Introduction to Organic Chemistry
For None-Chemistry Students
PART ONE
Classification and Naming

What is meant by “Organic”?

Organic literally means “derived from living organisms” — organic chemistry was originally the study of compounds extracted from living organisms and their natural products.
Chemicals extracted from plants and animals were originally called “organic” because they came from living organisms

What is Organic Chemistry?

Organic chemistry is concerned with the study of the structure and properties of compounds containing carbon. All organic compounds contain carbon atoms. It was believed that only living organisms could create organic compounds. This concept has been changed in 1828 after urea, NH_2CONH_2 (organic compound) was prepared in the laboratory.

What is special about Carbon?

1. Carbon atoms form stable bonds to many other elements like H, O, N, S, P, F, Cl, Br, I, ... In addition to carbon itself. Most organic compounds contain hydrogen, and sometimes oxygen, nitrogen, sulfur, phosphorus, etc.

2. Due to the nature of carbon atom and its bonding variety and complexity, it can form complex structures, such as long chains, branched chains, rings, complex 3D structures, etc. Therefore, more than 15,000,000 organic compounds are known, compared to about 500,000 known inorganic compounds.

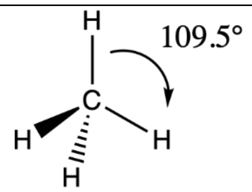
3. Organic chemistry is basic in life science. Carbohydrates, vitamins, enzymes, proteins, fats, lipids, DNA, RNA and many more are all biologically active organic compounds.

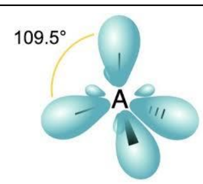
4. Organic chemistry and organic compounds are extremely important in medicine, food, agriculture, fertilizers, fuel, petroleum, paints, plastics, rubbers, textiles, …., . Actually, all of these and much more, never stand without carbon. *NO CARBON NO LIFE*.

Chemically speaking:

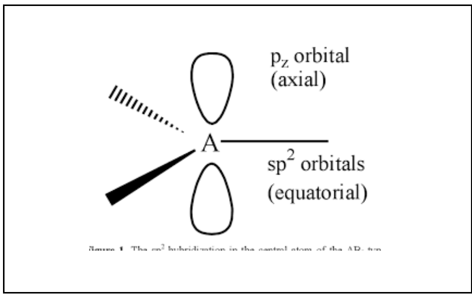
The chemical bonds formed by carbon occur by the use of its hybrid orbitals, which are formed by mixing (hybridizing) the atomic orbitals.

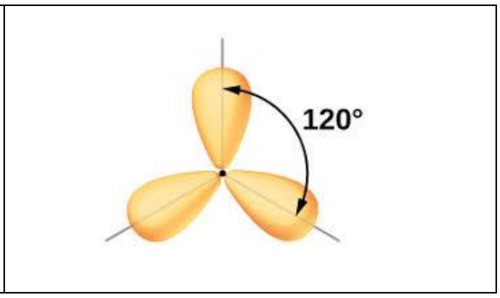
- sp^3 hybridization: carbon is bonded to 4 other atoms. (mixing of the 2s orbital with the 3 orbitals of 2p), the geometric shape around the sp^3 carbon is tetrahedral, (3D structure).



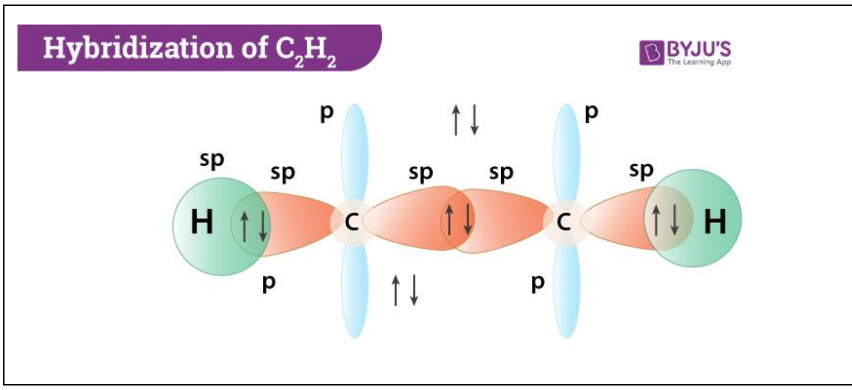


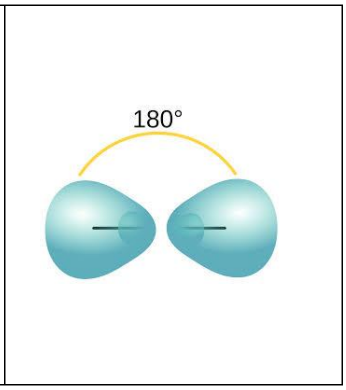
- Sp^2 hybridization: carbon is bonded to 3 other atoms. (mixing of the 2s and 2 orbitals of 2p), the geometric shape around the sp^2 carbon is <u>planar triangular</u>, (2 D structure).



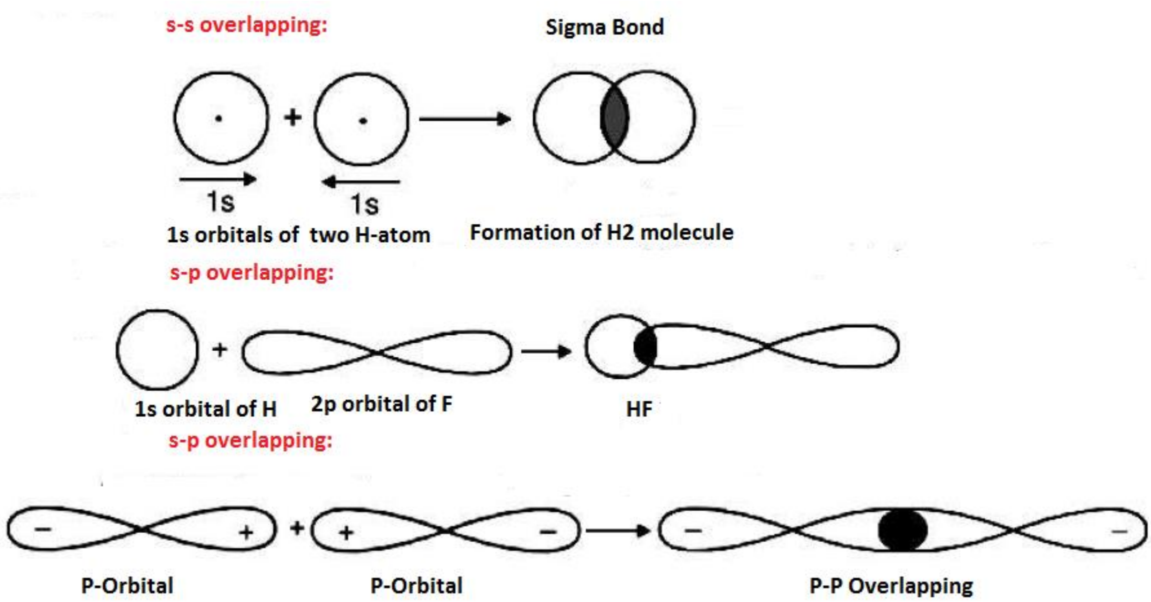


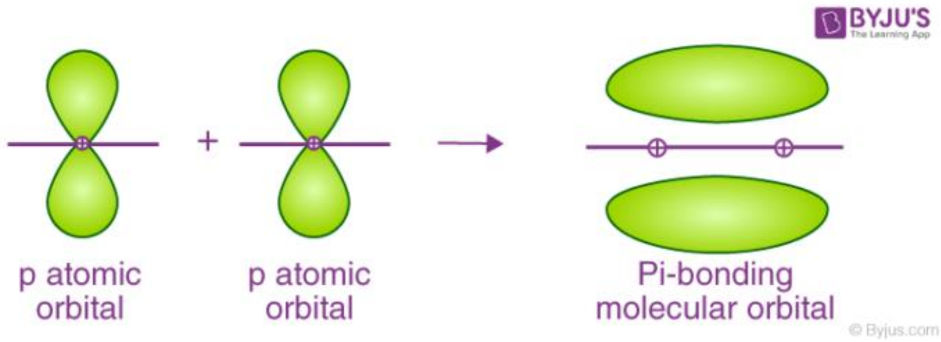
- sp hybridization: carbon is bonded to 2 other atoms. (mixing of the 2s and 1 orbital of p), the geometric shape around the sp carbon is <u>linear</u>.

