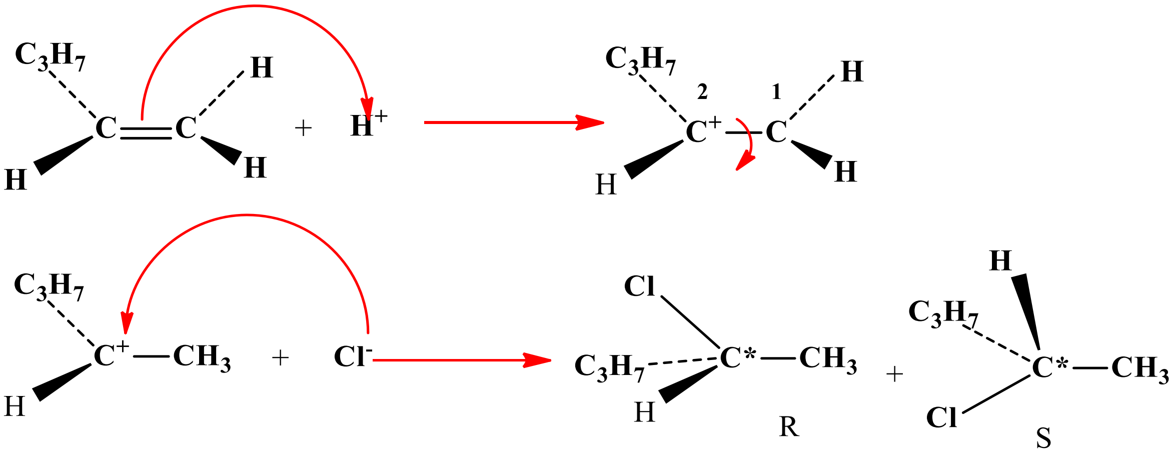
Addition Electrophiles:

- Addition of HCl on C_3H_7-CH=CH_2
- Addition of I_2 on C_2H_5-CH=$CHCH_3$(E)

Development of the following reaction mechanisms:

1- Addition of HCl on C_3H_7-CH=CH_2

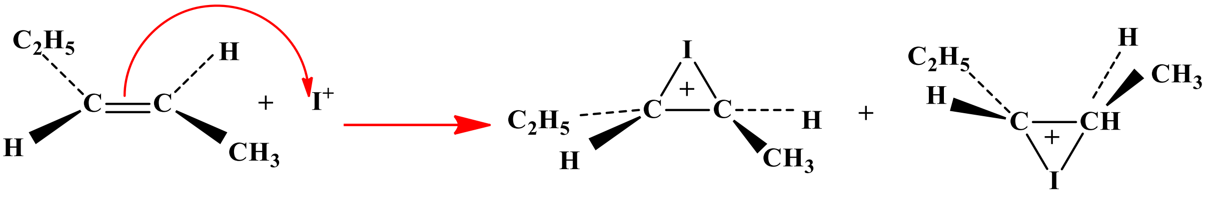
Application of the Markovnikov rule; the H^+ electrophile binds to the doubly bonded carbon to give the most stable carbocation:



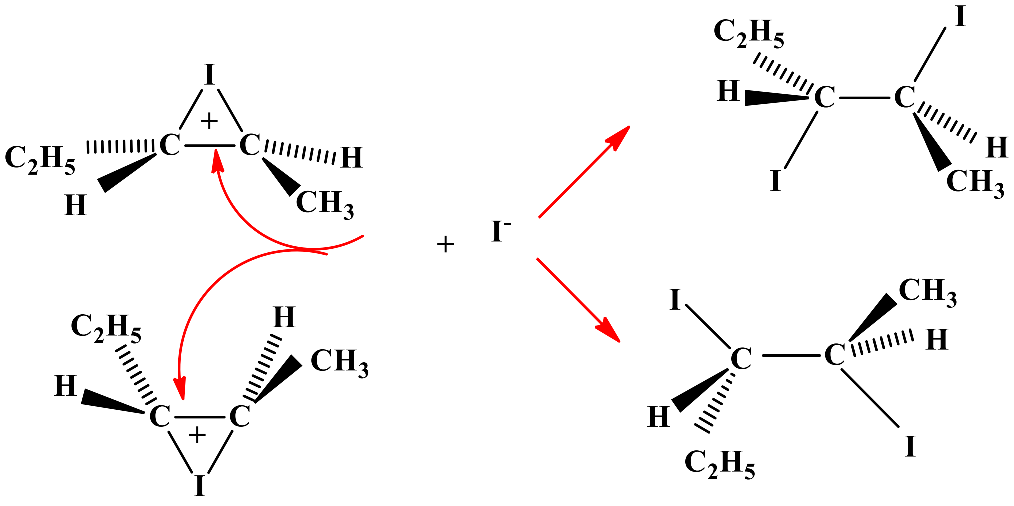
Mixture of enantiomers

2-Chloropentane R and S

2) Addition of I_2 to C_2H_5-CH=CH-CH_3 (E). Here contains the electrophile I^+ which forms two enantiomerically bridged ions:

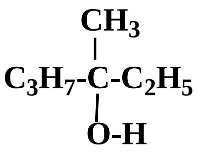


The subsequent attack by I- is done on the opposite side to I +. The latter then settles definitively on the least substituted C. We have trans-addition or anti-addition either:



Elimination Reaction:

A is subjected to acid dehydration

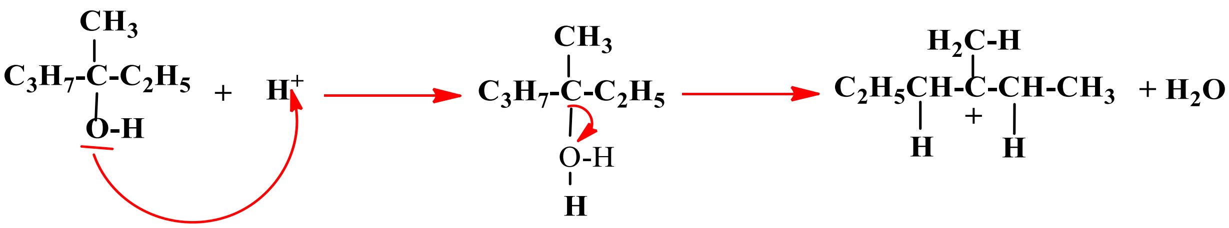


$$C_3H_7\text{-}\underset{\displaystyle O\text{-}H}{\overset{\displaystyle CH_3}{C}}\text{-}C_2H_5$$

