Organic Chemistry

Incorporating Hydrocarbons ,Alcohols, Carboxylic acids and Detergents

Prepared by Chirongo bita
0752394969

Introduction to Organic chemistry

- Organic chemistry is the branch of chemistry that studies carbon compounds present in living things, once living things or synthetic/man-made.
- Compounds that makes up living things whether alive or dead mainly contain carbon.
- Carbon is tetravalent.
- It is able to form stable covalent bonds with itself and many non-metals like hydrogen, nitrogen , oxygen and halogens to form a variety of compounds.
- This is because:

i. carbon uses all the four valence electrons to form four strong covalent bond.

ii. carbon can covalently bond to form a single, double or triple covalent bond with itself. This is called **Catenation**

iii. carbon atoms can covalently bond to form a very long chain or ring.

iv. When carbon covalently bond with Hydrogen, it forms a group of organic compounds called **Hydrocarbons.**

A.HYDROCARBONS (HCs)

Hydrocarbons are a group of organic compounds containing /made up of **hydrogen** and **carbon** atoms **only**.

Depending on the type of bond that exist between the individual carbon atoms, hydrocarbon are classified as:

(i) Alk**a**nes
(ii) Alk**e**nes
(iii) Alk**y**nes

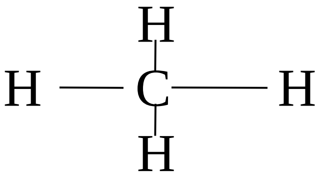
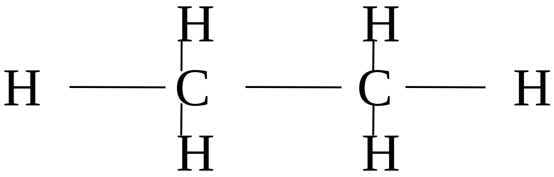
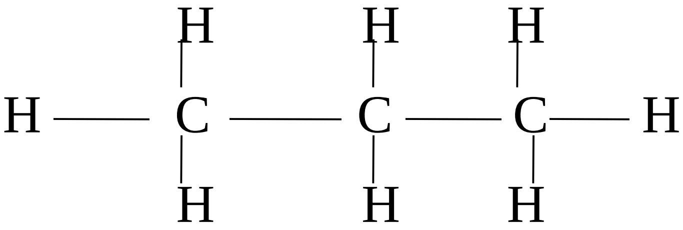
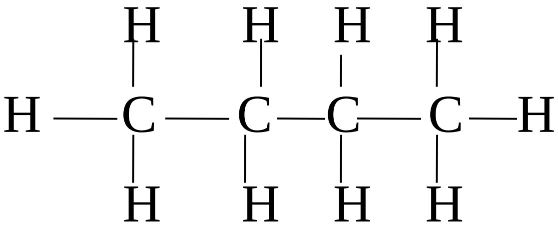
(i) Alkanes

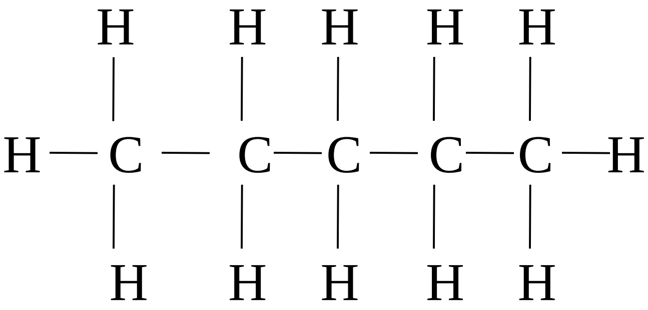
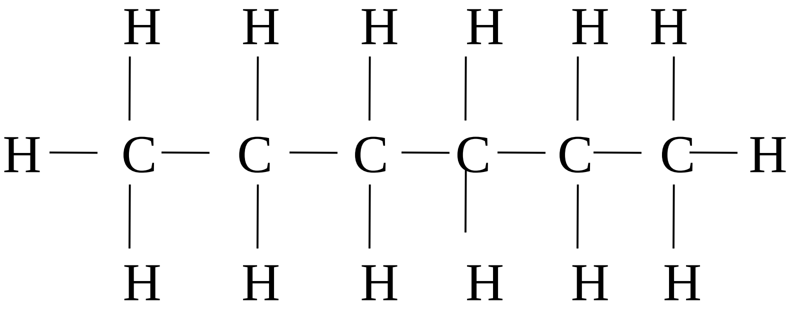
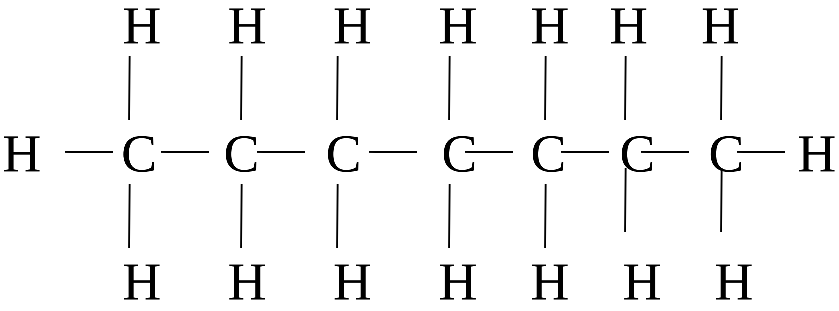
(a)Nomenclature/Naming

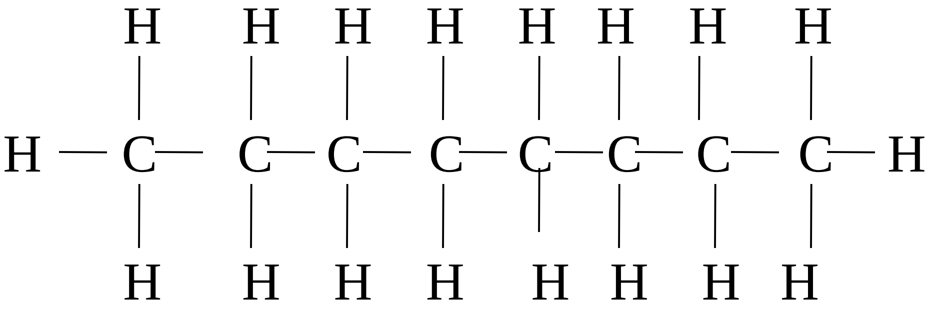
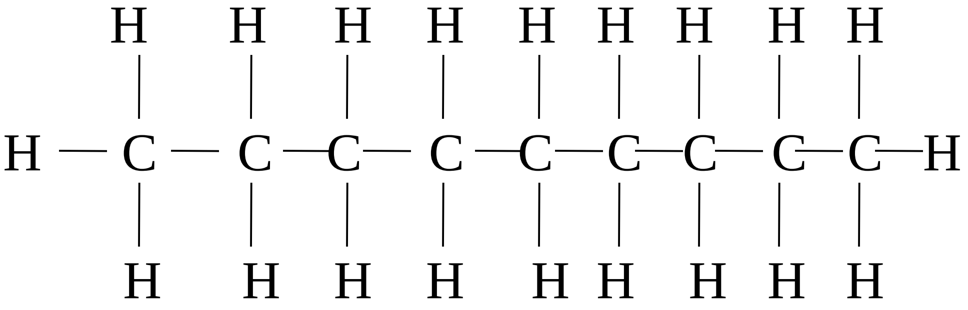
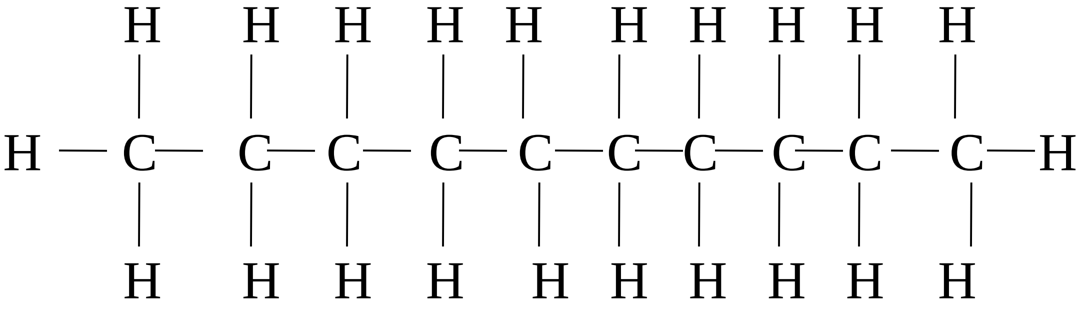
These are hydrocarbons with a general formula $\mathbf{C_nH_{2n+2}}$ where **n** is the number of Carbon atoms in a molecule.

The carbon atoms are linked by **single** bond to each other and to hydrogen atoms.

They include:

n	General/Molecula formula	Structural formula	Name
1	CH_4	 $\mathrm{H-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-H}$	Meth**ane**
2	C_2H_6	 $\mathrm{H-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-H}$ **CH_3CH_3**	Eth**ane**
3	C_3H_8	 $\mathrm{H-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-H}$ **$CH_3CH_2\ CH_3$**	Prop**ane**
4	C_4H_{10}	 $\mathrm{H-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-H}$ **$CH_3\ (CH_2)\ _2CH_3$**	But**ane**

5	C_5H_{12}	 $CH_3(CH_2)_3CH_3$	Pent**ane**
6	C_6H_{14}	 $CH_3(CH_2)_4CH_3$	Hex**ane**
7	C_7H_{16}	 $CH_3(CH_2)_5CH_3$	Hept**ane**

8	C_8H_{18}	 $\begin{array}{cccccccccc} & H & H & H & H & H & H & H & H & \\ & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \\ H- & C- & C- & C- & C- & C- & C- & C- & C- & H \\ & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \\ & H & H & H & H & H & H & H & H & \end{array}$ **$CH_3\ (CH_2)\ _6CH_3$**	Oct**ane**
9	C_9H_{20}	 $\begin{array}{ccccccccccc} & H & H & H & H & H & H & H & H & H & \\ & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \\ H- & C- & C- & C- & C- & C- & C- & C- & C- & C- & H \\ & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \\ & H & H & H & H & H & H & H & H & H & \end{array}$ **$CH_3\ (CH_2)\ _7\ CH_3$**	Non**ane**
10	$C_{10}H_{22}$	 $\begin{array}{cccccccccccc} & H & H & H & H & H & H & H & H & H & H & \\ & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \\ H- & C- & C- & C- & C- & C- & C- & C- & C- & C- & C- & H \\ & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \vert & \\ & H & H & H & H & H & H & H & H & H & H & \end{array}$ **$CH_3\ (CH_2)\ _8CH_3$**	dec**ane**

Note

1.The **general formula/molecular formular** of a compound is the **number** of each **atoms** of elements making the **compound** e.g.

Decane has a general/molecular formula $\mathbf{C_{10}H_{22}}$;this means there are 10 carbon atoms and 22 hydrogen atoms in a molecule of decane.

2.The **structural formula** is the **arrangement / bonding** of **atoms** of each element making the **compound** e.g

Decane has the structural formula as in the table above ;this means the 1st carbon from left to right is bonded to three hydrogen atoms and one carbon atom.

The 2nd carbon atom is joined/bonded to two other carbon atoms and two Hydrogen atoms. e.t.c.

3.Since carbon is **tetravalent** ,each atom of carbon in the alkane **MUST** always be bonded using **four** covalent bond /four shared pairs of electrons.

4.Since Hydrogen is **monovalent** ,each atom of hydrogen in the alkane **MUST** always be bonded using **one** covalent bond/one shared pair of electrons.

5.One member of the alkane differ from the next/previous by a **$-CH_2-$** group.

e.g

Propane differ from ethane by one carbon and two hydrogen atoms from ethane.

Ethane differ from methane also by one carbon and two hydrogen atoms

6.A group of compounds that differ by a -CH_2 - group from the next /previous **consecutively** is called a **homologous series**.

7.A homologous series: (Characteristics)

1. Differ by a CH_2 group from the next /previous consecutively
2. (ii) Have similar **chemical properties**
3. (iii)Have similar **chemical formula** that can be represented by a general formula e.g
4. Alkanes have the general formula C_nH_{2n+2}.
5. The physical properties (e.g.melting/boiling points)show **steady** gradual change)

8.The 1st four alkanes have the prefix **meth_,eth_,prop_** and **but_** to represent 1,2,3 and 4 carbons in the compound. All other use the numeral prefix **pent_,hex_,hept_** , etc to show also the number of carbon atoms.

9.If one **hydrogen** atom in an alkane is removed, an **alkyl** group is formed.e.g

Alkane name	molecular structure C_nH_{2n+2}	Alkyl name	Molecular structure C_nH_{2n+1}
methane	CH_4	methyl	CH_3
ethane	CH_3CH_3	ethyl	$CH_3\ CH_2$
propane	$CH_3\ CH_2\ CH_3$	propyl	$CH_3\ CH_2\ CH_2$
butane	$CH_3CH_2CH_2\ CH_3$	butyl	$CH_3\ CH_2\ CH_2\ CH_2$

(b)Isomers of alkanes

Isomers are compounds with the same molecular **general formula** but different molecular **structural formula**.

Isomerism is the existence of a compounds having the same general/molecular formula but different structural formula.

The 1st three alkanes do not form isomers.Isomers are named by using the IUPAC(**I**nternational **U**nion of **P**ure and **A**pplied **C**hemistry) system of **nomenclature /naming.**

The IUPAC system of nomenclature uses the following basic rules/guidelines:

1.Identify the **longest** continuous **carbon** chain to get/determine the parent alkane.

2.Number the longest chain form the end of the chain that is **near** the **branches** so as the branch get the lowest number possible

3. Determine the **position**, **number** and **type** of branches.

Name them as **methyl**, **ethyl**, **propyl** e.tc. according to the number of carbon chains **attached** to the parent **alkane**. Name them **fluoro-**,**chloro-**,**bromo-**,**iodo-** if they are **halogens**

4.Use prefix **di-**,**tri-**,**tetra-**,**penta-**,**hexa-** to show the **number** of branches attached to the parent alkane.

Practice on IUPAC nomenclature of alkanes

(a)Draw the structure of:

(i)2-methylbutane

Procedure

1. Identify the longest continuous carbon chain to get/determine the parent alkane.

Butane is the parent name

$\mathbf{CH_3\ CH_2\ CH_2\ CH_3}$

2. Number the longest chain form the end of the chain that is near the branches so as the branch get the lowest number possible

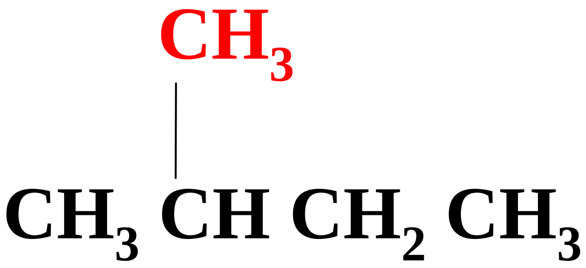
The methyl group is attached to Carbon **“2”**

3. Determine the position, number and type of branches.

Name them as methyl, ethyl, propyl e.tc. according to the number of carbon chains attached to the parent alkane i.e

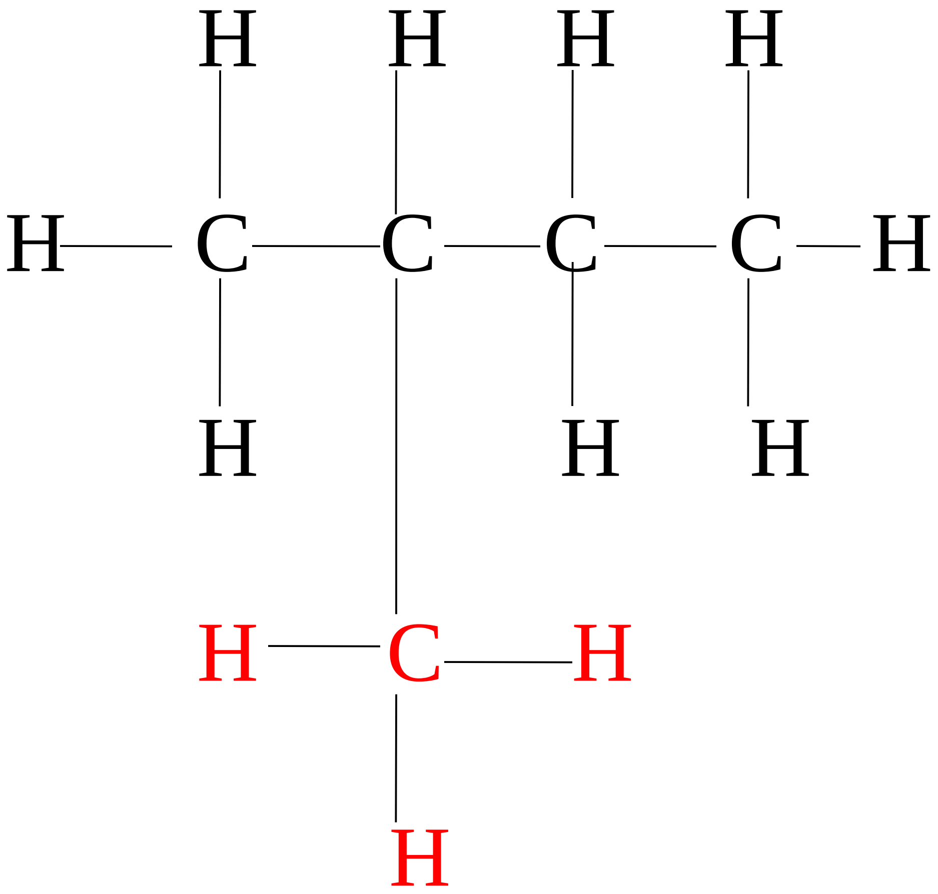
Position of the branch at carbon “2”
Number of branches at carbon “1”
Type of the branch “methyl” hence

<u>Molecular formula</u>



$$\begin{array}{l} \qquad\;\; \mathbf{CH_3} \\ \qquad\;\; | \\ \mathbf{CH_3\ CH\ CH_2\ CH_3} \end{array} \quad \mathbf{//\ CH_3\ CH\ (}CH_3\mathbf{)\ CH_2CH_3}$$

Structural formula



(ii)2,2-dimethylbutane

Procedure

1. Identify the longest continuous carbon chain to get/determine the parent alkane.

Butane is the parent name $\mathbf{CH_3\ CH_2\ CH_2\ CH_3}$

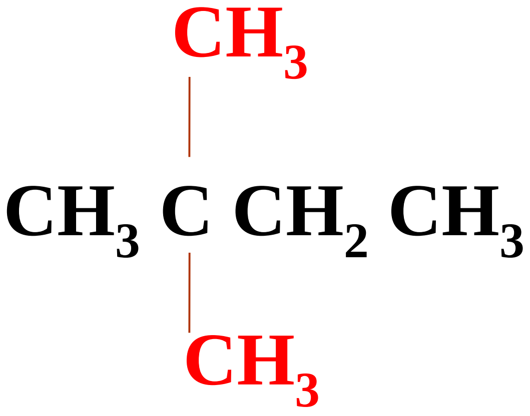
2. Number the longest chain form the end of the chain that is near the branches so as the branch get the lowest number possible

The methyl group is attached to Carbon **“2”**

3. Determine the position, number and type of branches. Name them as methyl, ethyl, propyl e.tc. according to the number of carbon chains attached to the parent alkane i.e

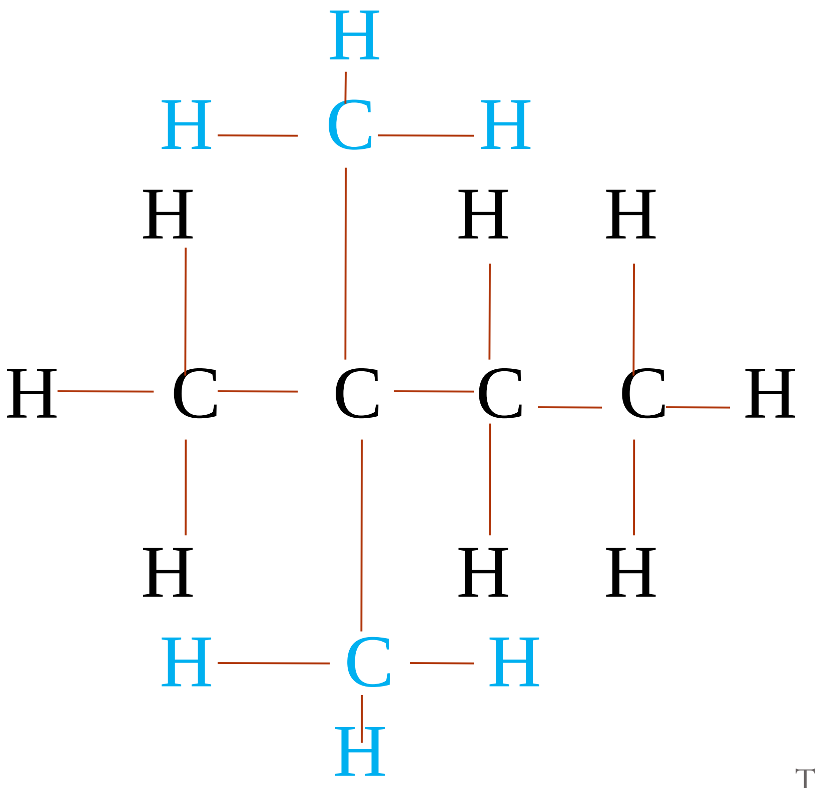
Position of the branch at carbon “2”
Number of branches at carbon “2”
Type of the branch two“methyl” hence

Molecular formular



$CH_3\,\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}\,CH_2\,CH_3$ // $CH_3\,C\,(CH_3)_2\,CH_2CH_3$

Structural formula



(iii) 2,2,3-trimethylbutane

Procedure

1. Identify the longest continuous carbon chain to get/determine the parent alkane.

Butane is the parent name **$CH_3\ CH_2\ CH_2\ CH_3$**

2. Number the longest chain form the end of the chain that is near the branches so as the branch get the lowest number possible

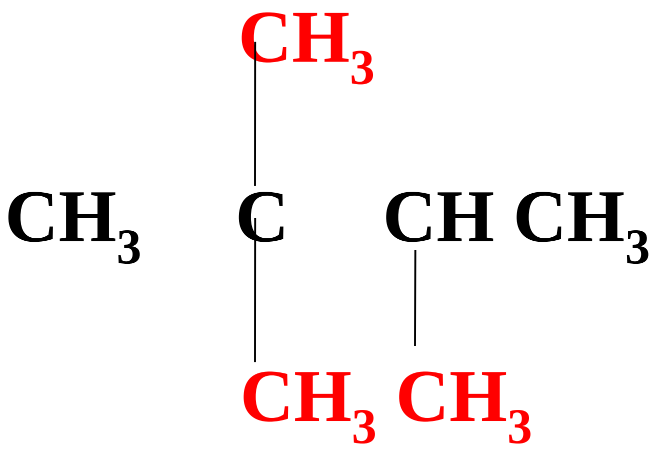
The methyl group is attached to Carbon **“2 and 3”**

3. Determine the position, number and type of branches. Name them as methyl, ethyl, propyl e.tc. according to the number of carbon chains attached to the parent alkane i.e

Position of the branch at carbon “2 and 3”

Number of branches at carbon “3”

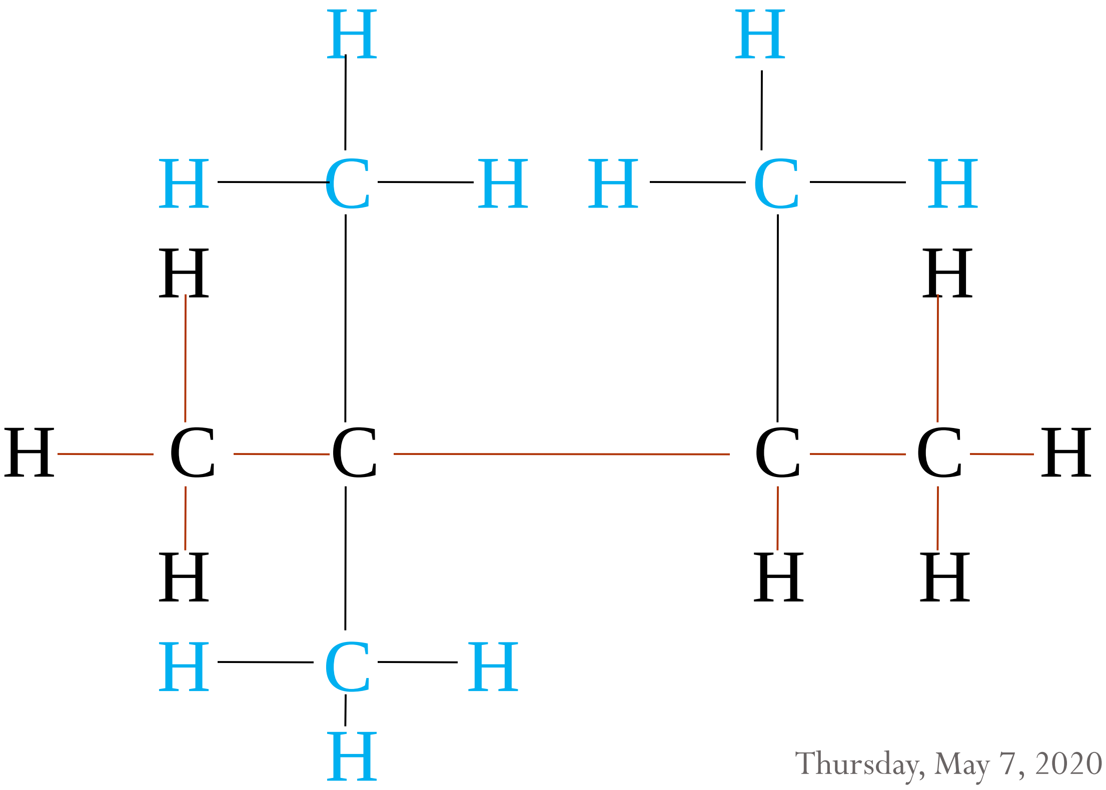
Type of the branch three “methyl” hence



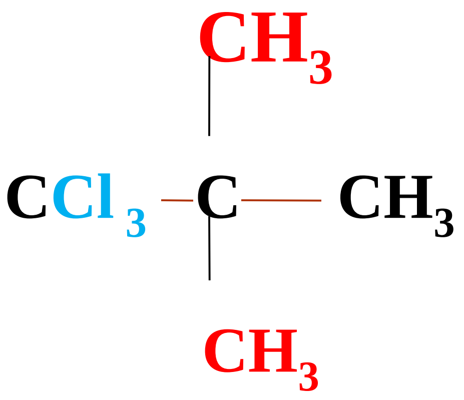
$$CH_3\ \underset{CH_3}{\overset{CH_3}{C}}\ \underset{CH_3}{CH}\ CH_3$$

$// CH_3\ C\ (CH_3)_3\ CH_2CH_3$

Structural formula



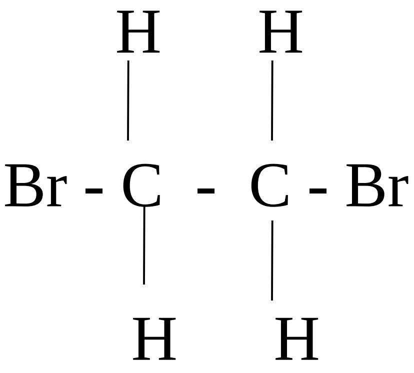
(ii) 1,1,1-trichloro-2,2-dimethyl-propane



$$\begin{array}{ccc} & \mathrm{CH_3} & \\ & | & \\ \mathrm{CCl_3} - & \mathrm{C} & - \mathrm{CH_3} \\ & | & \\ & \mathrm{CH_3} & \end{array}$$

// $C\,Cl_3\,C\,(CH_3)_2\,CH_3$

(iii) 1,2-dibromothane

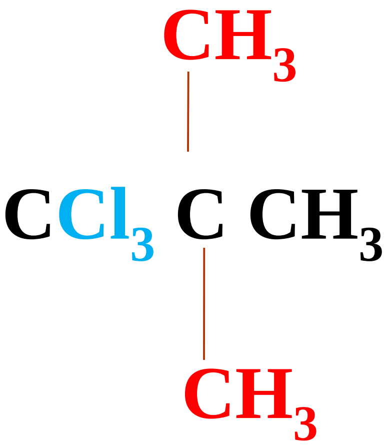


$$\begin{array}{ccccc} & \mathrm{H} & & \mathrm{H} & \\ & | & & | & \\ \mathrm{Br} - & \mathrm{C} & - & \mathrm{C} & - \mathrm{Br} \\ & | & & | & \\ & \mathrm{H} & & \mathrm{H} & \end{array}$$

<u>Molecular formular</u> CH_2BrCH_2Br

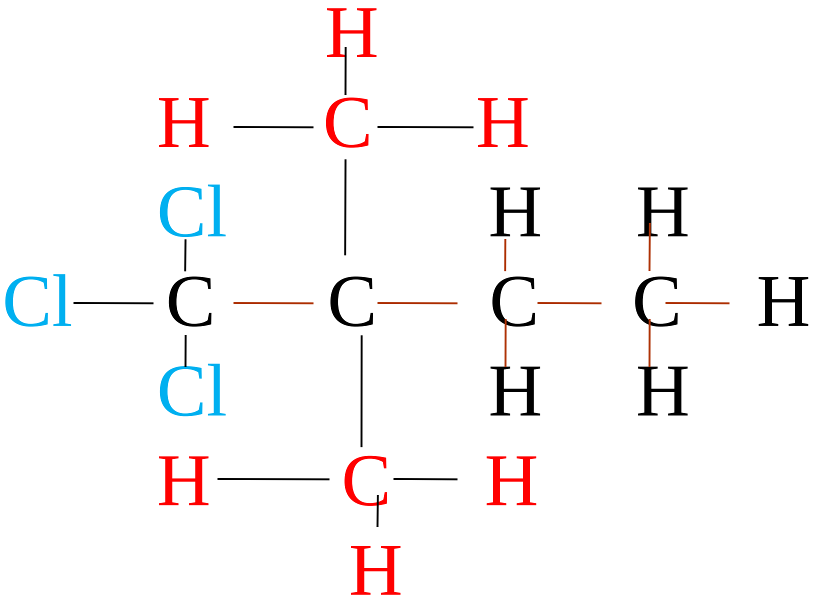
(ii) 1,1,1-tetrachloro-2,2-dimethyl-butane

Molecular formular



$CCl_3\underset{CH_3}{\overset{CH_3}{C}}CH_3$ // $CCl_3\,C\,(CH_3)_2\,CH_3$

Structural formula



(c)Occurrence and extraction

Crude oil ,**natural gas** and **biogas** are the main sources of alkanes:

(i)Natural gas is found on top of crude oil deposits and consists mainly of methane.