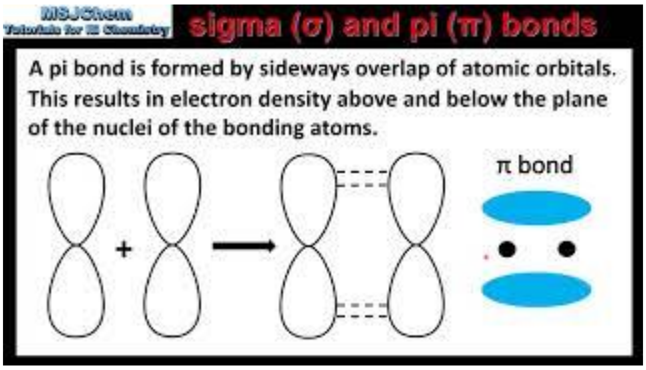


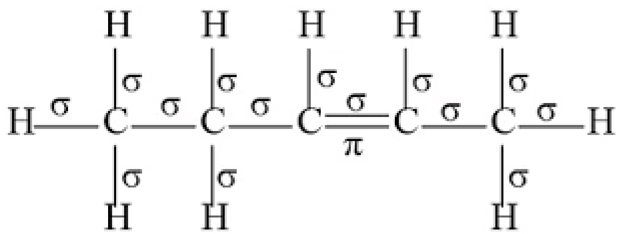


<u>Sigma (σ) and Pi (π) bonds</u>:

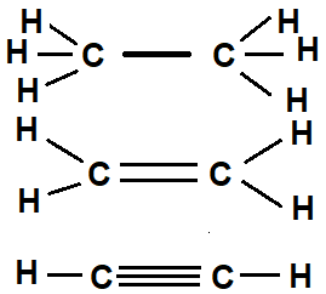








$CH_3CH_2CHCHCH_3$



Carbon/carbon bonds

All are σ bonds

one σ , one π

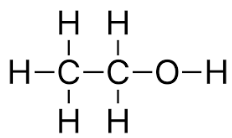
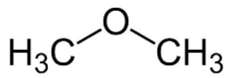
one σ , two π

Sigma bonds are stronger than pi bonds.

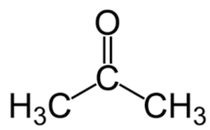
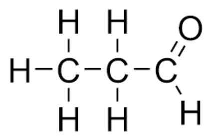
When carbon is bonded to 4 other atoms, all bonds formed are <u>single</u>, and 3D <u>saturated</u> structures are formed.
<u>Double bonds</u> are formed when carbon is bonded to 3 other atoms. (alkenes)
<u>Triple bonds</u> are formed when carbon is bonded to 2 other atoms. (alkynes)
Double and triple bonds are called <u>multiple</u> bonds. Organic compounds with multiple bonds are called <u>unsaturated</u>.

<u>Structural Isomers</u>:
They are compounds having identical molecular formulas, but with different arrangements of atoms (different connectivity of the atoms). The atoms in each molecule are connected in a different order. This type of isomers is called <u>structural isomers</u>. There are other types of isomers which are <u>not</u> important to us now.

<u>Example</u>: C_2H_6O would be ethyl alcohol or dimethyl ether.

	
Ethyl alcohol	Dimethyl ether

<u>Example</u>: C_3H_6O would be acetone or propyl aldehyde. We will see more examples later.

	
Acetone	Propyl aldehyde

Functional Groups:
Functional group is defined as a collection of atoms of certain characteristic arrangement that defines the chemical and physical properties of certain class of organic compounds.

<u>Hydrocarbons</u> contain the simplest functional groups. They contain only carbon and hydrogen. They include alkanes, alkenes, alkynes, and aromatic hydrocarbons.

<u>Functional groups that contain oxygen atoms</u>, like alcohols, ethers, aldehydes, ketones, carboxylic acids, and esters.

Other functional groups contain nitrogen atoms, like amines and amides.

Also, sulfur-containing organic compounds like thiols and others, . . .

Mixed functional groups are also occurring.

Organic compounds are classified according to their <u>functional groups</u>.

PART ONE:

Classification and Naming of Organic Compounds

Based on their functional groups, organic compounds may contain the following categories:

I. Hydrocarbons:

A hydrocarbon is an organic compound consisting entirely hydrogen and carbon.

Generally, hydrocarbons are colorless compounds.

They can be gases (like methane and propane), liquids (like hexane and benzene), low melting-point solids or waxes (like paraffin wax).

Hydrocarbons may be aromatic or none-aromatic. None-aromatic are also called aliphatic.

Hydrocarbons may be saturated or unsaturated.

Classification of Hydrocarbons:

1. *Saturated hydrocarbons*:
They are entirely composed of single bonds. They are called alkanes. They would be:

i) Acyclic, with a general formula of C_nH_{2n+2}, "n" is the number of carbon atoms.

ii) Cyclic, called cycloalkanes, with a general formula of C_nH_{2n} when are with one ring only.

2. *Unsaturated hydrocarbons*:

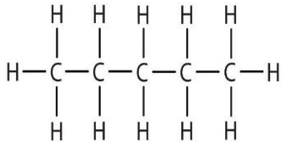
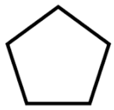
i) Alkenes: contain one double bond or more. The general formula is C_nH_{2n} if they are acyclic and have one double bond only.

ii) Alkynes: contain one triple bond or more. The general formunbmkla is C_nH_{2n-2} if they are acyclic and have one triple bond only.

The first ten aliphatic (-ane, -ene, -yne) hydrocarbons are listed below:

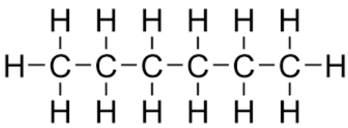
# of carbon atoms	***Alkane*** C_nH_{2n+2}	***Alkene*** C_nH_{2n}	***Alkyne*** C_nH_{2n-2}	***Cycloalkane*** C_nH_{2n}
1	Methane	-----	----	-----
2	Ethane	Ethene (ethylene)	Ethyne (acetylene)	-----
3	Propane	Propene (Prppylene)	Propyne	cyclopropane
4	Butane	Butene (Butylene)	Butyne	cyclobutane
5	Pentane	Pentene	Pentyne	cyclopentane
6	Hexane	Hexene	Hexyne	cyclohexane
7	Heptane	Heptene	Heptyne	cycloheptane
8	Octane	Octene	Octyne	cyclohctane
9	Nonane	Nonene	Nonyne	cyclononane
10	Decane	Decene	Decyne	cyclodecane

The above table is illustrated by the example below:

 Pentane	 cyclopentene, C_5H_8
$CH_3CH_2C{\equiv}CCH_3$ 2-pentyne, C_5H_8	 Cyclopentane, C_5H_{10}

Hydrocarbons are represented in different ways:

a) <u>Structural formula</u>: it shows how atoms are bonded to each other.

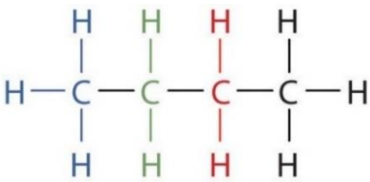


b) <u>Condensed formula</u>:

<u>Example</u>:

The condensed form of n-hexane is: $CH_3CH_2CH_2CH_2CH_2CH_3$ *or* $CH_3(CH_2)_4CH_3$

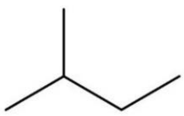
Example: n-butane

 condenses to $CH_3CH_2CH_2CH_3$

c) <u>Line-angle formula</u>:

Carbons are at the ends and at the corners, with the correct number of hydrogens.

Pentane



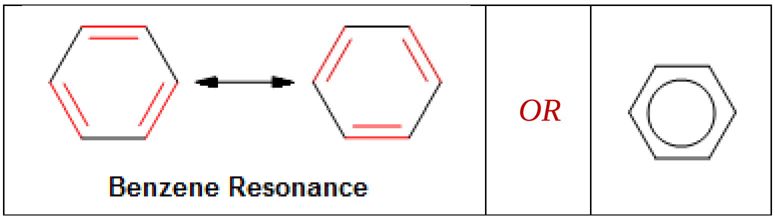
Isopentane

	$CH_3CH_2CH_2CH_2CH_2CH_3$
Angle-line formula	Condensed formula
n-hexane	

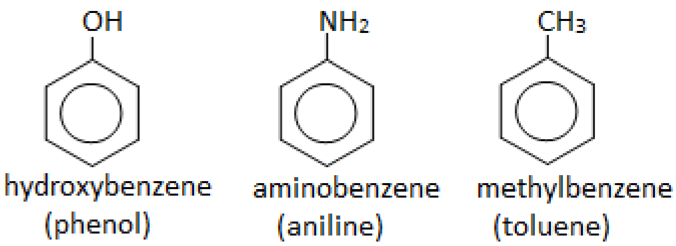
d) Closed formula: shows the number of atoms of each element in the molecule. The closed formula of the butane and hexane are C_4H_{10} and C_6H_{12} respectively.