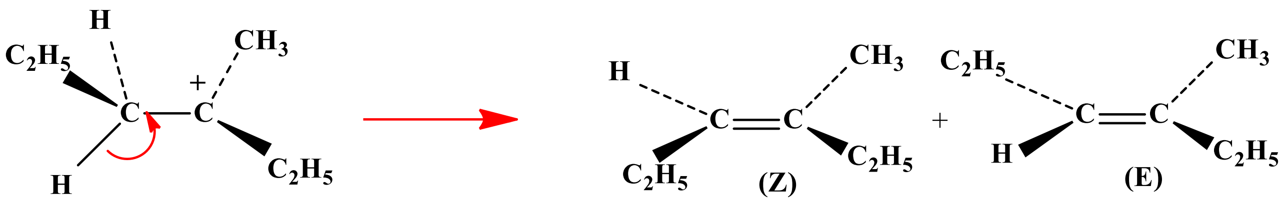
A

3-methyl hexan-3-ol

The dehydration reaction is catalyzed by H+. The carbocation formed by dehydration evolves by the loss of a porton by a carbon near C+. Three cases may arise:

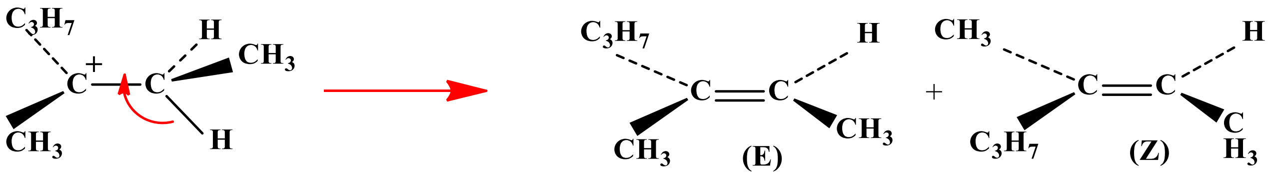


a)



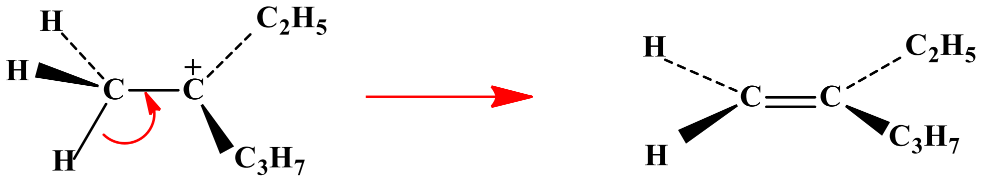
3-methylhex-3-ene Z and E**B**

b)



3-methylhex-2-ene Z et E **C**

c)

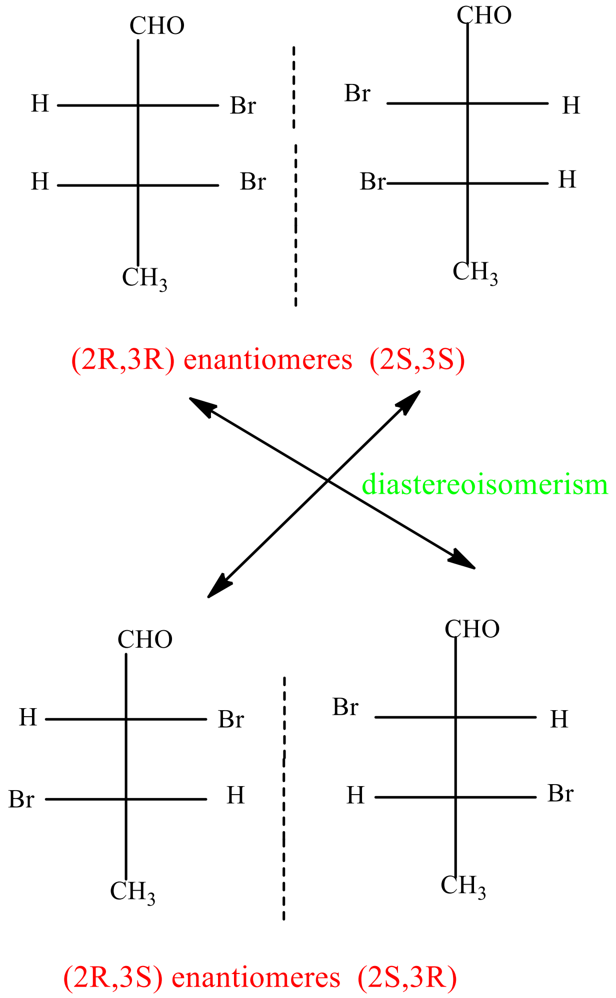


2-ethylpent-1-ene**D**

Saytzeff's rule applied to formation of the 3 alkenes shows that the most abundant alkene is the most substituted (the most stable alkene).

Solutions of topics of synthesis 1

<u>Exercise1</u>:



The number of stereoisomers that can exist is equal to 2^n where n is the number of asymmetric carbon so 4 stereoisomers

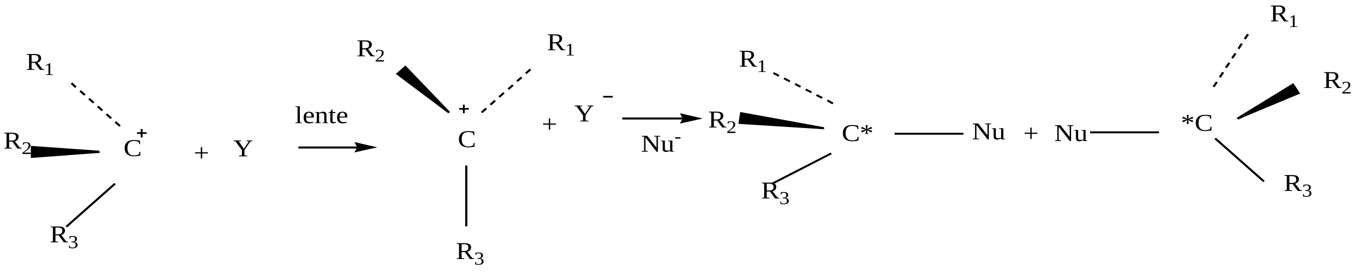
1. Characteristics of SN1 and SN2 reactions:

SN1:-favored in polar solvent

Has two steps

* Slow formation of a stable high class carbocation;

* Rapid attack of the planar carbocation by the nucleophile Nu^-: which substitutes for the nucleofuge Y^-: of the substrate.
If C, site of the attack is asymmetrical, the product obtained is a racemic mixture.



racemic mixture

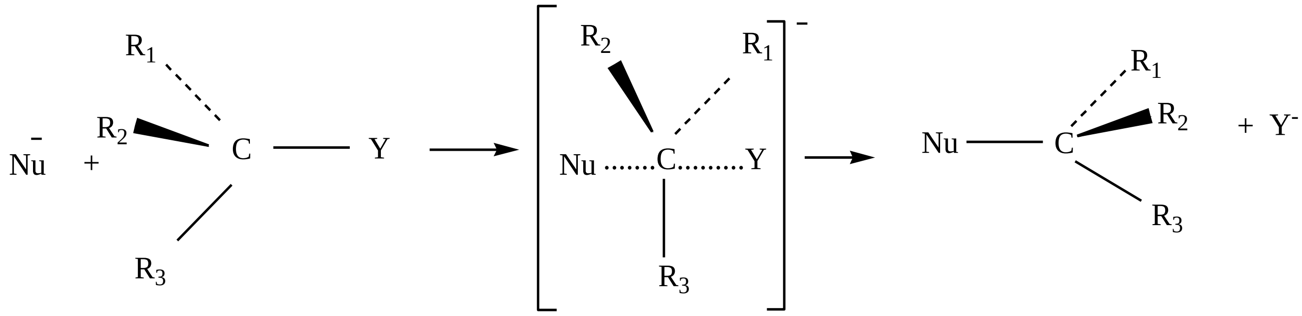
The reaction is monomolecular and $V=K[R_1R_2R_3C\text{-}Y]$

a) SN2: a single concerted step, bimolecular

$V= K[R_1\text{-}C\text{-}Y][Nu^-]$

-The carbon, site of the attack, preferably null or primary

-Reaction with configuration inversion (walden inversion)



4. A nucleophilic substitution reaction will preferably be SN1 if C, the site of the attack, is tertiary and secondary. An SN2 takes place on a C preferably null or primary

a) $OH^- + \underset{\text{C primaire}}{CH_3\text{-}CH(CH_3)\text{-}CH_2Cl} \xrightarrow{SN2} CH_3\text{-}CH(CH_3)\text{-}CH_2OH + Cl^-$

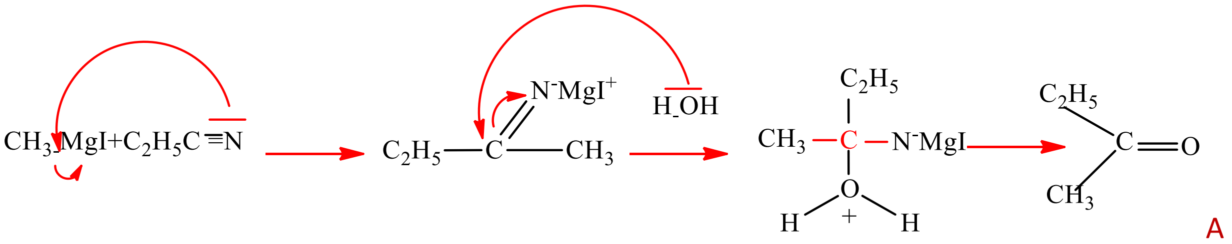
b) $OH^- + \underset{\text{C tertaire}}{C_2H_5\text{-}C(CH_3)_2\text{-}Cl} \xrightarrow{SN1} C_2H_5\text{-}C(CH_3)\text{-}OH + Cl^-$

c) $OH^- + \underset{\text{C secondaire}}{C_2H_5\text{-}CH(CH)\text{-}Cl} \xrightarrow[\text{ou SN2}]{SN1} C_2H_5\text{-}CH(CH_3)\text{-}OH + Cl^-$

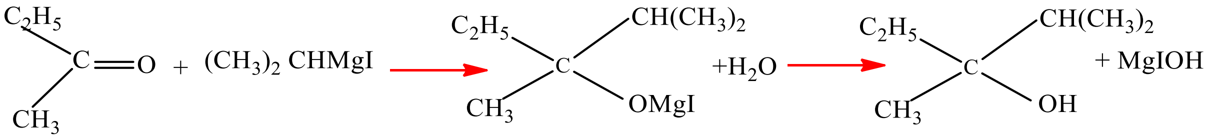
If the secondary carbon is very congested, an SN1 is favoured. In the present case, only the experimental conditions (solvent, etc.) orient SN1 or SN2.

Exercise 2 :

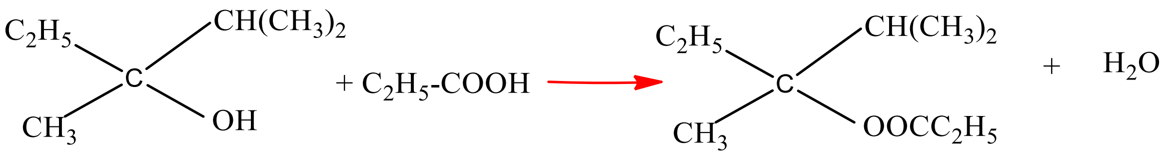
1)



+MgIOH + NH_3

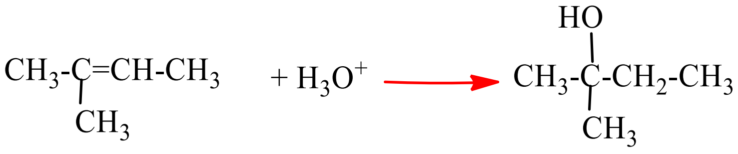


B



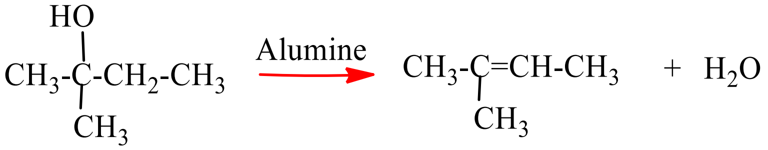
C

2)