(ii)Biogas is formed from the decay of waste organic products like animal dung and cellulose.

When the decay takes place in absence of oxygen , 60-75% by volume of the gaseous mixture of methane gas is produced.

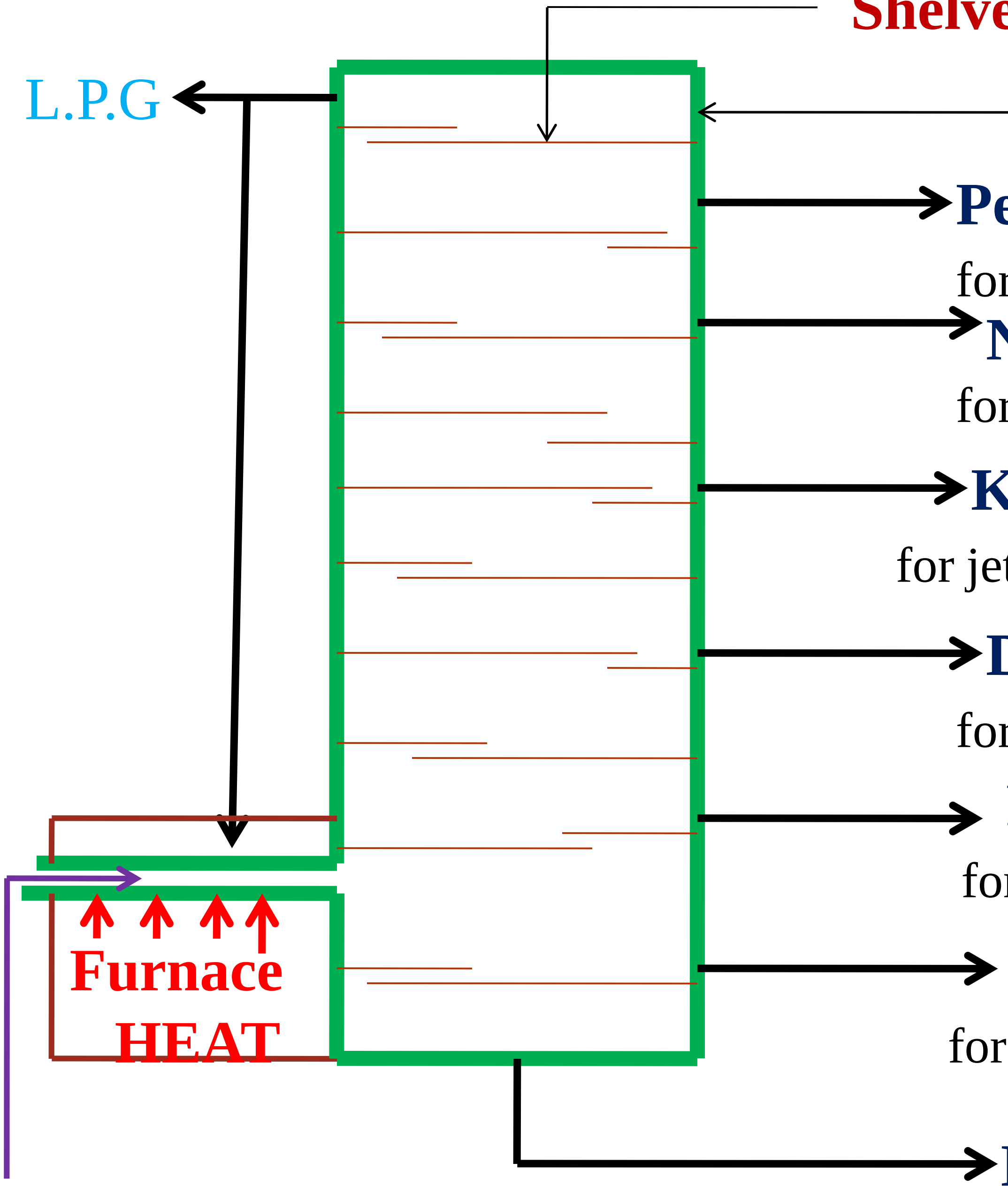
(iii)Crude oil is a mixture of many flammable hydrocarbons/substances.

Using fractional distillation, each hydrocarbon fraction can be separated from the other.

The hydrocarbon with lower /smaller number of carbon atoms in the chain have lower boiling point and thus collected first.

As the carbon **chain increase**, the **boiling** point, **viscosity** (ease of flow) and colour **intensity** increase as **flammability** decrease.

Hydrocarbons in crude oil are not pure.
They thus have no sharp fixed boiling point.



Shelves(to increase surface area)

L.P.G

Fractionating column

Petrol/gasoline

for driving light motor vehicles

Naphtha

for making other chemicals

Kerosene

for jet fuel and domestic lighting/heating

Diesel oil

for driving heavy motor vehicles

Fuel oil

for driving factory machines and ships

Lubricating oil

for reducing friction in machines

Furnace

HEAT

Bitumen/Asphalt

for tarmacking roads

Crude oil

Carbon atoms in a molecule	Common name of fraction	Uses of fraction
1-4	Gas	L.P.G gas for domestic use
5-12	Petrol	Fuel for petrol engines
9-16	Kerosene/Paraffin	Jet fuel and domestic lighting/cooking
15-18	Light diesel	Heavy diesel engine fuel
18-25	Diesel oil	Light diesel engine fuel
20-70	Lubricating oil	Lubricating oil to reduce friction.
Over 70	Bitumen/Asphalt	Tarmacking roads

(d)School laboratory preparation of alkanes

In a school laboratory, alkanes may be prepared from the reaction of a sodium alkanoate with solid sodium hydroxide /soda lime.

Chemical equation:

Sodium alkanoate +soda lime -> alkane +Sodium carbonate

$C_nH_{2n+1}COONa(s) + NaO\mathbf{H}(s) \rightarrow C_nH_{2n+2} + Na_2CO_3(s)$

The “H” in NaO**H** is transferred/moves to the C_nH_{2n+1} in $C_nH_{2n+1}COONa(s)$ to form $C_nH_{2n+\mathbf{2}}$.

Examples

1. **Meth**ane is prepared from the heating of a mixture of sodium **ethan**oate and soda lime and collecting over water

Sodium ethanoate + soda lime->

methane + Sodium carbonate

$CH_3COONa(s) + NaO\mathbf{H}(s) \rightarrow CH_4 + Na_2CO_3(s)$

The “H” in NaO**H** is transferred/moves to the CH_3 in $CH_3COONa(s)$ to form CH_4.

2. **Eth**ane is prepared from the heating of a mixture of sodium **prop**anoate and soda lime and collecting over water

Sodium **prop**anoate + soda lime->

ethane+Sodium carbonate

$CH_3\,CH_2COONa(s) + NaO\mathbf{H}(s) \rightarrow CH_3\,CH_3 + Na_2CO_3(s)$

The “H” in NaO**H** is transferred/moves to the $CH_3\,CH_2$ in $CH_3\,CH_2COONa$ (s) to form $CH_3\,CH_3$

3. **Prop**ane is prepared from the heating of a mixture of sodium **but**anoate and soda lime and collecting over water

Sodium **but**anoate+soda lime->**prop**ane+Sodium carbonate

$CH_3\ CH_2CH_2COONa(s)$ +NaO**H**(s) -> $CH_3\ CH_2CH_3$ + $Na_2CO_3(s)$

The “H” in NaO**H** is transferred/moves to the $CH_3\ CH_2\ CH_2$ in $CH_3\ CH_2CH_2COONa$ to form $CH_3\ CH_2CH_3$

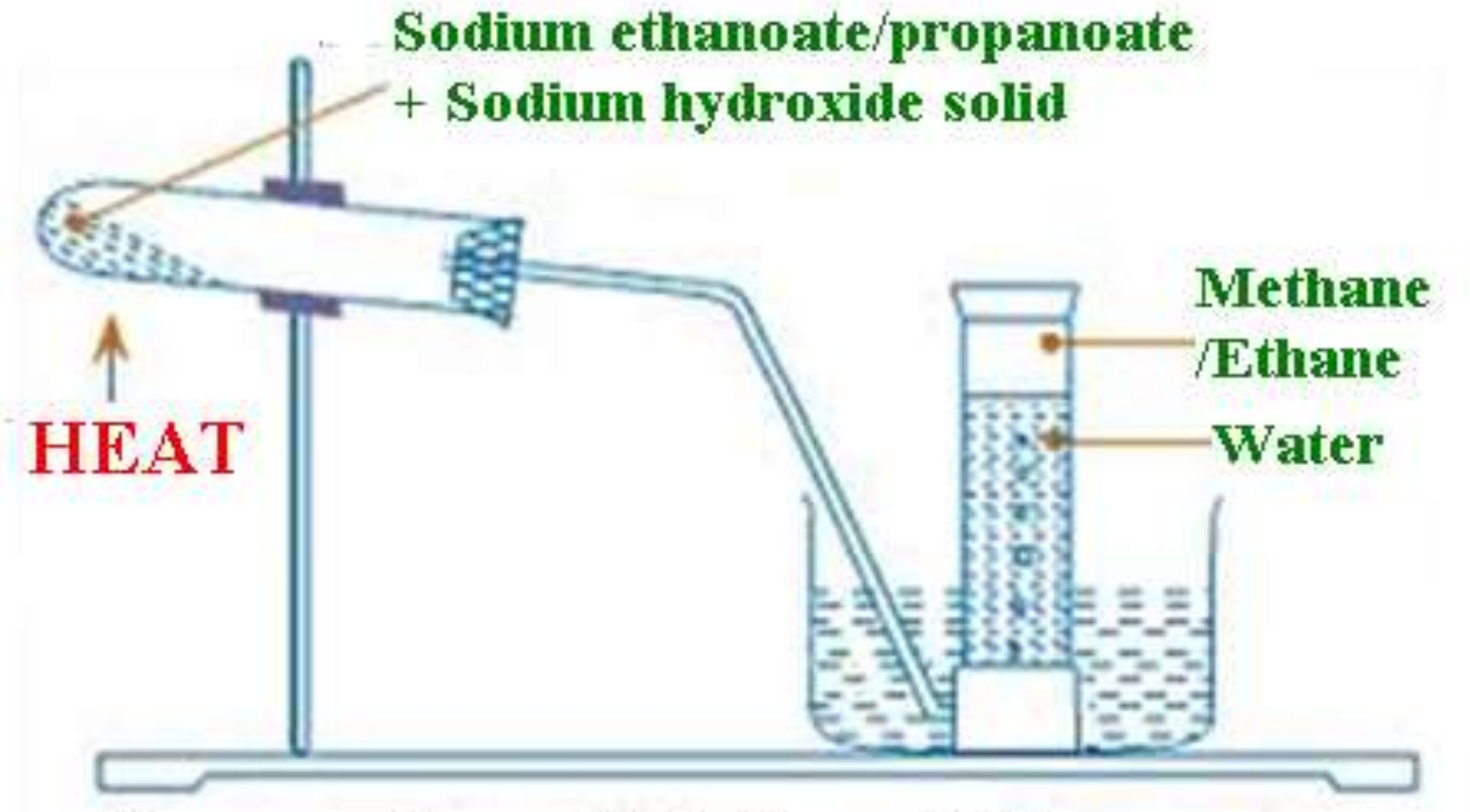
4. **But**ane is prepared from the heating of a mixture of sodium **pent**anoate and soda lime and collecting over water

Sodium **pent**anoate + soda lime -> **but**ane + Sodium carbonate

$CH_3\ CH_2\ CH_2CH_2COONa(s)$+NaO**H**(s) ->
$CH_3\ CH_2CH_2CH_3$ + $Na_2CO_3(s)$

The “H” in NaO**H** is transferred/moves to the $CH_3CH_2\ CH_2\ CH_2$ in $CH_3\ CH_2CH_2\ CH_2COONa$ (s) to form $CH_3\ CH_2\ CH_2CH_3$

Laboratory set up for the preparation of alkanes



Preparation of Methane/Ethane

Properties of alkanes

- Alkanes are colourless gases, solids and liquids that are not poisonous.
- They are slightly soluble in water.
- The solubility decrease as the carbon chain increase.
- The melting and boiling point increase as the carbon chain increase.
- This is because of the increase in van-der-waals / intermolecular forces as the carbon chain increase.
- The 1st four straight chain alkanes (methane, ethane, propane and butane) are therefore gases

The next six (pentane ,hexane, heptane,octane,nonane, decane) are liquids.

From unidecane ,alkane with 11 carbon atoms are solids .

The density of straight chain alkanes increase with increasing carbon chain as the **intermolecular** forces increases.

This reduces the volume occupied by a given mass of the compound.

Summary of physical properties of alkanes

Alkane	General formula	Melting point(K)	Boiling point(K)	Density gcm^{-3}	State at room(298K) temperature and pressure atmosphere (101300Pa)
Methane	CH4	90	112	0.424	gas
Ethane	CH_3CH_3	91	184	0.546	Gas
Propane	$CH_3CH_2CH_3$	105	231	0.501	gas
Butane	$CH_3(CH_2)_2CH_3$	138	275	0.579	gas
Pentane	$CH_3(CH_2)_3CH_3$	143	309	0.626	liquid
Hexane	$CH_3(CH_2)_4CH_3$	178	342	0.657	liquid
Heptane	$CH_3(CH_2)_5CH_3$	182	372	0.684	liquid
Octane	$CH_3(CH_2)_6CH_3$	216	399	0.703	liquid
Nonane	$CH_3(CH_2)_7CH_3$	219	424	0.708	liquid
Octane	$CH_3(CH_2)_8CH_3$	243	447	0.730	liquid

Chemical properties

(i)Burning.

Alkanes burn with a **blue**/non-luminous **non-sooty**/non-smoky flame in **excess** air to form carbon(IV) oxide and water.

Alkane + Air -> carbon(IV) oxide +water (excess air/oxygen)

Alkanes burn with a **blue**/non-luminous **non-sooty**/non-smoky flame in **limited** air to form carbon(II) oxide and water.

Alkane + Air -> carbon(II) oxide +water (limited air)

Examples

1.(a) Methane when ignited burns with a **blue non sooty** flame in **excess** air to form carbon(IV) oxide and water.

Methane + Air -> carbon(IV) oxide +water (excess air)

(b) Methane when ignited burns with a **blue non sooty** flame in **limited** air to form carbon(II) oxide and water.

Methane + Air **->** carbon(**II**) oxide +water (excess air/oxygen)

$$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l/g)$$

2.(a) Ethane when ignited burns with a **blue non sooty** flame in **excess** air to form carbon(IV) oxide and water.

Ethane + Air **->** carbon(**IV**) oxide +water (excess air/oxygen)

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l/g)$$

(b) Ethane when ignited burns with a **blue non sooty** flame in **limited** air to form carbon(II) oxide and water.

Ethane + Air **->** carbon(**II**) oxide +water (excess air/oxygen)

$$2C_2H_6(g) + 5O_2(g) \rightarrow 4CO(g) + 6H_2O(l/g)$$

3.(a) Propane when ignited burns with a **blue non sooty** flame in **excess** air to form carbon(IV) oxide and water.

Propane + Air -> carbon(**IV**) oxide +water (excess air/oxygen)

$C_3H_8(g)+ 5O_2(g)\text{->} 3CO_2(g) +4H_2O(l/g)$

(b) Ethane when ignited burns with a **blue non sooty** flame in **limited** air to form carbon(II) oxide and water.

Propane + Air -> carbon(**II**) oxide +water (excess air/oxygen)

$2C_3H_8(g)+ 7O_2(g)\text{->} 6CO(g) +8H_2O(l/g)$

ii)Substitution

Substitution reaction is one in which a hydrogen atom is replaced by a halogen in presence of ultraviolet light.

Alkanes react with halogens in presence of ultraviolet light to form halogenoalkanes.

During substitution:

(i)the halogen molecule is split into free atom/radicals.

(ii)one free halogen radical/atoms knock /remove one hydrogen from the alkane leaving an alkyl radical.

(iii) the alkyl radical combine with the other free halogen atom/radical to form halogenoalkane.

(iv)the chlorine atoms substitute repeatedly in the alkane.

Each substitution removes a hydrogen atom from the alkane and form hydrogen halide.

(v)substitution stops when all the hydrogen in alkanes are replaced with halogens.

Substitution reaction is a highly explosive reaction in presence of **sunlight / ultraviolet** light that act as **catalyst**.

Examples of substitution reactions

Methane has no effect on bromine or chlorine in diffused light/dark.

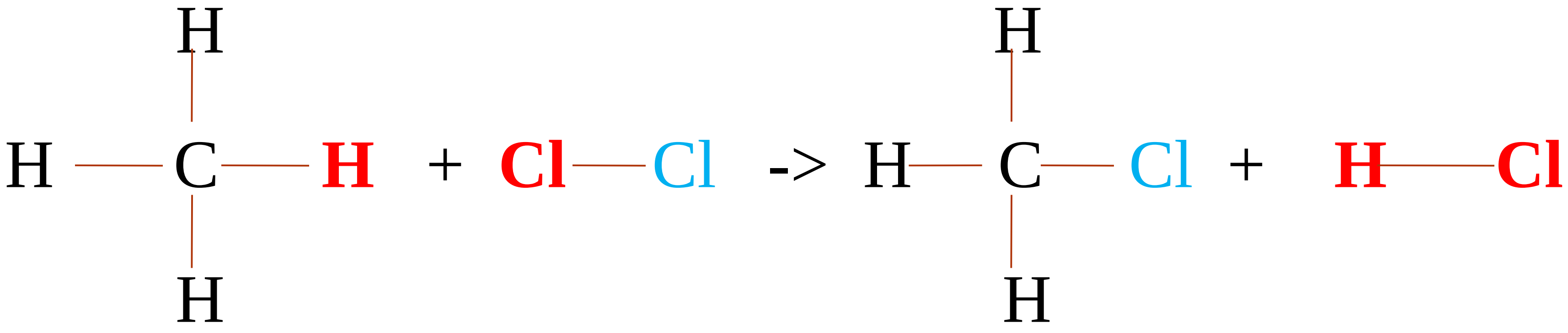
In sunlight , a mixture of chlorine and methane explode to form colourless mixture of chloromethane and hydrogen chloride gas.

The pale green colour of chlorine gas fades.

Chemical equation

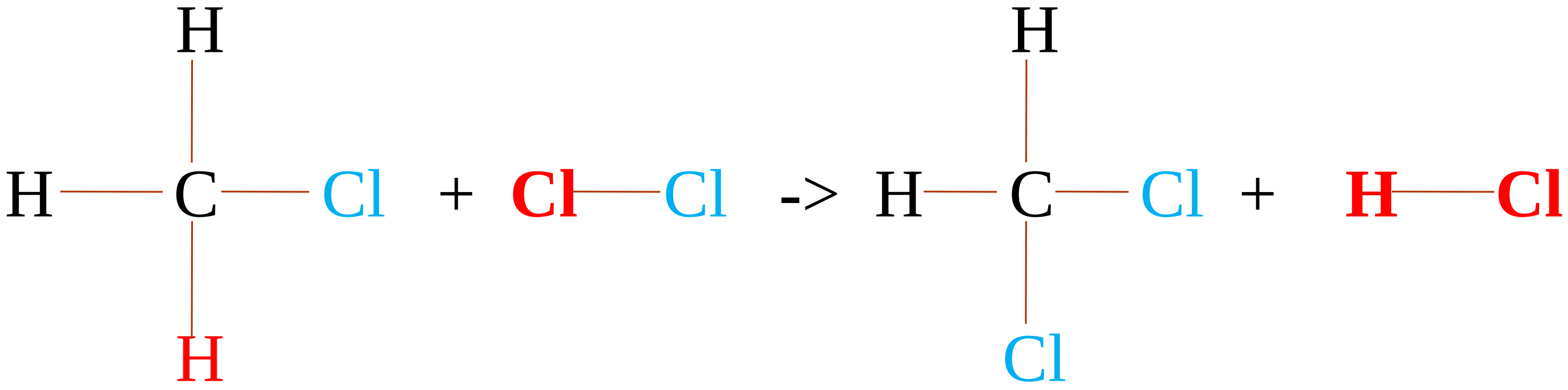
1.(a)Methane + chlorine ->Chloromethane+Hydrogen chloride

$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$



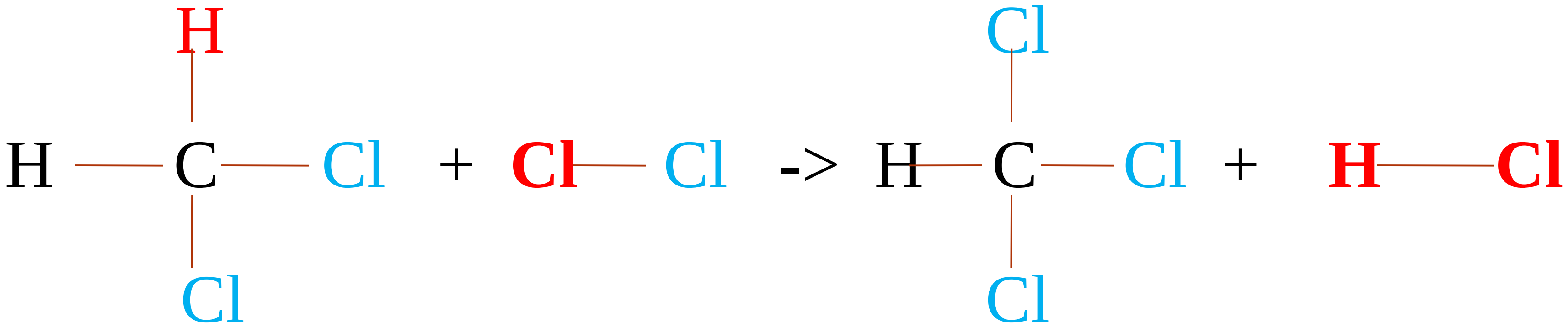
$$\mathrm{H{-}\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}{-}H \;+\; Cl{-}Cl \;\text{->}\; H{-}\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}{-}Cl \;+\; H{-}Cl}$$

chloromethane



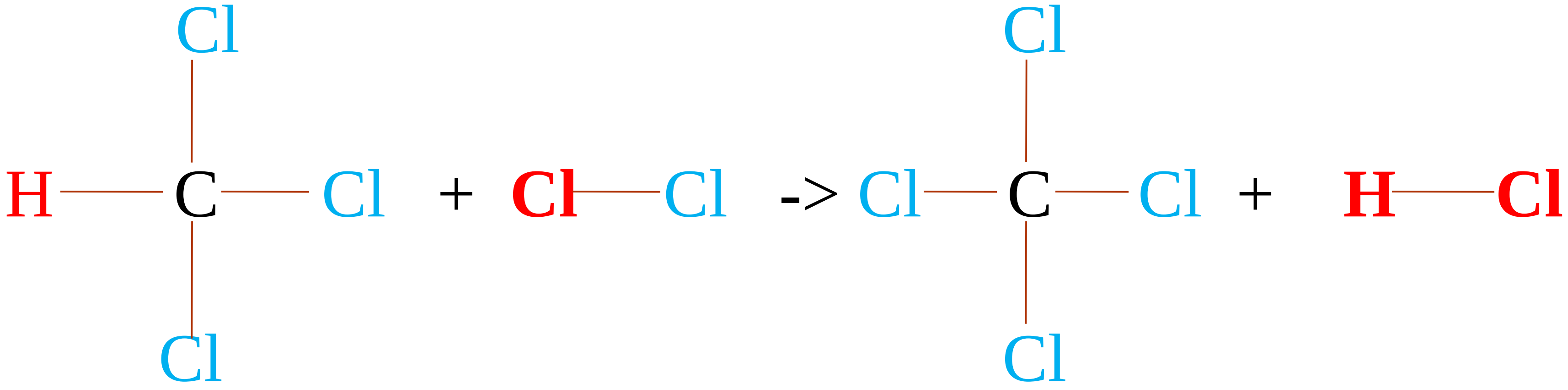
$$\mathrm{H{-}\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}{-}Cl \;+\; Cl{-}Cl \;\text{->}\; H{-}\overset{\overset{H}{|}}{\underset{\underset{Cl}{|}}{C}}{-}Cl \;+\; H{-}Cl}$$

Dichloromethane



$CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$

trichloromethane



$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$

tetrachloromethane

Ethane has no effect on bromine or chlorine in diffused light/dark.

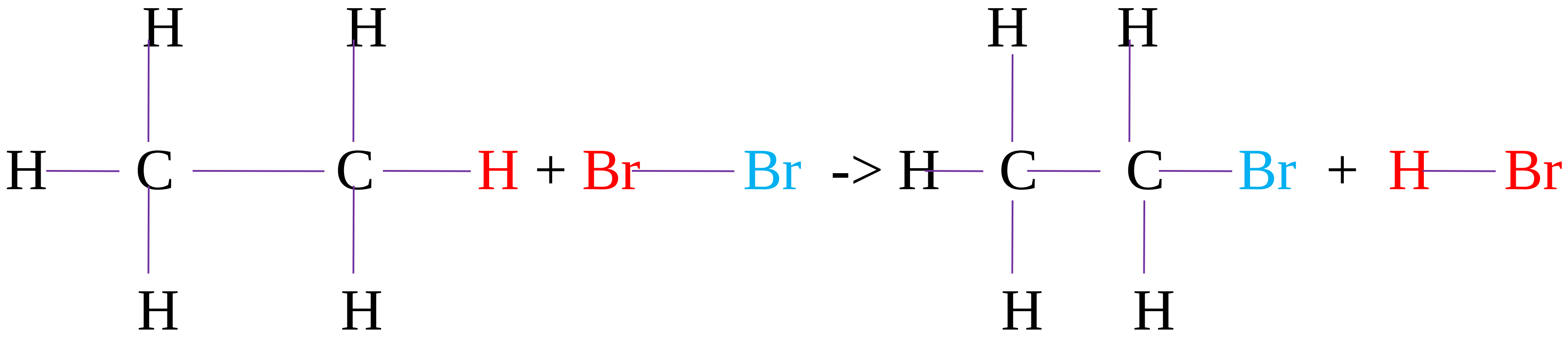
In sunlight , a mixture of bromine and ethane explode to form colourless mixture of bromoethane and hydrogen chloride gas.

The red/brown colour of bromine gas fades.

