ORGANIC CHEMISTRY

INTRODUCTION:

Organic chemistry is the study of carbon and its compounds.

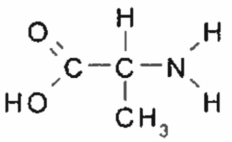
However, some compounds such as CO_2, carbonates, hydrogen carbonates, carbides, and cyanides are traditionally classed as inorganic compounds.

Organic chemistry is better defined as the chemistry of HYDROCARBONS (molecules containing H and C) and their derivatives.

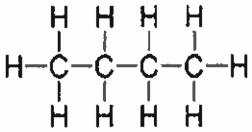
Carbon can form a very large number of compounds. There are over 3 000 000 known carbon compounds and 100 000 new ones are isolated and synthesized every year.

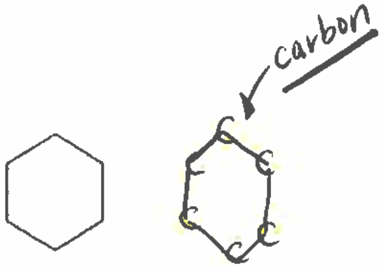
The most significant feature of carbon atoms is their ability to form COVALENT bonds with other carbon atoms. Since it has four valence electrons it can form 4 covalent bonds.

e.g.



Unique nature of carbon:
a) Can from strong repetitive covalent bonds:
e.g.





A CHAIN OF ATOMS
or ACYCLIC COMPOUNDS

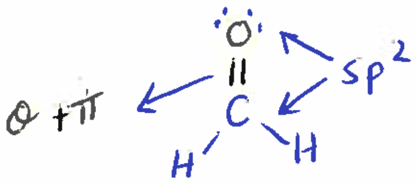
A RING OF ATOMS
or CYCLIC COMPOUNDS

b) Can form multiple bonds with other atoms

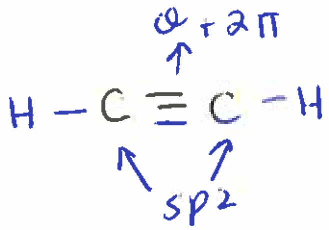
eg.1) double bond between carbon, sp^2 hybridization

h

eg.2) double bond between carbon and oxygen, sp^2 hybridization

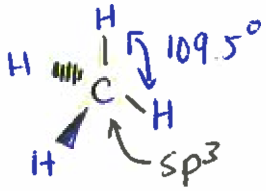


eg.3) triple bond between carbon atoms, sp hybridization



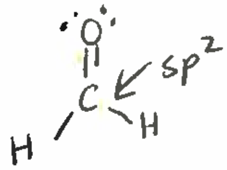
c) can form a variety of geometric shapes:

1) - 4 single bonds around a carbon atom
- the 4 covalent bonds are directed toward the corners of a regular tetrahedron
eg. CH_4, CCl_4



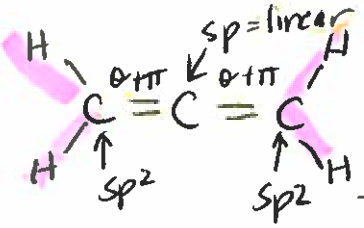
tetrahedral

2) - 2 single bonds and one double bond lie in a plane eg. HCHO



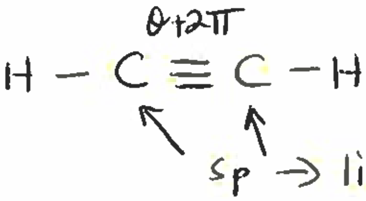
trigonal planar

3) - two double bonds line in a straight line eg. C_3H_4



→ trigonal planar

4) - one single and one triple bond also lie in a straight line eg. C_2H_2

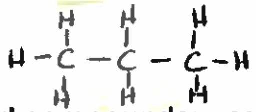


→ linear

CLASSIFICATION OF ORGANIC COMPOUNDS

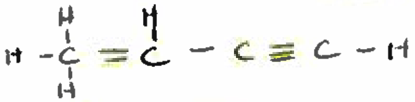
Saturated compounds: - contain single covalent bonds ONLY. $C-C$

e.g.



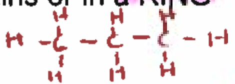
Unsaturated compounds: - contain multiple bonds $C=C$ $C\equiv C$

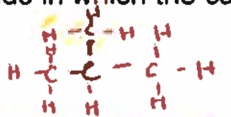
e.g.

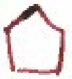


remember octet rule for C

Aliphatic compounds: - these are compounds in which the carbon atoms join in STRAIGHT or BRANCHED chains or in a RING

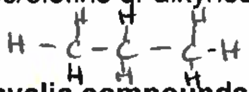




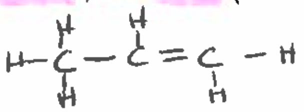


Acyclic compounds: - these are straight chained; saturated (alkanes/paraffins) or unsaturated (alkenes/olefins or alkynes/acetylenes)

e.g.



or

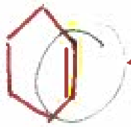


Carbocyclic compounds: - these are compounds in which the carbon atoms are arranged in a ring structure. This group is divided into Alicyclic and Aromatic compounds

Alicyclic compounds: - these rings can be saturated or unsaturated

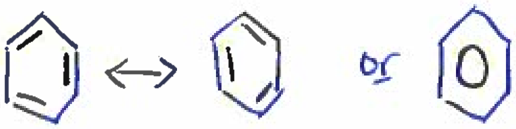
eg.

or



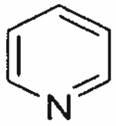
double bond $C=C$

Aromatic compounds: - these are unsaturated compounds in which carbon atoms are arranged in a ring. They have a certain stability and pleasant smell. They are based on the benzene ring. C_6H_6



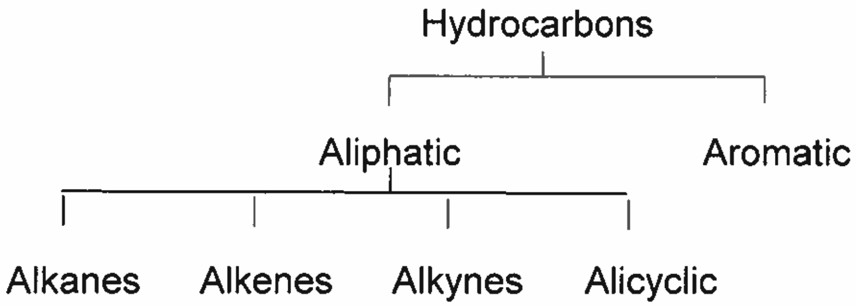
Heterocyclic compounds - These are ring compounds having one or more atoms in the ring which are other than carbon.

eg. pyridine



furan

General Classification of Hydrocarbons



Generally
-organic molecules are composed of a skeleton of carbon atoms, covered with hydrogen atoms and sometimes with groups composed of other atoms attached to the skeleton

-**FUNCTIONAL GROUPS** - the atom or group of atoms which defines the structure of a particular "FAMILY" of organic compound and also determines their properties.

e.g.→ $-OH$ (alcohol) $-X$ (alkyl halide), $-\overset{O}{\overset{\|}{C}}\text{-}H$ (aldehyde)

-Organic compounds are always classified into different **Homologous series** (families) according to their functional group.

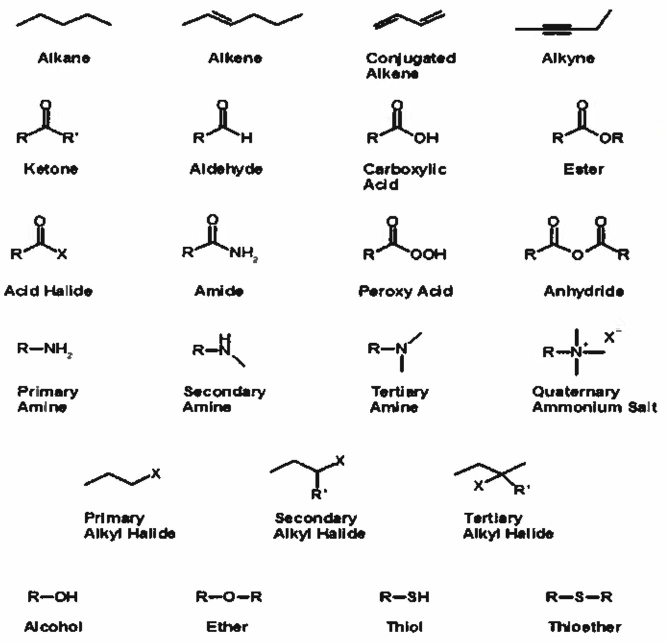
$-\overset{O}{\overset{\|}{C}}\text{-}OH$ (carboxylic acid)

-A **homologous series** is one in which the formula of each member differs from that of the preceding member in a constant regular way. In such a series one finds:

✓ a) similar chemical properties and

✓ b) a progressive but gradual change in physical properties

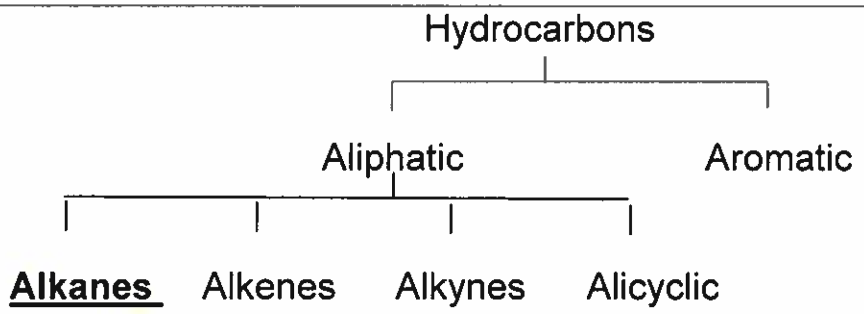
Major Organic Chemistry Functional Groups



R = alkyl group

R = alkyl chain

ALKANES (or paraffins)



- saturated hydrocarbons
- hydrocarbons in which C,C bonds are **all single covalent bonds**
- homologous series of compounds whose structure differ from each other by a specific structural unit "-CH_2"
- general formula C_nH_{2n+2}

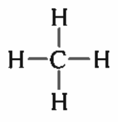
A list of the **first 10 alkanes** is given below.