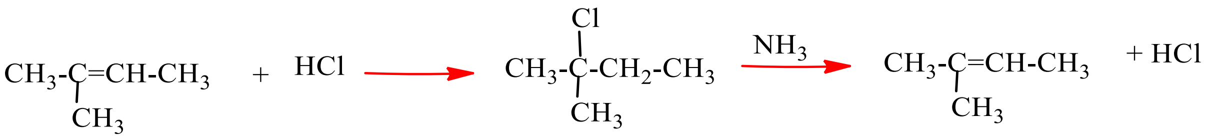
$$\mathrm{CH_3\text{-}\underset{\underset{CH_3}{|}}{C}{=}CH\text{-}CH_3} + \mathrm{H_3O^+} \longrightarrow \mathrm{CH_3\text{-}\overset{\overset{HO}{|}}{\underset{\underset{CH_3}{|}}{C}}\text{-}CH_2\text{-}CH_3}$$

D



$$\mathrm{CH_3\text{-}\overset{\overset{HO}{|}}{\underset{\underset{CH_3}{|}}{C}}\text{-}CH_2\text{-}CH_3} \xrightarrow{\text{Alumine}} \mathrm{CH_3\text{-}\underset{\underset{CH_3}{|}}{C}{=}CH\text{-}CH_3} + \mathrm{H_2O}$$

E



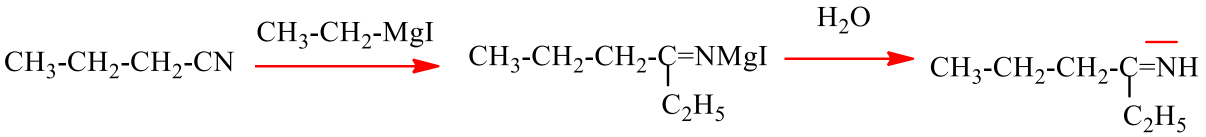
$$\mathrm{CH_3\text{-}\underset{\underset{CH_3}{|}}{C}{=}CH\text{-}CH_3} + \mathrm{HCl} \longrightarrow \mathrm{CH_3\text{-}\overset{\overset{Cl}{|}}{\underset{\underset{CH_3}{|}}{C}}\text{-}CH_2\text{-}CH_3} \xrightarrow{\mathrm{NH_3}} \mathrm{CH_3\text{-}\underset{\underset{CH_3}{|}}{C}{=}CH\text{-}CH_3} + \mathrm{HCl}$$

F **G**

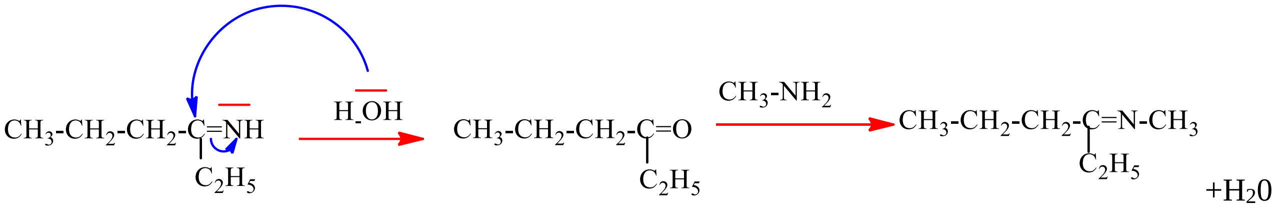
3)

$CH_3\text{-}CH_2\text{-}CH_2\text{-}Br$ + KCN $\longrightarrow$ $CH_3\text{-}CH_2\text{-}CH_2\text{-}CN$ + KBr

H Butanitrile



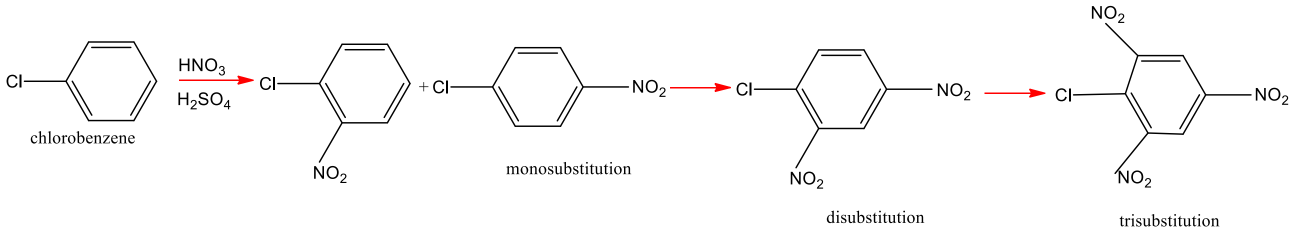
$$\mathrm{CH_3\text{-}CH_2\text{-}CH_2\text{-}CN} \xrightarrow{\mathrm{CH_3\text{-}CH_2\text{-}MgI}} \mathrm{CH_3\text{-}CH_2\text{-}CH_2\text{-}\underset{\underset{C_2H_5}{|}}{C}{=}NMgI} \xrightarrow{\mathrm{H_2O}} \mathrm{CH_3\text{-}CH_2\text{-}CH_2\text{-}\underset{\underset{C_2H_5}{|}}{C}{=}\overline{N}H}$$



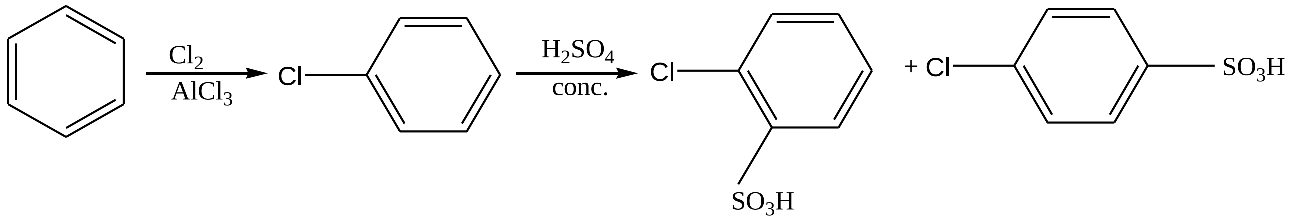
3-hexanone **I** 3-hexylidene, methanamine **J**