Chemical equation

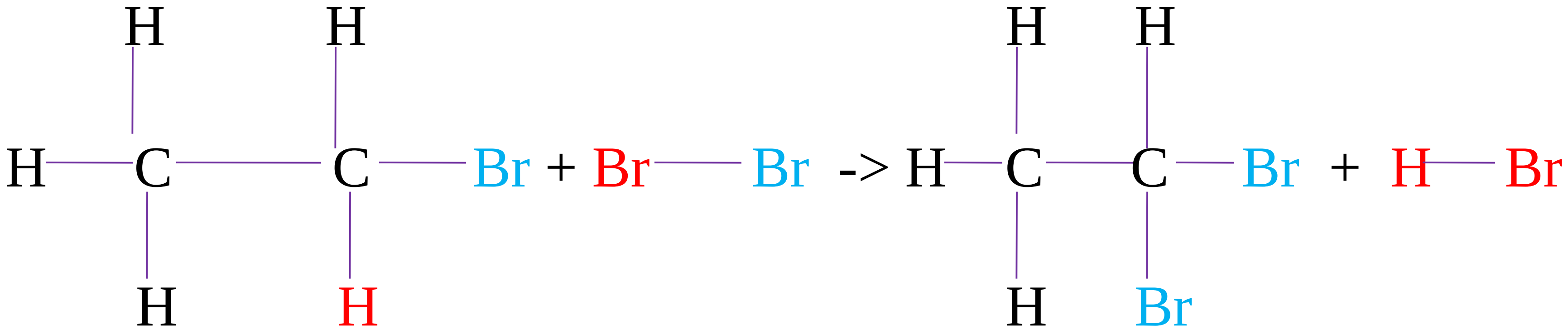
(a)Ethane + Bromine ->
bromoethane +Hydrogen chloride

$CH_3CH_3(g)+ Br_2(g)\text{->} CH_3CH_2Br\ (g)+HBr\ (g)$



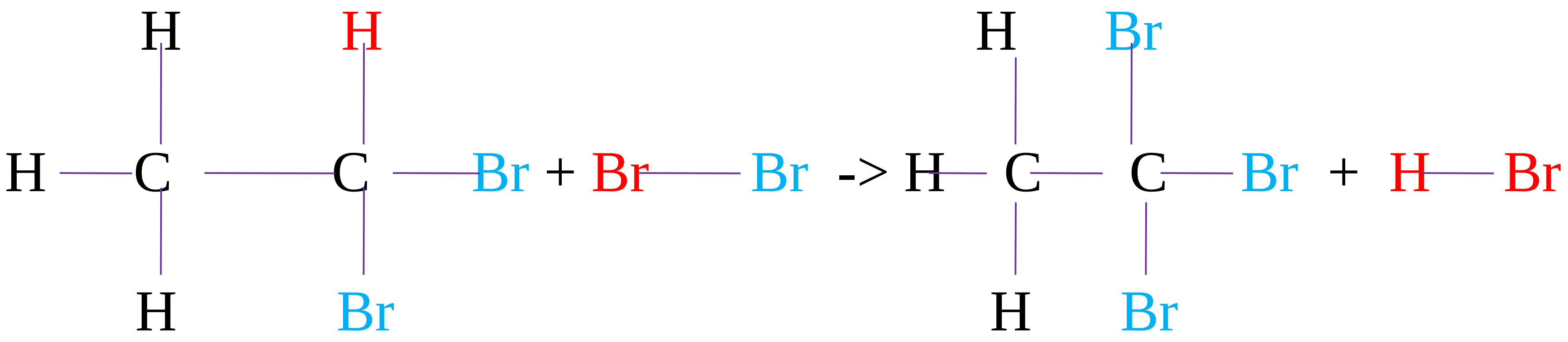
$$\mathrm{H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H + Br-Br \rightarrow H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-Br + H-Br}$$

bromoethane



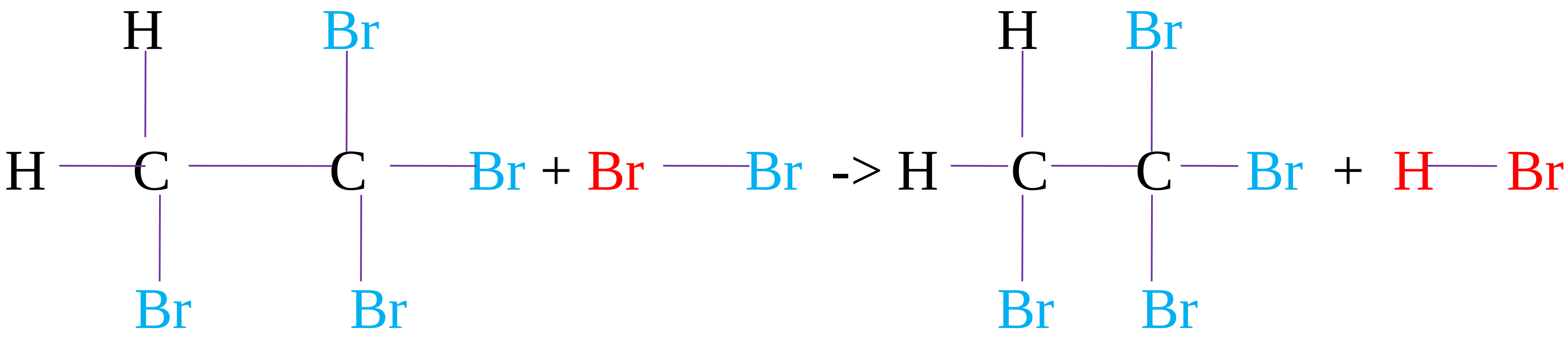
$$\mathrm{H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-Br + Br-Br \rightarrow H-\underset{H}{\overset{H}{C}}-\underset{Br}{\overset{H}{C}}-Br + H-Br}$$

1,1-dibromoethane



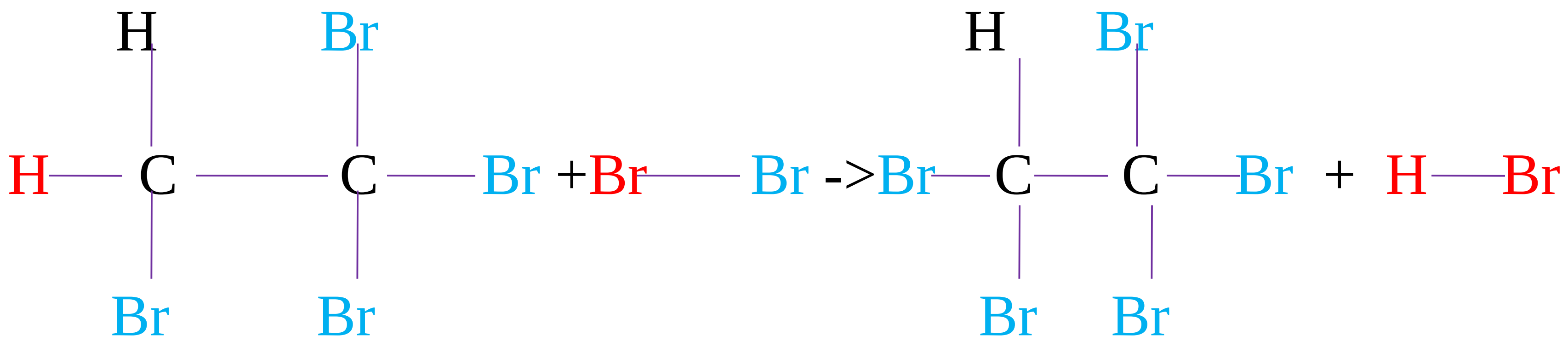
$CH_3CHBr_2 + Br_2 \rightarrow CH_3CBr_3 + HBr$

1,1,1-tribromoethane



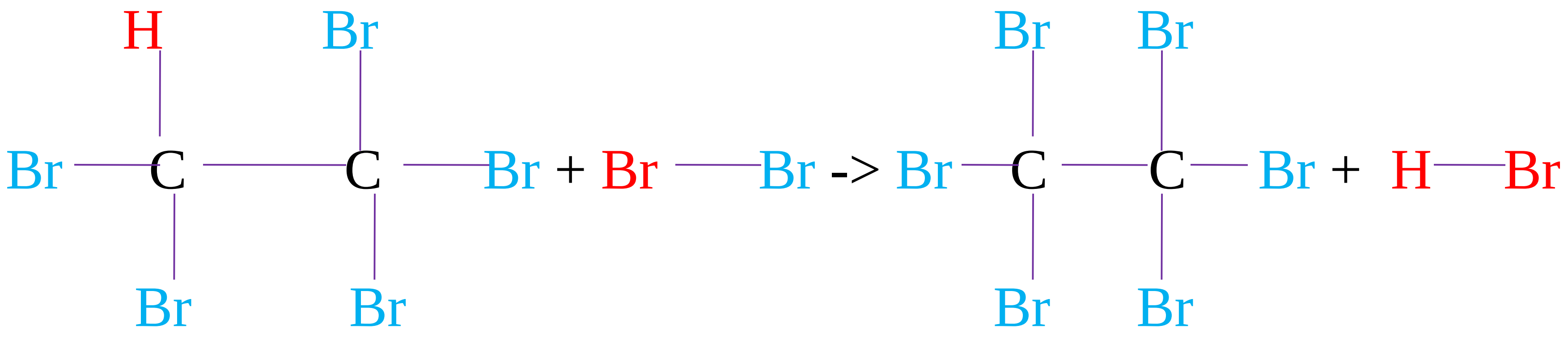
$CH_2BrCBr_3 + Br_2 \rightarrow CH_2BrCBr_3 + HBr$

1,1,1,2-tetrabromoethane



$$\mathrm{H-\underset{Br}{\overset{H}{C}}-\underset{Br}{\overset{Br}{C}}-Br + Br-Br \rightarrow Br-\underset{Br}{\overset{H}{C}}-\underset{Br}{\overset{Br}{C}}-Br + H-Br}$$

1,1,1,2,2-pentabromoethane



$$\mathrm{Br-\underset{Br}{\overset{H}{C}}-\underset{Br}{\overset{Br}{C}}-Br + Br-Br \rightarrow Br-\underset{Br}{\overset{Br}{C}}-\underset{Br}{\overset{Br}{C}}-Br + H-Br}$$

1,1,1,2,2,2-hexabromoethane

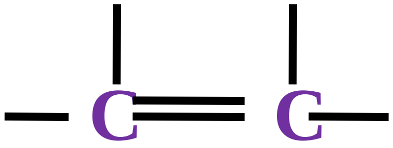
Uses of alkanes

- Most alkanes are used as fuel e.g.
- Methane is used as biogas in homes.
- Butane is used as the Laboratory gas.
- On cracking ,alkanes are a major source of Hydrogen for the manufacture of ammonia/Haber process.
- In manufacture of Carbon black which is a component in printers ink.
- In manufacture of useful industrial chemicals like methanol, ethanol, and chloromethane.

(ii) Alkenes

(a)Nomenclature/Naming

These are hydrocarbons with a general formula C_nH_{2n}

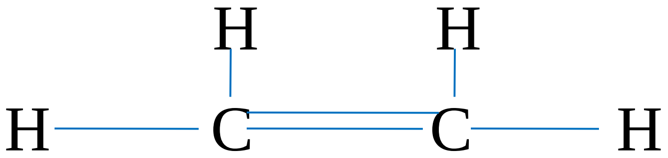
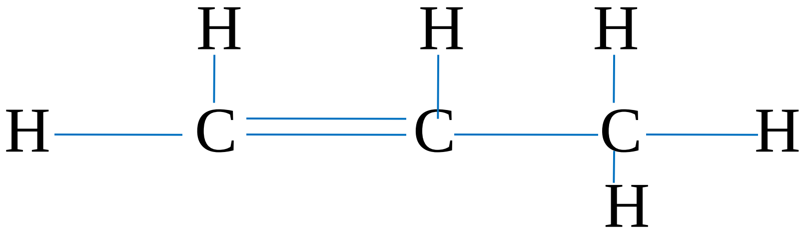
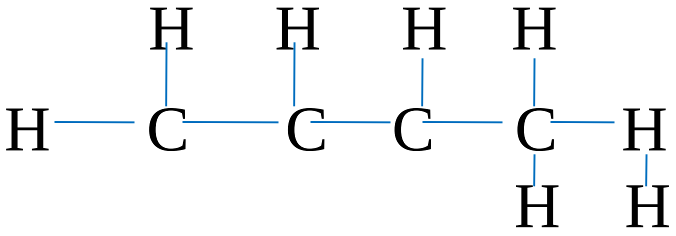
and  $-\overset{|}{C}=\overset{|}{C}-$ double bond as the **functional** group

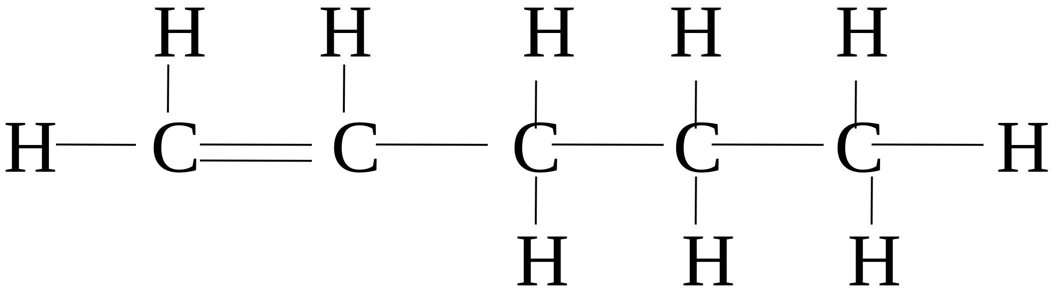
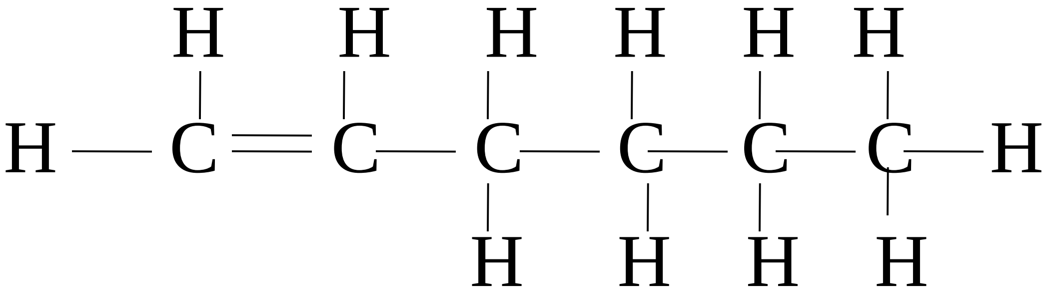
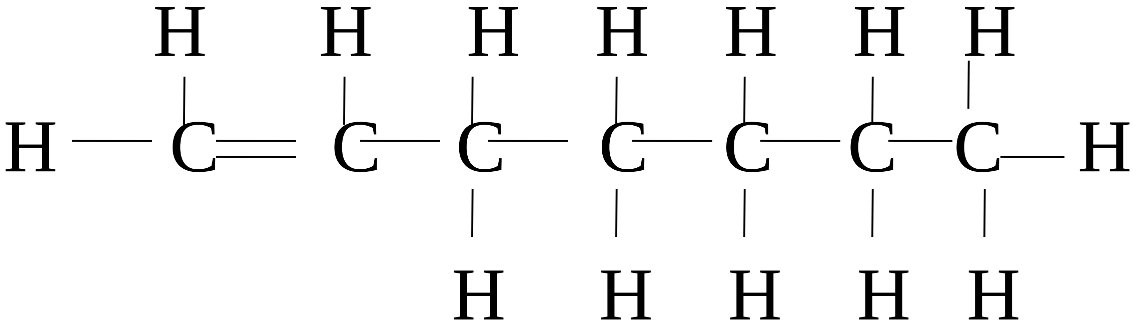
.

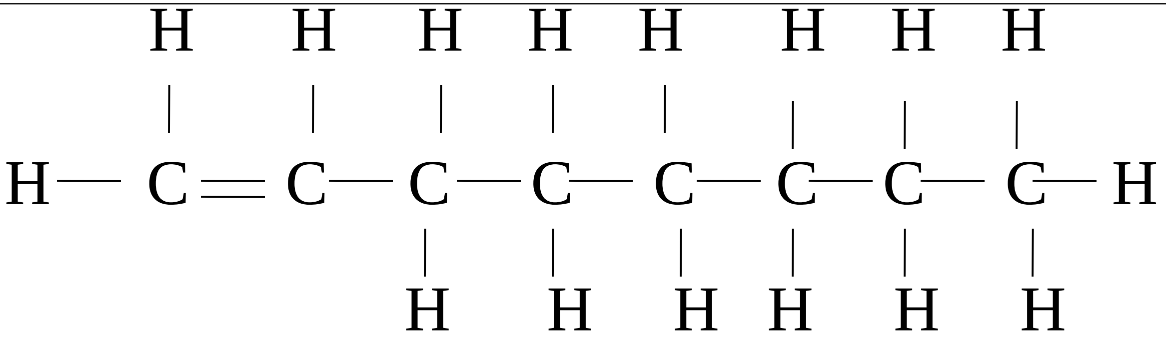
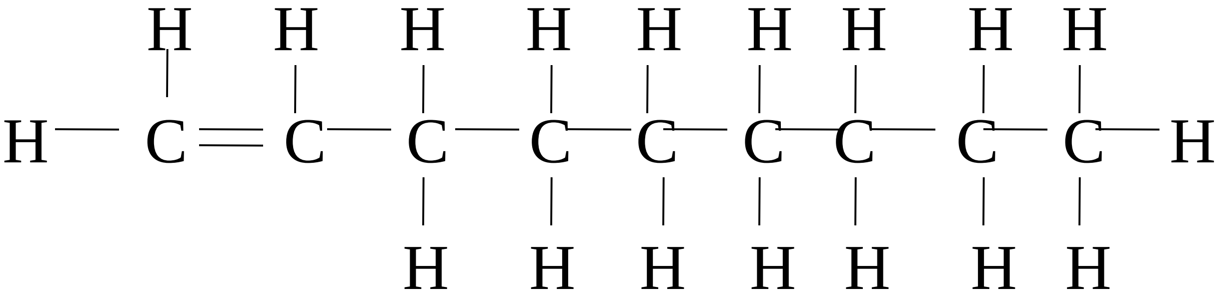
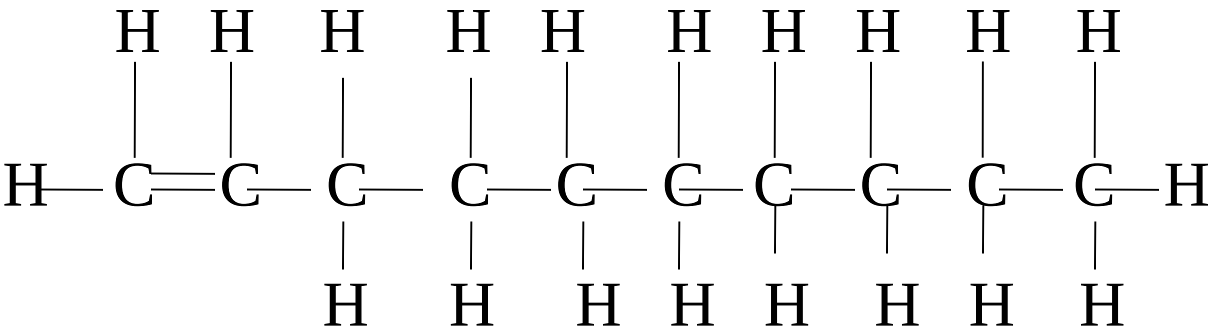
n is the number of Carbon atoms in the molecule.

The carbon atoms are linked by at least **one double** bond to each other and **single** bonds to hydrogen atoms.

They include:

n	General/ Molecular formula	Structural formula	Name
1		Does not exist	
2	C_2H_6	 $CH_2\ CH_2$	Eth**ene**
3	C_3H_8	 $CH_2\ CH\ CH_3$	Prop**ene**
4	C_4H_{10}	 $CH_2\ CH\ CH_2CH_3$	But**ene**

5	C_5H_{12}	 $CH_2\ CH\ (CH_2)_2CH_3$	Pent**ene**
6	C_6H_{14}	 $CH_2\ CH\ (CH_2)_3CH_3$	Hex**ene**
7	C_7H_{16}	 $CH_2\ CH\ (CH_2)_4CH_3$	Hept**ene**

8	C_8H_{18}	 $CH_2\ CH\ (CH_2)_5CH_3$	Oct**ene**
9	C_9H_{20}	 $CH_2\ CH\ (CH_2)_6CH_3$	Non**ene**
10	$C_{10}H_{22}$	 $CH_2\ CH\ (CH_2)_7CH_3$	dec**ene**

Note

1.Since carbon is **tetravalent** ,each atom of carbon in the alkene **MUST** always be bonded using **four** covalent bond /four shared pairs of electrons including at the double bond.

2.Since Hydrogen is **monovalent** ,each atom of hydrogen in the alkene **MUST** always be bonded using **one** covalent bond/one shared pair of electrons.

3.One member of the alkene ,like alkanes,differ from the next/previous by a CH_2 group.
They also form a homologous series.

e.g
Propene differ from ethene by one carbon and two Hydrogen atoms from ethene.

4.A homologous series of alkenes like that of alkanes:

(i) differ by a CH_2 group from the next /previous

(ii)have similar chemical properties

(iii)have similar chemical formula represented by the general formula C_nH_{2n}

(iv)the physical properties show gradual change.

5.The $-\underset{|}{C}=\underset{|}{C}-$ double bond in alkene is the functional group.

A functional group is the **reacting site** of a molecule /compound.

6. The $-\overset{|}{C}=\overset{|}{C}-$ double bond in alkene can easily be broken to accommodate two more monovalent atoms.

The $-\underset{|}{C}=\underset{|}{C}-$ double bond in alkenes make it thus **unsaturated.**

7. An unsaturated hydrocarbon is one with a double $-\overset{|}{C}=\overset{|}{C}-$ or triple $-C\equiv C-$ carbon bonds in their molecular structure.

Unsaturated hydrocarbon easily reacts to be **saturated**.

8.A saturated hydrocarbon is one without a double $-\overset{|}{C}=\overset{|}{C}-$ or triple $-C\equiv C-$ carbon bonds in their molecular structure.

Most of the reactions of alkenes take place at the $-\underset{|}{C} = \underset{|}{C}-$ bond.

(b)Isomers of alkenes

Isomers of alkenes like alkanes have the same molecular **general formula** but different molecular **structural formula**.

Isomers of alkenes are also named by using the IUPAC(**I**nternational **U**nion of **P**ure and **A**pplied **C**hemistry) system of **nomenclature/naming.**

The IUPAC system of nomenclature of naming alkenes uses the following basic rules/guidelines:

1.Identify the longest continuous/straight carbon chain which contains the **=C = C= double** bond to get/determine the **parent** alkene.

2.Number the longest chain form the end of the chain which contains the **=C = C= double** bond so he **=C = C= double** bond lowest number possible.

3 Indicate the positions by splitting "**alk**-positions-**ene**" e.g. but-2-ene, pent-1,3-diene.

4.The position **indicated** must be for the carbon atom at the **lower** position in the **=C = C= double bond.**i.e

But-2-ene means the double =C = C= is between Carbon "2"and "3"

Pent-1,3-diene means there are two double bond one <u>between</u> carbon "1" and "2"and another <u>between</u> carbon "3" and "4"

5. Determine the position, number and type of branches.

Name them as methyl, ethyl, propyl e.tc. according to the number of alkyl carbon chains attached to the alkene.

Name them fluoro-,chloro-,bromo-,iodo- if they are halogens

6.Use prefix di-,tri-,tetra-,penta-,hexa- to show the number of **double** =C = C= bonds and **branches** attached to the alkene.

7.Position isomers can be formed when the =C = C= double bond is shifted between carbon atoms e.g.

But-2-ene means the double =C = C= is between Carbon “2”and “3”
But-1-ene means the double =C = C= is between Carbon “1”and “2”
Both But-1-ene and But-2-ene are **position isomers** of Butene

8.Position isomers are molecules/compounds having the same general formular but different position of the functional group. i.e.

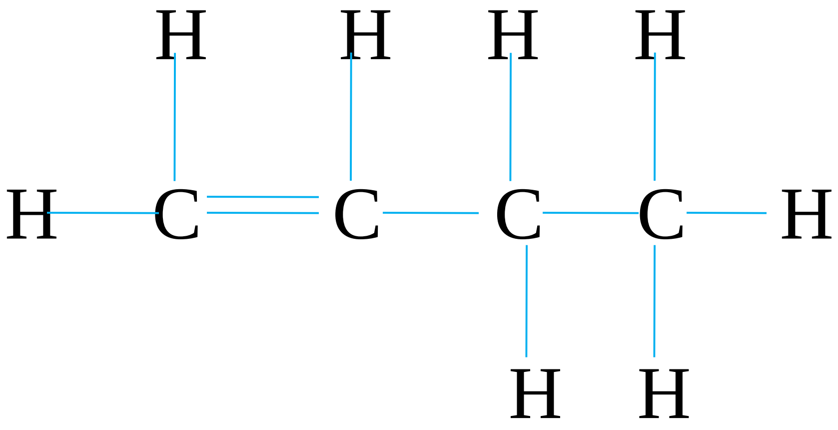
Butene has the molecular/general formular C_4H_8 position but can form both But-1-ene and But-2-ene as position isomers.

9. Like alkanes ,an alkyl group can be attached to the alkene. Chain/branch isomers are thus formed.

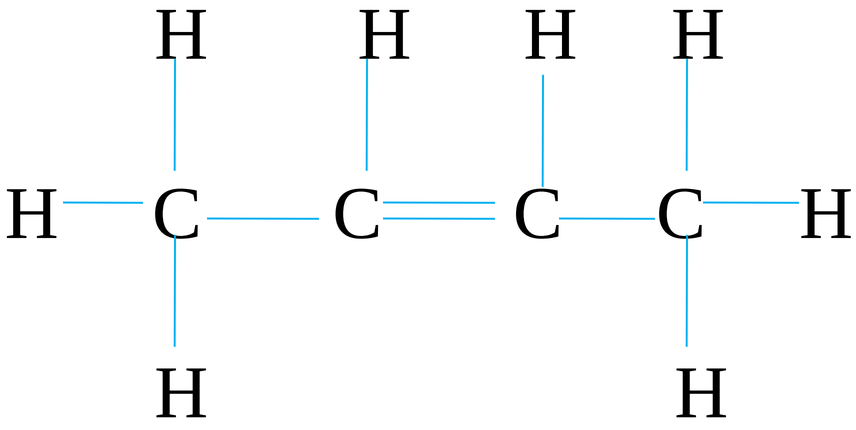
10.Chain/branch isomers are molecules/compounds having the same general formula but different structural formula . e.g

Butene and 2-methyl propene both have the same general formualr but different branching chain.