CH_4	**methane**
C_2H_6	**ethane**
C_3H_8	**propane**
C_4H_{10}	**butane**
C_5H_{12}	**pentane**
C_6H_{14}	**hexane**
C_7H_{16}	**heptane**
C_8H_{18}	**octane**
C_9H_{20}	**nonane**
$C_{10}H_{22}$	**decane**

Note in each case the Greek or Latin ***prefixes*** used to **indicate the number of carbons** in the particular alkane. Also note that every one **ends in -ane**. Learn the above list very well as these root names are the basis of all hydrocarbons.

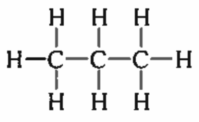
Expanded Structural Diagrams

The normal structures (n-alkanes) of a few alkanes are shown below.



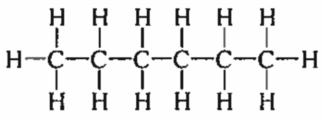
$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

methane



$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

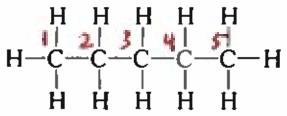
propane



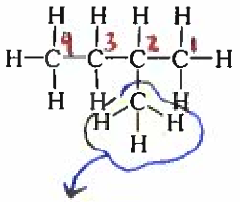
$$\begin{array}{ccccccccccccccc} & & H & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & H & & \end{array}$$

hexane

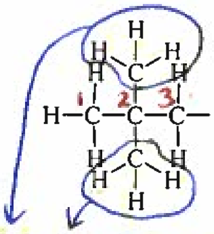
Different compounds that have the **same molecular formula** are called **isomers**. The three different isomers of pentane (C_5H_{12}) are shown below. Since they are unique compounds, they have unique names and properties.



pentane
(bp 36°C)



2-methylbutane
(bp 28°C)



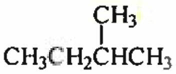
2,2-dimethylpropane
(bp 9°C)

Structures can also be shown using condensed or line diagrams.

Condensed Structural Diagrams:
These diagrams all carbon atoms and the number of hydrogens bonded to each.

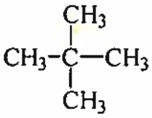
$CH_3CH_2CH_2CH_2CH_3$

pentane



$CH_3CH_2CH(CH_3)CH_3$

2-methylbutane

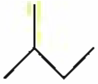


$CH_3C(CH_3)_2CH_3$

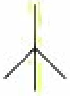
2,2-dimethylpropane

Line Diagrams:
These diagrams show only the carbon-carbon bonds themselves.

pentane



2-methylbutane



2,2-dimethylpropane

In line diagrams, it is assumed that **each carbon has four bonds** and that **hydrogens are attached** at the appropriate locations. The ***number of hydrogens present** must be **determined** by completing the **bonding capacity of carbon (4).**

Hydrogens can be **replaced or *substituted*** by other elements or groups. For example, a hydrogen of methane (CH_4) may be replaced by a **chlorine** atom to form **chloromethane** (CH_3Cl). Branched alkanes contain substitutions derived from smaller alkanes.

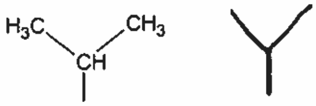
These substituted groups are named by **dropping the -ane** from the name of the corresponding alkane and replacing it by **-yl**. They are known collectively as **alkyl groups**. The general formula for an alkyl group is C_nH_{2n+1} since it contains one less hydrogen than the parent alkane with the formula C_nH_{2n+2}.
To devise a system of nomenclature that could be used for even the most complicated compounds, the **International Union of Pure and Applied Chemists (IUPAC)** developed a system that is used throughout the world today. Since this system follows much the same pattern for all families of organic compounds, we shall consider it in some detail as applied to alkanes.

ALKANES AND ALKYL RADICALS

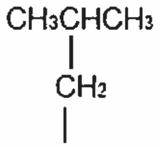
Alkane	Formula	Melting Point (°C)	Phase at Room Temperature	Alkyl Group	Formula
Methane	CH_4	-183	gas	methyl	$-CH_3$
Ethane	C_2H_6	-172	gas	ethyl	$-C_2H_5$
Propane	C_3H_8	-187	gas	propyl	$-C_3H_7$
Butane	C_4H_{10}	-135	gas	butyl	$-C_4H_9$
Pentane	C_5H_{12}	-130	liquid	pentyl	$-C_5H_{11}$
Hexane	C_6H_{14}	-94	liquid	hexyl	$-C_6H_{13}$
Heptane	C_7H_{16}	-91	liquid	heptyl	$-C_7H_{15}$
Octane	C_8H_{18}	-57	liquid	octyl	$-C_8H_{17}$
Nonane	C_9H_{20}	-54	liquid	nonyl	$-C_9H_{19}$
Decane	$C_{10}H_{22}$	-30	liquid	decyl	$-C_{10}H_{21}$

There are some **structural isomers** of **propyl** and **butyl groups** that **require special names**.

isopropyl

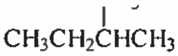


isobutyl



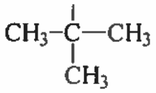
CH_3CHCH_3, CH_2

sec-butyl



$CH_3CH_2CHCH_3$

t-butyl or tert-butyl



CH_3-C-CH_3, CH_3

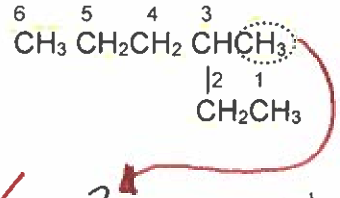
or $-C(CH_3)_3$

Halogen substituent - if the substituent is a halogen then the names used are:
-Cl -chloro -Br -bromo -F -fluoro -I - iodo

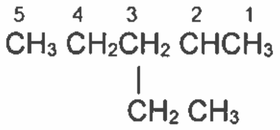
Other common substituents -NO_2 -nitro NH_2-amino

RULES FOR NAMING BRANCHED ALKANE CHAINS ✱✱✱

a) find the **parent chain**, longest chain of carbon atoms and give proper alkane name. *It is not necessary that the longest chain be written in a straight line.* ***Number the carbons*** on the parent chain so that the branch or substituent is at the **LOWEST** C value



This is an alkyl group.



X wrong

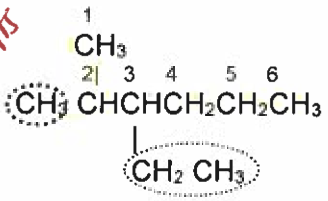
✓ 3-methyl hexane

5 carbon chain

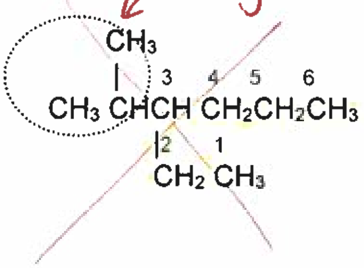
∴ this is correct
6 carbon chain

If there are two chains with the SAME LENGTH, then choose the one with MOST SUBSTITUENTS.

2 substituents

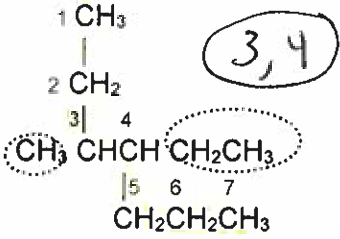


only one substituent

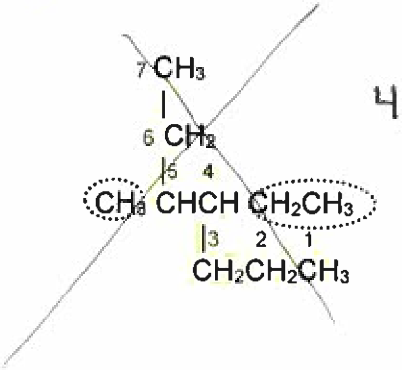


✓3-ethyl-2-methyl hexane

b) Number each carbon atom, starting at the end **nearer the first branch point**.



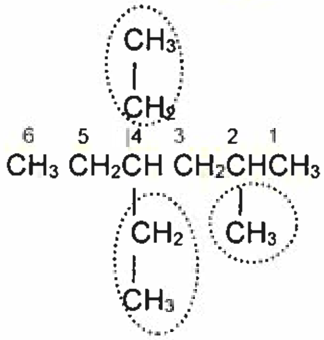
3,4 ✓



4,5

✓ 4-ethyl-3-methyl heptane

c) Name and assign a number to **each substituent** along the parent chain.