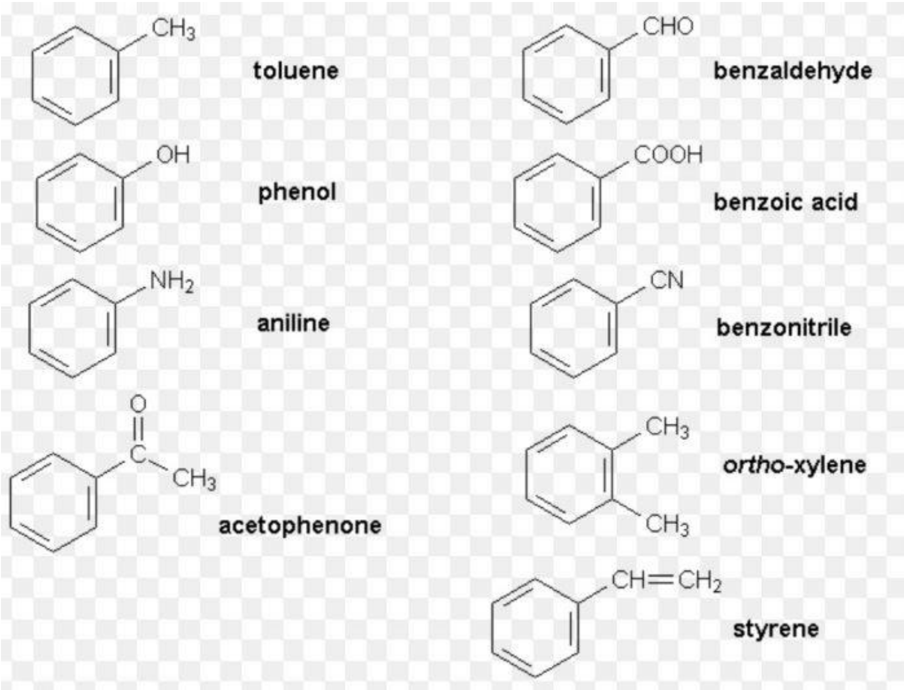
3. *Aromatic hydrocarbons* (*Also known as Arenes*):

As we know, aromatic compounds are those that contain the benzene ring, C_6H_6, or its structural derivatives. (remember the Kekulé structures, resonance, C_6H_6 ….)



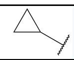
More Examples on Aromatics:





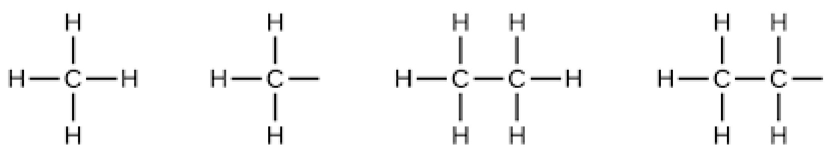
<u>Alkyl groups</u>:

Alkanes with no branches are called ***<u>normal alkanes</u>***, denoted by the letter n-. Examples are shown in the table above (n-hexane and n-pentane). Branches on hydrocarbons are called ***<u>alkyl groups</u>*** and denoted by the letter R–. Examples on the most common alkyl groups are shown below:

Group	R–	CH_3–	CH_3CH_2–	$CH_3CH_2CH_2$–	$(CH_3)_2CH$–	
Name	Alkyl	Methyl	Ethyl	Propyl	Isopropyl	Cyclopropyl

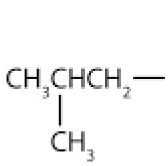
Group	$CH_3CH_2CH_2CH_2$–	$CH_3CHCH_2CH_3$	$(CH_3)_2CHCH_2$–	$(CH_3)_3C$–
Name	n-Butyl	sec-butyl	Isobutyl	tert-butyl

Structures of some of the alkyl groups are shown below:



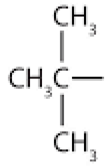
CH_3— a methyl group CH_3CH_2— an ethyl group $CH_3CH_2CH_2$— a propyl group $CH_3CH_2CH_2CH_2$— a butyl group

R— any alkyl group

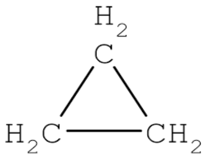
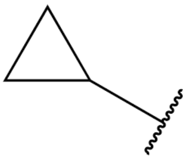
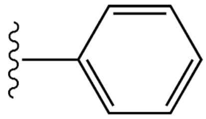


Isobutyl group

Sec-butyl group



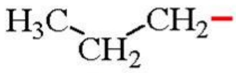
Tert-butyl group

		
Cyclopropane	Cyclopropyl group	Phenyl group

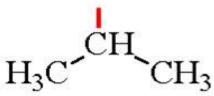
ALKYL GROUPS
(8 common ones)

CH_3- methyl group

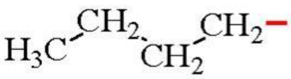
CH_3-CH_2- ethyl group



propyl group

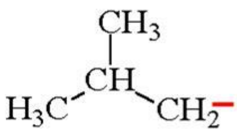


isopropyl group

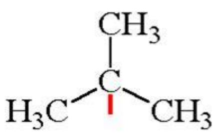


butyl group

s-butyl group



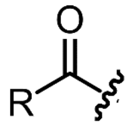
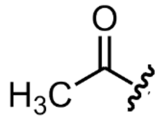
isobutyl group



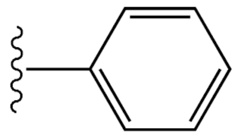
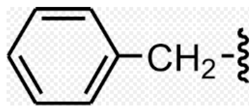
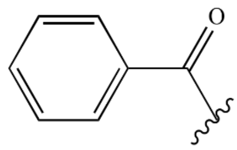
t-butyl group

Acyl and acetyl groups:

Acetyl group is a special case of acyl group where the alkyl group of the aceyl (R▯) is a methyl group in acetyl. These groups have carbonyl carbon connected the alkyl group as shown below:

	
Acyl group	Acetyl group (*it is acyl with R=methyl*)

Phenyl, benzyl and benzoyl groups:

		
Phenyl group	Benzyl group	Benzoyl group

IUPAC (*International Union of Pure and Applied Chemistry*) rules for naming hydrocarbons:

1. Identify the *longest carbon chain.* This chain determines the parent name of the alkane.

2. If there are two choices of the same length, then the parent chain is the longest chain that has the greatest number of "branches".

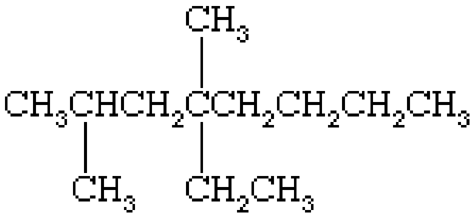
3. Number the carbons on the chain beginning at the end that is closest to any of the branches (substituents), thus ensuring the lowest possible numbers for positions of substituents.

4. Use these numbers to designate the location of the substituent groups (branches).

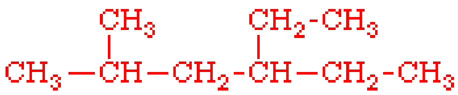
5. Prefixes like di−, tri−, tetra−, penta− , . . . will also be used in naming compounds with same type of substituent.

Examples:

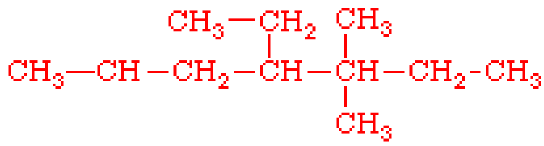
$$\begin{array}{l} \;\;1\quad\;\;2\quad\;\;3\;\;4\quad\;\;5\quad\;\;6\quad\;\;7 \\ CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2CH_2CH_2CH_3 \end{array}\qquad \text{3-methylheptane}$$



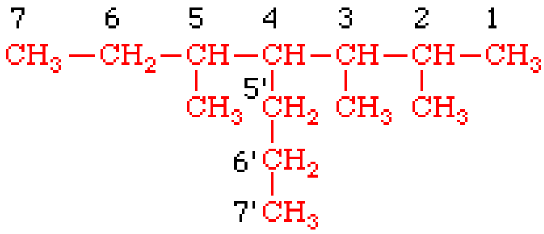
4-ethyl-2,4-dimethyloctane



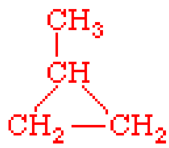
4-ethyl-2-methylhexane



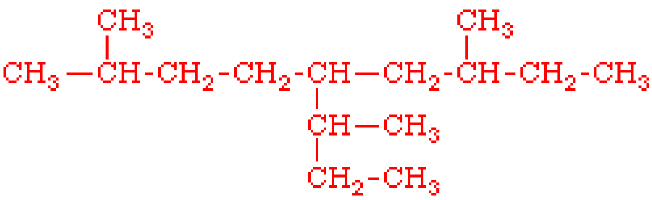
4-ethyl-3,3-dimethylheptane



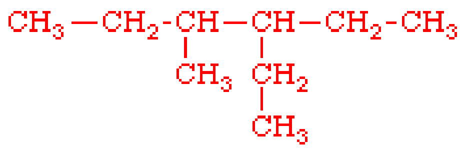
2,3,5-trimethyl-4-propylheptane
(NOT: 2,3-dimethyl-4-sec-butylheptane)



methylcyclopropane

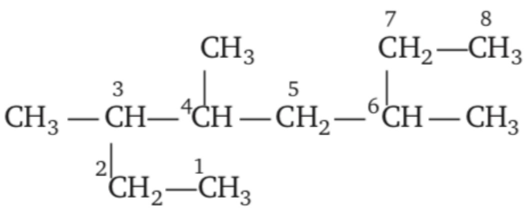


5-sec-butyl-2,7-dimethylnonane



3-ethyl-4-methylhexane

The sum of the substituents' positions should be the smallest (***lowest sum rule***).