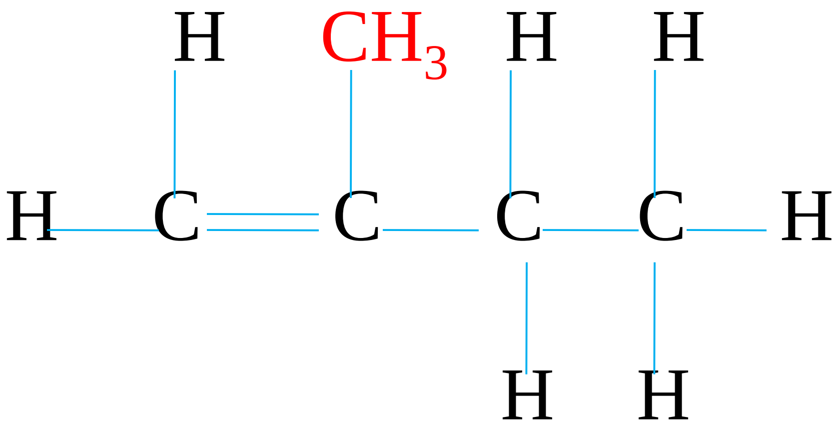
Practice on IUPAC nomenclature of alkenes



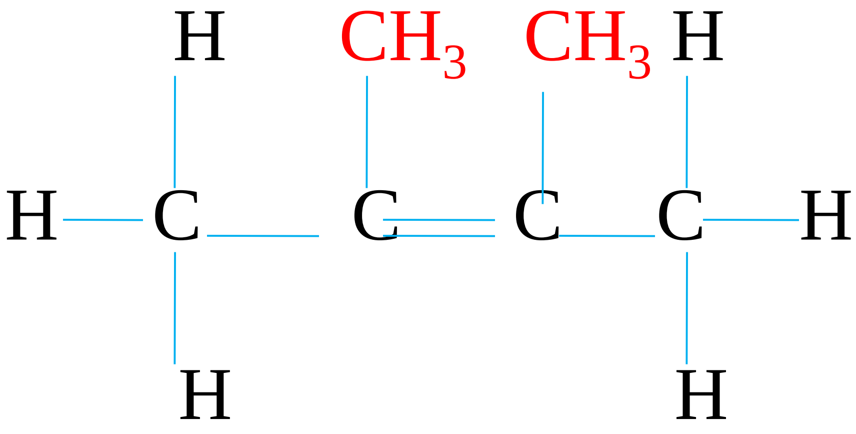
But-1-ene(double bond is between carbon “1-2”



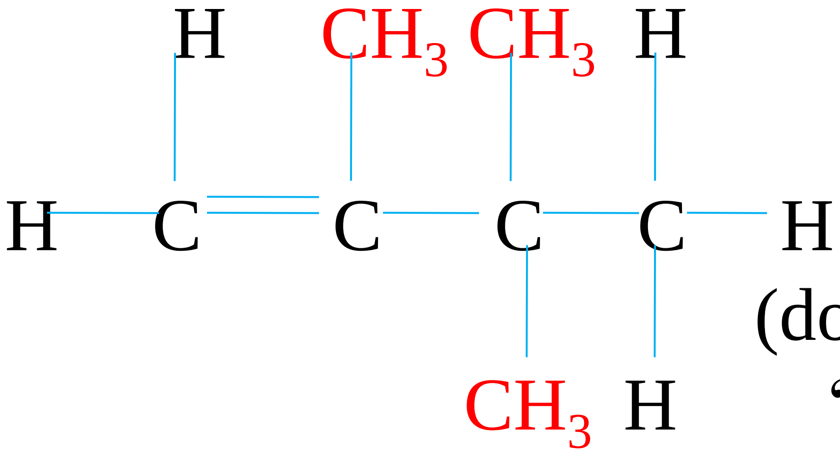
But-2-ene(double bond is between carbon “2-3”



2-methylbut-1-ene(double bond is between carbon “1-2” and methyl group at carbon “2”

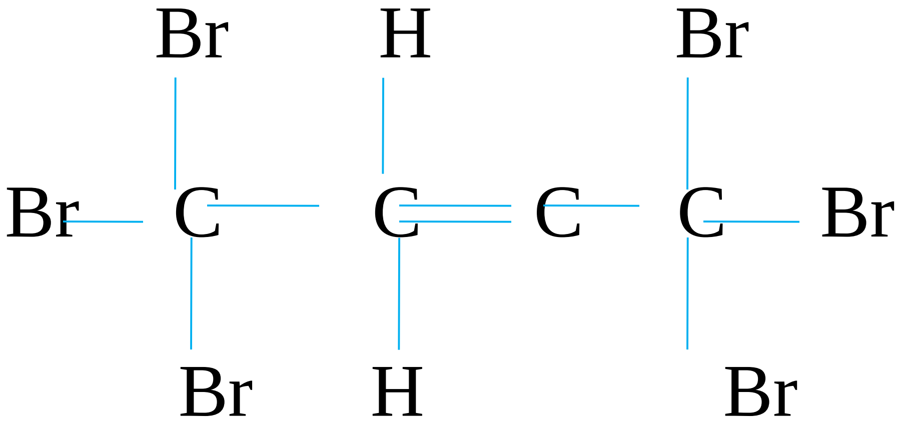


2,3-dimethylbut-2-ene (double bond is between carbon “2-3” and two methyl group at carbon “2-3”



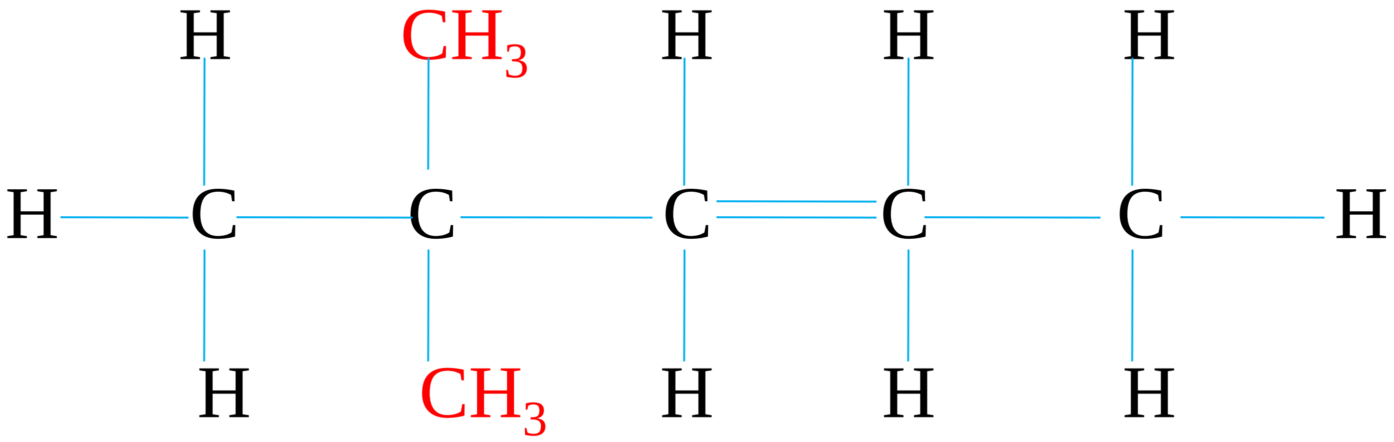
$$\begin{array}{ccccccccccc} & & H & & CH_3 & & CH_3 & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & = & C & - & C & - & C & - & H \\ & & & & & & | & & | & & \\ & & & & & & CH_3 & & H & & \end{array}$$

2,3,3-trimethylbut-1-ene (double bond is between carbon “1-2” and methyl group at carbon “2,3,3”



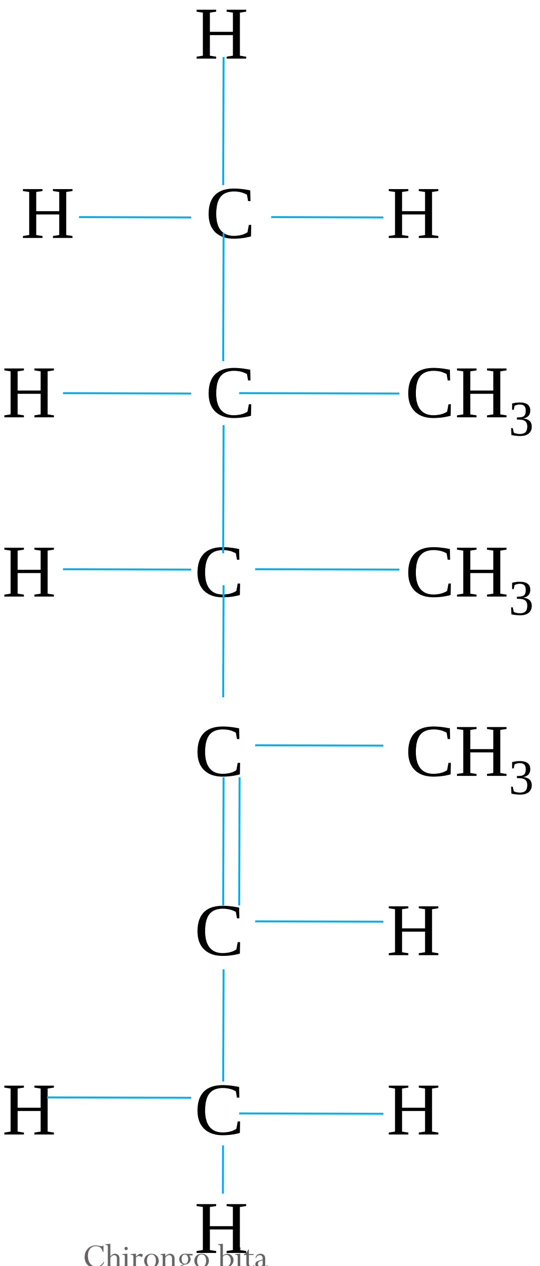
$$\begin{array}{ccccccccccc} & & Br & & H & & & & Br & & \\ & & | & & | & & & & | & & \\ Br & - & C & - & C & = & C & - & C & - & Br \\ & & | & & | & & & & | & & \\ & & Br & & H & & & & Br & & \end{array}$$

1,1,1,4,4,4-hexabromobut-2-ene carbon “2-3” and six bromine atoms at carbon “1,4”



4,4-dimethylpent-2-ene
(double bond between Carbon “2-3” and two methyl group at carbon “4”)

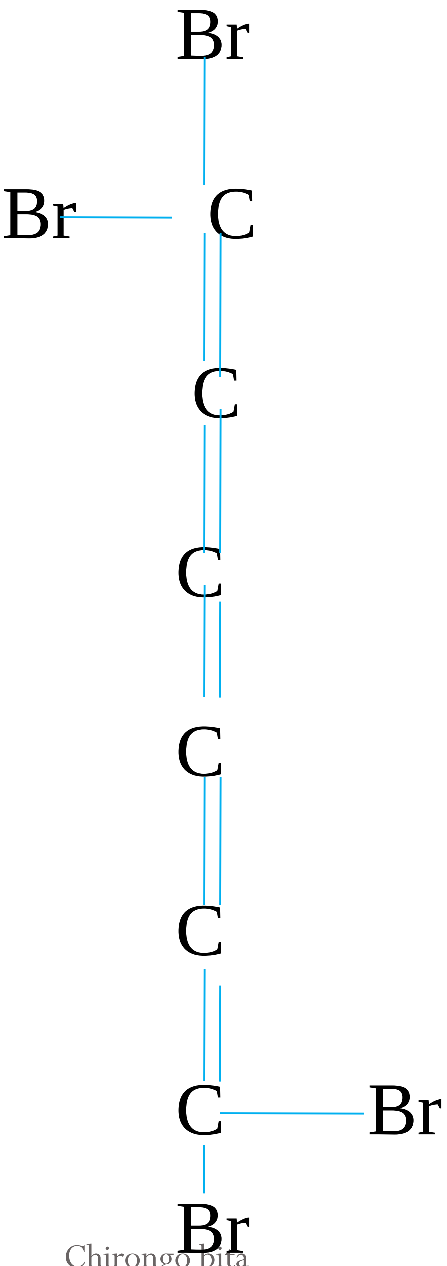
$H_2C\ CHCH_2\ CH_2\ CH_3$ Pent -1- ene
(After drawing the structural formula the double bond is between Carbon “1-2”



3,4,5-trimethylhex-2- ene

(i)double bond between Carbon "2-3,"

(ii)three methyl groups at carbon "3.4,5")



1,1,6,6-tetrabromohex-1,2,3,4,5-pentaene

(i)double bond between Carbon “**2**-3, **3**-4, **4**-5, **5**-6, **1**-2,”

(ii)four Bromine groups at carbon “1,1,6,6”)

.$H_2C\ C(CH_3)C(CH_3)_2\ CH_2\ CH_3$

2,3,3-trimethylpent -1- ene

$H_2C\ C(CH_3)C(CH_3)_2\ C(CH_3)_2\ CH_3$

2,3,3,4,4-pentamethylpent -1- ene

$H_3C\ C(CH_3)C(CH_3)\ C(CH_3)_2\ CH_3$

2,3,4,4-tetramethylpent -2- ene

$H_2C\ C(CH_3)C(CH_3)\ C(CH_3)\ CH_3$

2,3,4-trimethylpent -1,3- diene

$H_2C\ CBrCBr\ CBr\ CH_3$

2,3,4-tribromopent -1,3- diene

H_2C CHCH CH_2

But -1,3- diene

Br_2C CBrCBr CBr_2

1,1,2,3,4,4-hexabromobut -1,3- diene

I_2C CICI CI_2

1,1,2,3,4,4-hexaiodobut -1,3- diene

H_2C $C(CH_3)C(CH_3)$ CH_2

2,3-dimethylbut -1,3- diene

H_2CCCH_2

prop -1,2,- diene

(c)Occurrence and extraction

At indusrial level,alkenes are obtained from the cracking of alk**a**nes.

Cracking is the process of breaking long chain alkanes to smaller/shorter alk**a**nes, an alk**e**ne and hydrogen gas at high temperatures.

Cracking is a major source of useful hydrogen gas for manufacture of ammonia/nitric(V)acid/HCl i.e.

Long chain alkane->shorter alk**a**ne+ Alk**e**ne+ Hydrogen

1.When irradiated with high energy radiation, Propane undergo cracking to form methane gas, ethene and hydrogen gas.

Chemical equation

$CH_3CH_2CH_3$ (g) -> CH_4(g) +CH_2=CH_2(g)

2.Octane undergo cracking to form hydrogen gas, butene and butane gases

Chemical equation

$CH_3(CH_2)_6CH_3$ (g) ->

$CH_3CH_2CH_2CH_3$(g)+CH_3 CH_2CH=CH_2(g)

(d)School laboratory preparation of alkenes

In a school laboratory, alk**e**nes may be prepared from dehydration of alkanols using:

(i) concentrated sulphuric(VI)acid(H_2SO_4).

(ii)aluminium(III)oxide(Al_2O_3) i.e

Alkanol --Conc. H_2SO_4 --> Alkene + Water

Alkanol --Al_2O_3 --> Alkene + Water e.g.

1.(a)At about 180°C,concentrated sulphuric(VI)acid dehydrates/removes water from ethanol to form eth**e**ne.

The gas produced contain traces of carbon(IV)oxide and sulphur(IV)oxide gas as impurities.

It is thus passed through concentrated sodium /potassium hydroxide solution to remove the impurities.

Chemical equation

CH_3CH_2**OH** (l)-conc H_2SO_4/180°C-->

$CH_2=CH_2$(g)+ **H_2O**(l)

(b)On heating strongly aluminium(III)oxide(Al_2O_3),it dehydrates/removes water from ethanol to form eth**e**ne.

Ethanol vapour passes through the hot aluminium (III) oxide which catalyses the dehydration.

Activated aluminium(III)oxide has a very high affinity for water molecules/elements of water and thus dehydrates/ removes water from ethanol to form eth**e**ne.

Chemical equation

CH_3CH_2**OH** (l) --(Al_2O_3/strong heat-->

$CH_2=CH_2$(g) + **H_2O**(l)

2(a) Propan-1-ol and Propan-2-ol(position isomers of propanol) are dehydrated by conc H_2SO_4 at about **180ºC** to prop**e**ne(propene has no position isomers).

Chemical equation

$CH_3CH_2\ CH_2\mathbf{OH}$ (l) -- conc H_2SO_4/180ºC -->

$CH_3CH{=}CH_2$(g) + $\mathbf{H_2O}$(l)

Propan-**1**-ol Prop-**1**-ene

$CH_3CH\mathbf{OH}\ CH_3$ (l) -- conc H_2SO_4/180ºC -->

$CH_3CH{=}CH_2$(g) + $\mathbf{H_2O}$(l)

Propan-**2**-ol Prop-**1**-ene

(b) Propan-1-ol and Propan-2-ol(position isomers of propanol) are dehydrated by heating strongly aluminium (III)oxide(Al_2O_3) form prop**e**ne

Chemical equation

$CH_3CH_2\ CH_2\mathbf{OH}$ (l) -- Heat/Al_2O_3 -->

$CH_3CH{=}CH_2$(g) + $\mathbf{H_2O}$(l)

Propan-**1**-ol Prop-**1**-ene

$CH_3CH\mathbf{OH}\ CH_3$ (l) -- Heat/Al_2O_3 -->

$CH_3CH{=}CH_2$(g) + $\mathbf{H_2O}$(l)

Propan-**2**-ol Prop-**1**-ene

3(a) Butan-1-ol and Butan-2-ol (position isomers of butanol) are dehydrated by conc H_2SO_4 at about 180^oC to But-1-**e**ne and But-2-**e**ne respectively

Chemical equation

$CH_3CH_2\ CH_2\ CH_2\mathbf{OH}$ (l) -- conc $H_2SO_4/180^oC$ -->

$CH_3\ CH_2CH{=}CH_2$(g) + $\mathbf{H_2O}$(l)

Butan-**1**-ol But-**1**-ene

CH_3CH**OH** CH_2CH_3 (l)-- conc H_2SO_4/180ºC -->
$CH_3CH{=}CH\ CH_2$(g) + **H_2O**(l)
Butan-**2**-ol But-**2**-ene

(b) Butan-1-ol and Butan-2-ol are dehydrated by heating strongly aluminium (III) oxide (Al_2O_3) form But-1**-e**ne and But-2**-e**ne respectively.

<u>Chemical equation</u>

$CH_3CH_2\ CH_2\ CH_2$**OH** (l) -- Heat/Al_2O_3 -->
$CH_3\ CH_2CH{=}CH_2$(g) + **H_2O**(l)
Butan-**1**-ol But-**1**-ene

CH_3CH**OH** CH_2CH_3 (l) -- Heat/Al_2O_3 -->
$CH_3CH{=}CH\ CH_2$(g) + **H_2O**(l)
Butan-**2**-ol But-**2**-ene

Laboratory set up for the preparation of alk**enes**/**ethene**

Caution:

(i) Ethanol is highly inflammable,

(ii) Conc H_2SO_4 is highly corrosive on skin contact.

(iii) Common school thermometer has maximum calibration of **110°C** and thus cannot be used.It breaks/cracks.

Some broken porcelain or sand should be put in the flask when heating to:

(i)prevent bumping which may break the flask.

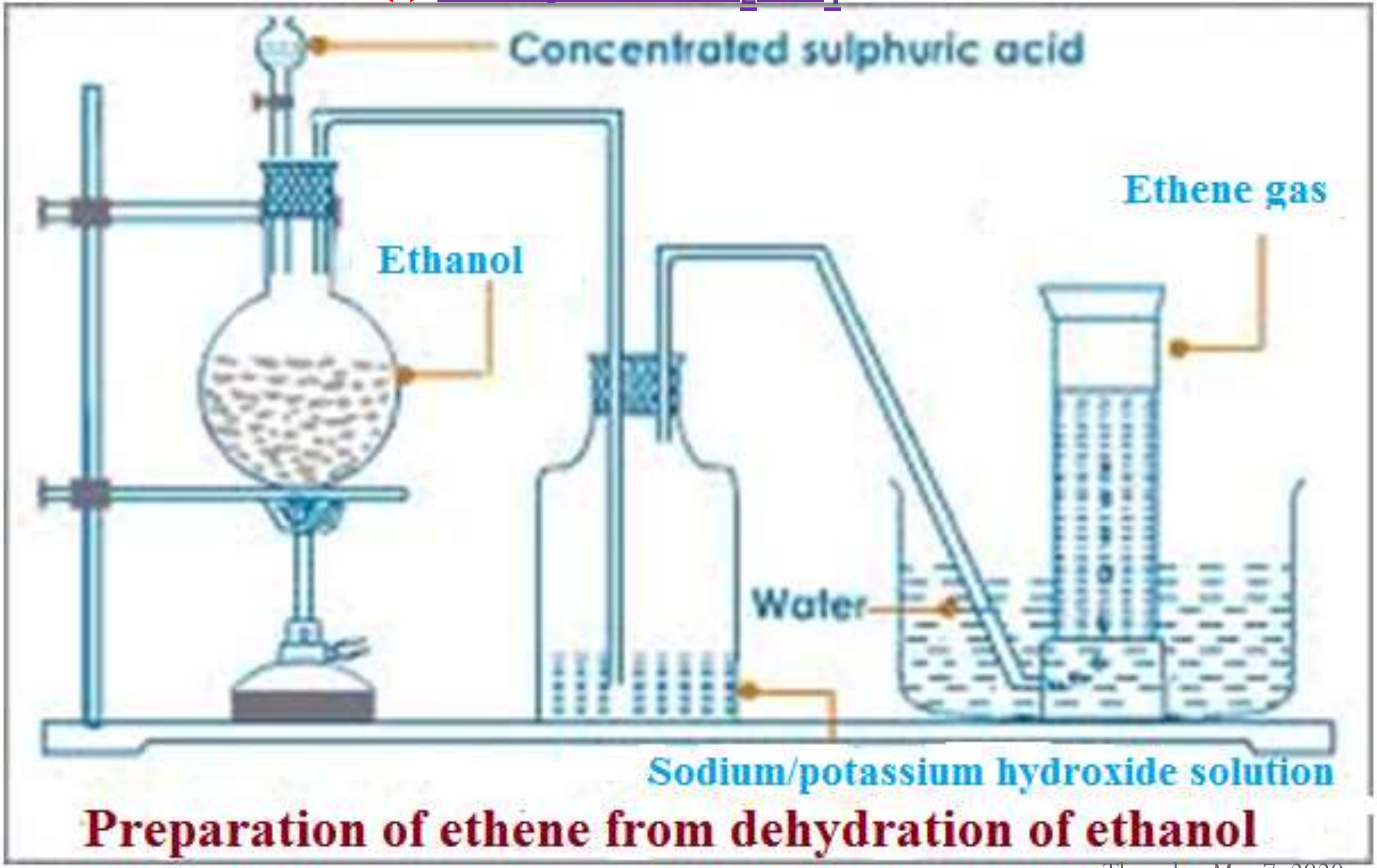
(ii)ensure uniform and smooth boiling of the mixture

The temperatures should be maintained at above160°C.

At **lower** temperatures another compound -**ether** is predominantly formed instead of ethene gas.

Preparation of ethene by dehydration of ethanol

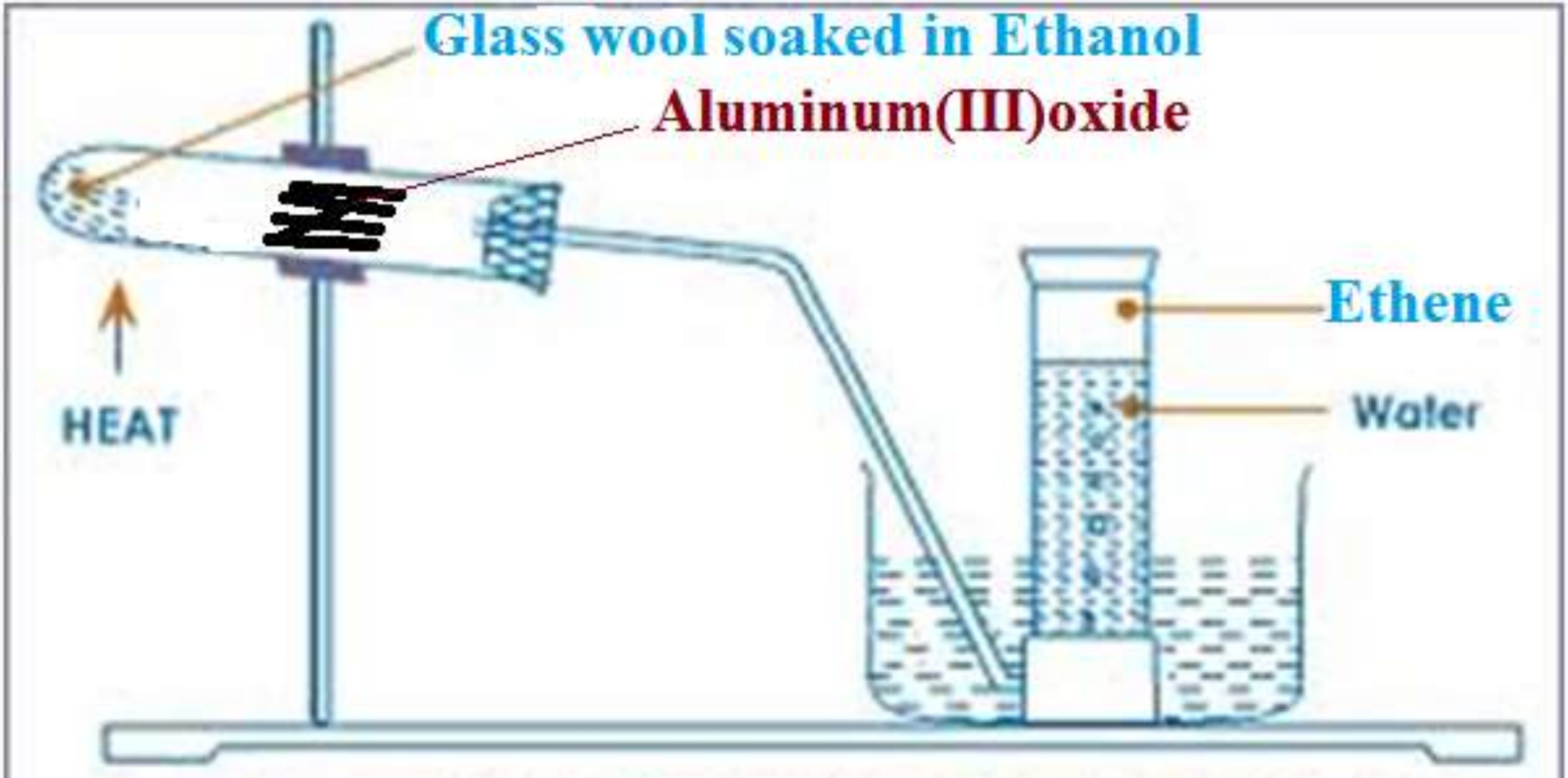
(i) using Conc H_2SO_4



Preparation of ethene from dehydration of ethanol

Preparation of ethene by dehydration of ethanol

(ii)**using aluminium(III)oxide**



Preparation of ethene from dehydration of ethanol

(e)Properties of alkenes

I. Physical properties

Like alk**a**nes, alk**e**nes are colourless gases, solids and liquids that are not poisonous.

They are slightly soluble in water.

The solubility in water decrease as the carbon chain/ molar mass increase but very soluble in organic solvents like tetrachloromethane and methylbenzene.

Melting/boiling point increase as carbon chain increase. This is because of the increase in van-der-waals /intermolecular forces as the carbon chain increase.

The 1st four straight chain alk**e**nes (eth**e**ne,prop**e**ne,but-1-**e**ne and pent-1-**e**ne)are gases at room temperature/ pressure.

Summary of physical properties of the 1st five alk**e**nes

Alkane	General formula	Melting point (°C)	Boiling point (°C)	State at room(298K) temperature and pressure atmosphere (101300Pa)
Eth**e**ne	CH_2CH_2	-169	-104	Gas
Prop**e**ne	CH_3 $CHCH_2$	-145	-47	Gas
But**e**ne	CH_3CH_2 $CHCH_2$	-141	-26	Gas
Pent-1-**e**ne	$CH_3(CH_2$ $CHCH_2$	-138	30	Liquid
Hex-1-**e**ne	$CH_3(CH_2)$ $CHCH_2$	-98	64	Liquid

II. Chemical properties of Alkenes

(a)Burning/combustion

Alkenes burn with a **yellow**/ luminous **sooty**/ **smoky** flame in **excess** air to form carbon(IV) oxide and water.

In excess air/oxygen

Alkene + Air -> carbon(**IV**) oxide + water

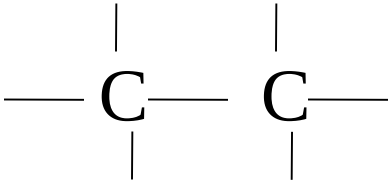
In limited air

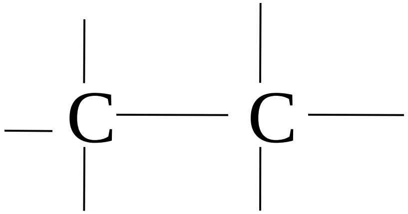
Alkenes burn with a **yellow**/ luminous **sooty**/ smoky flame in **limited** air to form carbon(II) oxide and water.

Alkene + Air -> carbon(**II**) oxide + water

Burning of alkenes with a **yellow**/ luminous **sooty**/ smoky flame is a confirmatory test for the **presence** of the **=C=C=** double bond because they have **higher C:H ratio.**

A homologous series with = C = C= double or **$-C\equiv C-$** triple bond is said to be **unsaturated.**

A homologous series with  $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$ single bond is said to be **saturated**.

Most of the reactions of the unsaturated compound involve trying to be saturated to form a  $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$ single bond.

Examples of burning alkenes

1.(a) Eth**ene** when ignited burns with a **yellow sooty** flame in **excess** air to form carbon(IV) oxide and water.

Eth**ene** + Air -> carbon(**IV**) oxide + water

$\mathbf{C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l/g)}$

(b) Eth**ene** when ignited burns with a **yellow sooty** flame in **limited** air to form carbon(II) oxide and water.