2-methyl

4-ethyl

4-ethyl } di

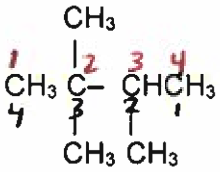
4,4-diethyl-2-methylhexane

↑ both numbers must be stated.

d) Write the **name as one word**, with **hyphens separating prefixes**, and **commas separating numbers**. List ***substituents in alphabetical order***. If there are 2 or more of the same side chain, use prefixes di, tri, tetra, etc., **BUT ignore these prefixes alphabetizing**. For **iso groups** alphabetize with the **letter i**, since they are one word. For **sec- and tert-** the **b for butyl** is used alphabetically instead of the s- or t- for sec or tert

e.g.1	4-ethyl-2,4-dimethylhexane
e.g. 2	1-isoproply-2-methylcylcohexane
e.g. 3	2, 2-dibromo-5-t-butyl-4-ethyl-7,8-dimethyldecane

e) If you are left with the choice of number a chain (e.g. two substituents equal numbers of carbon atoms from each end of the chain), look for the **next substituent number to be as low as possible.**

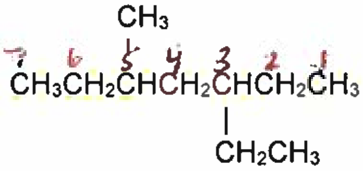


$CH_3\overset{CH_3}{\underset{CH_3}{C}}-\underset{CH_3}{C}HCH_3$

✓2,2,3

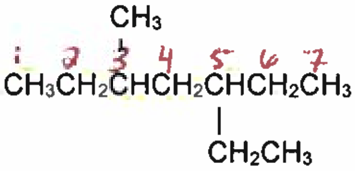
~~2,3,3~~ 2,2,3-trimethyl butane

f) If there is a choice of substituent number, and none of the above guidelines gives a definitive answer, then the lower is given to the group that comes first in the alphabet.



$CH_3CH_2\overset{CH_3}{C}HCH_2\underset{CH_2CH_3}{C}HCH_2CH_3$

NOT



$CH_3CH_2\overset{CH_3}{C}HCH_2\underset{CH_2CH_3}{C}HCH_2CH_3$

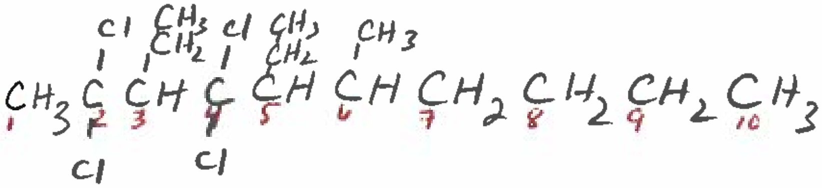
3-ethyl-5-methylheptane ✓

3-methyl-5-ethylheptane ✗

From Name to Structural Formula

This is much easier – start with the parent chain, number the carbons from left to right and then add the appropriate substituents as indicated in the name:

E.g. 2,2,4,4-tetrachloro-3,5-diethyl-6-methyldecane

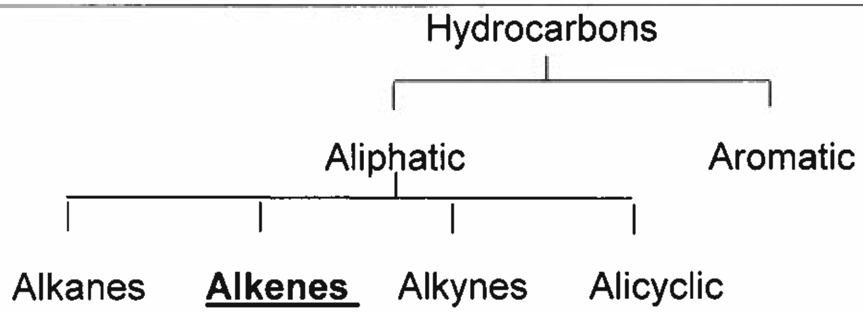


$CH_3\overset{Cl}{\underset{Cl}{C}}\overset{CH_2CH_3}{C}H\overset{Cl}{\underset{Cl}{C}}\overset{CH_2CH_3}{C}H\overset{CH_3}{C}HCH_2CH_2CH_2CH_3$

NOTE – Order of Priority: Lowest to Highest (use once families studied)

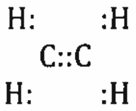
Alkyl [-R];
Nitro [-NO_2];
Halide [-X];
Alkyne;
Alkene;
Ether [R-O-R];
Amines [-$N(R/H)_2$];
Alcohols [-OH];
Ketones [-RCOR];
Aldehydes [-COH];
Amides [-$CON(R/H)_2$];
Esters [-COOR];
Carboxylic acids [-COOH] ← carboxylic carbon must be carbon #1 when numbering

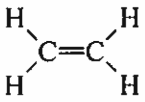
ALKENES



- sometimes called olefins
- unsaturated hydrocarbon molecules containing double bonds (σ + π)
- general formula: $\mathbf{C_nH_{2n}}$

simplest: 2 carbons → ethene





C_2H_4

Nomenclature:

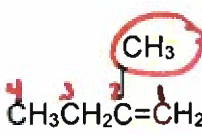
1. Replace **"ane"** ending of alkane with **"ene"**. If there is **more than one double bond** change "ne" ending of alkane to "**diene**" ending for 2 double bonds, **"triene"** ending for 3 double bonds etc.

buta-1,2-diene

2. When numbering the parent hydrocarbon,

e.g. $\overset{1}{C}H_2=\overset{2}{C}H-\overset{3}{C}H_2\overset{4}{C}H_3$ is named 1-butene or but-1-ene

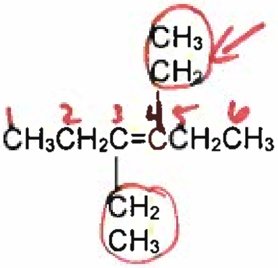
$CH_3-CH=CH-CH_3$ is named 2-butene or but-2-ene



$$\begin{array}{l} \qquad\quad CH_3 \\ \qquad\quad | \\ \overset{4}{C}H_3\overset{3}{C}H_2\overset{2}{C}=\overset{1}{C}H_2 \end{array}$$

methyl

is named 2-methyl-1-butene / 2-methyl(but-1-ene)

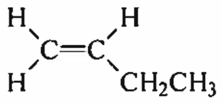


$$\begin{array}{l} \qquad\quad CH_3 \\ \qquad\quad CH_2 \\ \qquad\quad | \\ \overset{1}{C}H_3\overset{2}{C}H_2\overset{3}{C}=\overset{4}{C}\overset{5}{C}H_2\overset{6}{C}H_3 \\ \qquad\quad | \\ \qquad\quad CH_2 \\ \qquad\quad CH_3 \end{array}$$

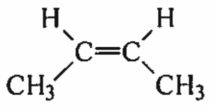
is named 3,4-diethyl-3-hexene / 3,4-diethyl hex-3-ene

- the **double bond takes precedence over the other functional groups** -- it is given the lowest carbon number

Recall - structural isomers – have the **same chemical formula**, but **different structure**
eg. C_4H_8
a) 1-butene

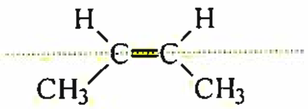


b) 2-butene

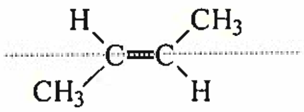


The structure of 2-butene can be represented in two ways:

c) cis-2-butene



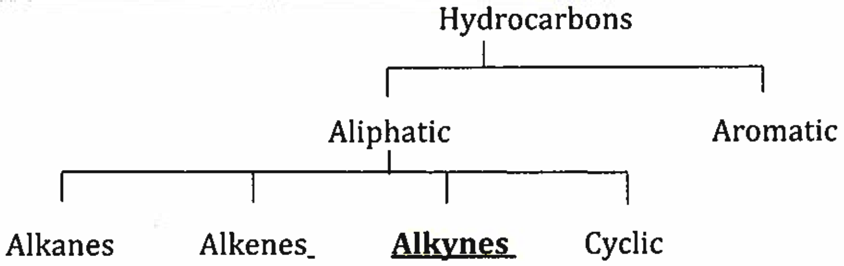
d) trans-2-butene



<u>c) and d) are geometric isomers</u>. Structural isomers **that differ only with respect to the position (geometric arrangement)** of their **substituent groups are called positional isomers or geometric isomers.**
These result because rotation about the C=C bond cannot occur.