3, 4, 6-trimethyloctane

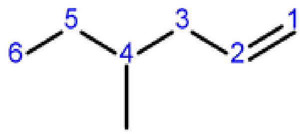
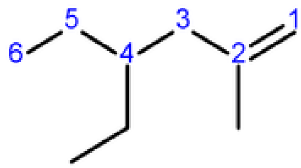
NOT : 3,5,6 (the other option above)

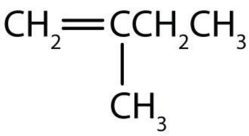
Alkenes and Alkynes:

IUPAC (systematic) System naming of Alkenes

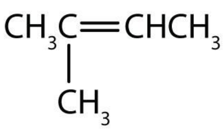
- The longest carbon chain containing the carbon-carbon double bond is selected as the parent alkene.
- The suffix 'ane' of the alkane is replaced by 'ene'.
- If a double bond occurs twice or thrice in the parent chain the alkene is called diene or triene, respectively.
- The longest chain is numbered starting from the end which gives the lowest number to the carbon atom of the double bond and that number is written just before the suffix 'ene'.
- If while numbering the chain the double bond gets the same number from either side the carbon chain is numbered in such a manner that the substituent gets the lowest number.
- In case there are two or more double bonds, the lowest sum rule should be followed.
- The names and positions of other groups (substituents) are indicated by prefixes.

Examples on alkenes:

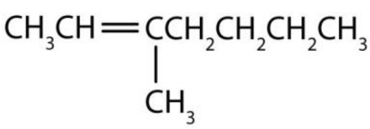
 hex-1-ene	 4-methylhex-1-ene	 4-ethyl-2-methylhex-1-ene
1-hexene	4-methyl-1-hexene	4-ethyl-2-methyl-1-hexene



2-methyl-1-butene

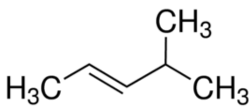


2-methyl-2-butene NOT 3-methyl-2-butene



3-methyl-2-heptene

<u>More Examples on Alkenes</u>:

$H_2C{=}CH{-}CH_2{-}CH_2{-}CH_3$	1-pentene
$CH_3{-}CH{=}CH{-}CH_2{-}CH_3$	2-pentene
$CH_3CH_2CH{=}CHCH_2CH_3$	3-hexene
$CH_3{-}CH_2{-}CH{=}CH{-}CH_2{-}CH_2{-}CH_3$	3-heptene
	4-methyl-2-pentene

$H_2C{=}CH_2$ — Ethene

$H_2C{=}CH{-}CH_3$ — Propene

Cyclopentene

<u>Priority Rule</u>:

Priority of Alkene and alkyne (in the same molecule) in naming:

- Numbering to give lowest sum
- Name alphabetically. –ene then –yne

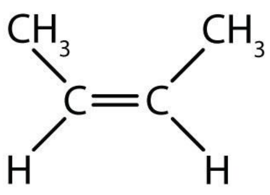
<u>Example</u>:

$$CH \equiv C - CH = CH - CH_3$$

pent-3-ene-1-yne

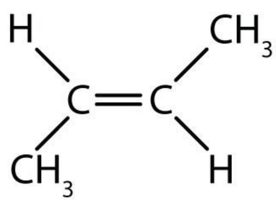
NOT (Other way of numbering): pent-2-ene-4-yne

<u>Geometric isomers:</u>



cis-2-butene

$Z - Isomer$



trans-2-butene

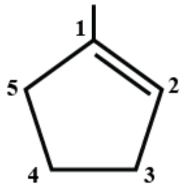
$E - Isomer$

cis isomer is also named as Z-isomer (Zusammen ; ‘together’ in German)

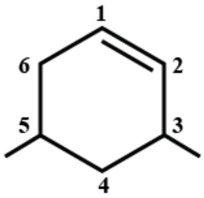
Trans isomer is also named as E-isomer (Entgegen ; ‘opposite’ in German)

Isomers of organic compounds

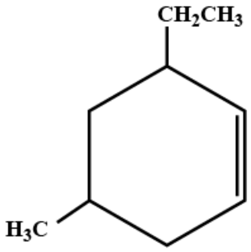
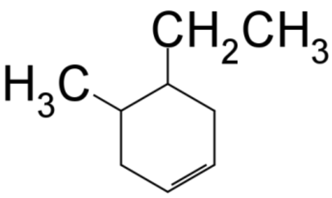
H.W: draw the structure of 4-methyl 2,6-octadiene?



1-Methylcyclopentene
(not 2-methylcyclopentene)

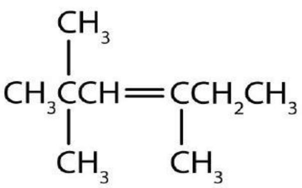


3,5-Dimethylcyclohexene
(not 4,6-dimethylcyclohexene)

	
3-ethyl-5-methylcyclohexene	4-ethyl-5-methylcyclohexene ***NOT***: 5-ethyl-4-methylhexene

Two groups with double bond that are common in naming hydrocarbons:

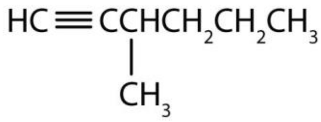
- $H_2C{=}CH–$ Vinyl group
- $H_2C{=}CH–CH_2–$ Allyl group



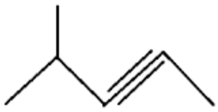
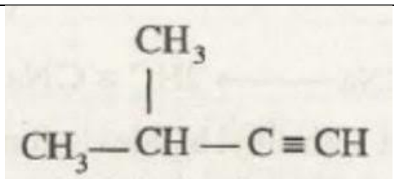
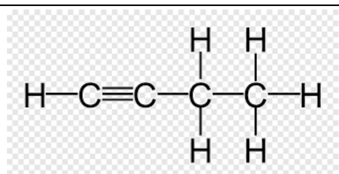
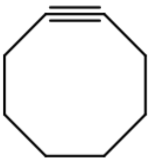
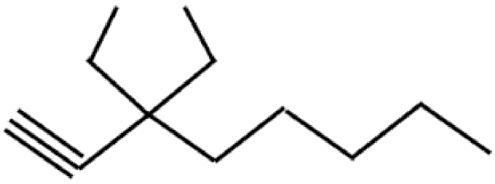
2,2,4-trimethyl-3-hexene

<u>Examples on alkynes</u>: (C_nH_{2n-2})

$H-C\equiv C-H$	Ethyne (Acetylene)
$\equiv\!-CH_3$	Propyne (C_3H_4)
$H-C\equiv C-CH_2-CH_3$	1-Butyne (C_4H_6)
$H_3C-C\equiv C-CH_3$	2-Butyne (C_4H_6)
$H_3C-C\equiv C-CH_2CH_3$	2-pentyne (C_5H_8)

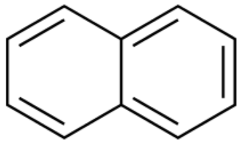
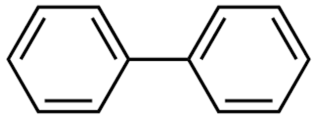
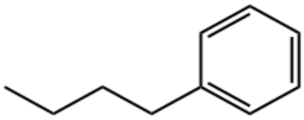
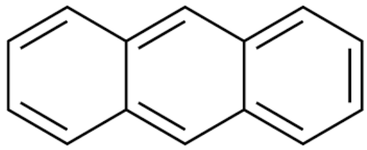
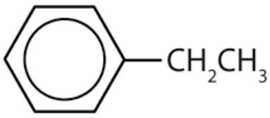
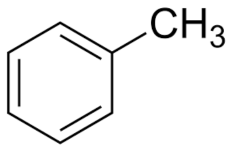


3-methyl-1-hexyne

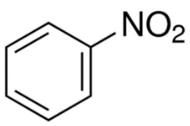
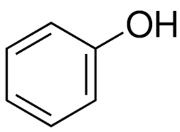
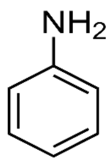
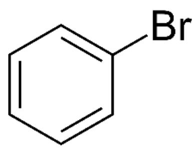
 **3-Hexyne**	 **4-methyl-pent-2-yne**
 3-methyl butyne	 butyne
 cyclooctyne	 3,3-diethyl-1-octyne

Organic compounds may contain any combination of double and triple bonds, with or without cyclic structures. ….

Examples on aromatic hydrocarbons:

 Naphthalene	 Biphenyl
 n-butyl benzene	 Anthracene
 Ethyl Benzene	 Toluene

Examples on aromatic compounds with elements other that carbon and hydrogen:

			
Nitrobenzene	Phenol	Aniline	Bromobenzene *Or* phenyl bromide

II. Organic Compounds with Functional Groups containing elements other than Hydrogen and Carbon:

This category of organic compounds contains other elements besides carbon and hydrogen. These elements are like oxygen, nitrogen, sulfur and halides (F, Cl, Br, I). A collection of some types of atoms together in certain way in a molecule of a compound makes that compound chemically and physically behave in certain way. This collection of atoms is called functional group. Examples on functional groups are shown below:

A. Halide-containing functional groups:

Alkyl halides may have common names or IUPAC names. The *common names* of alkyl halides consist of two parts: the name of the alkyl group plus the root of the name of the halogen plus the ending -*ide*. The IUPAC way of naming uses the name of the parent alkane with a prefix indicating the halogen substituents, preceded by number indicating its location. Usually, common names are used with small alkyl halides (up to 4 carbon atoms). IUPAC names are used with larger molecules. For example, the common name of CH_3CH_2Cl is ethyl chloride and its IUPAC name chloroethane.

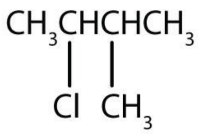
As a substituent (or a group) on the alkane chain, the halogens are named as shown in the list below:

Name:	Fluro−	Chloro−	Bromo−	Iodo−
Group:	F−	Cl−	Br−	I−

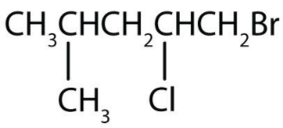
The general form of the alkyl halide is R−X, where X is one of the halide substituents.