Eth**ene** + Air -> carbon(**II**) oxide +water

$\mathbf{C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l/g)}$

2.(a) Prop**ene** when ignited burns with a **yellow sooty** flame in **excess** air to form carbon(IV) oxide and water.

$\mathbf{2C_3H_6(g) + 9O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l/g)}$

(b) Prop**ene** when ignited burns with a **yellow sooty** flame in **limited** air to form carbon(II) oxide and water.

$\mathbf{C_3H_6(g) + 3O_2(g) \rightarrow 3CO(g) + 3H_2O(l/g)}$

(b)Addition reactions

An addition reaction is one which an unsaturated compound reacts to form a saturated compound.

Addition reactions of alkenes are named from the reagent used to cause the addition/convert the double =C=C= to single bond.

(i)Hydrogenation

Hydrogenation is an addition reaction in which **hydrogen** in presence of **Palladium/Nickel** catalyst at high temperatures react with alk**e**nes to form alk**a**nes.

Examples

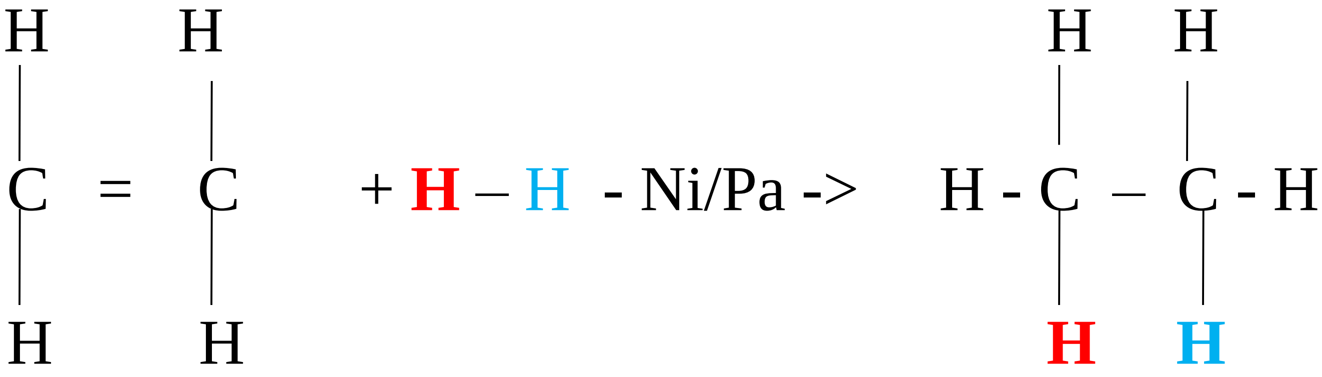
1.When Hydrogen gas is passed through liquid vegetable and animal **oil** at about $180^{o}C$ in presence of Nickel catalyst,solid **fat** is formed.

Hydrogenation is thus used to **harden** oils to solid fat especially margarine.

During hydrogenation, one hydrogen atom in the hydrogen molecule attach itself to one carbon and the other hydrogen to the second carbon breaking the double bond to single bond.

Chemical equation

$$H_2C{=}CH_2 \quad + \quad H_2 \quad \text{-Ni/Pa->} \quad H_3C \ - \ CH_3$$

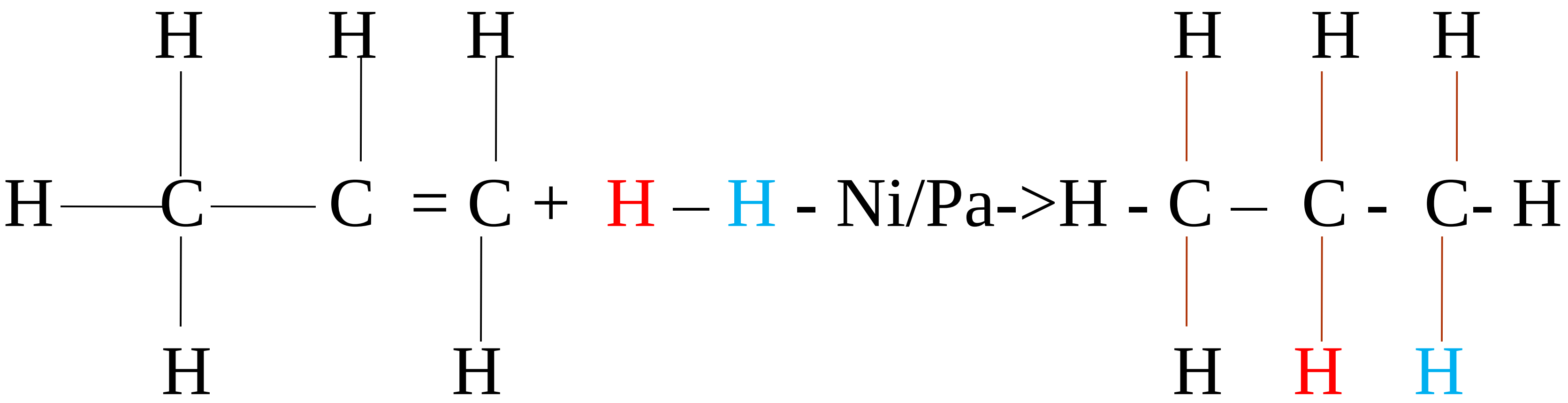


$$\underset{H}{\overset{H}{C}} = \underset{H}{\overset{H}{C}} \quad + \ \mathbf{H} - H \ \text{- Ni/Pa ->} \quad H - \underset{\mathbf{H}}{\overset{H}{C}} - \underset{\mathbf{H}}{\overset{H}{C}} - H$$

2.Prop**e**ne undergo hydrogenation to form Propane

Chemical equation

$$H_3C\ CH{=}CH_2 \quad + \quad H_2 \quad \text{-Ni/Pa->} \quad H_3C\ CH_2 \ - \ CH_3$$

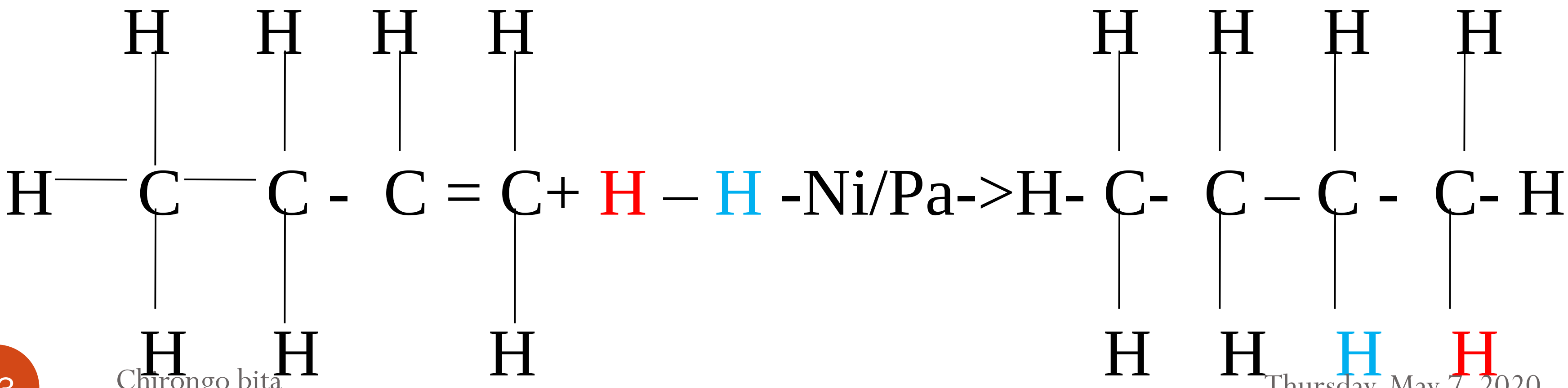


$$\mathrm{H-\underset{H}{\overset{H}{C}}-\overset{H}{C}=\underset{H}{\overset{H}{C}} + H-H \xrightarrow{Ni/Pa} H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H}$$

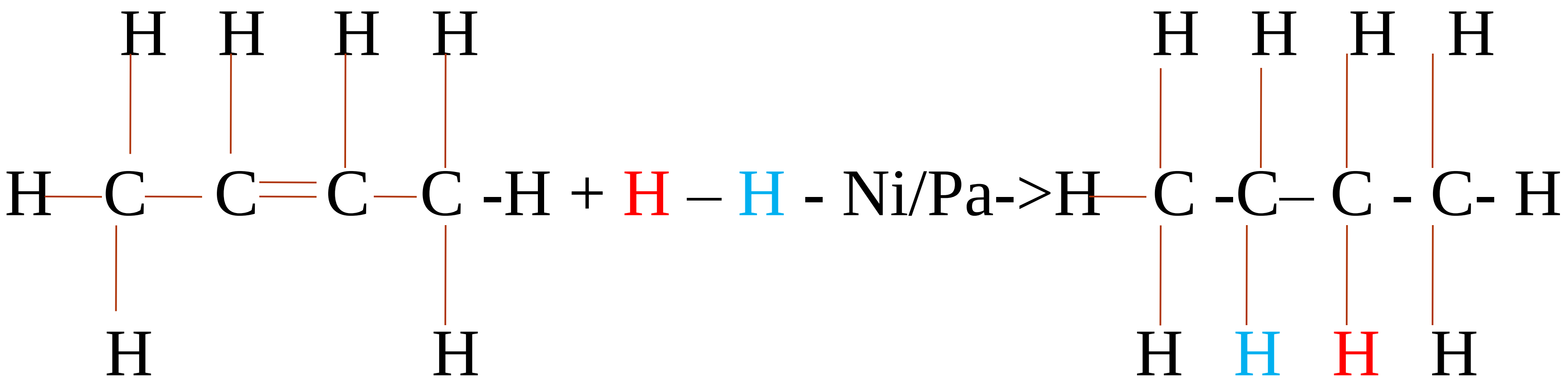
3.Both But-1-**e**ne and But-2-**e**ne undergo hydrogenation to form Butane

But-1-**e**ne + Hydrogen –Ni/Pa-> Butane

$H_3C\ CH_2\ CH{=}CH_2 + H_2$ -Ni/Pa-> $H_3C\ CH_2CH - CH_3$



$$\mathrm{H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{H}{C}=\underset{H}{\overset{H}{C}} + H-H \xrightarrow{Ni/Pa} H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H}$$

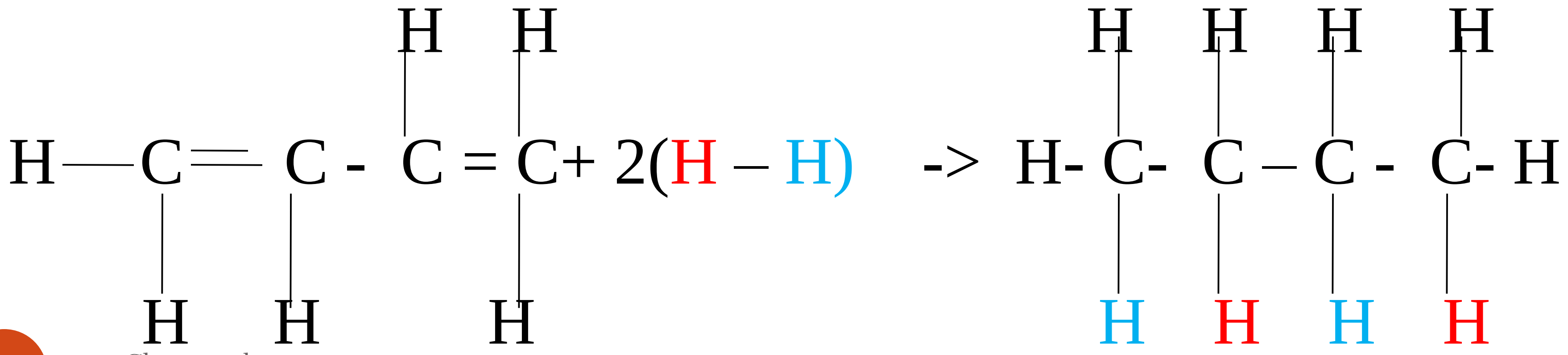


$$H-C-C=C-C-H + H-H \xrightarrow{Ni/Pa} H-C-C-C-C-H$$

But-1,3-di**e**ne should undergo hydrogenation to form Butane. The reaction uses **two** moles of hydrogen molecules/**four** hydrogen atoms to break the two double bonds.

But-1,3-di**e**ne + Hydrogen –Ni/Pa-> Butane

H_2C CH CH=CH_2 + **2**H_2 -Ni/Pa-> H_3C CH_2CH - CH_3



$$H-C=C-C=C + 2(H-H) \rightarrow H-C-C-C-C-H$$

(ii) Halogenation.

Halogenation is an addition reaction in which a halogen (Fluorine, chlorine, bromine, iodine) reacts with an alk**e**ne to form an alkane.

The double bond in the alk**e**ne break and form a single bond.

The colour of the halogen **fades** as the number of moles of the halogens remaining unreacted decreases/reduces.

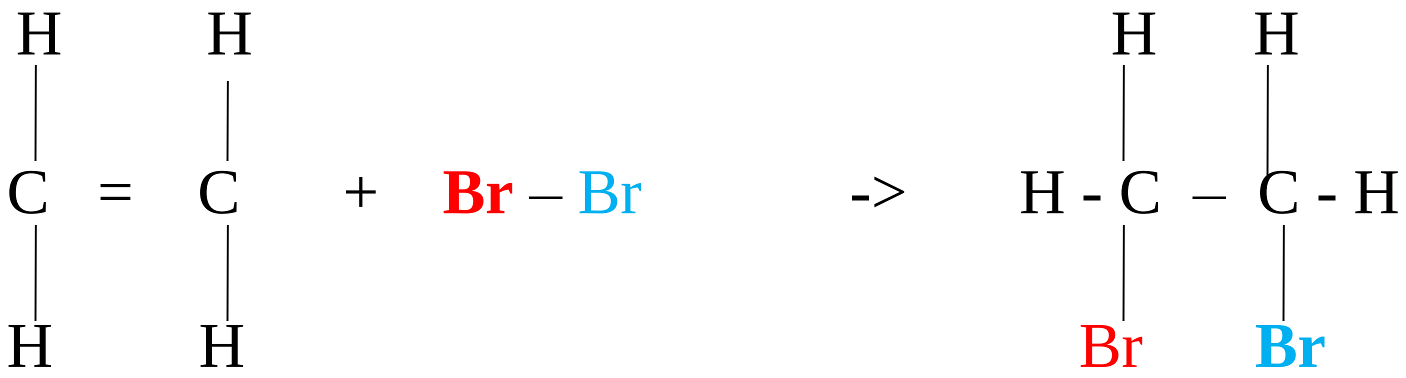
One bromine atom bond at the 1st carbon in the double bond while the other goes to the 2nd carbon.

<u>Examples</u>

1Ethene reacts with bromine to form 1,2-dibromoethane.

<u>Chemical equation</u>

$$H_2C{=}CH_2 \quad + \quad Br_2 \longrightarrow H_2\,Br\,C \; - \; CH_2\,Br$$



$$\begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} \quad + \quad Br - Br \quad -> \quad \begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H - & C & - & C & - H \\ & | & & | & \\ & Br & & Br & \end{array}$$

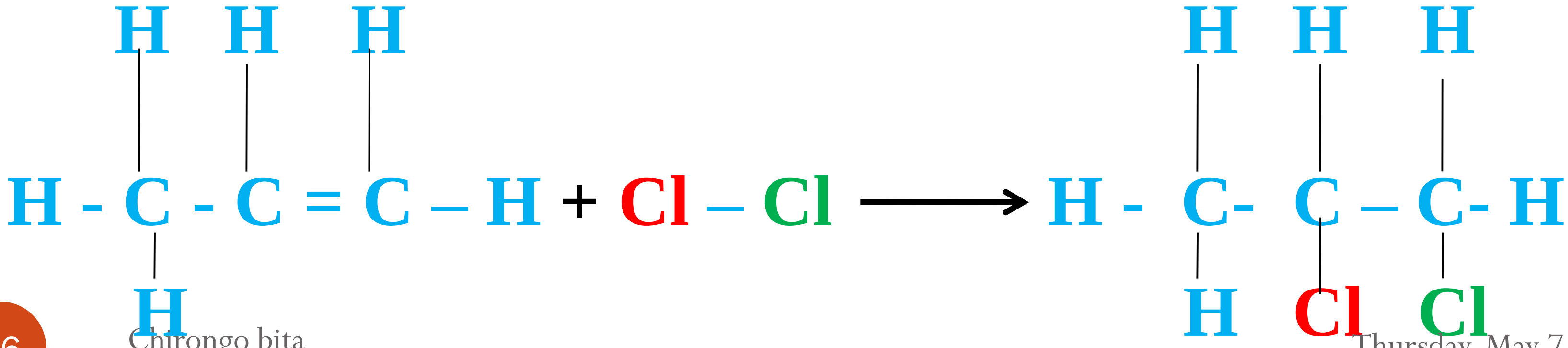
Ethene + Bromine ⟶ 1,2-dibromoethane

2.Propene with chlorine forms 1,2-dichloropropane.

<u>Chemical equation</u>

$H_3C\ CH=CH_2 + Cl_2 \longrightarrow H_3C\ CHCl - CH_2Cl$

Propene + Chlorine 1,2-dichloropropane



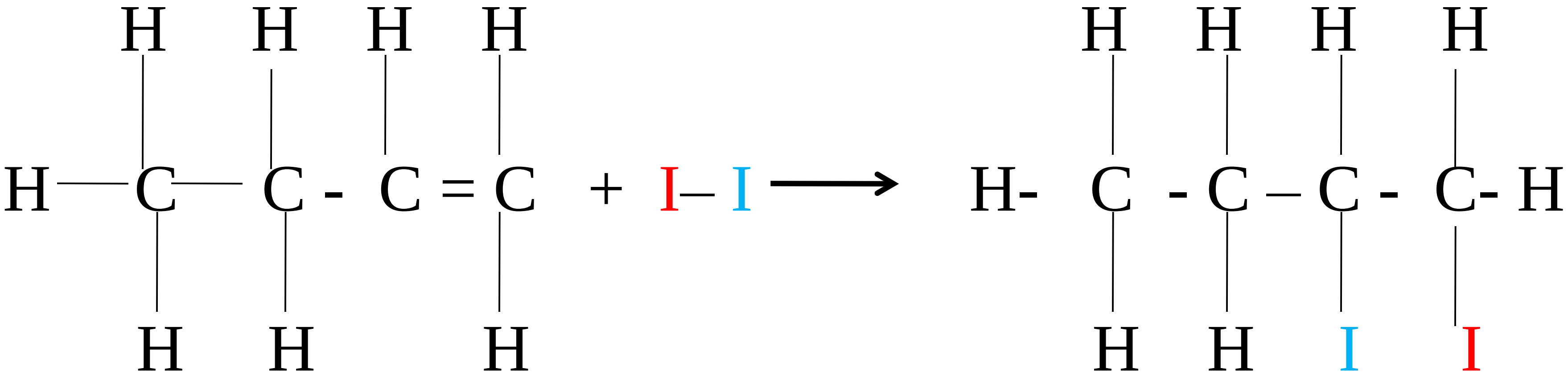
$$H - \begin{array}{c} H \\ | \\ C \\ | \\ H \end{array} - \begin{array}{c} H \\ | \\ C \end{array} = \begin{array}{c} H \\ | \\ C \end{array} - H + Cl - Cl \longrightarrow H - \begin{array}{c} H \\ | \\ C \\ | \\ H \end{array} - \begin{array}{c} H \\ | \\ C \\ | \\ Cl \end{array} - \begin{array}{c} H \\ | \\ C \\ | \\ Cl \end{array} - H$$

3.Both But-1-**e**ne and But-2-**e**ne undergo halogenation with iodine to form 1,2-diiodobutane

<u>Chemical equation</u>

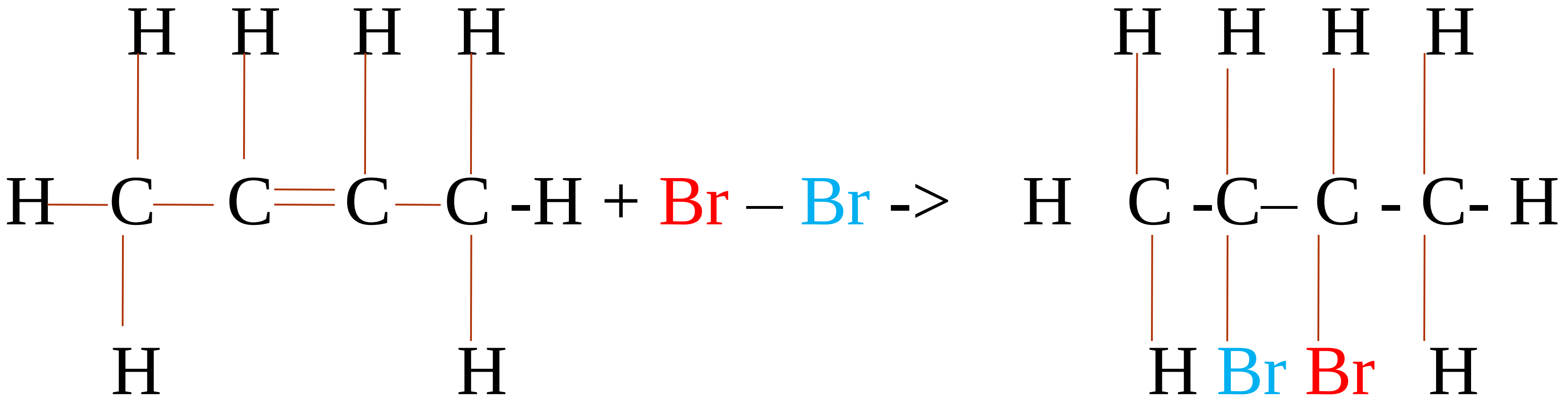
But-1-**e**ne + iodine ⟶ 1,2-diiodobutane

$H_3C\ CH_2\ CH{=}CH_2 \quad + \quad I_2 \qquad H_3C\ CH_2CH\ I -\ CH_2I$



But-2-**e**ne + Fluorine 2,3-difluorobutane

$H_3C\ CH{=}\ CH\text{-}CH_2 \quad + \quad F_2 \quad \text{->} \quad H_3C\ CHFCHF -\ CH_3$

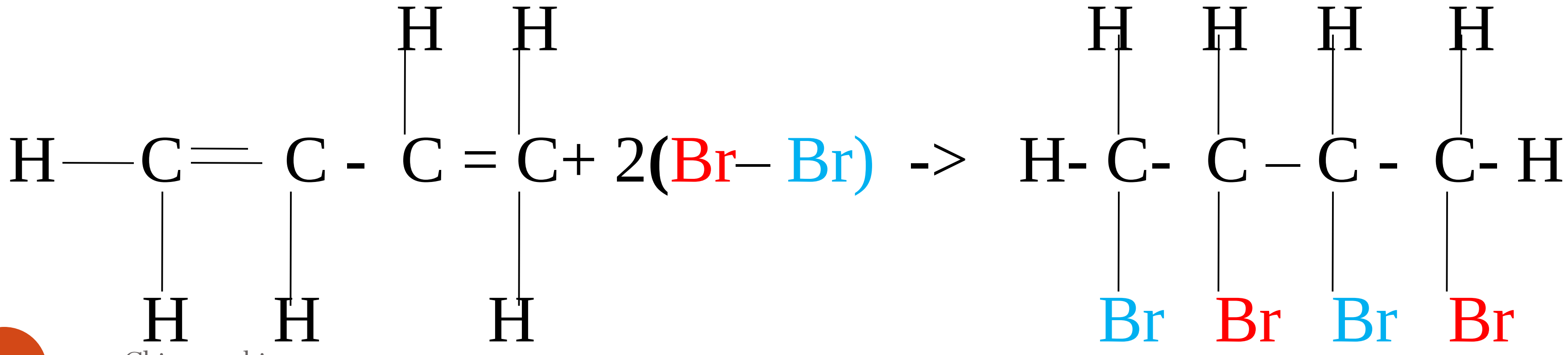


$$H-C-C=C-C-H + Br-Br \rightarrow H\ C-C-C-C-H$$

But-1,3-di**e**ne should undergo using bromine to form 1,2,3,4-tetrabutane. The reaction uses **two** moles of bromine molecules / **four** bromine atoms to break the two double bonds.

But-1,3-di**e**ne + Bromine -> 1,2,3,-tetrabromobutane

$H_2C\ CH\ CH{=}CH_2$ + **2**Br_2 -> $H_3C\ CH_2CH$ - CH_3



$$H-C=C-C=C + 2(Br-Br) \rightarrow H-C-C-C-C-H$$

(iii) Reaction with hydrogen halides/Hydrohalogenation.

Hydrogen halides reacts with alk**e**ne to form a halogenoalkane.

The double bond in the alk**e**ne break and form a single bond.

The main compound formed is one which the **hydrogen** atom bond at the carbon with **more** **hydrogen** **(**Markonikoff's rule**)** .

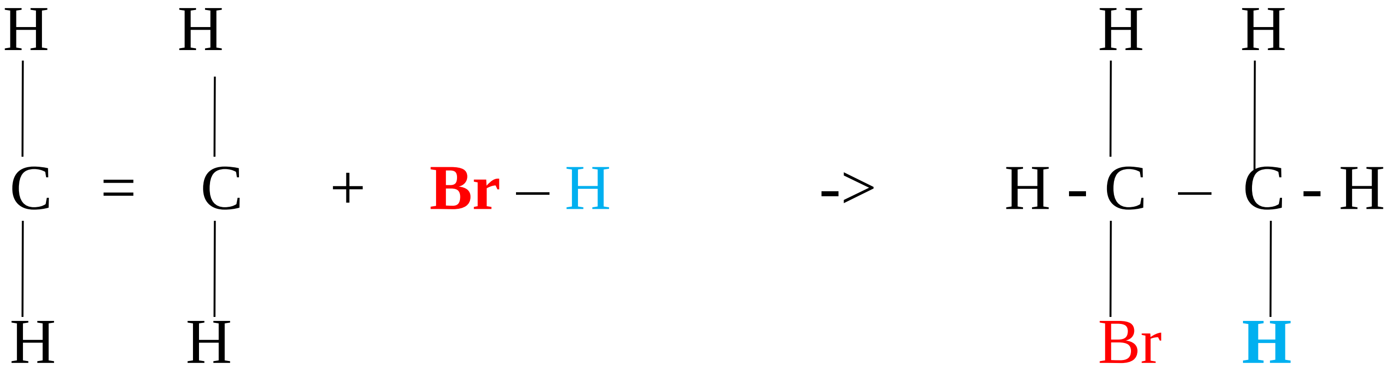
Examples

1. Ethene reacts with hydrogen bromide to form bromoethane.

Ethene + Bromine → bromoethane

Chemical equation

$H_2C=CH_2 + HBr \longrightarrow H_3C - CH_2Br$



$$\begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} + \mathbf{Br} - H \rightarrow \begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H - & C & - & C & - H \\ & | & & | & \\ & Br & & \mathbf{H} & \end{array}$$

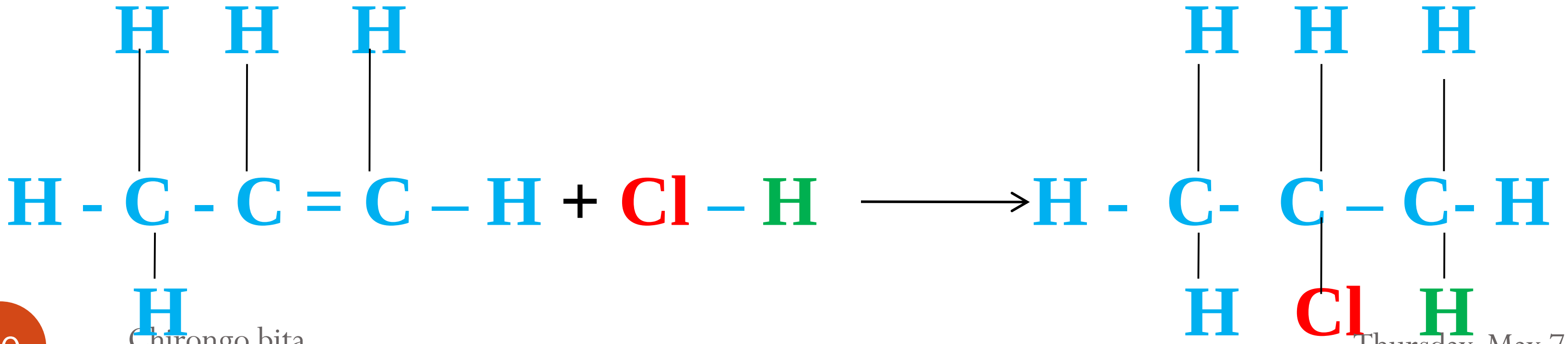
Ethene + Hydrogen bromide ⟶ bromoethane

2.Propene with hydrogen chloride forms 2-chloropropane.