In the previous example of cis-2-butene and trans-2-butene, the shapes are "C" and "zigzag" respectively. (E-Z nomenclature - involves more complex substituents: Z – the substituents are on the same side of the double bond, while in E they are on opposite side of the double bond)

ALKYNES



- unsaturated hydrocarbon molecules containing triple bonds ($\sigma + 2\pi$)
- they are linear
- the general formula is: $\mathbf{C_nH_{2n-2}}$

H:C:::C:H $H{-}C{\equiv}C{-}H$ ethyne (acetylene)

<u>NOMENCLATURE</u>:

1. Replace the "ane" ending of the alkane with "yne"

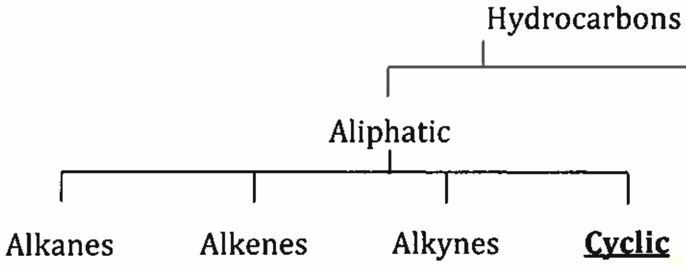
2. Number in the same fashion as alkenes

e.g. $\overset{1}{C}H_3-\overset{2}{C}\equiv\overset{3}{C}-\overset{4}{C}H$

2-butyne
but-2-yne

<u>or</u>

CYCLOALKANES, CYCLOALKENES AND CYCLOALKYNES

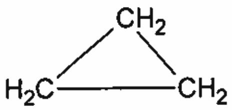


- compounds that contain a ring structure

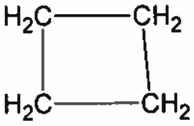
CYCLOALKANES

- also known as NAPHTHENES
- to assign names to these compounds, count up the number of C atoms in the ring to obtain a name as if it were a straight chain alkane, then add the **prefix "CYCLO"** just before the name
- if there is an alkyl substituent in place of a hydrogen atom, on one of the carbons then the name of the alkyl group is added before the cycloalkane name

Cyclopropane b.p. -34.4°C

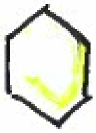


Cyclobutane b.p. -13°C



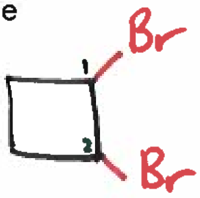
Cyclopentane b.p. 49.5°C

Cyclohexane b.p. 81.4°C



- if two hydrogen atoms have been replaced by similar alkyl groups, then the position of these in indicated by the **lowest possible numbers of the carbon atoms of the ring bearing them**

1,2-dibromocyclobutane

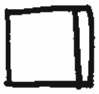


CYCLOALKENES and CYCLOALKYNES

- when numbering carbons, the same rules apply as in the alkenes and alkynes

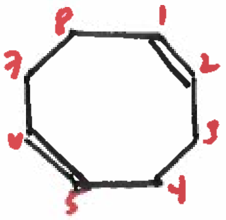
cyclobutene

ring ↑ 4 ↑ //



cyclohexene

1,5-cycloctadiene



Note that the formation of the ring removes two hydrogens from the formula of any cyclic hydrocarbon. For example, the alkane butane has the formula C_4H_{10} whereas cyclobutane has the formula C_4H_8.

AROMATIC HYDROCARBONS (ARENES)

- these are unsaturated with the general formal: $\mathbf{C_nH_{2n-6}}$

- many arenes and derivatives have pleasant odours
- many are toxic and some are carcinogenic
- they are flammable and burn with a yellow flame
- the simple ones are good solvents but are TOXIC

Simplest - benzene, C_6H_6 - colourless, b.p. 80° C, planar molecule, less dense than H_2O, insoluble in water

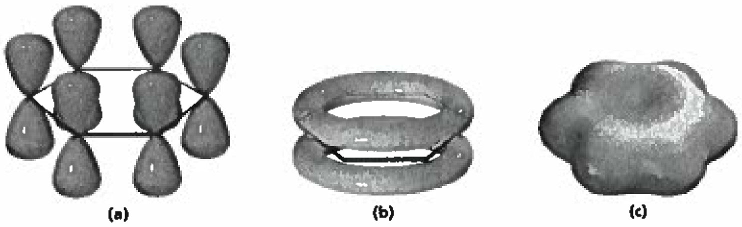
structure: is a resonance of two possibilities

In other words, the electrons involved in the "double" bonds or pi bonds are shared equally among all 6 carbons. These pi electrons are said to be *delocalized* in this arrangement. Every carbon is sp^2 hybridization state with one electron involved in pi bonding. This means that benzene has a planar structure as shown in these models:

a) 6 half-filled *p* orbitals

b) π-bonding (delocalized electrons)

c) electron density diagram



this shows that all bonds are the same length and that the electrons are delocalized (e^- are evenly spread around the ring and shared between the 6 C)

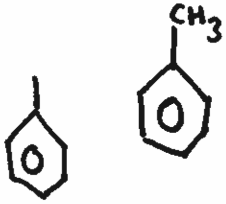
- as a result of its stability, **benzene is an unreactive compound compared to other double bonded compounds**

NOMENCLATURE:

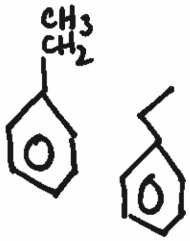
- the benzene ring C's are numbered **1-6 in a clockwise direction**
- different groups may replace H and the numbers need to be kept as low as possible

1. Monosubstituted alkyl benzenes:

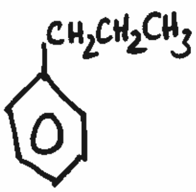
methylbenzene (toluene)



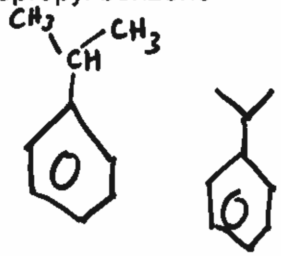
ethylbenzene



propylbenzene



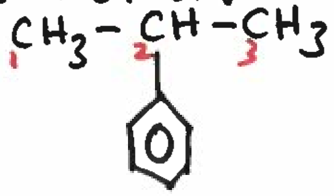
isopropyl benzene



If they are attached by any other C than the carbon, the benzene ring is used as a branch(substituent). The C_6H_5 is called a ***PHENYL*** group.

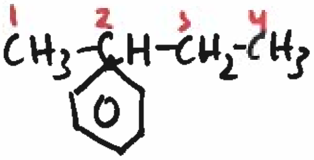
e.g. 2-phenylpropane

or isopropyl benzene

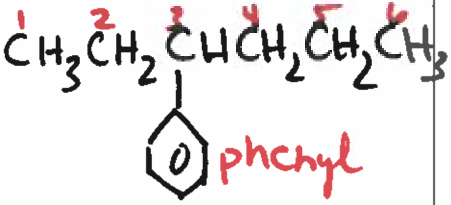


2-phenylbutane

sec-butyl benzene



3-phenylhexane

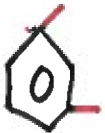


2. Two groups attached:

ORTHO

ortho => subs. are side by side

META



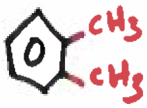
meta => a carbon btwn the 2 subs.

PARA

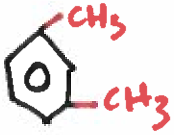
para => subs. are opposite each other.

e.g. dimethylbenzenes (xylenes)

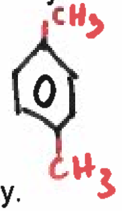
o-dimethylbenzene



m-dimethylbenzene



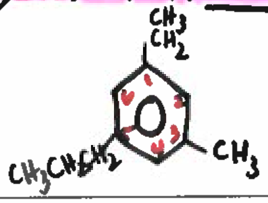
p-dimethylbenzene

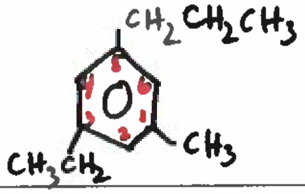


3. Poly-substituted - the groups are listed alphabetically or by complexity.

e.g. 1-ethyl-3-methyl-5-propylbenzene or 1-methyl-3-ethyl-5-propylbenzene

✓ ✓





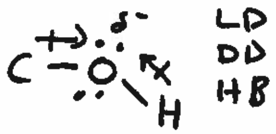
FUNCTIONAL GROUPS

ALCOHOLS

General formula:

"R-OH", where R is any alkyl group(any carbon chain or ring that is relatively unreactive) and -OH is the reactive part

- homologous series characterized by hydroxyl group



Physical Properties:

- as size of alkyl radical increases, alcohol's physical characteristics are more like the alkane
- like water, alcohols are capable of intermolecular hydrogen bonding this causes their boiling points to be higher than alkanes containing comparable numbers of carbon atoms
- alcohols of up to 4 carbons are soluble in water, increases in alkyl group causes a decrease in solubility in water -- this is because alcohols consist of two parts: the carbon chain which is non-polar (hydrophobic-water hating) and the hydroxyl group which is polar and hence attracted to water (hydrophilic - water loving)

← Polar ∴ hydrophilic

non-polar ∴ hydrophobic

Nomenclature:

2 methods:

- a) use alkyl name followed by alcohol – TRIVIAL

e.g. ethyl alcohol
propyl alcohol
iso propyl alcohol

- b) - use suffix "ol" after alkyl name "anol"(alkane), "enol"(alkene), "ynol"(alkyne) (IUPAC)

e.g. ethanol

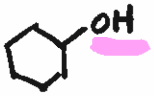
- the -OH group is numbered so that it is given the smallest C number

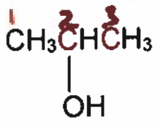
- the longest carbon chain must contain the -OH group

e.g. $\overset{1}{C}H_3OH$ methanol; methyl alcohol

CH_3CH_2OH ethanol; ethyl alcohol

cyclohexanol or cyclohexyl alcohol

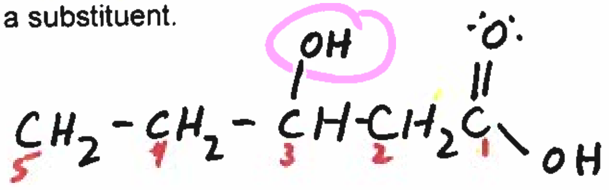




$\underset{\displaystyle OH}{\overset{1}{C}H_3\overset{2}{C}H\overset{3}{C}H_3}$

2-propanol
propan-2-ol 2-propyl alcohol

- in some instances, the -OH group is attached to complex carbon structures, in this case, the -OH is considered to be a substituent.