Exercise 3:

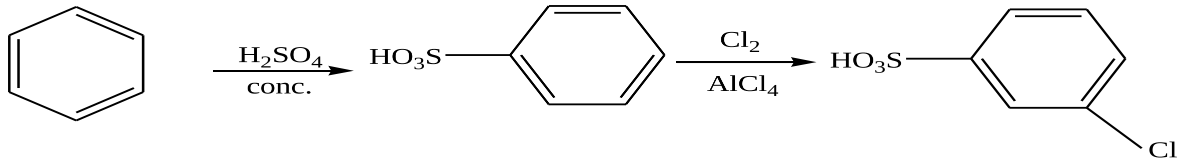
Complete the reactions:



The electrophilic substitution reaction starts with either chlorination or sulfonation. The products formed will therefore be different because the Cl and SO_3H substituents are different, the first being O and P director, and the second m. director. The 2 possibilities: (We assume a monosubstitution by Cl and a monosubstitution by SO_3H)

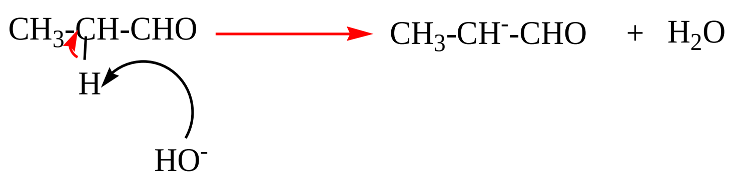


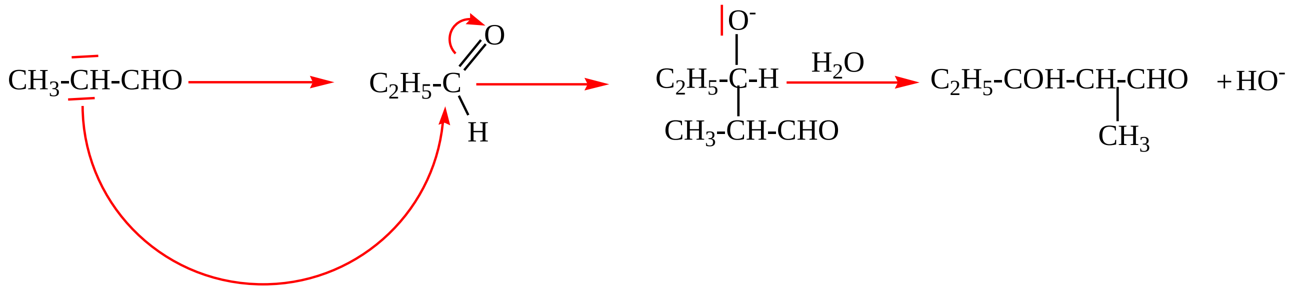
ortho and para chlorobenzene sulfonic acids



m-Chlorobenzene-sulfonic acid

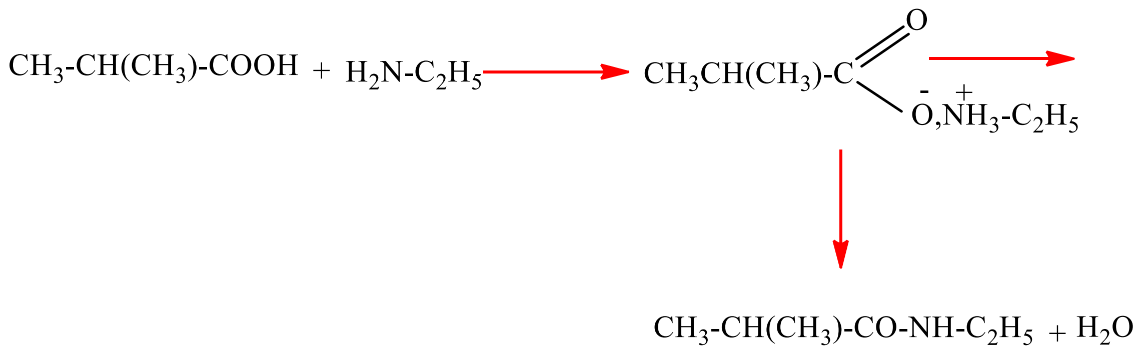
In a basic medium, two molecules of aldehyde with an H in α of C=O condense by a nucleophilic addition reaction (aldol reaction).





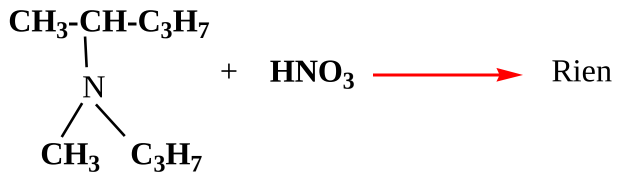
3-hydroxy-2-methyl pentanal

The first, basic amine gives an ammonium salt with a carboxylic acid. This is easily dehydrated by heat:



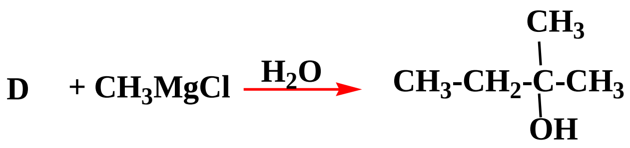
N-ethyl methyl propanamide

The following tertiary amine has no action on nitrous acid:

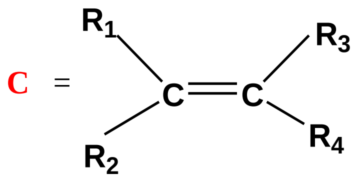


Exercise 4:

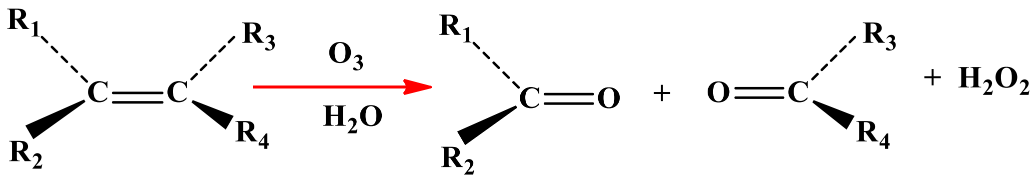
$$\mathbf{C \xrightarrow[H_2O]{O_3} E + H_2O_2}$$

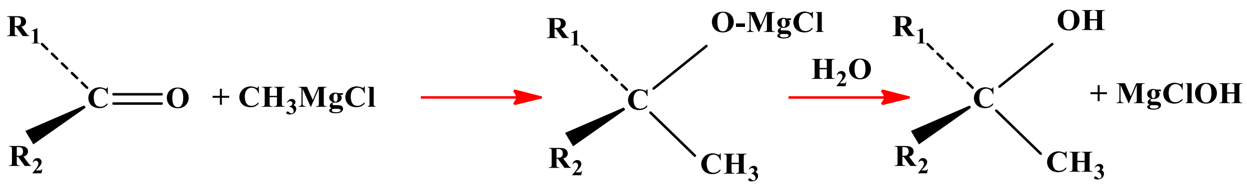


$$D + CH_3MgCl \xrightarrow{H_2O} CH_3\text{-}CH_2\text{-}\underset{OH}{\overset{CH_3}{C}}\text{-}CH_3$$



Ozonolysis of C leads to two carbonyl derivatives



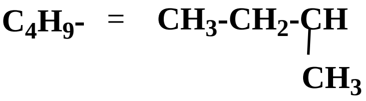


Hence, by identification R_1=R_2=C_2H_5 and D = C_2H_5-CO-$C_2H_5$3-Pentanone

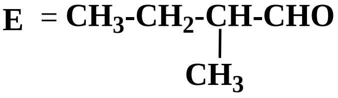
Fehling's liquor is a characteristic reagent of aldehydes. So E =R3CHO

Or, E=$C_5H_{10}O$, i.e. R_3=C_4H_9.R_4=H

E is optically active, so



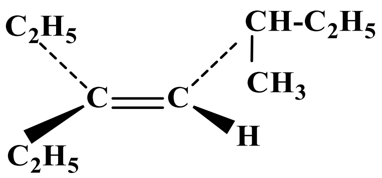
$$C_4H_9\text{-} = CH_3\text{-}CH_2\text{-}\underset{CH_3}{CH}$$



$$E = CH_3\text{-}CH_2\text{-}\underset{CH_3}{CH}\text{-}CHO$$

2-methyl butanal

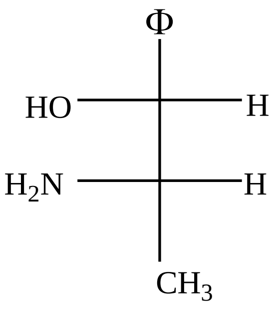
The Structure of C is deduced from that of Et D; that is:



3-ethyl,5-methyl hept-3-ene

Solutions of topics of synthesis 2

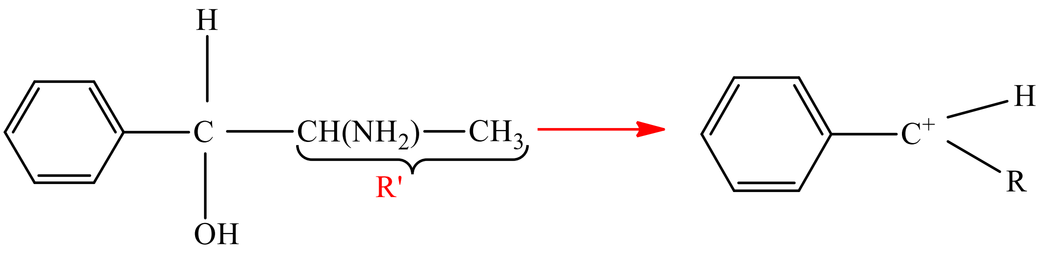
Exercise 1:

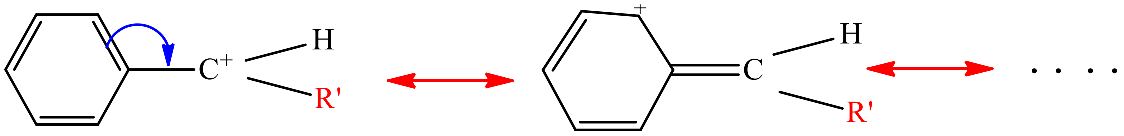


$$\text{F-CHOH-CH(NH}_2\text{)-CH}_3 + \text{H—C} \equiv \text{C}^- \longrightarrow \text{B} + \text{OH}^-$$

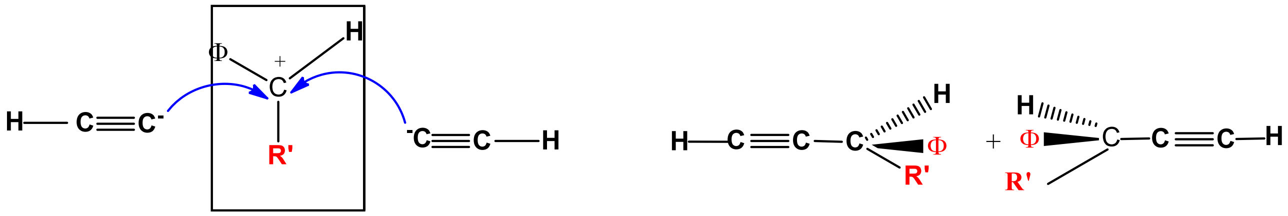
1) The reaction is a nucleophilic substitution reaction. Is it an SN1 or an SN2

The C* site of the attack is second, heavily congested. An SN1 is therefore favored. On the other hand, the carbocation possibly formed in this case is the seat of a conjugation which stabilizes it.