<u>Chemical equation</u>

$H_3C\ CH=CH_2 + HCl \rightarrow H_3C\ CHCl - CH_3$

Propene + Chlorine -> 2-chloropropane



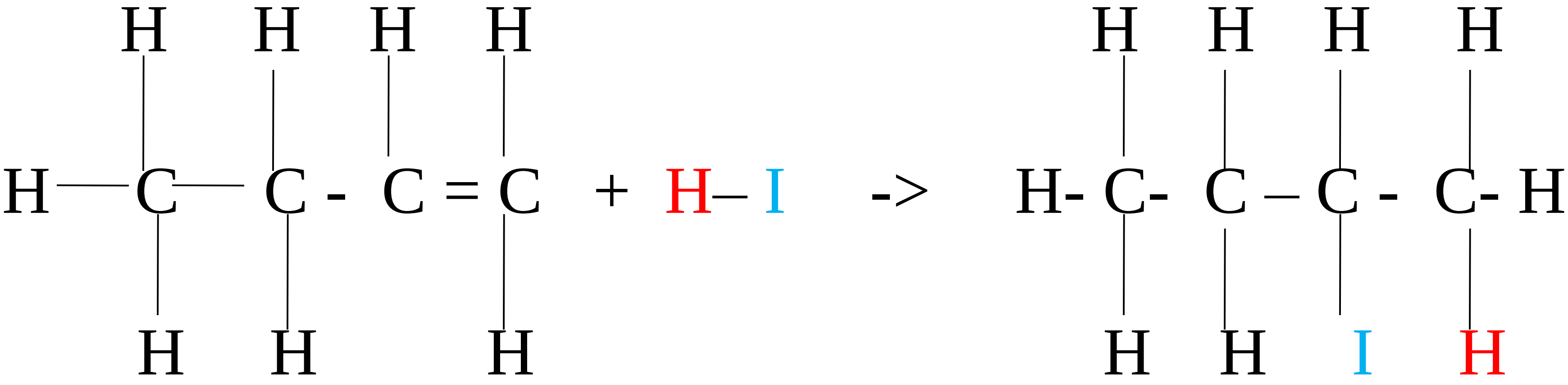
$$\begin{array}{ccccccc} & \mathbf{H} & & \mathbf{H} & & \mathbf{H} & \\ & | & & | & & | & \\ \mathbf{H} - & \mathbf{C} & - & \mathbf{C} & = & \mathbf{C} & - \mathbf{H} \\ & | & & & & & \\ & \mathbf{H} & & & & & \end{array} + \mathbf{Cl} - \mathbf{H} \longrightarrow \begin{array}{ccccccc} & \mathbf{H} & & \mathbf{H} & & \mathbf{H} & \\ & | & & | & & | & \\ \mathbf{H} - & \mathbf{C} & - & \mathbf{C} & - & \mathbf{C} & - \mathbf{H} \\ & | & & | & & | & \\ & \mathbf{H} & & \mathbf{Cl} & & \mathbf{H} & \end{array}$$

3.Both But-1**-e**ne and But-2**-e**ne react with hydrogen iodide to form 2-iodobutane

Chemical equation

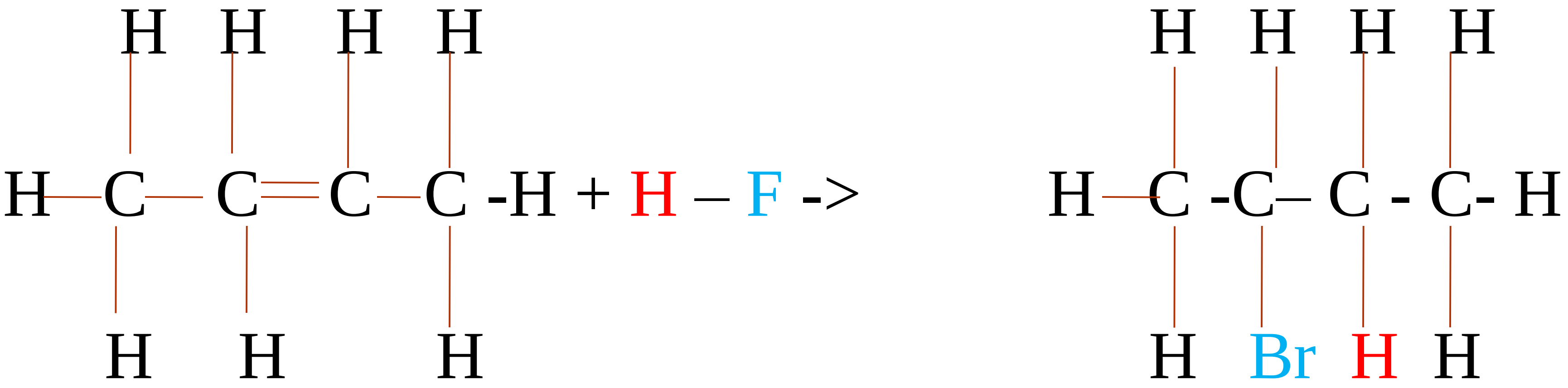
But-1**-e**ne + iodine -> 2-iodobutane

$H_3C\ CH_2\ CH{=}CH_2$ + HI ->$H_3C\ CH_2CH\ I$ - CH_3



But-2**-e**ne + Fluorine 2-fluorobutane

$H_3C\ CH{=}\ CH\text{-}CH_2$ + HF -> $H_3C\ CHFCHF$ - CH_3

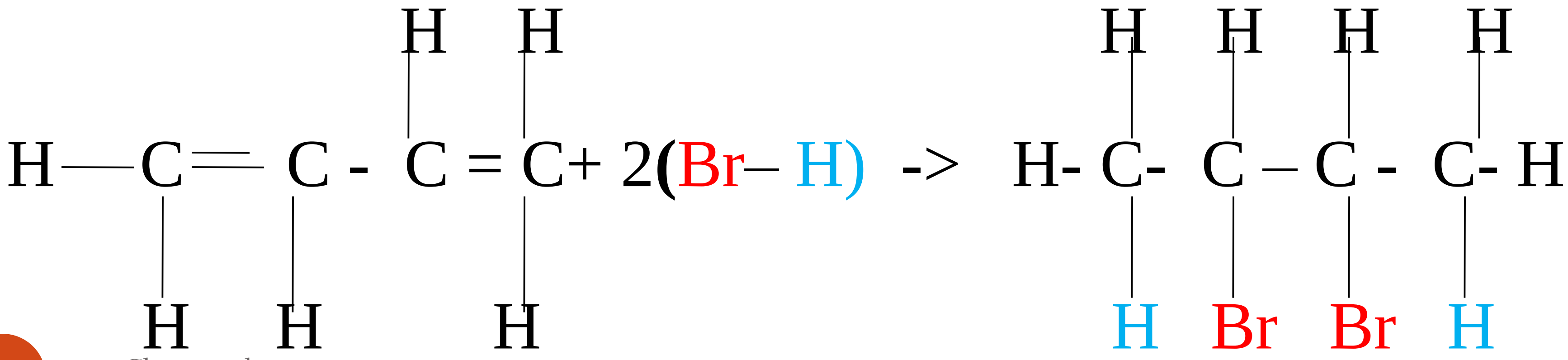


$$\mathrm{H{-}\underset{H}{\overset{H}{C}}{-}\underset{H}{\overset{H}{C}}{=}\overset{H}{C}{-}\underset{H}{\overset{H}{C}}\ {-}H + H - F \rightarrow H{-}\underset{H}{\overset{H}{C}}{-}\underset{Br}{\overset{H}{C}}{-}\underset{H}{\overset{H}{C}}{-}\underset{H}{\overset{H}{C}}{-}H}$$

But-1,3-di**e**ne react with hydrogen bromide to form (as the main product) 2,3-dibromobutane. The reaction uses **two** moles of hydrogen bromide molecules to break the two double bonds.

But-1,3-di**e**ne + Bromine -> 2,3,-dibromobutane

$H_2C\ CH\ CH{=}CH_2$ + **2**HBr -> $H_3C\ CHBrCH\ Br{-}\ CH_3$



$$\mathrm{H{-}\underset{H}{C}{=}\underset{H}{C}{-}\overset{H}{C}{=}\underset{H}{\overset{H}{C}} + 2(Br{-}H) \rightarrow H{-}\underset{H}{\overset{H}{C}}{-}\underset{Br}{\overset{H}{C}}{-}\underset{Br}{\overset{H}{C}}{-}\underset{H}{\overset{H}{C}}{-}H}$$

(iv) Reaction with bromine/chlorine water.

Chlorine and bromine water is formed when the halogen is dissolved in distilled water.

Chlorine water has the formula HOCl (hypochlorous /chloric(I)acid) .

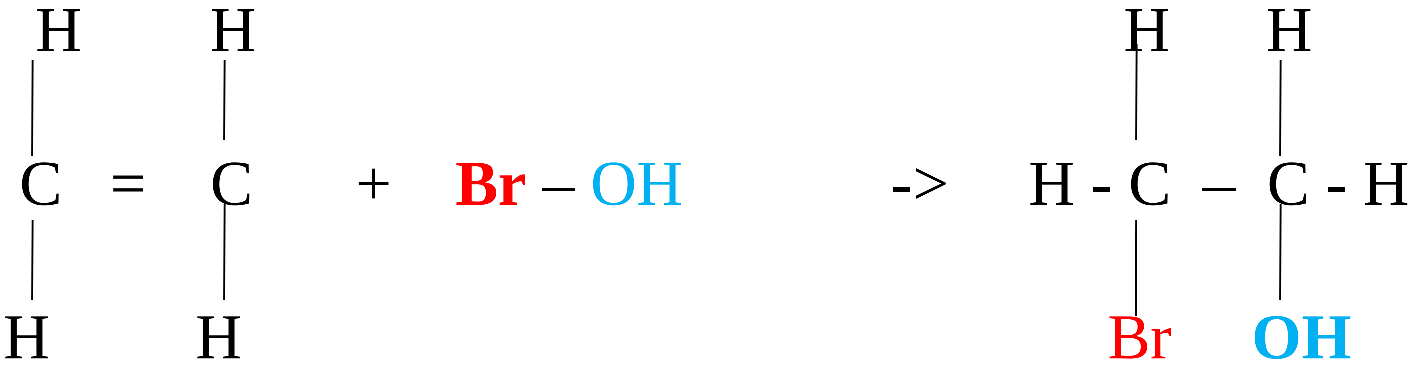
Bromine water has the formula HOBr(hydrobromic(I) acid).

During the addition reaction .the halogen move to one carbon and the OH to the other carbon in the alkene at the =C=C= double bond to form a **halogenoalkan<u>o</u>l.**

Bromine water + Alkene -> bromoalkan**o**l

Chlorine water + Alkene -> chloroalkan**o**l

<u>Examples</u>



$$\underset{H}{\overset{H}{C}} = \underset{H}{\overset{H}{C}} + Br-OH \rightarrow H-\underset{Br}{\overset{H}{C}}-\underset{OH}{\overset{H}{C}}-H$$

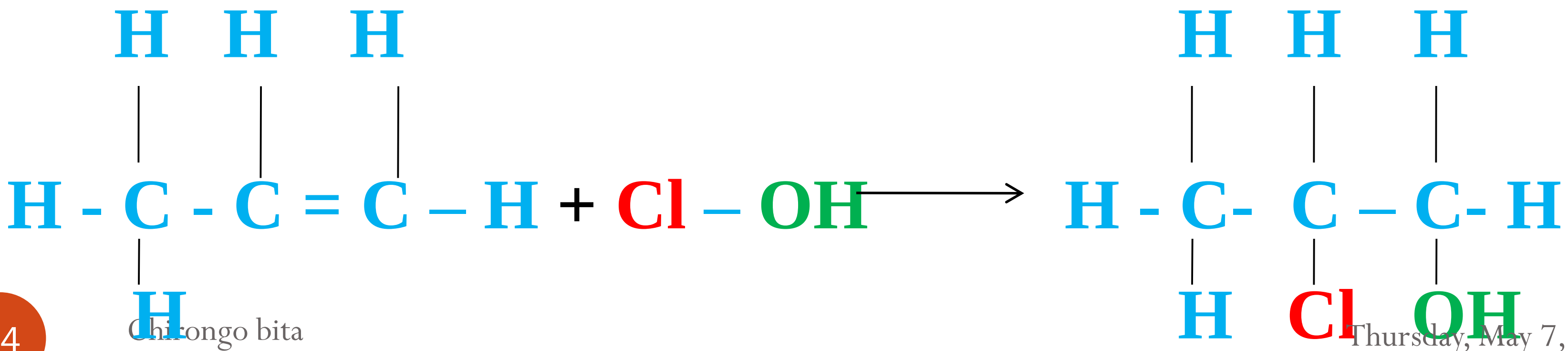
Ethene + Bromine water ⟶ bromoethanol

2.Propene with chlorine water forms 2-chloropropane or chloropropan-2-ol.

Chemical equation

$H_3C\ CH{=}CH_2 + HOCl \rightarrow H_3C\ CHCl - CH_2OH$

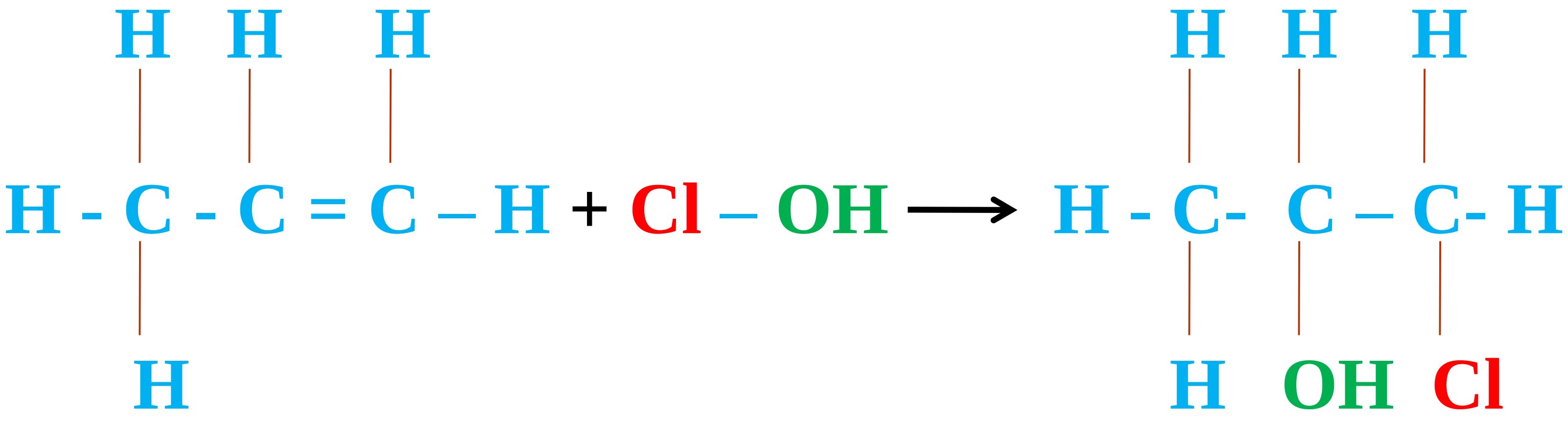
Propene + Chlorine water -> 2-chloropropan-1-ol



$$H-\underset{H}{\overset{H}{C}}-\overset{H}{C}=\overset{H}{C}-H + Cl-OH \longrightarrow H-\underset{H}{\overset{H}{C}}-\underset{Cl}{\overset{H}{C}}-\underset{OH}{\overset{H}{C}}-H$$

$H_3C\ CH{=}CH_2$ + HOCl -> $H_3C\ CHOH - CH_2Cl$

Propene + Chlorine water -> 1-chloropropan-2-ol



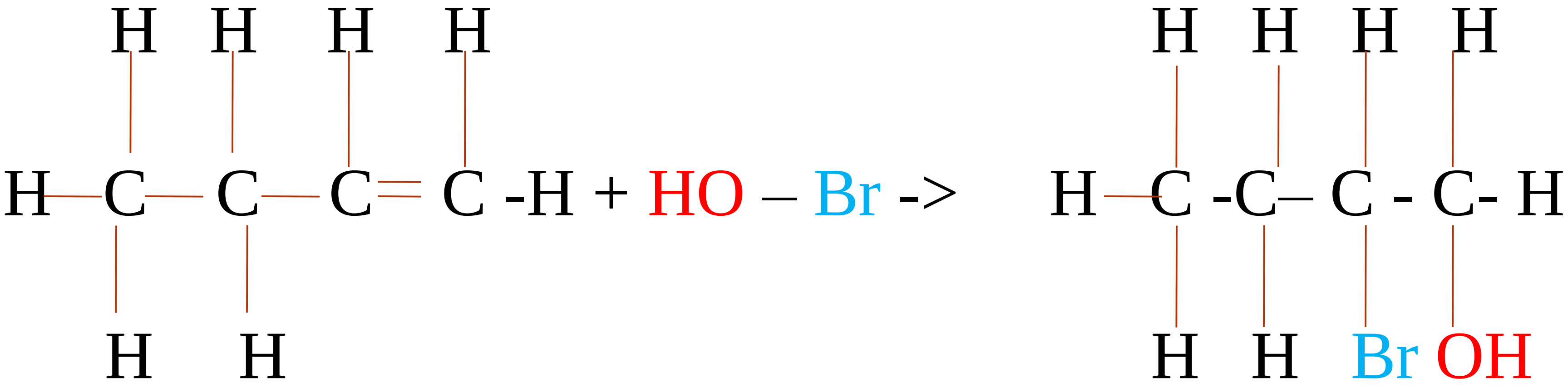
$$\underset{H}{\overset{H}{H-C}}-\overset{H}{C}=\overset{H}{C}-H + Cl-OH \longrightarrow \underset{H}{\overset{H}{H-C}}-\underset{OH}{\overset{H}{C}}-\underset{Cl}{\overset{H}{C}}-H$$

3.Both But-1-**e**ne and But-2-**e**ne react with bromine water to form 2-bromobutan-1-**ol** /3-bromobutan-2-**ol** respectively

<u>Chemical equation</u>

I.But-1-**e**ne + bromine water ⟶ 2-bromobutan-1-ol

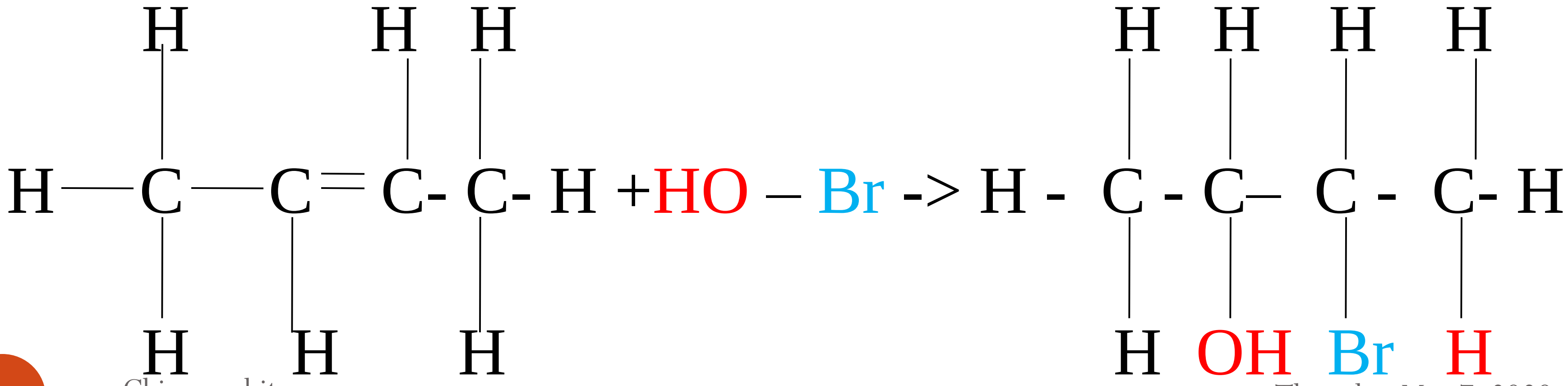
$H_3C\ CH_2\ CH{=}CH_2$+ HOBr → $H_3C\ CH_2CH\ Br -\ CH_2OH$



$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{H}{C}=\overset{H}{C}-H + HO-Br \rightarrow H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{Br}{\overset{H}{C}}-\underset{OH}{\overset{H}{C}}-H$$

But-2-**e**ne + bromine water ⟶ 3-bromobutan-2-ol

$$H_3C\ CH= CHCH_3 + HOBr \rightarrow H_3C\ CH_2OHCH\ Br\ CH_3$$



$$H-\underset{H}{\overset{H}{C}}-\underset{H}{C}=\overset{H}{C}-\underset{H}{\overset{H}{C}}-H + HO-Br \rightarrow H-\underset{H}{\overset{H}{C}}-\underset{OH}{\overset{H}{C}}-\underset{Br}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

But-1,3-di**e**ne react with bromide to form (as the main product) 2,3-dibromobutane.

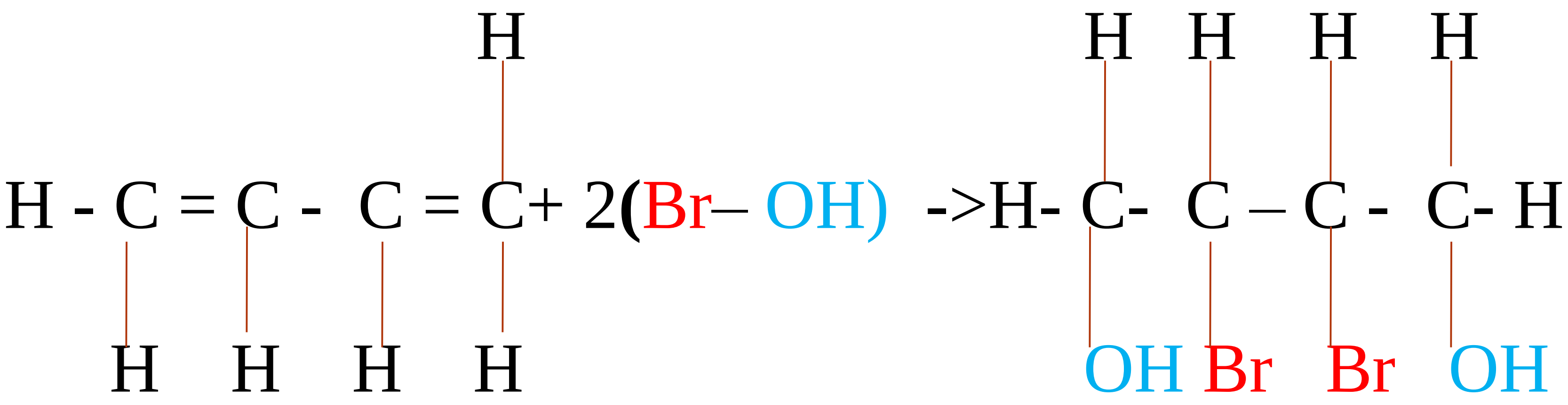
The reaction uses **two** moles of bromine water molecules to break the two double bonds.

But-1,3-di**e**ne + Bromine water ->

2,3,-dibromobutan-1,4-diol

H_2C= CH CH=CH_2+ **2**HOBr ->

CH_2OH CHBrCHBr CH_2OH



$$H-\underset{H}{C}=\underset{H}{C}-\underset{H}{C}=\overset{H}{\underset{H}{C}}+2(Br-OH)\rightarrow H-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{Br}{C}}-\overset{H}{\underset{Br}{C}}-\overset{H}{\underset{OH}{C}}-H$$

(v) Oxidation.

Alkenes are oxidized to alkanols with **duo/double** functional groups by oxidizing agents.

When an alk**e**ne is bubbled into orange acidified potassium /sodium dichromate (VI) solution, the colour of the oxidizing agent changes to green.

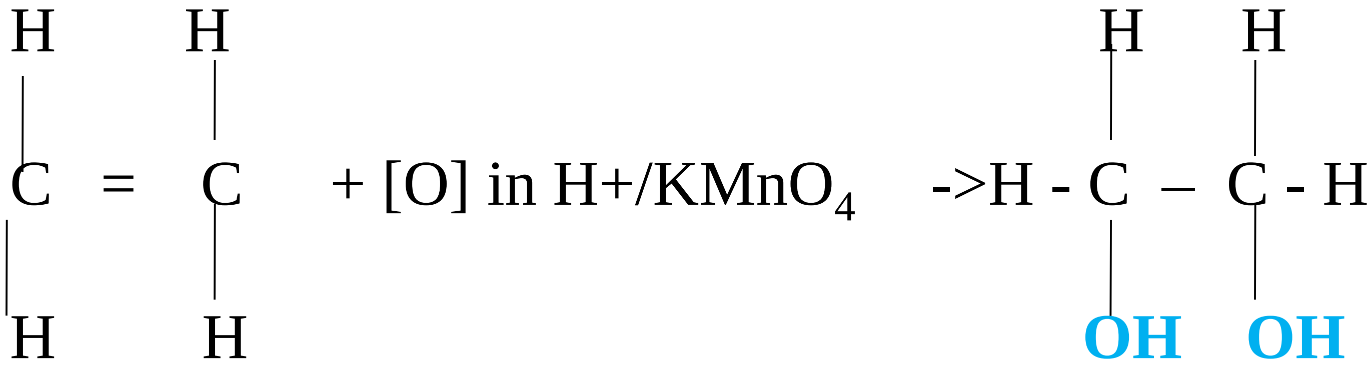
When an alk**e**ne is bubbled into purple acidified potassium / sodium manganate(VII) solution the oxidizing agent is decolorized.

Examples

1Ethene is oxidized to ethan-1,2-di**ol** by acidified potassium/sodium manganate(VII) solution/ acidified potassium/sodium dichromate(VI) solution.

The **purple** acidified potassium/sodium manganate(VII) solution is decolorized.

The **orange** acidified potassium/sodium dichromate(VI) solution turns to **green**.