$\underset{5}{C}H_2-\underset{4}{C}H_2-\underset{3}{C}H(OH)-\underset{2}{C}H_2\underset{1}{C}(=O)OH$

3-hydroxypentanoic acid

Structural Geometry of Alcohols:

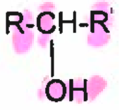
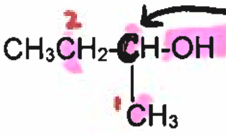
Primary alcohol (1°):

- only one alkyl group is attached to the hydroxyl bearing carbon atom

- R-OH, eg. $CH_3CH_2CH_2\overset{1}{C}H_2\mathbf{C}H_2OH$ carbon attached to only 1 carbon

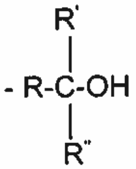
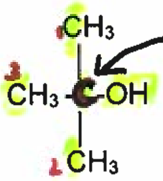
Secondary alcohol (2°):

-two alkyl groups are attached to the hydroxyl bearing carbon atom

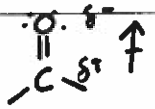
- 
$R-\underset{\underset{OH}{|}}{CH}-R'$
e.g. 
$CH_3\overset{2}{C}H_2-\underset{\underset{{}^{1}CH_3}{|}}{\mathbf{C}H}-OH$
carbon attached to 2 other carbons

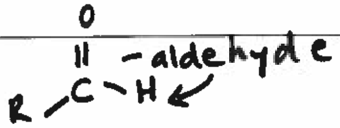
Tertiary alcohol (3°):

- three alkyl groups are attached to the hydroxyl bearing carbon atom

- 
$R-\overset{\overset{R'}{|}}{\underset{\underset{R''}{|}}{C}}-OH$
e.g. 
$\overset{3}{C}H_3-\overset{\overset{{}^{1}CH_3}{|}}{\underset{\underset{{}^{2}CH_3}{|}}{\mathbf{C}}}-OH$
carbon attached to 3 other carbons.

ALDEHYDES AND KETONES

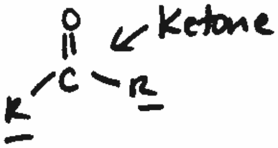




General formula:

"R-C=O", where R is any alkyl group (any carbon chain or ring that is relatively unreactive) and C=O is the reactive part

- homologous series characterized by carbonyl group 



Physical Properties:

- aldehydes and ketones can form weak hydrogen bonds between the carbonyl oxygen and the hydrogens of water. Some are therefore soluble in water
- solubility decrease when the length of hydrocarbon chain exceeds five carbons

- aldehydes and ketones are soluble in non-polar solvents

- they cannot form intermolecular hydrogen bonds because they lack hydroxyl (-OH) groups, consequently they have lower m.p.and b.p. than corresponding alcohols

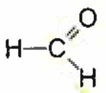
- aldehydes and ketones can attract one another through polar-polar interactions of their carbonyl groups, thus their m.p. andb.p. are higher than those of corresponding alkanes
-nearly all are liquids or solids at room temperature

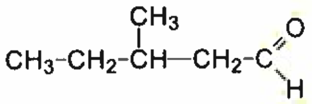
Nomenclature:

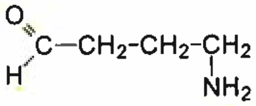

must be at the end of chain!

ALDEHYDES:
- the "ane" ending of longest hydrocarbon chain is changed to "al"

Since the carbonyl group of aldehydes is ALWAYS at carbon 1, it is not necessary to identify the location. Since aldehydes are at the end of a chain, they can not be cyclic.


methanal


3-methylpentanal


4-aminobutanal

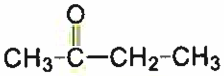
KETONES:


will be in the middle of chain!

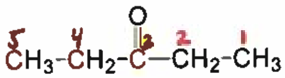
- the "ane" ending of longest hydrocarbon chain is changed to "one"

- substituent groups are named as before

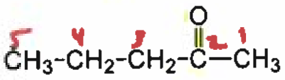
Ketones may or may not require a number to identify the location of the carbonyl group.


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

butanone

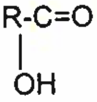

$CH_3-CH_2-\overset{\overset{O}{\|}}{C}-CH_2-CH_3$

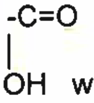
3-pentanone


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

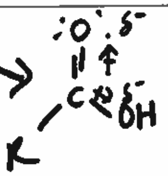
2-pentanone

CARBOXYLIC ACIDS

<u></u>**General formula**: 
$\underset{\underset{OH}{|}}{R-C}=O$


$\underset{\underset{OH}{|}}{-C}=O$

is the carboxyl group written as CO_2H or COOH



Physical Properties:

- are weak acids - ionize only slightly in solution to give a proton and a carboxylate ion

- low formula mass members of straight chain carboxylic acid series are colourless, volatile liquids with sharp unpleasant odour

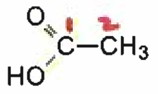
- higher members of series are non-volatile, low-melting waxy solids

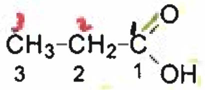
- like alcohols, carboxylic acids can form intermolecular hydrogen bonds, therefore they have higher m.p. and b.p. than compounds of similar formula mass

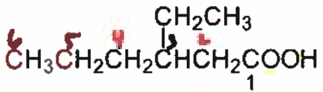
- carboxyl groups are polar, and forms hydrogen-bonding with water molecules, thus the first 4 members of homologous series are soluble, but the solubility of other members drops off sharply becoming soluble only in non-polar solvents

Nomenclature:

- "ane" ending of alkane changed to "oic" acid – the carbonyl carbon of the acid is always C#1

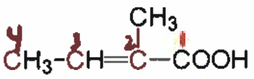

ethanoic acid
(acetic acid)


propanoic acid


$CH_3CH_2CH_2CH(CH_2CH_3)CH_2COOH$

3-ethylhexanoic acid

and sometimes 2 groups can appear.


$CH_3-CH=C(CH_3)-COOH$

2-methyl-2-butenoic acid

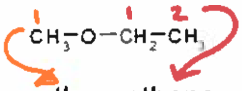
ETHERS

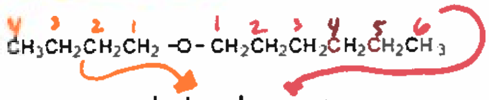
General formula: R-O-R'

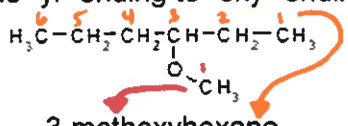
Nomenclature:

most commonly used method of naming ethers is a trivial one--the word ether is used as a general descriptive term to denote the type of compound and this is prefaced by the names of the substituents

IUPAC method - longest chain retains its alkyl name, the shorter chain (substituent) has its name changed from the "yl" ending to "oxy" ending

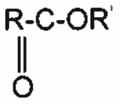

methoxyethane
(ethyl methyl ether)

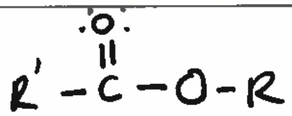

butoxyhexane
(butyl hexyl ether)


3-methoxyhexane

ESTERS

General formula: R-C-OR'


$R-C(=O)-OR'$

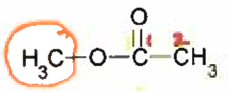


Physical Properties:

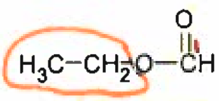
- esters are derivatives of carboxylic acids and are polar but cannot form hydrogen bonds with one another
-they have much lower b.p. than corresponding carboxylic acids
- low formula mass esters are soluble, esters containing more than four carbons have very limited solubility
- very volatile liquids with pleasant sweet odours

Nomenclature:

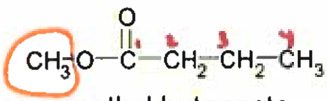
- first part of the name is that of the alkyl group attached to the oxygen; the second part is that of the acid which has its"-ic acid" ending changed to "-oate"


$H_3C-O-C(=O)-CH_3$

methyl ethanoate


$H_3C-CH_2-O-C(=O)H$

ethyl methanoate


$CH_3-O-C(=O)-CH_2-CH_2-CH_3$

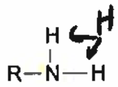
methyl butanoate

AMINES AND AMIDES

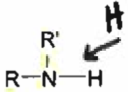
- organic compounds containing nitrogen

AMINES

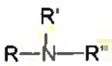
Amines are classified as primary, secondary or tertiary depending on the number of alkyl groups (R groups) bonded to the nitrogen.