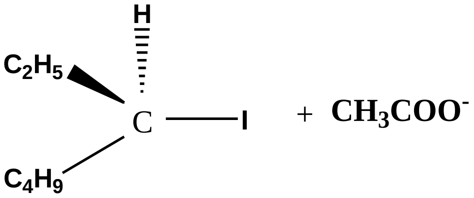




The reaction is therefore SN1

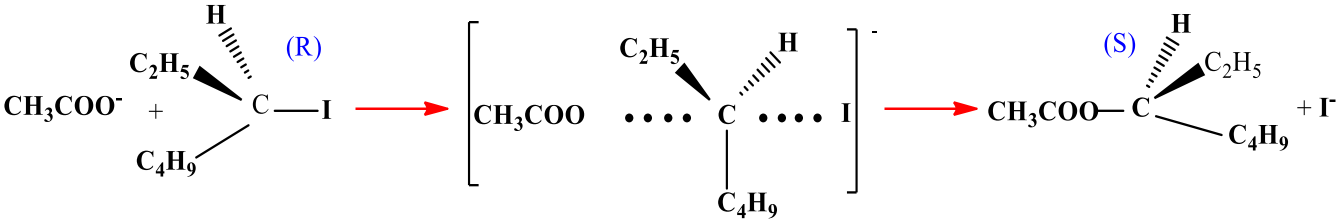


Racemic mixture (B)

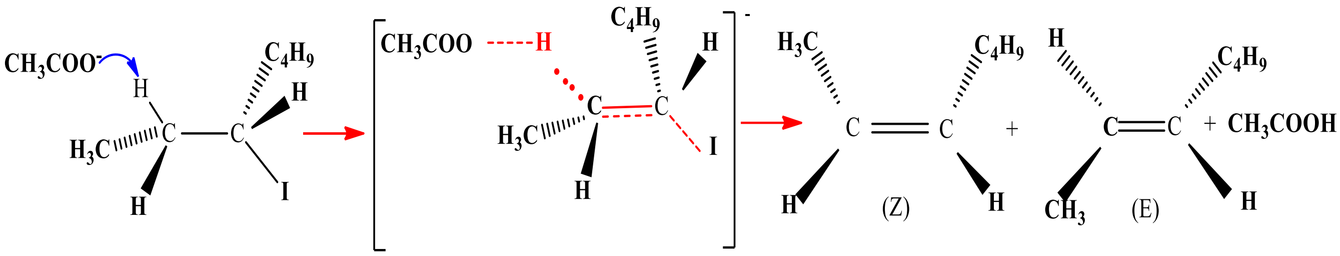


Reaction where v = k [A][B], the reaction SN is of order 2, hence an SN2

A single, biomolecular, concerted step takes place with dorsal attack of the nucleophile leading to a configuration inversion:



An E2 reaction is competitive with the SN2 reaction

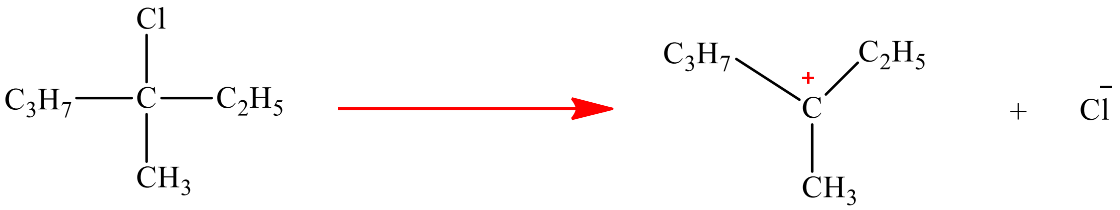


<u>Exercise 2</u>:

The halogen derivative is tertiary. An SN1 reaction is therefore favored. In a first step, monomolecular, slow, takes place the hetero lytic rupture which gives rise to the planar carbocation.

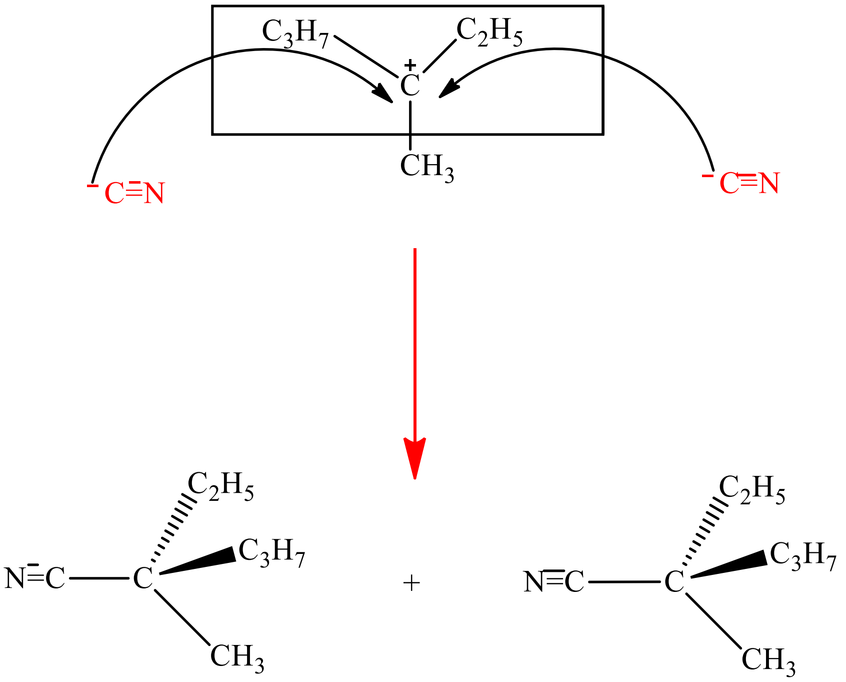
The latter is then rapidly attacked in a second step, randomly on one or the other of its faces by the nucleophilic reagent CN^-. Hence the formation of a racemic mixture:

* Slow formation of a stable high class carbocation;



carbocation plan

* Rapid attack of the planar carbcation by the nucleophile

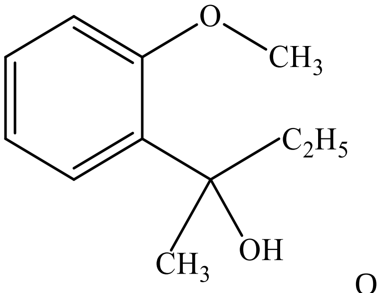


enantiomeres

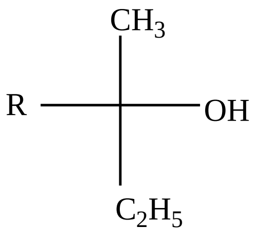
The first step is the rate-determining step. The monomolecular reaction is of order 1.