<u>Examples on Alkyl Halide</u>:

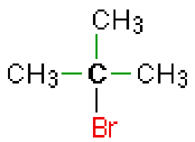
2-bromo pentane



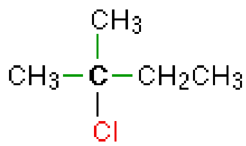
2-chloro-3-methyl-butane



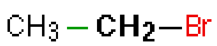
1-bromo-2-chloro 4-methyl-pentane



2-bromo-2-methyl propane

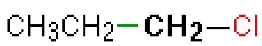


2-chloro-2-methyl butane



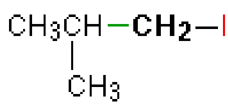
1-Bromo ethane

(Ethyl bromide)

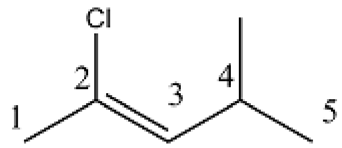


1-Chloro propane

(propyl chloride)



1-iodo-2-methyl- propane



2-chloro-4-methyl-2pentene

Note: alphabetical order of the substituents.

Priority Rule: Alkene > Alkyl Halide

Alkyne > Alkyl Halide

Example:

$$CH_3-CH=CH-CH_2Cl$$

1-Chloro-bute-2-ene

$$CH_3-CH=CH-CH_2-CH_2Cl$$

5-Chloro-bute-2-ene

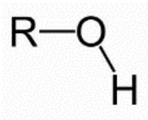
B. Oxygen-containing functional groups*:*

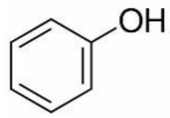
The most common oxygen-containing functional groups are mentioned below:
(ketal, acetal, … and others are examples that are not mentioned).

#	*Functional Group*	*Naming*	*Comments*
1	Alcohol: R−OH, R2−OH, R3−OH	− ol	1^o, 2^o and 3^o
2	Ether, R−O−R	Alkyl ether	
3	Aldehyde R−COH	− al	
4	Ketone R−CO−R	− one	
5	Carboxylic acid, R−COOH	− oic acid	
6	Ester, R−(CO)−O−R	alkyl alkanoate	

1. ***Alcohols***: (Alkan-ol; or Alkanediol, …)

The hydroxyl group -OH is the functional group for alcohols and phenols. In alcohols, it is connected to an alkyl carbon where as in phenols it is connected to benzene ring (aromatic).



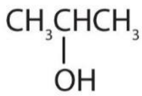


Alcohol Phenol

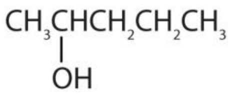
Naming of Alcohols:

1. Identify the longest chain to which the hydroxyl (—OH) group is attached.
2. Name this chain by dropping the -e at the end of the name of the hydrocarbon parent and add -ol.
3. Number the longest chain carbons to give the lowest possible number to the carbon bearing the hydroxyl group, and identify the carbon numbers of other substituents.
4. If there is more than one OH group add the prefix (di-, tri-, tetra-, etc.) immediately in front of the suffix -ol. (diol, triol, tetraol, etc.). The "- e" of the parent hydrocarbon is not dropped. Positions of each alcohol group is indicated by carbon number, separated by commas. (e.g.: 1,3- pentanediol).

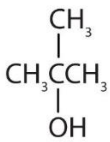
Examples:



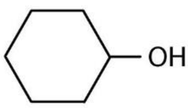
2-propanol 2^o alcohol



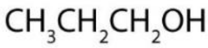
2-pentanol 2^o alcohol



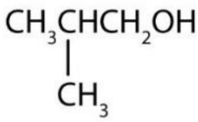
2-methyl-2-propanol 3^o alcohol



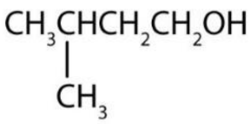
Cyclohexanol



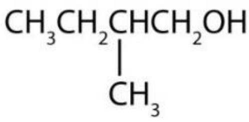
1-Propanol



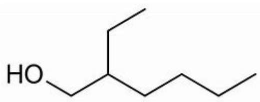
Isobutyl alcohol



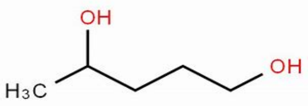
3-Methyl-1-butanol



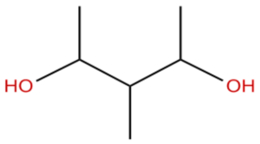
2-Methyl-1-butanol



2-ethyl-hexanol 1^{o} alcohol



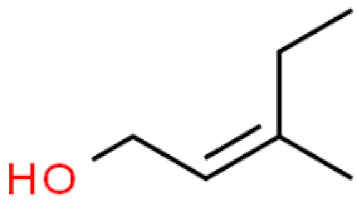
1,4-pentanediol



3-methyl-2,4-pentanediol

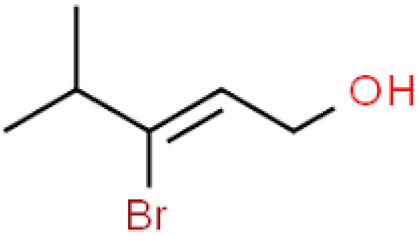
Priority Rule:

Alcohol > Alkene *and* Alcohol > Alkyne



3-methyl-2-pentene-1-ol

Priority Example: *This compound is alcohol (not alkene or alkyl halide)*



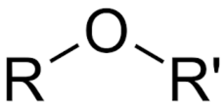
3-bromo-4-methyl-pent-2-ene-1-ol

2. *Ethers*:

Ether may be symmetric (with two identical groups around oxygen) or asymmetric (with two different groups around oxygen). Ethers have common names and IUPAC names.

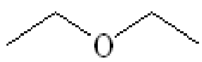
I) Common Names:
Naming the alkyl or aryl groups around oxygen in alphabetical order, then add the word "ether". For symmetrical ethers the -prefix "di" is used before the name of the alkyl/aryl group. The "di" also may be omitted. Diethyl ether for example would be ethyl ether.

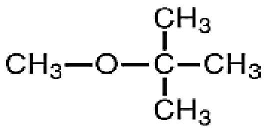
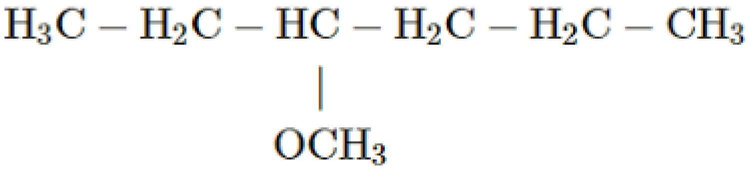
II) IUPAC Nomenclature: ***(Alkoxy alkane)***;

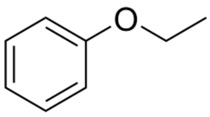
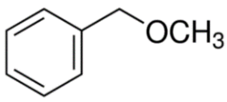
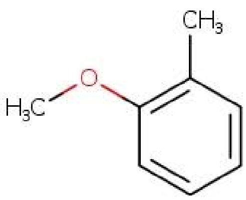


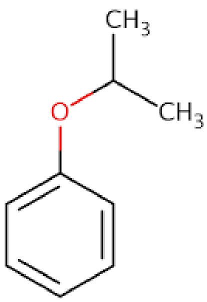
- The substituent group containing more carbon atoms is chosen as parent hydrocarbon, *(alkane).*
- The other substituent group attached to the oxygen atom is named with a prefix “oxy”, *(alkoxy)*

Examples:

$CH_3—O—CH_3$	Dimethyl ether *Or* Methyl ether *IUPAC*: Methoxy methane
$CH_3—O—CH_2CH_3$	Ethyl methyl ether *IUPAC*: Methoxy ethane
$CH_3CH_2—O—CH_2CH_3$ = 	Ethyl ether. (diethyl ether) *IUPAC*: Ethoxy ethane

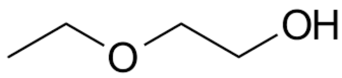
	t-butyl methyl ether *IUPAC*: 2-methoxy 2-methyl propane
 3-Methoxyhexane	

	Ethyl phenyl ether *IUPAC*: Ethoxy benzene
	Benzyl methyl ether Methoxy methyl benzene
	1-Methoxy-2-methyl benzene 2-methoxy toluene

	Isopropyl phenyl ether 2-phenoxy propane

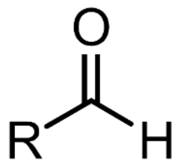
Priority: alcohol > ether

$CH_3CH_2OCH_2CH_2OH$



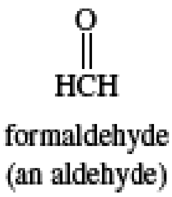
2-ethoxyethan-1-ol

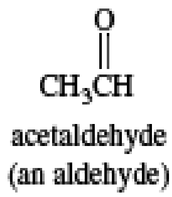
3. ***Aldehydes*** (alkan-al) [link 1]



Nomenclature of Aldehydes:

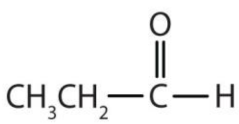
- Select the longest chain that contains the aldehyde carbonyl carbon, with largest number of brances.
- Replace the -e ending of the parent alkane by the suffix -al.
- The carbonyl carbon is always numbered "1." (It is not necessary to include the number in the name)
- Name the substituents attached to the chain in the usual way.