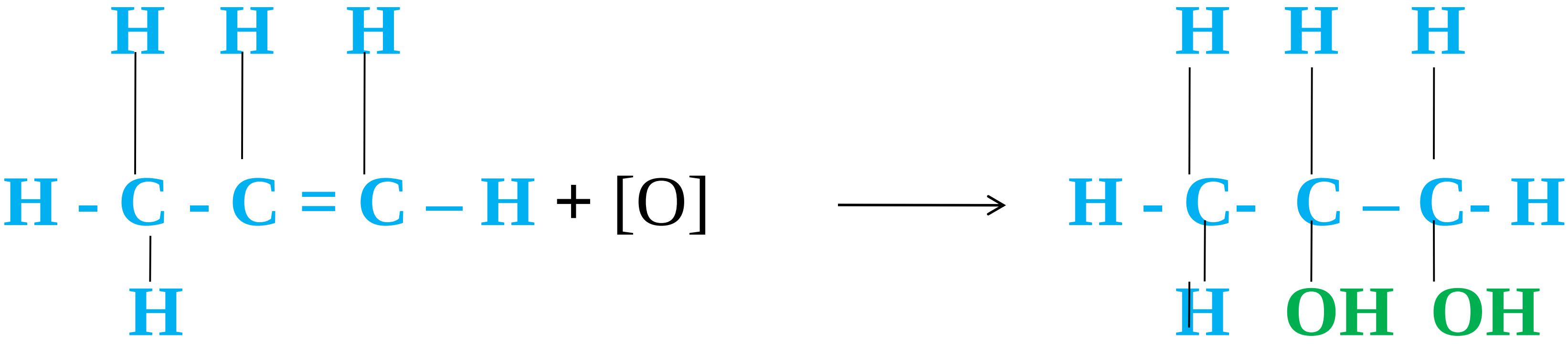
$$\underset{H}{\overset{H}{C}} \;=\; \underset{H}{\overset{H}{C}} \quad + [O] \text{ in } H+/KMnO_4 \quad \text{->}H - \underset{OH}{\overset{H}{C}} - \underset{OH}{\overset{H}{C}} - H$$

Ethene + [O] in H+/KMnO$_4$ $\longrightarrow$ ethan-1,2-di**ol**

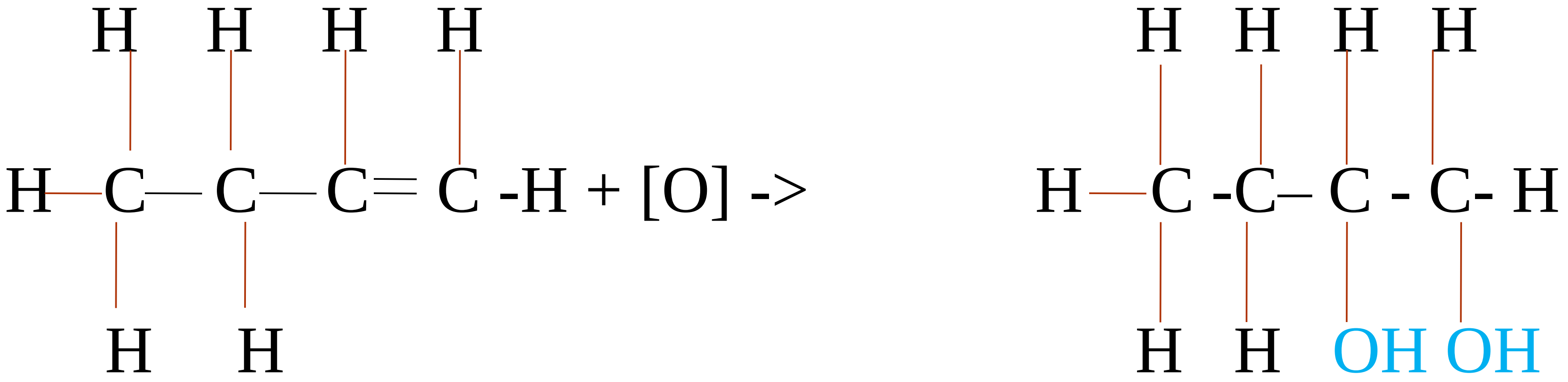
2. Propene is oxidized to propan-1,2-di**ol**

H_3C CH=CH_2 -**[O]** in H+/KMnO$_4$->H_3CCHOH -CH_2OH

Propene --**[O]** in H+/KMnO$_4$ --> propan-1,2-diol

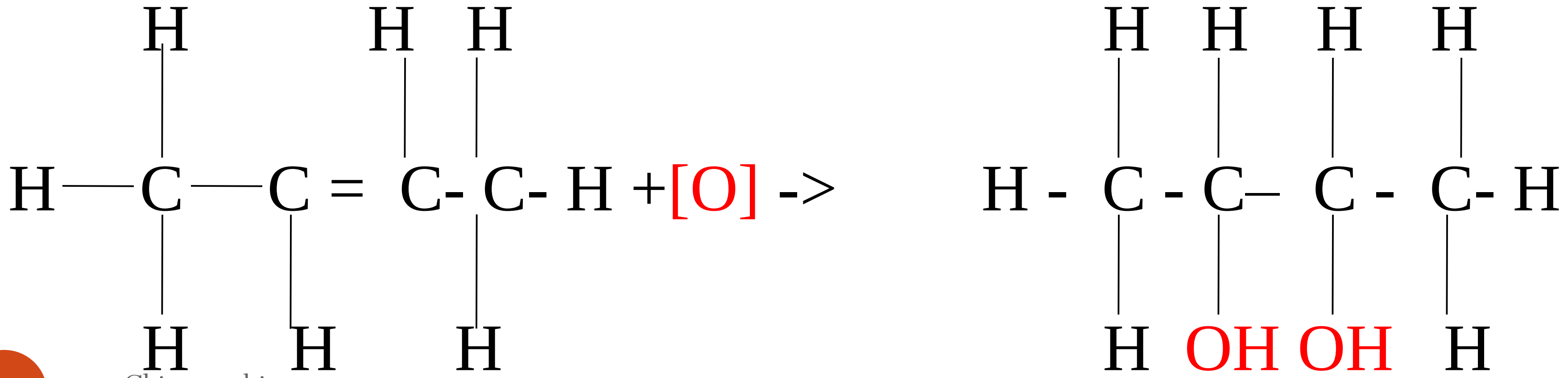


$$H - \underset{H}{\overset{H}{C}} - \overset{H}{C} = \overset{H}{C} - H + [O] \longrightarrow H - \underset{H}{\overset{H}{C}} - \underset{OH}{\overset{H}{C}} - \underset{OH}{\overset{H}{C}} - H$$



But-1-ene + [O] in H+/KMnO$_4$ -> butan-1,2-diol

But-2-ene + [O] in H+/KMnO$_4$ -> butan-2,3-diol



(v) Hydrolysis.

Hydrolysis is the reaction of a compound with water/addition of H-OH to a compound.

Alkenes undergo hydrolysis to form alkanols .This takes place in two steps:

(i)Alkenes react with **concentrated sulphuric(VI)acid** at room temperature and pressure to form **alkylhydrogen sulphate(VI)**.

Alkenes + concentrated sulphuric(VI)acid -> alkylhydrogen sulphate(VI)

(ii)On adding **water** to alkylhydrogen sulphate(VI) then warming, an alkanol is formed.

alkylhydrogen sulphate(VI) + water -warm-> Alkanol.

Examples

(i)Ethene reacts with cold concentrated sulphuric(VI)acid to form ethyl hydrogen sulphate(VII)

Examples

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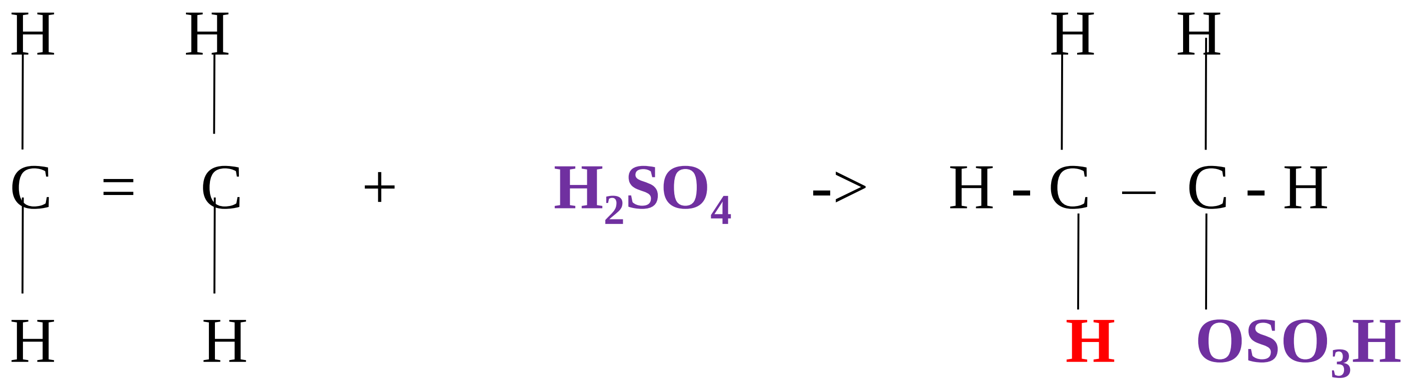
Chemical equation

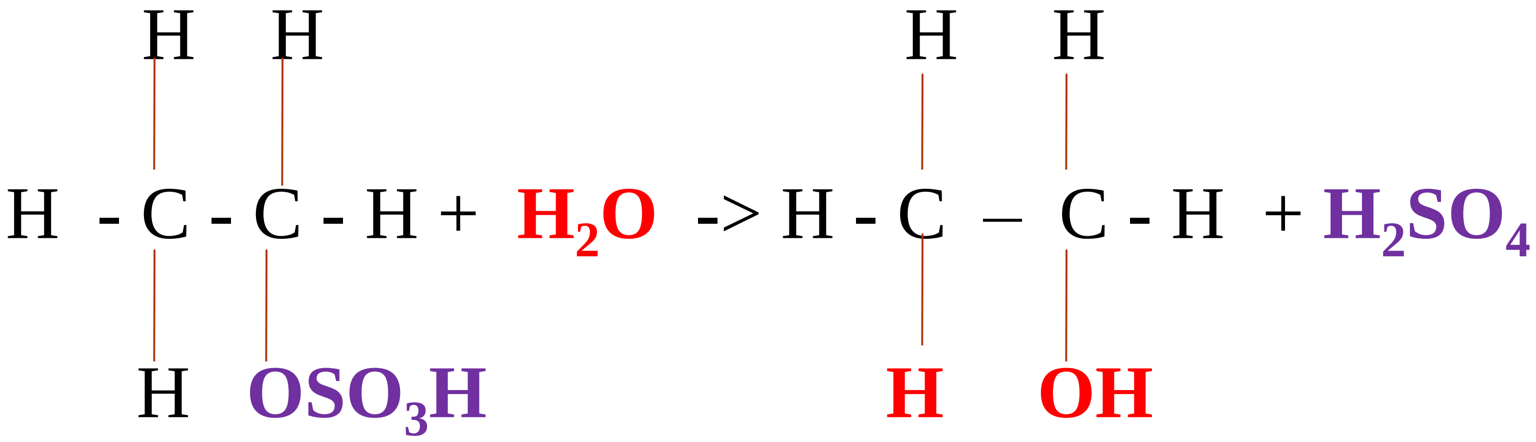
$$H_2C=CH_2 \quad + \mathbf{H_2SO_4} \quad \rightarrow \quad CH_3 - CH_2\mathbf{OSO_3H}$$



$$\begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} \quad + \quad \mathbf{H_2SO_4} \quad \rightarrow \quad \begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & \mathbf{H} & & \mathbf{OSO_3H} & & \end{array}$$

(ii) Ethylhydrogen sulphate(VI) is hydrolysed by water to ethanol

$$CH_3 - CH_2\mathbf{OSO_3H} \; + H_2O \quad \rightarrow CH_3 \; - \; CH_2OH \; + \mathbf{H_2SO_4}$$



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{OSO_3H}{C}}-H + H_2O \rightarrow H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-H + H_2SO_4$$

2. Propene reacts with cold concentrated

sulphuric(VI)acid to form propyl hydrogen sulphate(VII)

Chemical equation

$$CH_3CH{=}CH_2 \quad + \quad H_2SO_4 \quad \rightarrow \quad CH_3CH_2 - CH_2OSO_3H$$

(ii) Propylhydrogen sulphate(VI) is hydrolysed by water to propanol

Chemical equation

$$CH_3\ CH_2CH_2OSO_3H + H_2O \rightarrow CH_3CH_2OH + H_2SO_4$$

Polymers and fibres are giant molecules of organic compounds.

Polymers and fibres are formed when **small** molecules called monomers join together to form **large** molecules called polymers at high temperatures and pressures.

This process is called polymerization.

There are **two** types of polymerization:

(a)addition polymerization

(b)condensation polymerization

(a)addition polymerization

Addition polymerization is the process where a small unsaturated monomer from alkene molecule join together to form a large saturated molecule.

Only **alkenes** undergo addition polymerization.

Addition polymers are named from the alkene/monomer making the polymer and adding the prefix “**poly**” before the name of monomer to form a **polyalkene**

During addition polymerization

(i)the double bond in alkenes break

(ii)free radicals are formed

(iii)the free radicals collide with each other and join to form a larger molecule.

The more collisions the larger the molecule.

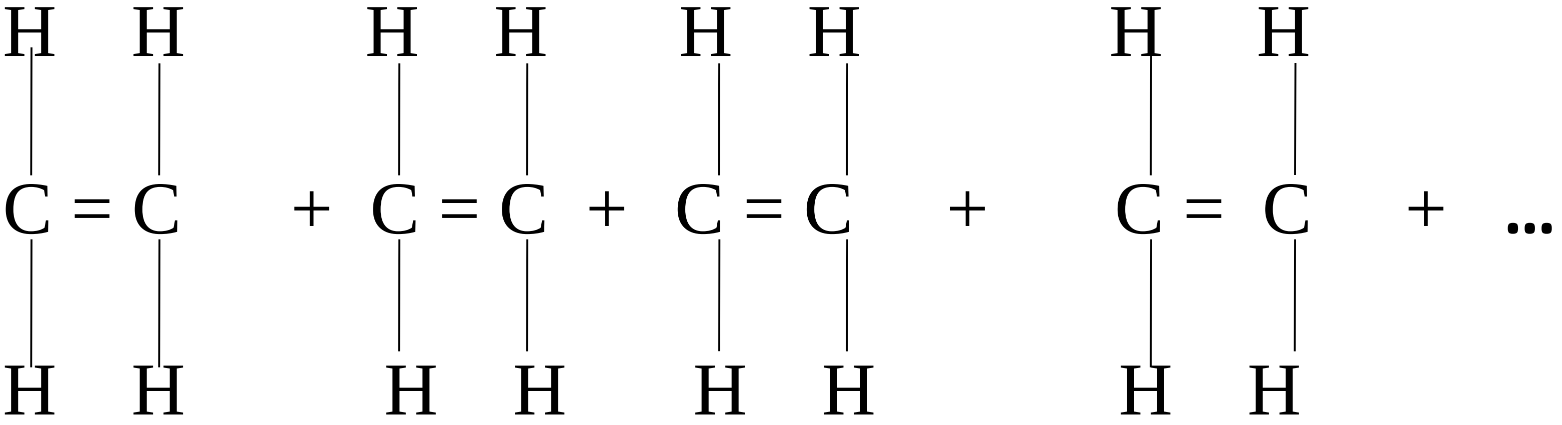
Examples of addition polymerization

1.Formation of **Polyethene**

Polyethene is an addition polymer formed when ethene molecule/monomer join together to form a large molecule/polymer at high temperatures and pressure.

During polymerization:

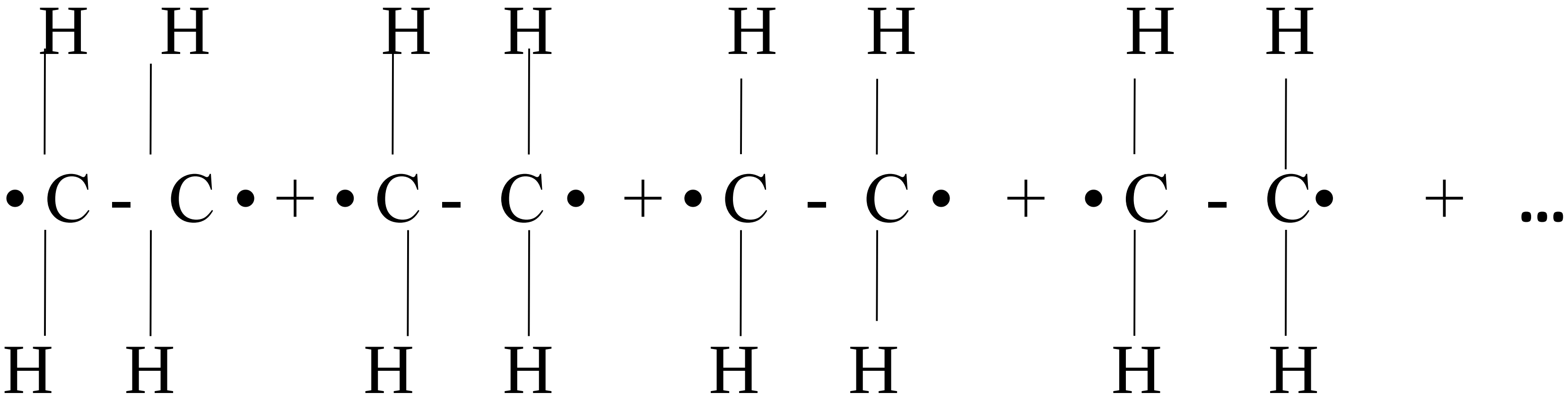
(i)many molecules are brought nearer to each other by the high pressure(reduce distance between reacting paticles)



$$\begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} + \begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} + \begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} + \begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array} + \ldots$$

Ethene +Ethene+ Ethene+ Ethene + ...

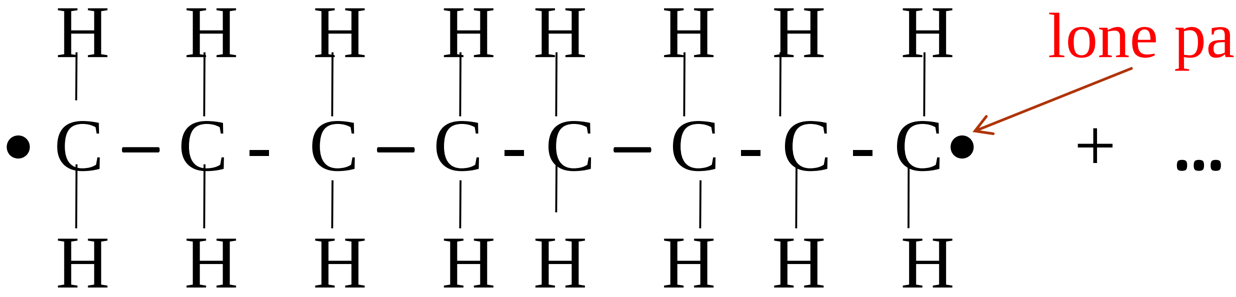
(ii)the double bond joining the ethene molecule break to free radicals



$$\begin{array}{ccc} H & & H \\ | & & | \\ \bullet C & - & C \bullet \\ | & & | \\ H & & H \end{array} + \begin{array}{ccc} H & & H \\ | & & | \\ \bullet C & - & C \bullet \\ | & & | \\ H & & H \end{array} + \begin{array}{ccc} H & & H \\ | & & | \\ \bullet C & - & C \bullet \\ | & & | \\ H & & H \end{array} + \begin{array}{ccc} H & & H \\ | & & | \\ \bullet C & - & C \bullet \\ | & & | \\ H & & H \end{array} + \ldots$$

Free ethene radical ...

(iii)the free radicals collide with each other and join to form a larger molecule

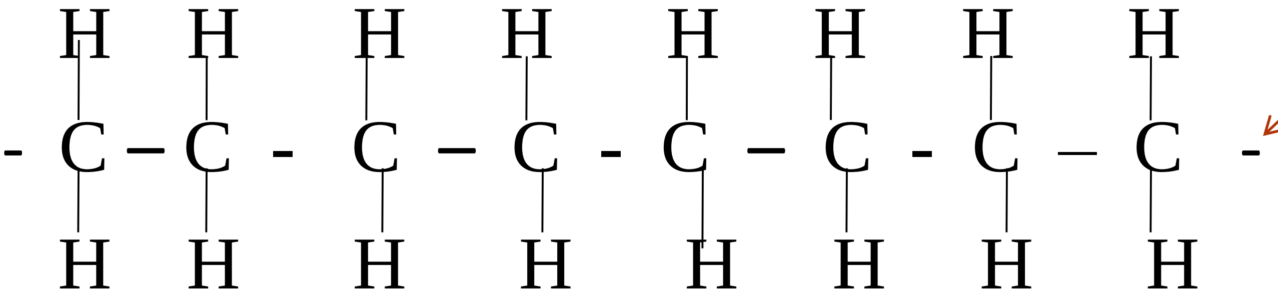


$$\bullet\,\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}\bullet \quad + \quad \ldots$$

lone pair of electrons

Lone pair of electrons can be used to join more monomers to form longer polyethene.

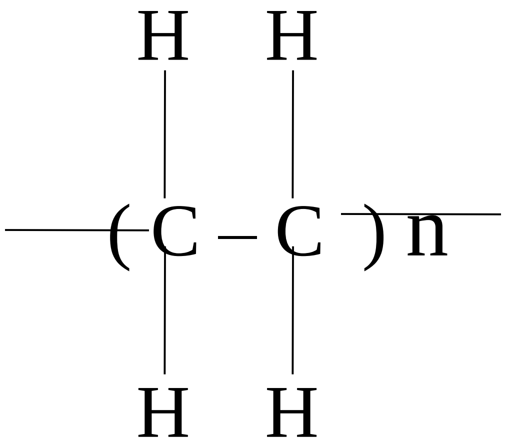
Polyethene molecule can be represented as:



$$-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-$$

extension of polymer

Since the molecule is a repetition of one monomer, then the polymer is:



$$-\!\left(\overset{H}{\underset{H}{C}} - \overset{H}{\underset{H}{C}} \right)_n\!-$$

Where n is the number of monomers in the polymer.

The number of monomers in the polymer can be determined from the molar mass of the polymer and monomer from the relationship:

Number of monomers/repeating units in monomer

$$= \frac{\text{Molar mass polymer}}{\text{Molar mass monomer}}$$

Examples

Polythene has a molar mass of 4760.Calculate the number of ethene molecules in the polymer(C=12.0, H=1.0)

Number of monomers/repeating units in polymer

$= \frac{\text{Molar mass polymer}}{\text{Molar mass monomer}}$ =>Molar mass polyethene = 4760

Molar mass ethene (C_2H_4)= 28

Substituting $\frac{4760}{28}$ = 170 ethene molecules

The **commercial** name of polyethene is **polythene**.

It is an elastic, tough, transparent and durable plastic.

Polythene is used:

(i)in making plastic bag

(ii)bowls and plastic bags

(iii)packaging materials

c)Test for the presence of $-\underset{|}{C}=\underset{|}{C}-$ double bond.

(i)Burning/combustion

All unsaturated hydrocarbons with a $-\overset{|}{C}=\overset{|}{C}-$ or $-C\equiv C-$ bond burn with a yellow **sooty** flame.

<u>Experiment</u>

Scoop a sample of the substance provided in a clean metallic spatula. Introduce it on a Bunsen burner.

Observation	Inference
Solid melt then burns with a yellow sooty flame	$-\overset{|}{C}=\overset{|}{C}-$ $-C\equiv C-$ bond

(ii)Oxidation by acidified $KMnO_4/K_2Cr_2O_7$

Bromine water ,**Chlorine** water and Oxidizing agents acidified **$KMnO_4$**/**$K_2Cr_2O_7$** change to **unique** colour in

presence of $-\overset{|}{C}=\overset{|}{C}-$ or $-C\equiv C-$ bond.

Experiment

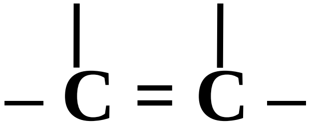
Scoop a sample of the substance provided into a clean test tube.

Add 10cm3 of distilled water.

Shake.

Take a portion of the solution mixture.

Add three drops of acidified $KMnO_4/K_2Cr_2O_7$.

Observation	Inference
Acidified $KMnO_4$ decolorized **Orange** colour of acidified $K_2Cr_2O_7$ turns **green** Bromine water is decolorized Chlorine water is decolorized	 $-\overset{\vert}{C}=\overset{\vert}{C}-$ $-C\equiv C-$ bond

(d)Some uses of Alkenes

1. In the manufacture of plastics e.g Polythene,polychloroethene,P.T.F.E
2. Hydrolysis of ethene is used in industrial manufacture of ethanol to produce beer.
3. In ripening of fruits.
4. In the manufacture of detergents.

Summary of properties of alkanes

(iii) Alkynes

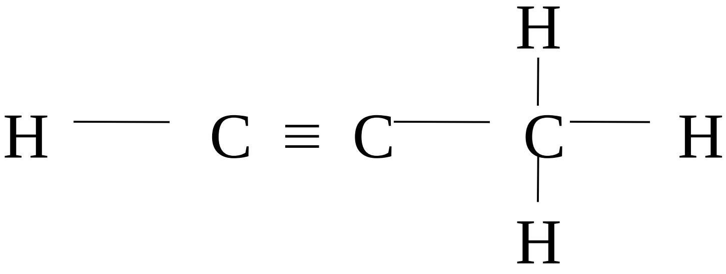
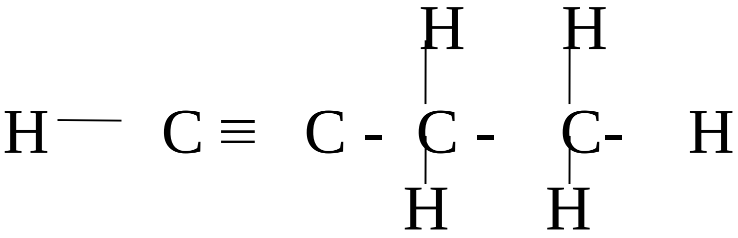
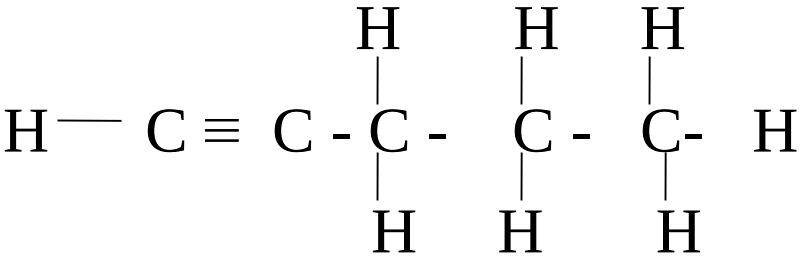
(a)Nomenclature/Naming

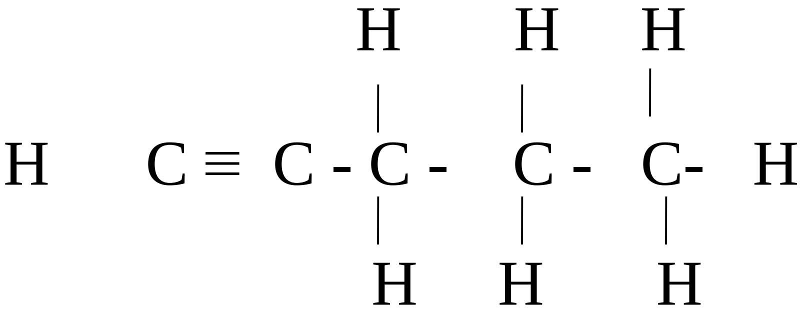
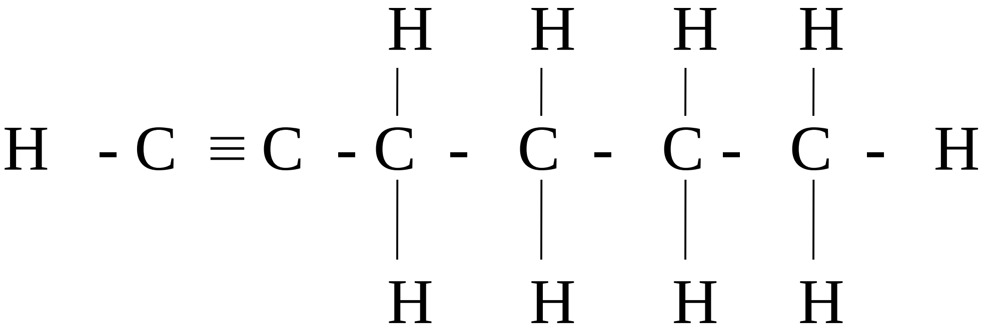
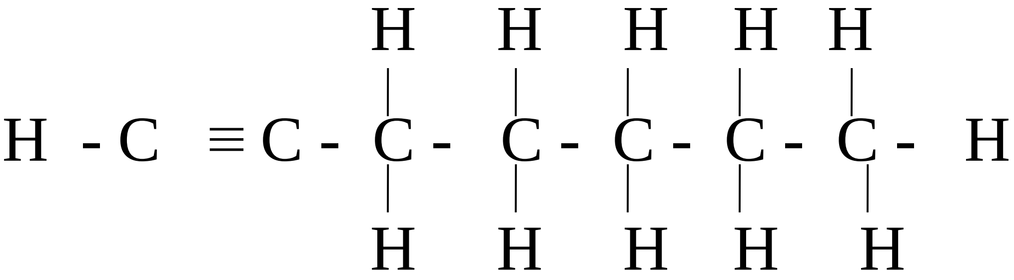
These are hydrocarbons with a general formula C_nH_{2n-2} and - **C ≡ C-** triple bond as the functional group .