Exercise 3:

(B) =

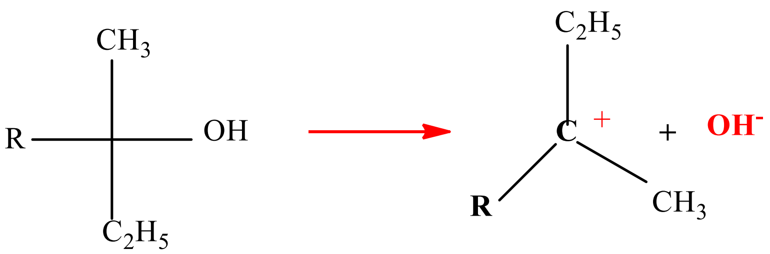


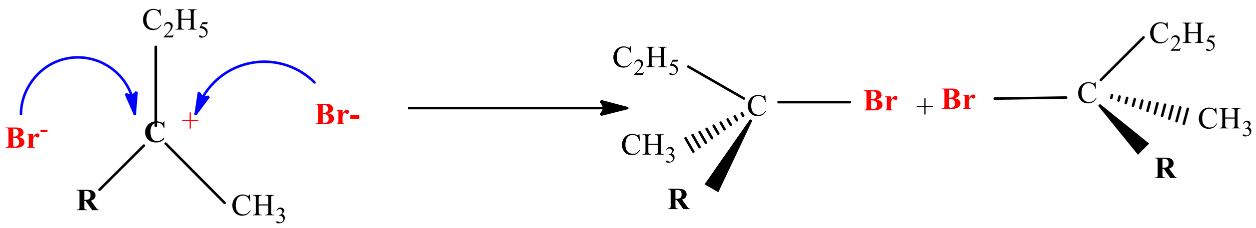
Or more simply



a) In the reaction of HBr on (B) a racemic mixture ((N)+(N')) is obtained, but (B) has a C*. Substitution of Br to OH retains the asymmetry of C.

Else by C* is tertiary: therefore an SN1 is favoured. It takes place in 2 steps:

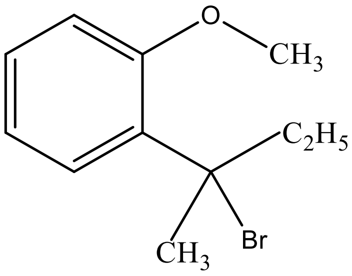




+H20

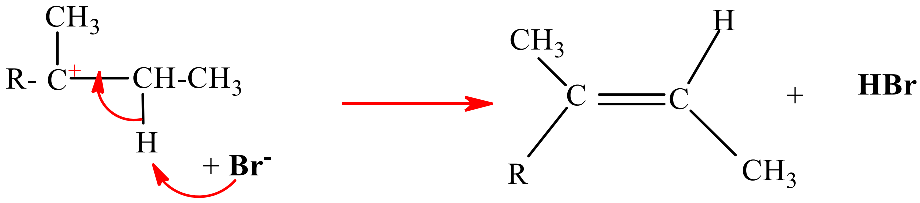
Racemic mixture

That is :



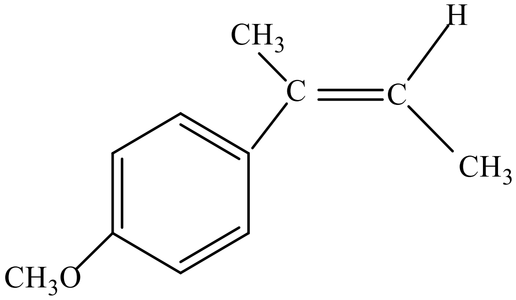
p-(1-bromo,1-methyl propyl) methoxybenzene

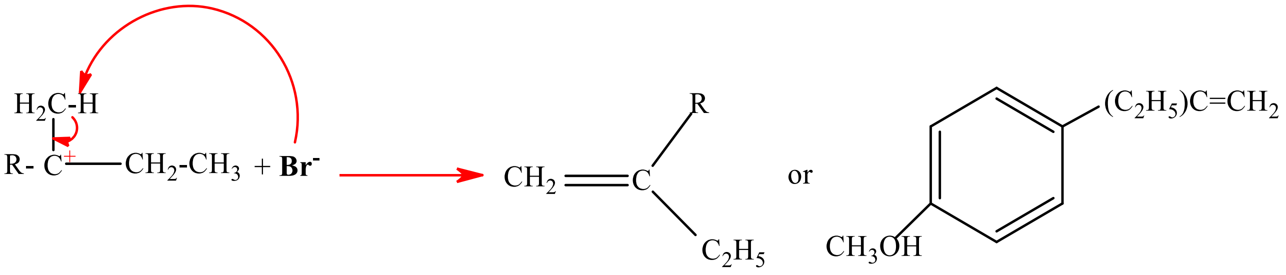
d)



M

Either: 2-(p-methoxyphenyl), 2-butene (Z and E formed indifferently)





M'

Either: 2-(p-methoxyphenyl), 1-butene

BIBLIOGRAPHY

- C. OUAHES. Annales corrigées de CHEMIE. Khawarysm Edition, Alger 1988.
- Arnaud. Paul,Cours de chimie organique, Dunod, 18e edition, 2004.
- François PREVOT, Marc BENEDETTI. Cours Geochimie organique environnementale. Geochimie organique environnementale, Lab Géochimie des Eaux (2014)
- M.BENYAROU course's. STEREOCHIMIE. EPST-Tlemcen 2012/2013
- Clayden, Greeves, Warren, Wothers. Chimieorganique. Edition De Boeck, 2003.
- J. DROUIN. Introduction à la chimie organique. Librairie du CEDRE, 2005
- NICOLA TAZZINI **CHIRALITY IN ORGANIC CHEMISTRY ORGANIC CHEMISTRY** (2020 **)**

Periodic Table

Key:

element name **atomic number** **symbol** atomic weight (mean relative mass)

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*lanthanoids	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**actinoids	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]