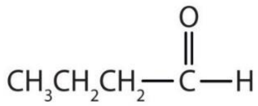
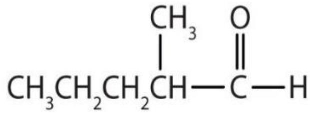
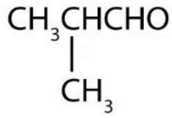


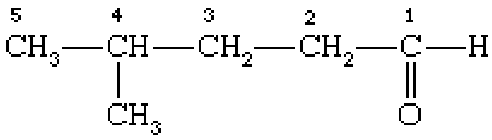
Methan**al** (Formaldehyde)

Ethanal (Acetaldehyde)

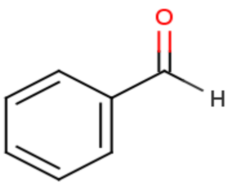


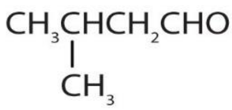
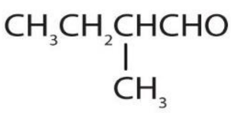
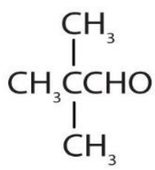
Propanal

	Butan<u>al</u>
	2-methyl pentan<u>al</u>
	2-methylpropan<u>al</u>

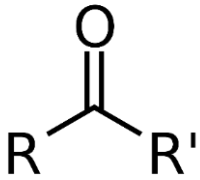


4-methylpentanal

	Benzaldehyde

	
Pentanal	3-Methylbutanal
	
2-Methylbutanal	2,2-Dimethylpropanal

4. Ketones (link 1 link 2) (Alkan-one)

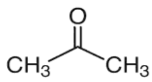
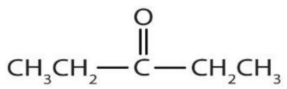


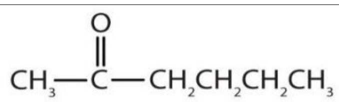
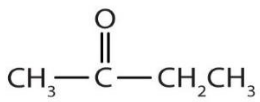
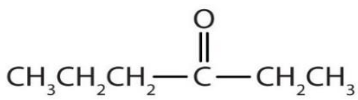
<u>Nomenclature of Ketones</u>:

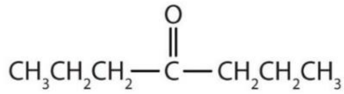
I) Common Name: Mentioning the groups around the carbonyl group, then add the suffix “ketone”.

II) IUPAC Name:

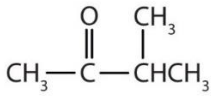
- Select the longest carbon chain containing the carbonyl carbon.
- Replace the -e ending of the parent alkane name by the suffix -one.
- Number the chain starting with the end <u>closest</u> to the ketone group (the carbonyl carbon should have the lowest possible number). The location number for the ketone group precedes the name for the longest chain.
- Name the substituents attached to the chain in the usual way.

 2-propan<u>one</u> (Acetone) ; dimethyl ketone
 3-Pentan<u>one</u> (diethyl ketone)

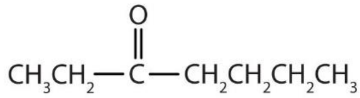
 2-hexanone *OR* butyl methyl ketone
 Ethyl methyl ketone *OR* 2-butanone
 3-hexanone *OR* Ethyl propyl ketone



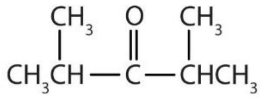
4-heptanone *OR* dipropyl ketone



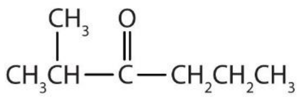
3-methyl-2-butanone *OR* isopropyl methyl ketone



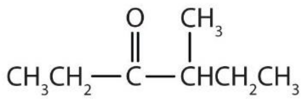
3-heptanone *OR* butyl ethyl ketone



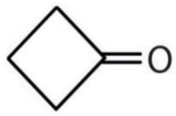
2,4-dimethyl-3-pentanone *OR* diisopropyl ketone



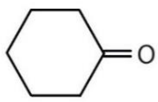
2-methyl-3-hexanone *OR* isopropyl propyl ketone



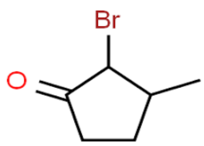
4-methyl-3-hexanone *OR* ethyl isobutyl ketone



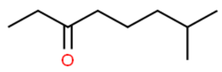
Cyclobutanone



Cyclohexanone



2-bromo-3-methyl cyclopentanone

	7-methyl-3-octanone

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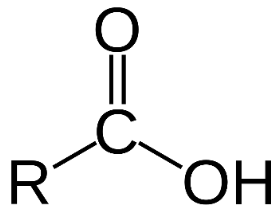
5. <u>Carboxylic Acids</u>: (alkan-oic acid) Link: [More examples]() ***(Carboxylic acids):***

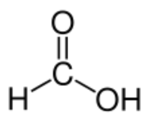
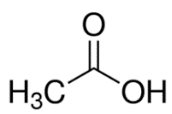


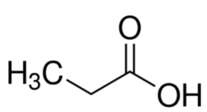
Nomenclature of Carboxylic Acids:

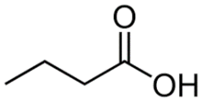
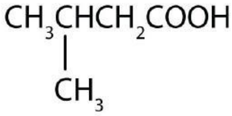
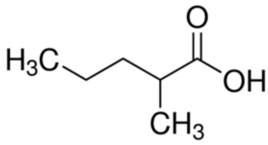
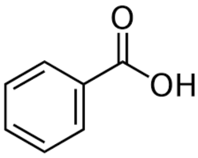
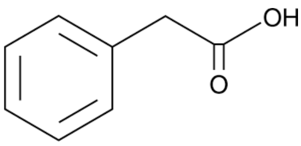
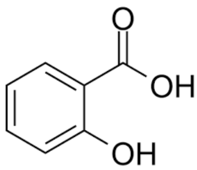
- Select the longest carbon chain <u>including the carboxyl carbon</u> to be the parent alkane.
- The -e ending of the parent alkane name is replaced by the suffix -oic acid.
- The carboxyl carbon is always numbered “1” but the number is not included in the name.
- Name the substituents attached to the chain in the usual way.

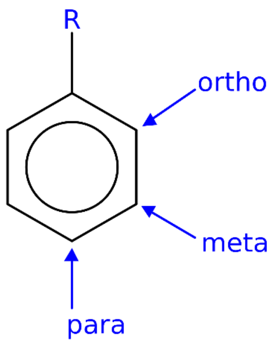
If there are other substituents present in the parent chain, the numbering is done to give the substituents the **lowest** number at the **first point of difference**

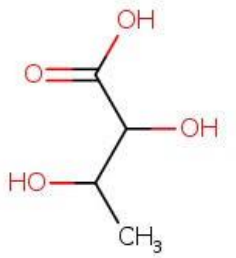
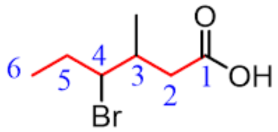
- Aromatic carboxylic acids (i.e., with a -CO_2H directly connected to a benzene ring) are named after the parent compound, benzoic acid.

	Methanoic acid (Formic acid)
	Ethanoic acid (Acetic acid)

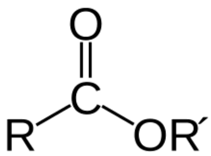
	Propanoic acid

	Butanoic acid
	3-methyl butanoic acid
	2-methyl pentanoic acid
	Benzoic acid phenyl methanoic acid
	phenyl ethanoic acid phenyl acetic acid
	Salicylic acid Ortho-hydroxy benzoic acid (*NOTE*: there are other names)



	2,3-dihydroxy butanoic acid
 4-bromo-3-methylhexanoic acid	

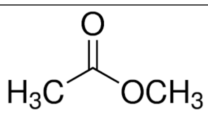
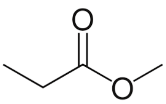
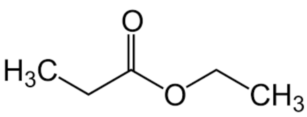
***6. <u>Esters</u>*:**



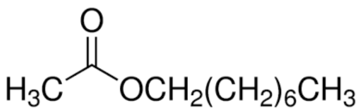
The General Name is: Alkyl alkanoate

<u>Alkyl</u>: The group connected to the oxygen.

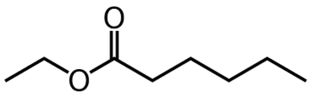
<u>Alkanoate</u>: Starts with the carbonyl carbon (*the carbonyl carbon is included in this part of the name*).