H Bonding

Primary Amine (1°)


H Bonding

Secondary Amine (2°)


no H Bonding

Tertiary amine (3°)

Physical properties of amines

– have unpleasant odours

– amines have hydrogen bonding which weaker than that found in the hydroxyl containing compounds as a result, their melting/boiling point is less than the comparable alcohol

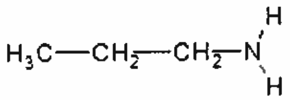
Nomenclature:

Two methods:

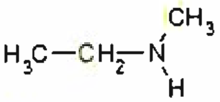
1) add the **prefix** "amino" to the corresponding longest alkane chain (IUPAC system) - the "amino" represents the NH_2 group

2) add the **suffix** "amine" to the longest alkane - the "amine" represents that the amine is a derivative of ammonia

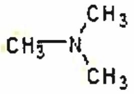
- if the amine is a secondary or tertiary amine, the letter N is used to show where the other alkyl substituent is attached using the IUPAC system. For the alternate system, N is used to indicate that the other alkyl substituent is attached to the nitrogen and the longest carbon chain will end in amine.


$H_3C-CH_2-CH_2-NH_2$

aminopropane
(propylamine)


$H_3C-CH_2-NH(CH_3)$

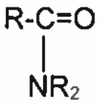
N-methylaminoethane
(ethylmethylamine)


$CH_3-N(CH_3)_2$

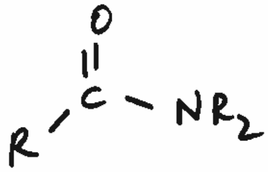
N,*N*-dimethylaminomethane
(trimethylamine)

AMIDES

general formula:



$R\text{-}C{=}O$ with NR_2 on the C

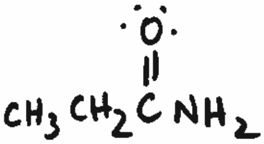


- the -OH group of the carboxylic group is replaced with NR_2

Nomenclature:

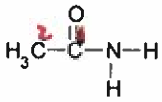
- replace "-oic acid" ending of corresponding carboxylic acid with "-amide"

eg. $C_2H_5CONH_2$ propanamide (1°)

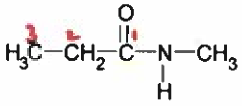


$CH_3CH_2C({=}O)NH_2$

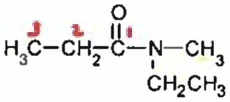
- if the H in the NH_2 group is substituted with an alkyl group, the compound is named by using the prefix N-, or N,N- followed by the corresponding substituent



ethanamide



N-methyl propanamide



N-ethyl-*N*-methyl propenamide

ORGANIC REACTIONS

Combustion Reactions

This is the complete oxidation of a hydrocarbon. alkanes, alkenes, alkynes

$$\text{hydrocarbon} + \text{oxygen} \xrightarrow{\text{spark}} \text{carbon dioxide} + \text{water}$$

$$C_2H_6(g) + 7/2\ O_2(g) \xrightarrow{\text{spark}} 2\ CO_2(g) + 3\ H_2O(v) + \text{heat}$$

Addition Reactions

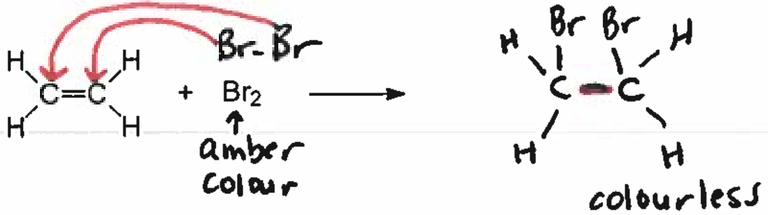
Addition reactions involve the addition of one or more particles to an organic molecule. These reactions occur in unsaturated hydrocarbons. There are four main types of addition reactions:

1. Halogenation

This reaction involves the addition of a halogen molecule to an unsaturated hydrocarbon. These reactions occur at room temperature because of the instability/reactivity of the double and triple bonds

if Br_2 is used, then it tests for saturation.

Eg. ethene + bromine



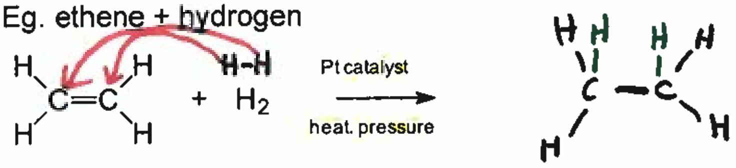
dibromoethane

(I_2 does not add to double bonds easily)

2. Hydrogenation

This reaction involves the addition of a hydrogen molecule to an unsaturated hydrocarbon. These reactions occur under high pressure, temperature, and with a catalyst. → (Pt, Pd or Ni)

Eg. ethene + hydrogen



ethane

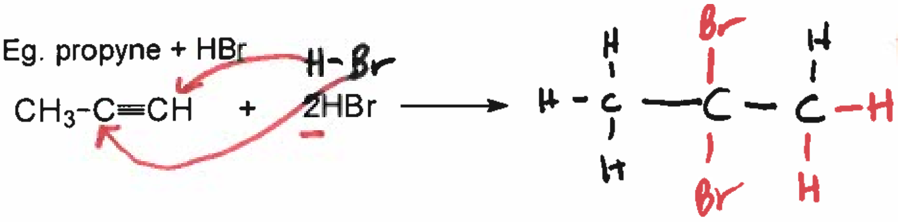
3. Hydrohalogenation

H-X

This reaction involves the addition of a hydrogen halide to an unsaturated hydrocarbon. These reactions occur at room temperature. The product must follow Markovnikov's Rule which states:

In general, for the addition reactions of an unsymmetrical reagent to an unsymmetrical alkene occurs so that the positive end of the reagent, usually H^+, adds to the carbon with the most hydrogens attached to it, that is the least substituted carbon. That is, the H adds to the carbon of the double bond with the most hydrogens directly attached to it. (The rich get richer)

Eg. propyne + HBr



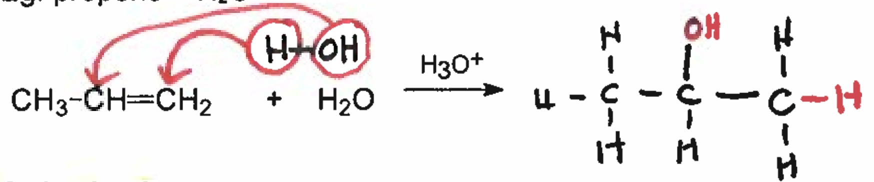
1,2-dibromopropane

4. Hydration

This reaction involves the addition of a water to an unsaturated hydrocarbon. These reactions occur with a catalyst in a strong acid. The product must also follow Markovnikov's Rule.

Eg. propene + H_2O

alcohol forms!



2-propanol

propan-2-ol

Substitution

Substitution reactions involve replacing a hydrogen atom with another atom or molecule.

Alkane Substitution

This reaction involves the substitution of a halogen atom with a hydrogen in an alkane. These reactions require high temperatures or UV light because of the low reactivity of alkanes due to the single bonds.

Eg. ethane + chlorine

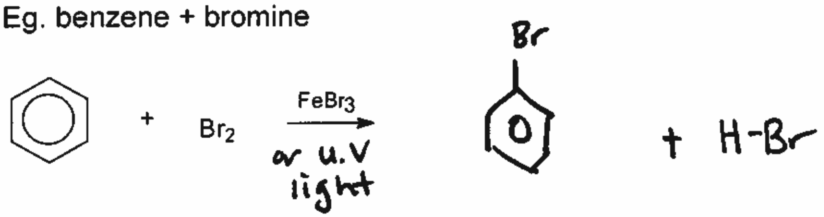
$$CH_3CH_3 + \underset{Cl-Cl}{Cl_2} \xrightarrow{u.v.\ light} HCl + CH_3CH_2Cl$$ a reactive alkyl halide

in practice a variety of products are obtained in a substitution reaction.

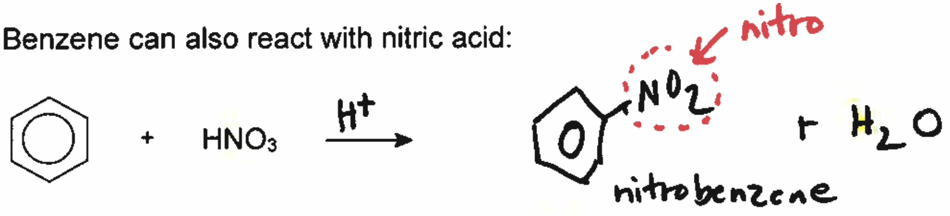
Aromatic Substitution

This reaction involves the substitution of a halogen atom with a hydrogen in benzene. These reactions require the help of $FeBr_3$ because of the low reactivity of benzene. This is due to the stability of benzene because the double bonds are delocalized (shared equally).