	Methyl ethanoate
	Methyl propanoate
	Ethyl propanate
$CH_3CH_2CH_2CH_2\overset{\overset{O}{\|}}{C}-OCH_2CH_3$	Ethyl pentanoate

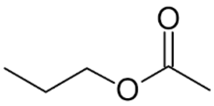
$CH_3COOCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$



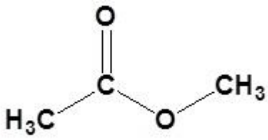
Octyl ethanoate



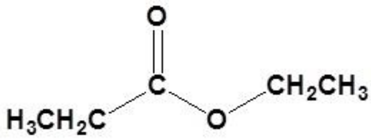
Ethyl hexanoate



Propyl ethanoate

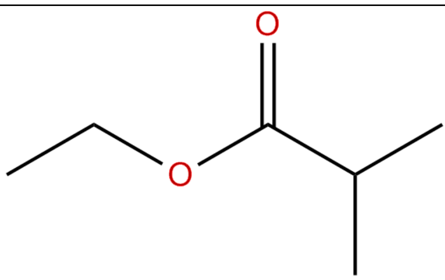


Methyl ethanoate

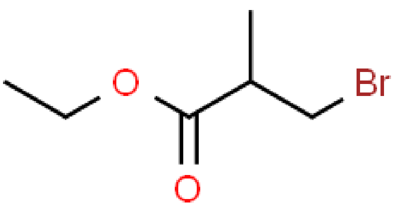


Ethyl propanoate

More examples Link (Esters):



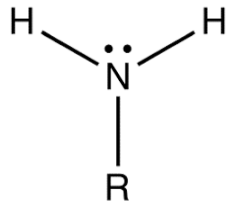
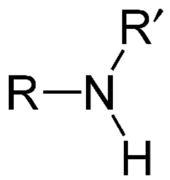
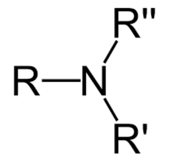
Ethyl-2-methyl propanoate

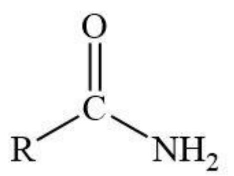
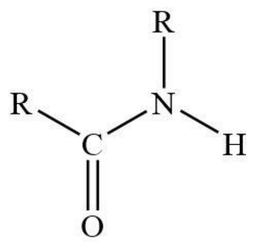
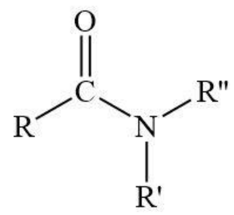


Ethyl-3-bromo-2-methyl propanoate

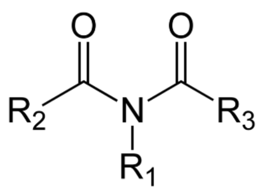
C. Nitrogen-containing functional groups:

The most common ones are:

	Amine group: derivative of ammonia (NH_3)		
1.			
	Primary, 1^o	Secondary , 2^o	Tertiary, 3^o

	Amide group: The functional group contains nitrogen connected to carbonyl group		
2.			
	Primary, 1^o	Secondary, 2^o	Tertiary, 3^o

	Imine group: The functional group contains carbon-nitrogen double bond
3.	

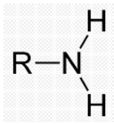
	Imide group: Nitrogen is connected to two carbonyl groups
4.	

We will consider the naming of amines and imides only (the first two groups).

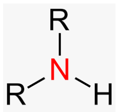
1. <u>Amines</u>:

Amines are the derivatives of ammonia (NH_3).

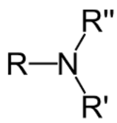
Depending on the number of alkyl groups connected to nitrogen, they are classified as primary, secondary and tertiary. The general structure is shown below:



1° Amine



2° Amine



3° Amine

The Substituent groups may be different or equivalent, or may be aliphatic or aromatic.

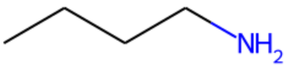
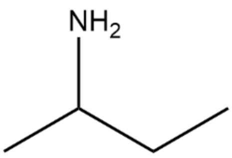
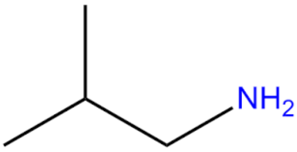
<u>Naming of amines</u>:

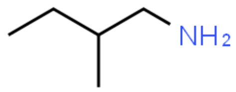
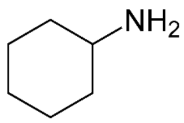
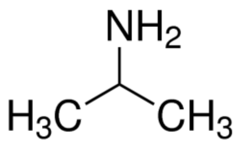
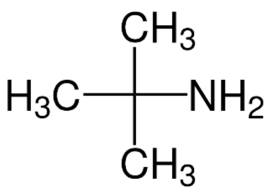
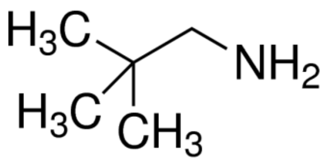
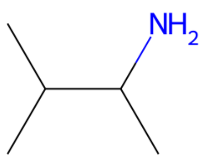
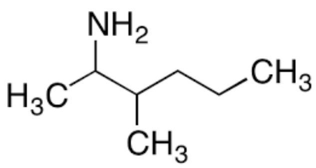
- The **IUPAC system:** The suffix **-amine** is added to the root alkyl name.

  I) <u>Primary amines (1°-amines)</u>: (One alkyl group is attached to the amine nitrogen)

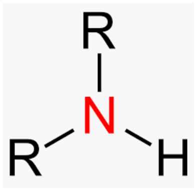
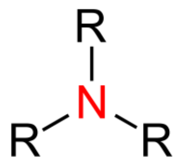
  The parent alkane name is the one with the longest carbon chain. Other branches are substituents. The carbon number at which the is nitrogen attached is written in the name. Also, the carbon numbers with substituents. Then the suffix amine is added.

  <u>Examples</u>

	1-Butanamine (the "1" is the number of carbon in the alkane part to which the nitrogen atom is attached)
 2-butanamine	2- Butanamine
	2-methyl-1-propanamine

	2-methyl butane-1-amine
	Cyclohexanamine 1° amine
	Isopropylamine 2-propanamine
	t-butylamine 2-methyl-2-propanamine
	2,2-dimethyl-1-propanamine
	3-methyl-2-butanamine
 . HCl	3-methyl-2-hexanamine 3-methyl hexane-2-amine

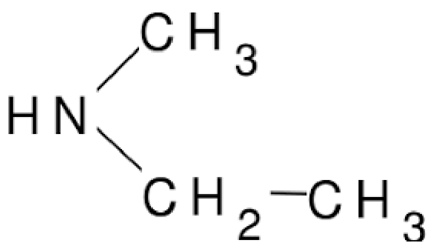
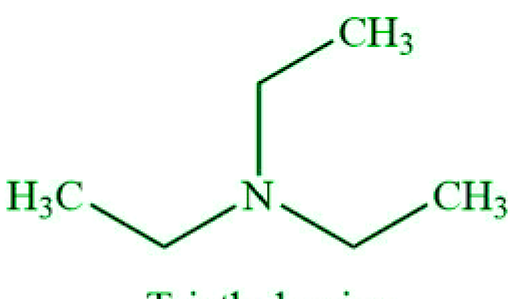
II) Secondary (2º) and tertiary (3º) amines:

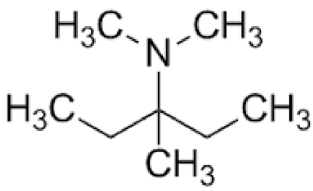
	
2º	3º
Two alkyl groups attached to nitrogen	Three alkyl groups attached to nitrogen

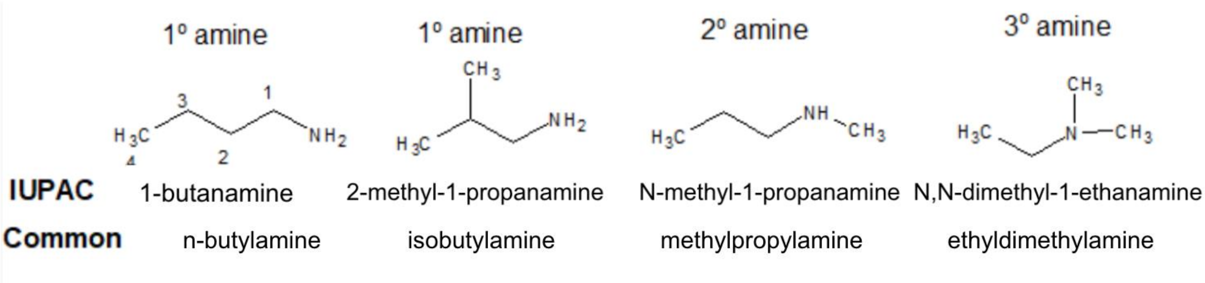
- IUPAC Naming:
  - Identity the longest carbon chain attached to the nitrogen atom, and that chain becomes the parent alkyl name.
  - The other alkyl groups are designated by the prefix **N-** before the alkyl group name.

- The **common nomenclature system:** ***(It is used for simple amines)***

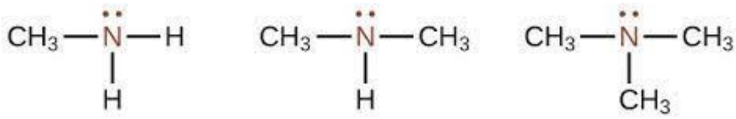
  Each alkyl substituent on nitrogen is named in alphabetical order, followed by the suffix **-amine**. See the examples below.

	N-methyl-1-ethanamine
 Triethylamine	
 N-butylethylamine	OR *(IUPAC)* N-ethylbutan-1-amine

 *N*,*N*,3-trimethylpentan-3-amine	N,N,3-trimethylpentan-3-amine

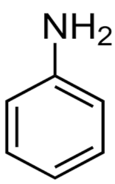
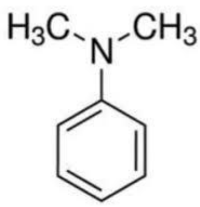


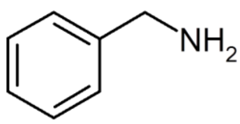
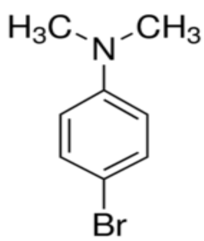
Examples using the <u>common names</u>.



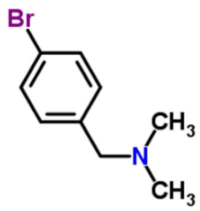
methyl amine	dimethyl amine	trimethyl amine
1° amine	2° amine	3° amine

More examples:

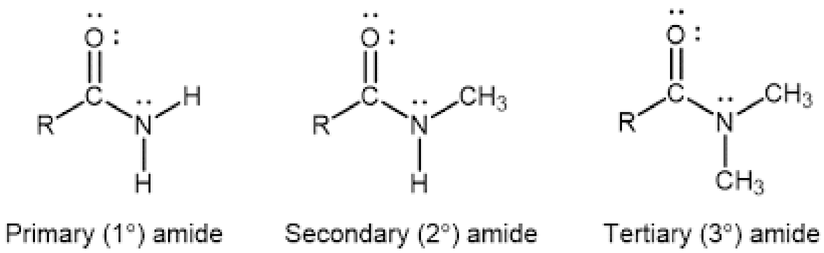
	
Aniline *or* phenyl amine	N.N-dimethyl N-phenyl amine OR N,N-Dimethylaniline

Benzyl amine	4-bromo N,N-dimethyl aniline N-(4-bromo phenyl) N,N-dimethyl amine


Common Name: 4-bromo benzyl dimethyl amine

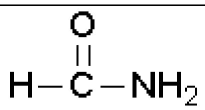
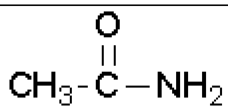
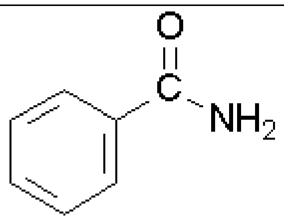
Amides: Link
An amide is a functional group that contains nitrogen connected to a carbonyl group. They may be primary, secondary or tertiary. The general structure of amides is shown below:

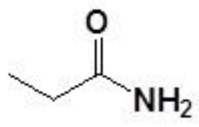


1° amide 2° amide 3° amide

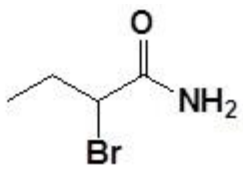
I) Primary amides:

They named by changing the name of the corresponding benzoic acid by dropping the -oic acid or -ic acid endings and adding -amide. The carbonyl carbon is given the number "1" location. It is not necessary to include the location number in the name because the functional group is at the end of the parent chain since the amide is primary.

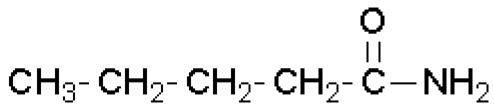
	methanamide or formamide (*methanoic acid*)
	ethanamide or acetamide (*ethanoic acid*)
	Benzamide *(benzoic acid)*



Propanamide



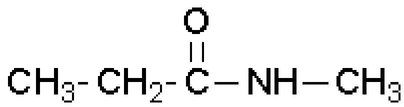
2-Bromobutanamide



Pentamide

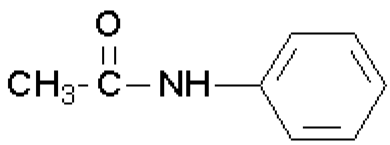
II) Secondary and Tertiary amides:

The longest chain is used to indicate the amide as before. Then a letter N is used to indicate that the other alkyl groups are attached to nitrogen.



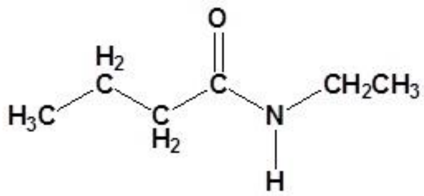
N-methylpropanamide

(*propanoic acid, methyl is attached to N*)

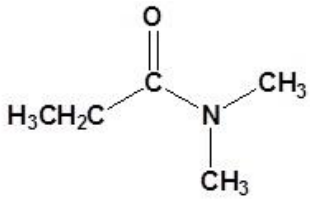


N-phenylethanamide or N-phenylacetamide

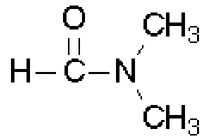
Tertiary amides are named in the same way as secondary amides, but with two N's



N-Ethylbutanamide

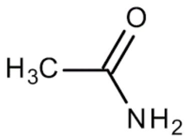


N,N-Dimethylpropanamide

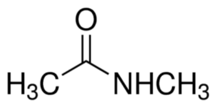


N,N-dimethylformamide
N,N-dimethylmethanamide

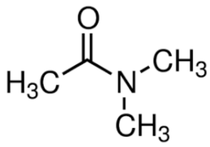
<u>Examples</u>:



Acetamid, or
Ethanamide
1^o amide



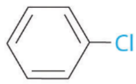
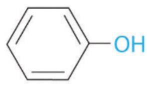
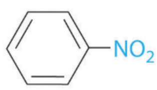
N-methylacetamide
2^o amide



N,N-dimethylacetamide
3^o amide

There are other functional groups that contain sulfur, and other elements, or with different collection of elements like ketene group, CH_2=C=O. They are out of the scope of this introductory material.

THE END
July 2021
Modified Dec 2021, Dec 2022

Class	General Formula	Example	Common Name (Systematic Name)	Common Suffix/Prefix (Systematic)
		Hydrocarbons		
Alkanes	RH	CH_3CH_3	ethane	-ane
Alkenes	RR′C=CR″R‴	$H_2C{=}CH_2$	ethylene (ethene)	-ene
Alkynes	RC≡CR′	HC≡CH	acetylene (ethyne)	(-yne)
Arenes	ArH[a]		benzene	-ene
		Halogen-Containing Compounds		
Alkyl halides	RX	CH_3CH_2Cl	ethyl chloride (chloroethane)	halide (halo-)
Aryl halides	ArX[a]		chlorobenzene	halo-
		Oxygen-Containing Compounds		
Alcohols	ROH[a]	CH_3CH_2OH	ethyl alcohol (ethanol)	-ol
Phenols	ArOH[b]		phenol	-ol
Ethers	ROR′	$H_3CH_2COCH_2CH_3$	diethyl ether	ether
Aldehydes	RCHO	$CH_3\overset{\overset{O}{\Vert}}{C}H$	acetaldehyde (ethanal)	-aldehyde (-al)
Ketones	RR′C=O	$CH_3\overset{\overset{O}{\Vert}}{C}CH_3$	acetone (2-propanone)	-one
Carboxylic acids	RCO_2H	$CH_3\overset{\overset{O}{\Vert}}{C}OH$	acetic acid (ethanoic acid)	-ic acid (-oic acid)
		Carboxylic Acid Derivatives		
Esters	RCO_2R'	$CH_3\overset{\overset{O}{\Vert}}{C}OCH_3$	methyl acetate (methyl ethanoate)	-ate (-oate)
Amides	RCONHR′	$CH_3\overset{\overset{O}{\Vert}}{C}NHCH_3$	*N*-methylacetamide	-amide
		Nitrogen-Containing Compounds		
Amines	RNH_2, RNHR′, RNR′R″	$CH_3CH_2NH_2$	ethylamine	-amine
Nitriles	RC≡N	$H_3CC{\equiv}N$	acetonitrile	-nitrile
Nitro compounds	$ArNO_2$[a]		nitrobenzene	nitro-

[a]R indicates an alkyl group [b]Ar indicates an *aryl* group.

Representing the formulas of organic compounds:

Closed formula:

Expanded structural formula: Shows all atoms and bonds in the molecule.

Condensed structural formula: Shows only specific bonds. (Some of the C—H bonds are omitted).

Line-angle formula: Skeletal structures in which bonds are represented by line segments. Two lines are connected by an angle, which represents a carbon atom. The H's on C's are usually not shown.

Give Example

Hydrocarbon and Alkane Nomenclature:

Hydrocarbons are compounds that contain only carbon and hydrogen.

Saturated hydrocarbons contain single bonds only.

Unsaturated hydrocarbons contain multiple bonds (double and triple).

Give Examples

Alkanes:

They are saturated hydrocarbons. They can be cyclic or acyclic.

They have the general formula of C_nH_{2n+2} when the structure contains no cyclic parts.

The general formula for cyclic alkanes with only one cycle is C_nH_{2n}.

Give Examples

Nomenclature of Alkanes:

Cycloalkanes:

Common Physical Properties of Alkanes:

Reactions of Alkanes:

Chapter 1: Alkanes
Chapter 2: Unsaturated hydrocarbons
Chapter 3: Alcohols, phenols, ethers
Chapter 4: Aldehydes and ketones
Chapter 5: Carboxylic Acids and Esters
Chapter 6: Amines and Amides