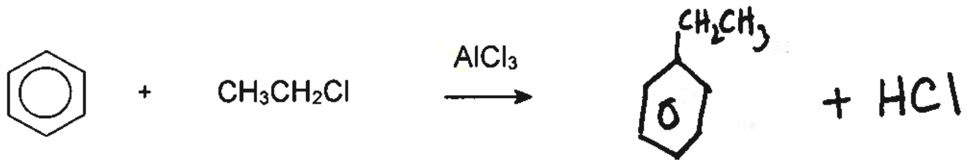
Eg. benzene + bromine



Benzene can also react with nitric acid:

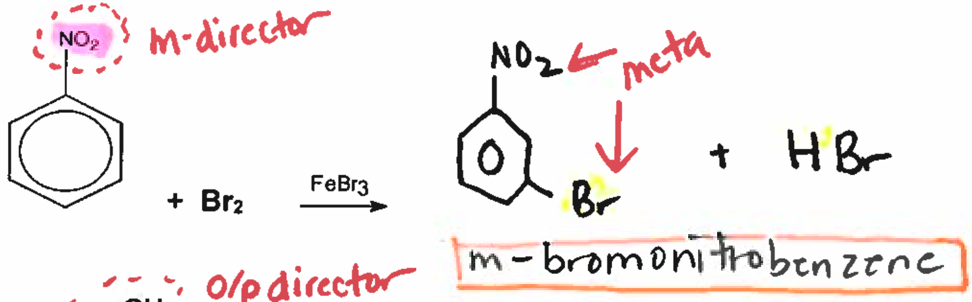


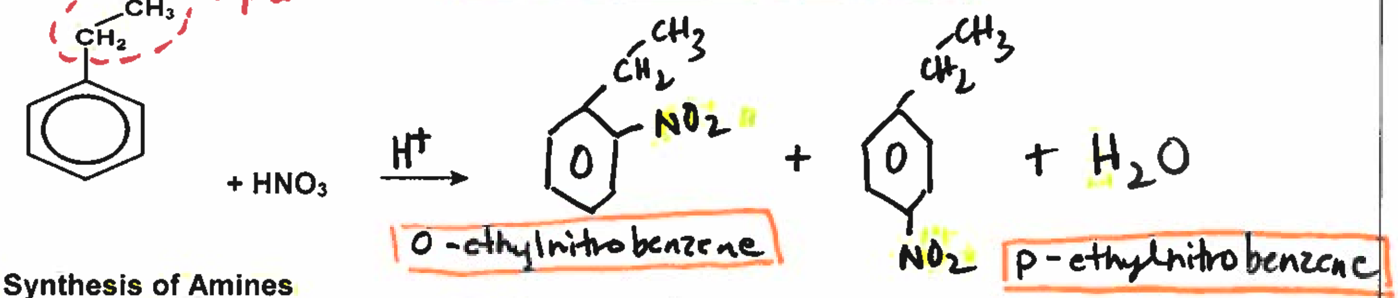
Benzene can also react with an alkyl halide with the help of $AlCl_3$:



NOTE: when substitution reactions occur on a substituted benzene ring, the substituent on the ring will direct where the next substituent will go. The following are:

Ortho-para directors:-OH; -N(R)$_2$; -OR; -R; -X; -NHCOR
Meta Directors are: -NO$_2$; -CN; -SO$_3$H; -COR; -COOH } will be given

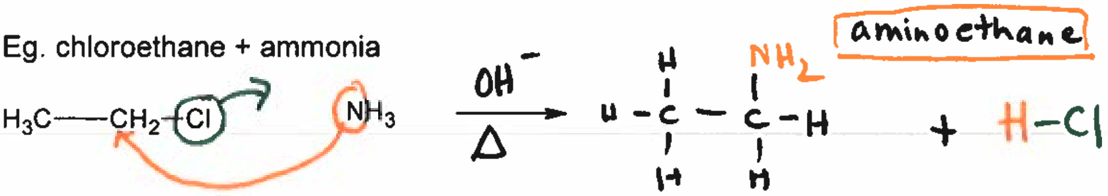




Synthesis of Amines

The synthesis of amines involves substitution reactions with an alkyl halide and ammonia.

Eg. chloroethane + ammonia

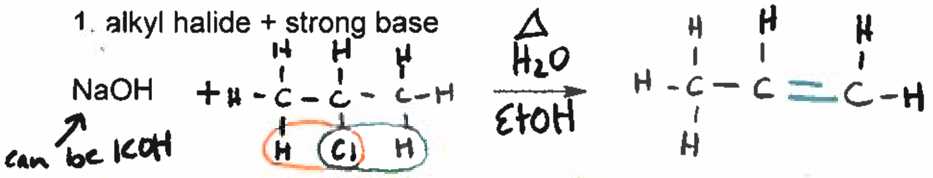


Elimination

Elimination reactions involve the removal of a small molecule from the original molecule. These reactions form alkenes. There are two kinds of elimination reactions that we will look at:

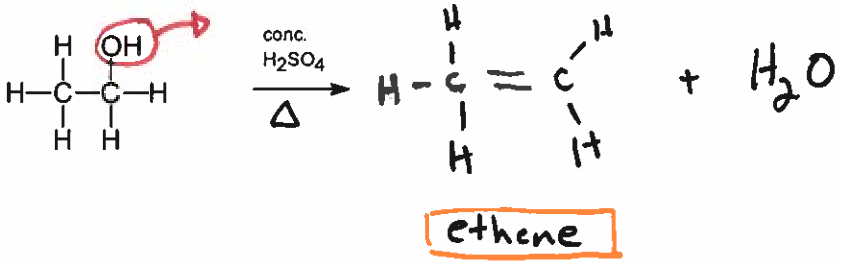
EtOH => ethanol

1. alkyl halide + strong base



2. Dehydration of an alcohol in sulphuric acid with a catalyst

↘ makes H_2O



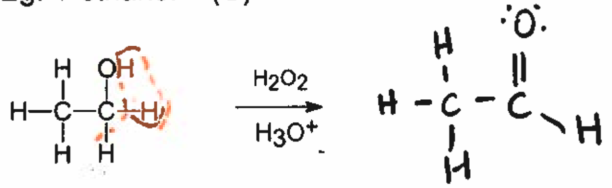
Oxidation

Oxidation reactions involve the gaining of oxygen or the loss of hydrogen. There are many oxidizing agents that are frequently used such as $KMnO_4$, $K_2Cr_2O_7$, and H_2O_2. These reactions require concentrated sulphuric acid.

[O] => an oxidizing agent

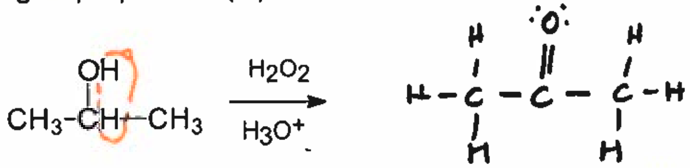
Oxidation of alcohols

Primary alcohols are oxidized to produce aldehydes.
Eg. 1-ethanol + (O)



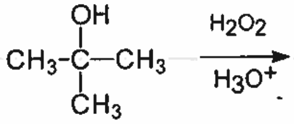
ethanal

Secondary alcohols are oxidized to produce ketones.
Eg. 2-propanol + (O)



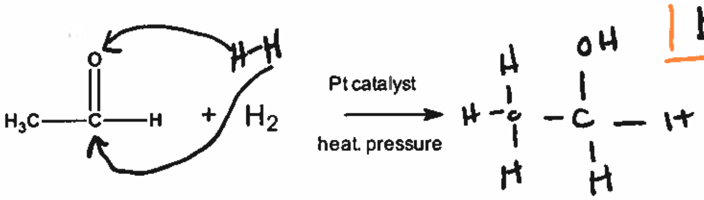
propanone

Tertiary alcohols do not oxidize because there is no hydrogen to remove.



no reaction

The reversal of these reactions involve the hydrogenation in high temperature and pressure with a catalyst. (Pt, Pd, Ni)



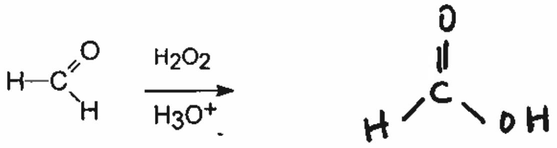
butanol

(1° alcohol)

** Ketone forms a 2° OH

Oxidation of carbonyl groups

Aldehydes are oxidized to produce carboxylic acids.
Eg. methanal + (O)



methanoic acid

Ketones do not oxidize because there is no hydrogen to remove.

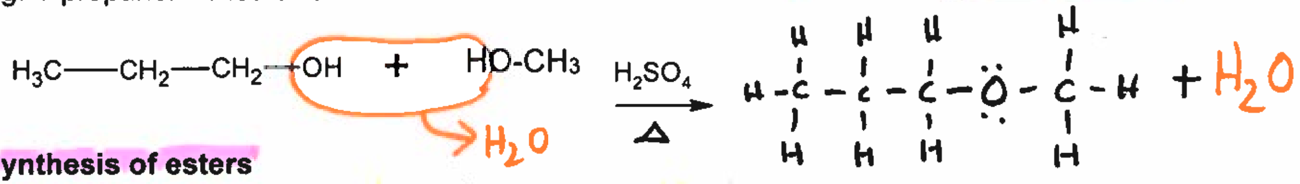
Condensation

Condensation reactions involve the removal of a water molecule. These reactions require concentrated sulphuric acid and sometimes high temperatures.

Synthesis of ethers

This reaction involves the condensation of two alcohols.
Eg. 1-propanol + methanol

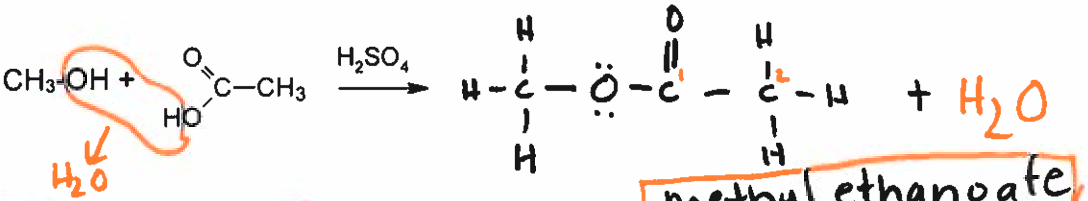
methoxy propane



Synthesis of esters

This reaction involves the condensation of a carboxylic acid and an alcohol.

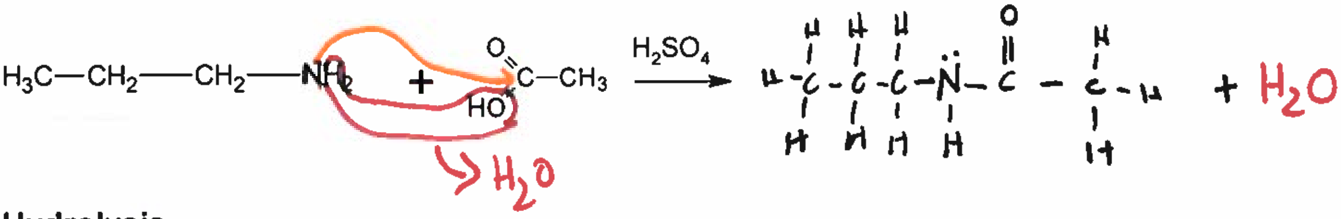
Eg. methanol + ethanoic acid



methyl ethanoate

Synthesis of amides

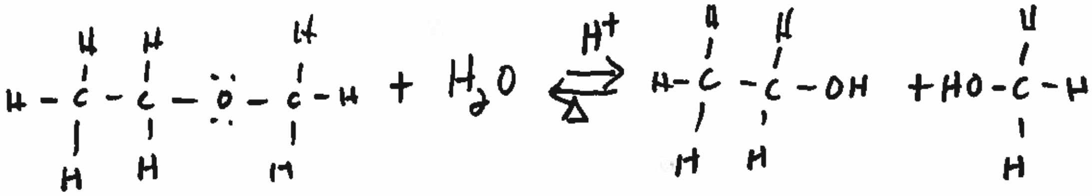
This reaction involves the condensation reaction of a carboxylic acid and an amine.



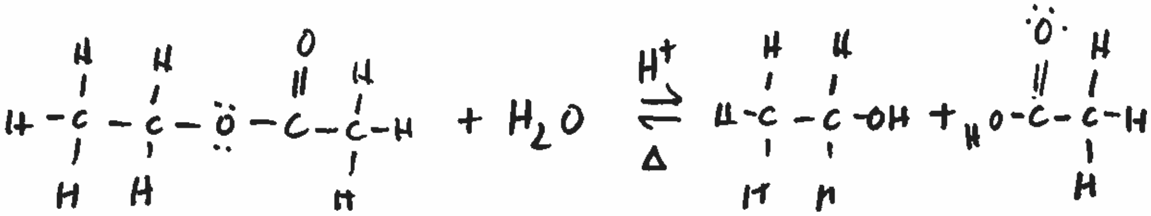
Hydrolysis

The reversal of these condensation reactions are hydrolysis reactions. This reaction involves the addition of water in the presence of a strong acid or base.

① Ethers



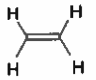
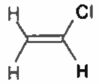
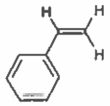
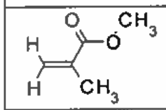
② Esters



POLYMERS

Many of organic molecules, such as plastics, and many of the essential molecules in your body, are polymers. These very long molecules are made by linking many smaller molecules called monomers. Many polymers are made of just one type of monomer, but they can be made from a combination of two or more different monomers.

Table 1: Examples of Common Monomers used in Addition Polymerization

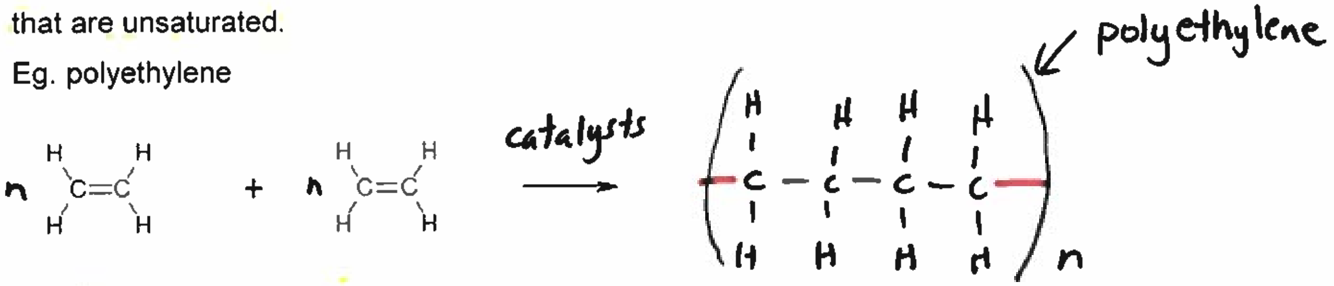
Monomer Structure	Monomer Name	Polymer	Uses
	ethylene	polyethylene	films, coating for milk cartons, wire insulation, plastic bags, bottles, toys
	vinyl chloride	polyvinyl chloride (PVC)	raincoats, pipes, credit cards, bags, floor tiles, shower curtains, garden hoses, wire insulation, gutters, down spouts
	styrene	polystyrene	electrical insulation, packing material, combs
	methyl methacrylate	Plexiglas, Lucite	glass substitutes, paints
	tetrafluoroethylene	Teflon	gaskets, bearings, insulation, non-stick pan coatings, chemical resistant films

→ always contain ALL the atoms of the original monomers

Addition polymers

These are formed through addition reactions as we previously learned. They require monomers that are unsaturated.

Eg. polyethylene

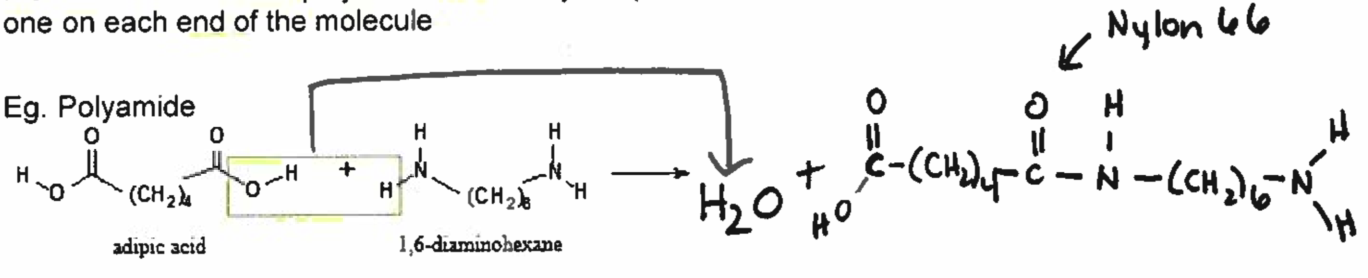


Condensation polymers

These are formed through condensation reactions as we previously learned. They require monomers that contain hydroxyl groups.

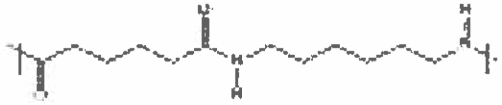
NOTE: Condensation polymerization always requires that there are TWO functional groups, one on each end of the molecule

Eg. Polyamide

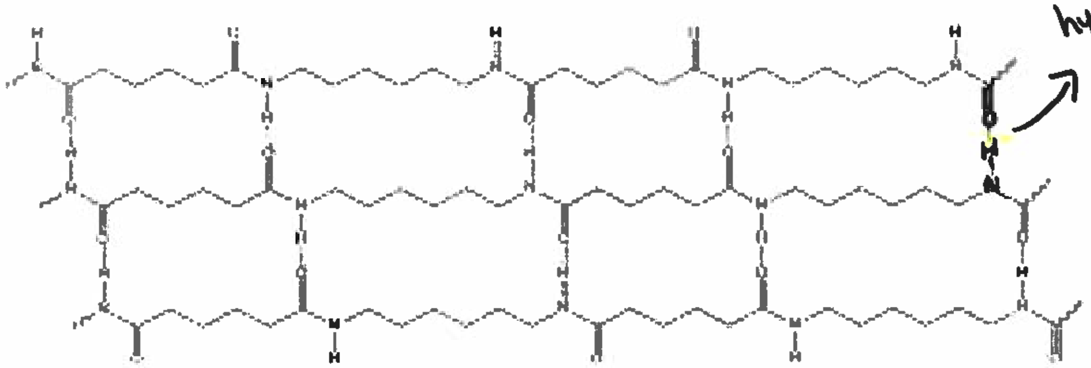


Crosslinking

To increase the strength of polymers, we can choose monomers that are capable of bonding with other polymer chains through crosslinks. We can think of this as connecting paperclips in rows with paperclips connecting rows together.



Repeating Unit
Nylon 6,6



hydrogen bonding

-the hydrogen bonding causes the strands to stay together