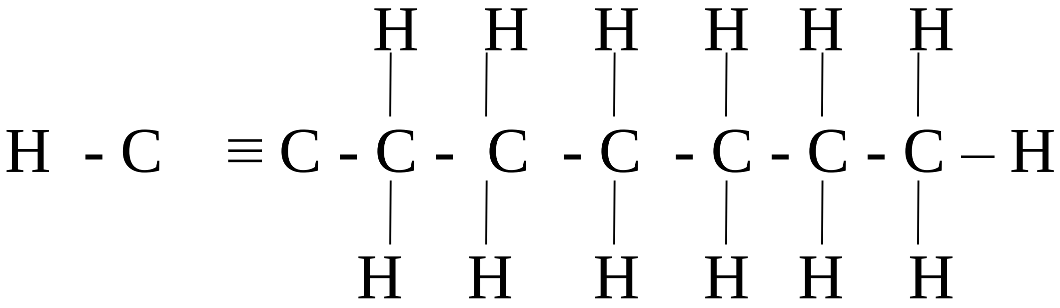
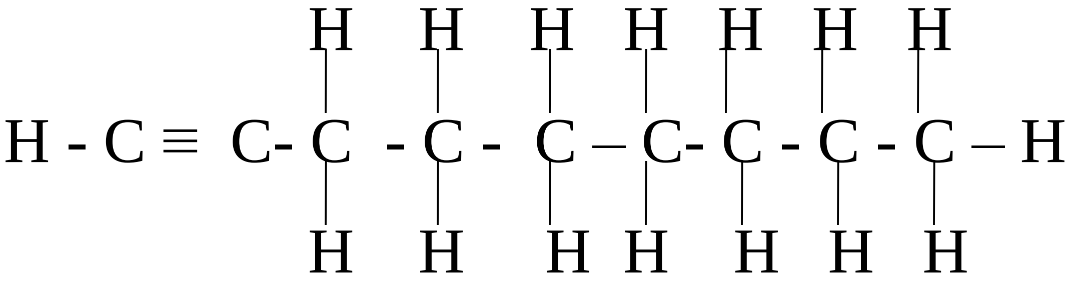
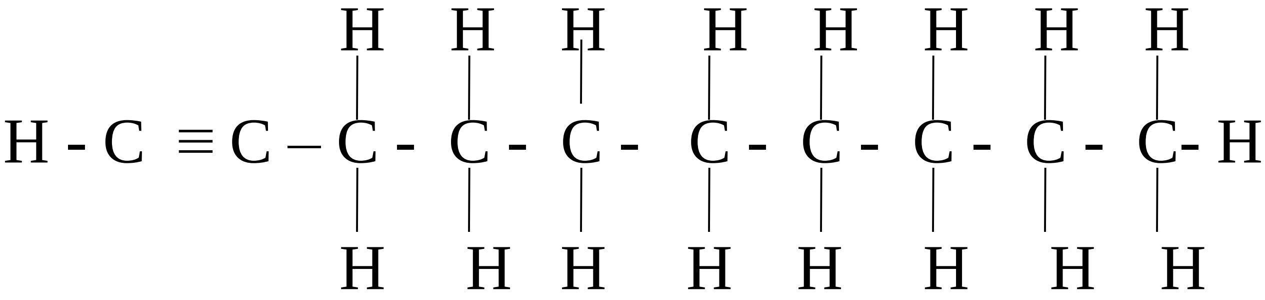
n is the number of Carbon atoms in the molecule.

The carbon atoms are linked by at least one **triple** bond to each other and single bonds to hydrogen atoms.

They include:

n	General/Molecular formula	Structural formula	Name
2	C_2H_2	$H-C\equiv C-H$	Eth**y**ne
3	C_3H_4	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-H$ $CH\ \ C\ \ CH_3$	Prop**y**ne
4	C_4H_6	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ $CH\ \ C\ \ CH_2CH_3$	But**y**ne
5	C_5H_8	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ $CH\ \ C\ \ (CH_2)_2CH_3$	Pent**y**ne

5	C_5H_8	 $H\ C \equiv C - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - H$ $CH\ \ C\ \ (CH_2)_2CH_3$	Pent**y**ne
6	C_6H_{10}	 $H - C \equiv C - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - H$ $CH\ \ C\ \ (CH_2)_3CH_3$	Hex**y**ne
7	C_7H_{12}	 $H - C \equiv C - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - \underset{H}{\overset{H}{C}} - H$ $CH\ \ C\ \ (CH_2)_4CH_3$	Hept**y**ne

8	C_8H_{14}	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ $CH\ \ C\ \ (CH_2)_5CH_3$	Octyne
9	C_9H_{16}	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ $CH\ \ C\ \ (CH_2)_6CH_3$	Nonyne
10	$C_{10}H_{18}$	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ $CH\ \ C\ \ (CH_2)_7CH_3$	Decyne

Note

1. Since carbon is **tetravalent** ,each atom of carbon in the alk**y**ne **MUST** always be bonded using **four** covalent bond /four shared pairs of electrons including at the triple bond.

2. Since Hydrogen is **monovalent** ,each atom of hydrogen in the alk**y**ne **MUST** always be bonded using **one** covalent bond/one shared pair of electrons.

3. One member of the alk**y**ne ,like alk**e**nes and alk**a**nes, differ from the next/previous by a CH_2 group(molar mass of 14 **a**tomic **m**ass **u**nits).

They thus form a homologous series.

e.g

Prop**y**ne differ from eth**y**ne by (14 a.m.u) one carbon and two Hydrogen atoms from eth**y**ne.

4.A homologous series of alkynes like that of alkanes:

(i) differ by a CH_2 group from the next /previous consecutively

(ii) have similar chemical properties

(iii)have similar chemical formula with general formula C_nH_{2n-2}

(iv)the physical properties also show steady gradual change.

5.The $-C\equiv C-$ triple bond in alkyne is the functional group. The functional group is the **reacting site** of the alkynes.

6. The $-C\equiv C-$ triple bond in alkyne can easily be broken to accommodate more /four more monovalent atoms.

The $-C\equiv C-$ triple bond in alkynes make it thus **unsaturated** like alkenes.

7. Most of the reactions of alkynes like alkenes take place at the $-C\equiv C-$ **triple** bond.

(b)Isomers of alkynes

Isomers of alkynes have the same molecular **general formula** but different molecular **structural formula**.

Isomers of alkynes are also named by using the IUPAC (**I**nternational Union of **P**ure and **A**pplied **C**hemistry) system of **nomenclature /naming.**

The IUPAC system of nomenclature of naming alkynes uses the following basic rules/guidelines:

1.Identify the longest continuous/straight carbon chain which contains the $-C\equiv C-$ **triple** bond to get/determine the **parent** alkene.

2. Number the longest chain form the end of the chain which contains the $-C\equiv C-$ **triple** bond so as $-C\equiv C-$ **triple** bond get lowest number possible.

3 Indicate the positions by splitting “**alk**-position-**yne**” e.g. but-2-yne, pent-1,3-diyne.

4.The position **indicated** must be for the carbon atom at the **lower** position in the $-C\equiv C-$ **triple bond.** i.e

But-2-yne means triple at Carbon “2”and “3”

Pent-1,3-diyne means two $-C\equiv C-$ triple bonds; one between carbon “1” and “2”and between carbon “3” and “4”

5. Determine the position, number and type of branches.

Name them as methyl, ethyl, propyl e.tc. according to the number of alkyl carbon chains attached to the alkyne.

Name them fluoro-,chloro-,bromo-,iodo- if they are halogens

6.Use prefix di-,tri-,tetra-,penta-,hexa- to show the number of **triple** $-C\equiv C-$ bonds and **branches** attached to the alk**y**ne.

7.Position isomers can be formed when the $-C\equiv C-$ triple bond is shifted between carbon atoms e.g.

But-2-**y**ne means triple $-C\equiv C-$ is between Carbon “2”and “3”

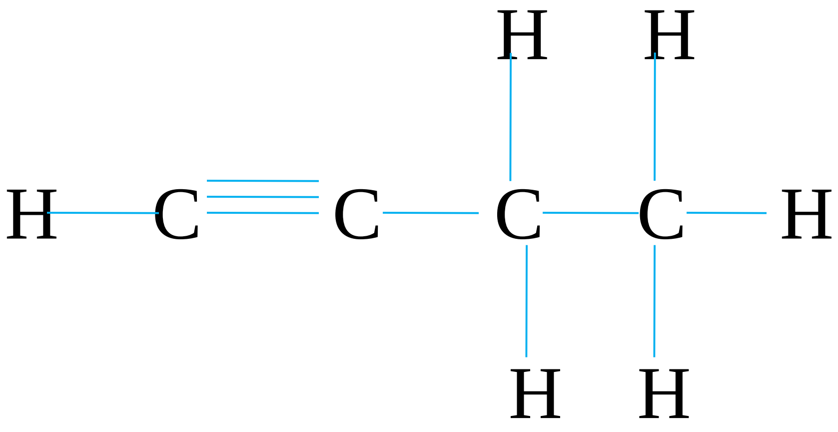
But-1-**y**ne means triple $-C\equiv C-$ Carbon “1”and “2”

But-1-**y**ne and But-2-yne are position isomers of But**y**ne.

9. Like alkanes and alkenes , an alkyl group can be attached to the alk**y**ne. Chain/branch isomers are thus formed.e.g.

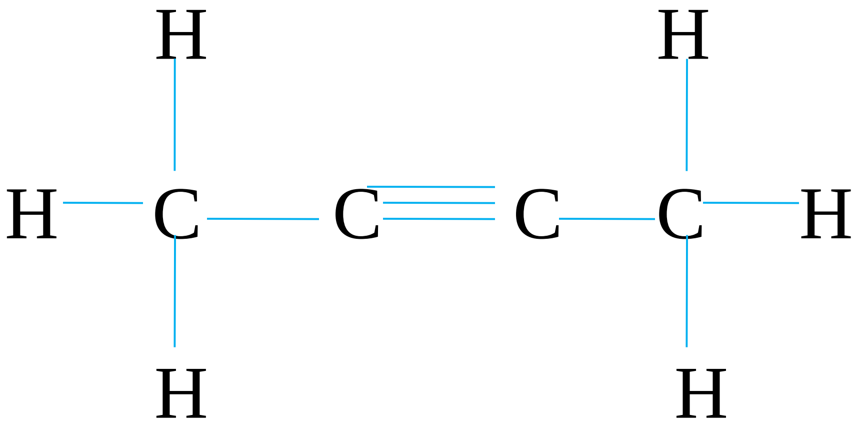
But**y**ne and 2-methyl prop**y**ne both have the same general formular but different branching chain.

Practice on IUPAC nomenclature of alkynes



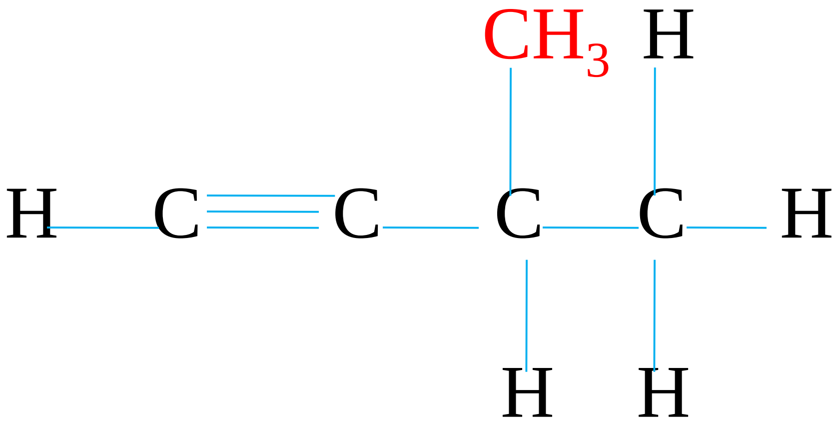
$$H-C\equiv C-CH_2-CH_3$$

But-1-yne(triple bond is between carbon “1-2”



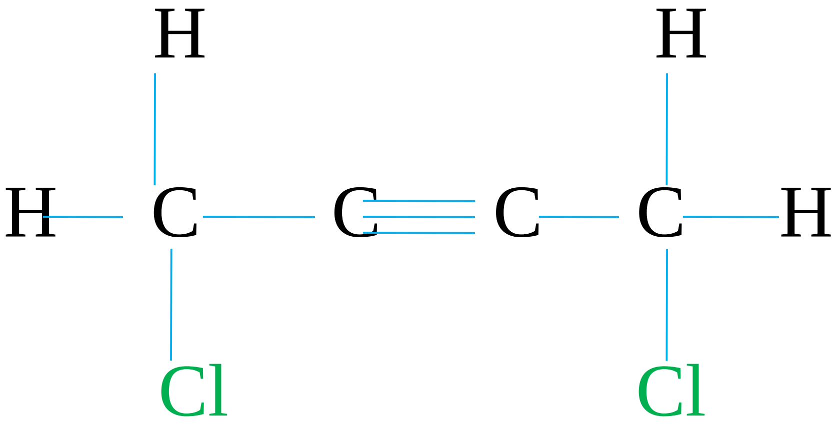
$$H_3C-C\equiv C-CH_3$$

But-2-yne(triple bond is between carbon “2-3”



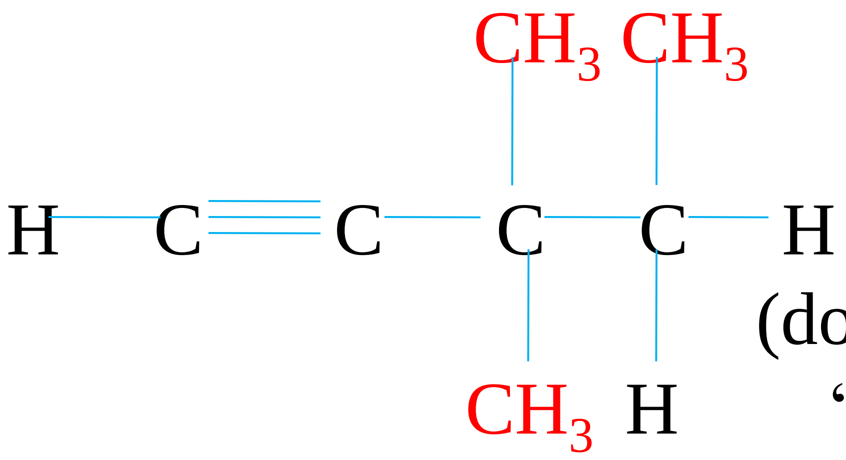
$$\begin{array}{ccccccccccc} & & & & & & CH_3 & & H & & \\ & & & & & & | & & | & & \\ H & - & C & \equiv & C & - & C & - & C & - & H \\ & & & & & & | & & | & & \\ & & & & & & H & & H & & \end{array}$$

3-methylbut-1-yne(double bond is between carbon “3-4” and methyl group at carbon “3”



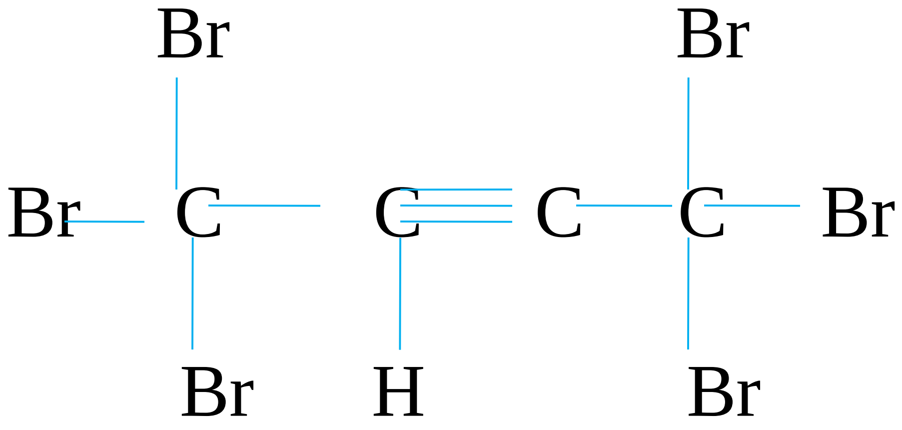
$$\begin{array}{ccccccccccc} & & H & & & & & & H & & \\ & & | & & & & & & | & & \\ H & - & C & - & C & \equiv & C & - & C & - & H \\ & & | & & & & & & | & & \\ & & Cl & & & & & & Cl & & \end{array}$$

1,4-dichlorobut-2-yne (double bond is between carbon “2-3” and two chlorine atoms at carbon “1&4”



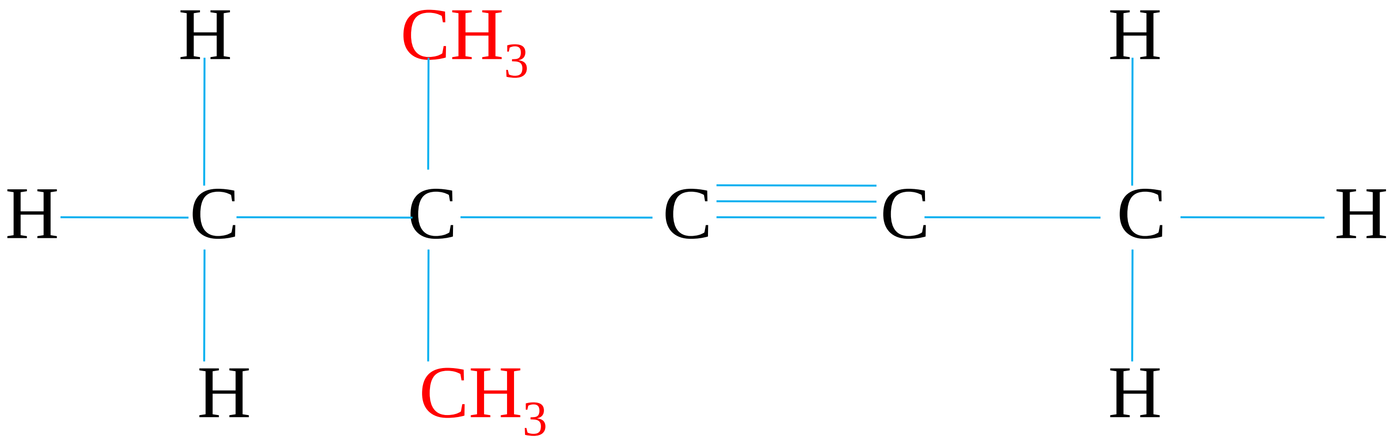
$$H-C\equiv C-\underset{CH_3}{\overset{CH_3}{C}}-\underset{H}{\overset{CH_3}{C}}-H$$

2,3,3-trimethylbut-1-yne (double bond is between carbon "1-2" and methyl group at carbon "2,3,3"



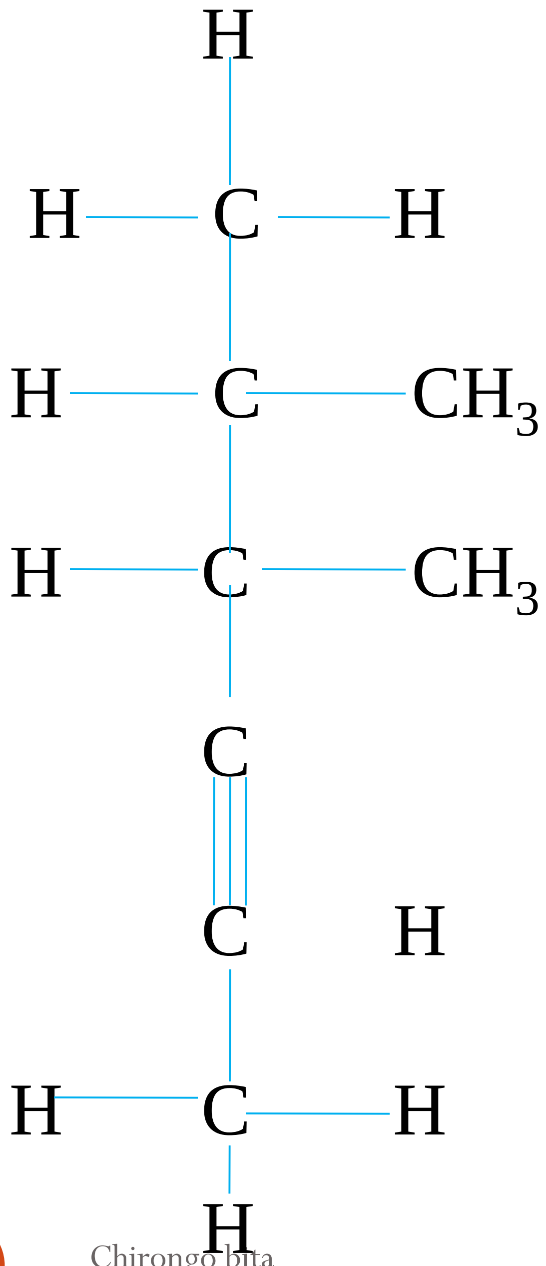
$$Br-\underset{Br}{\overset{Br}{C}}-\underset{H}{C}\equiv C\;\;C-\underset{Br}{\overset{Br}{C}}-Br$$

1,1,1,4,4,4-hexabromobut-2-yne carbon "2-3" and six bromine atoms at carbon "1,4"



4,4-dimethylpent-2-yne
(triple bond between Carbon “2-3” and two methyl group at carbon “4”)

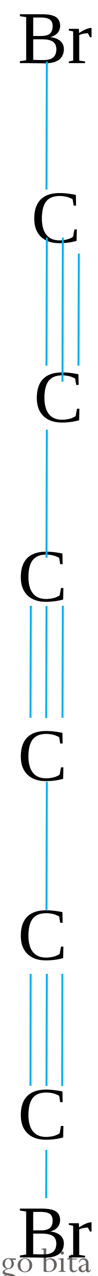
$H_2C\ CHCH_2\ C\ CH$ Pent -1- yne
(After drawing the structural formula the triple bond is between Carbon “1-2”



4,5-dimethylhex-2- yne

(i)Triple bond between Carbon “2-3,”

(ii)two methyl groups at carbon “4,5”)



1,6-dibromohex-1,3,5-triyne

(i)triple bond between Carbon "**1**-2, **3**-4, **5**-6,"

(ii)two Bromine atoms at carbon "1,6")

$H_3C\ CH(CH_3)C(CH_3)_2\ CCH$

3,3,4-trimethylpent -1- yne

$HC\ C\ C(CH_3)_2\ C(CH_3)_2\ CH_3$

3,3,4,4-tetramethylpent -1- yne

$H_3C\ C(CH_3)\ _2C\ C\ CH_3$

4,4-dimethylpent -2- yne

$HC\ CC(CH_3)\ _2\ C\ CH_3$

3,3,-dimethylpent -1,4- diyne

$BrC\ CC\ C\ CH_3$

1-bromopent -1,3- diyne

HC CC CH

But -1,3- diyne

BrC CBCB CBr

1,4-dibromobut -1,3- diyne

IC C C CI

1,4-diiodobut -1,3- diyne

$HC\ C\ C(CH_3)\ _2C(CH_3)\ _2\ CCH$

3,3,4,4-tetramethylhex -1,6- diyne

HCCCH

prop -1,2,- diyne

(c)Preparation of Alkynes.

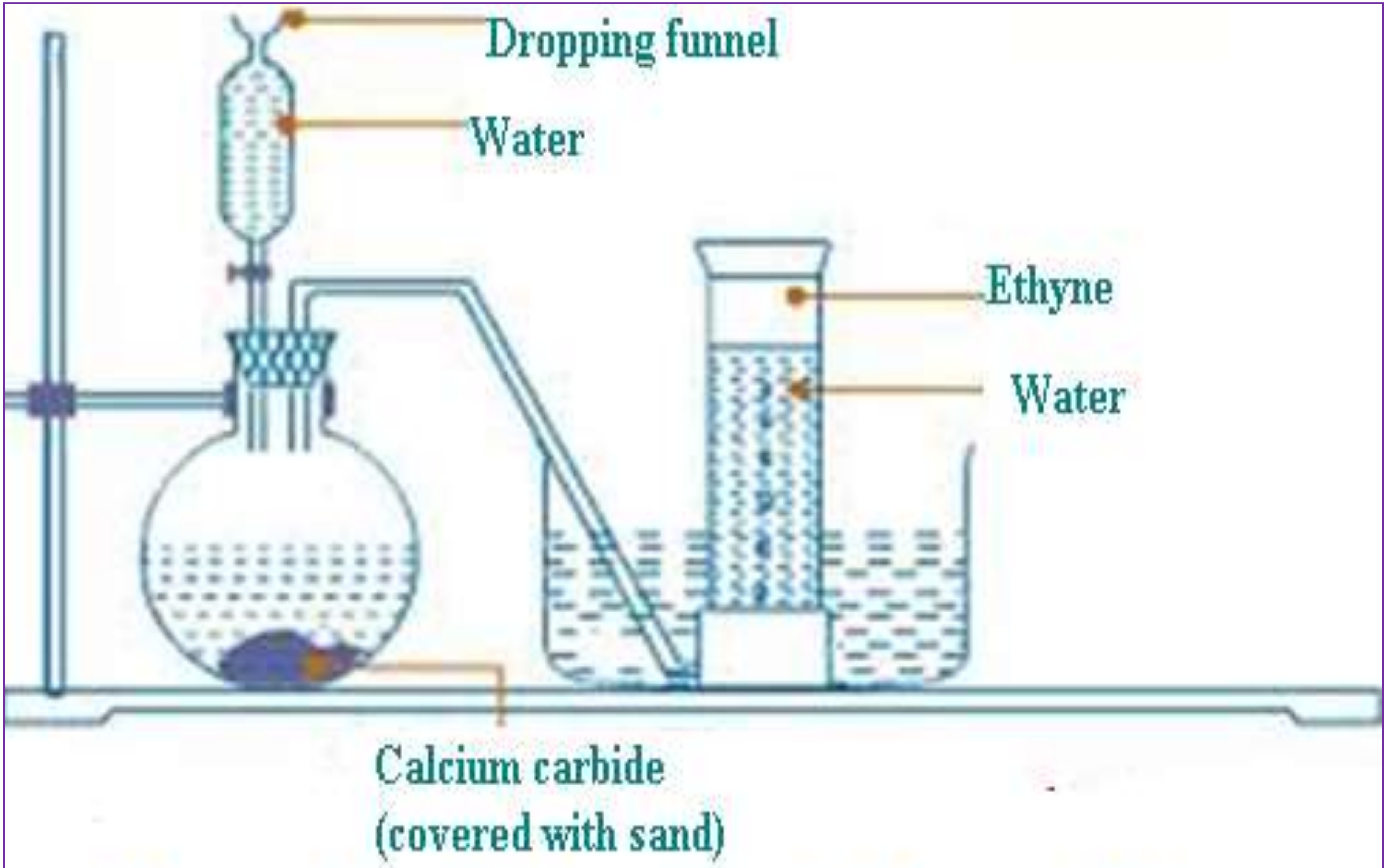
Ethyne is prepared from the reaction of **water** on **calcium carbide**.

The reaction is highly exothermic and thus a layer of sand should be put above the calcium carbide to absorb excess heat to prevent the reaction flask from breaking.

Copper(II)sulphate(VI) is used to catalyze the reaction

Chemical equation

$$CaC_2(s) + 2\,H_2O(l) \rightarrow Ca(OH)_2\,(aq) + C_2H_2\,(g)$$



Preparation of Ethyne from Calcium carbide

(d)Properties of alkynes

I. Physical properties

Like alk**a**nes and alk**e**nes,alkynes are colourles gases, solids and liquids that are not poisonous.

They are slightly soluble in water.

The solubility in water decrease as the carbon chain and as the molar mass increase but very soluble in organic solvents like tetrachloromethane and methylbenzene.

Ethyne has a pleasant taste when pure.

The melting and boiling point increase as the carbon chain increase.

This is because of the increase in van-der-waals /intermolecular forces as the carbon chain increase.

The 1st three straight chain alkynes (ethyne,propyne and but-1-yne)are gases at room temperature and pressure. The density of straight chain alkynes increase with increasing carbon chain as the intermolecular forces increases reducing the volume occupied by a given mass of the alkyne.

Summary of physical properties of the 1st five alkenes

Alkyne	General formula	Melting point(°C)	Boiling point(°C)	State at room(298K) temperature and pressure atmosphere (101300Pa)
Ethyne	$CH\ CH$	-82	-84	gas
Propyne	$CH_3\ C\ CH$	-103	-23	gas
Butyne	$CH_3CH_2\ CCH$	-122	8	gas
Pent-1-yne	$CH_3(CH_2)_2\ CCH$	-119	39	liquid
Hex-1-yne	$CH_3(CH_2)_3C\ CH$	-132	71	liquid

II. Chemical properties

(a)Burning/combustion

Alk**y**nes burn with a **yellow**/ luminous very **sooty**/ smoky flame in **excess** air to form carbon(IV) oxide and water.

Alk**y**ne + Air -> carbon(**IV**) oxide +water

Alk**e**nes burn with a **yellow**/ luminous very**sooty**/ smoky flame in **limited** air to form carbon(II) oxide/carbon and water.

Alk**y**ne + Air -> carbon(**II**) oxide /carbon +water

Burning of alk**y**nes with a **yellow**/ luminous very **sooty**/ smoky flame is a confirmatory test for the **presence** of the **- C = C –** triple bond because they have very **high C:H ratio.**

Examples of burning alkynes

1.(a) Ethyne when ignited burns with a **yellow** very **sooty** flame in **excess** air to form carbon(IV) oxide and water.

Ethyne + Air -> carbon(**IV**) oxide + water

Excess air/oxygen

$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l/g)$

(b) Ethyne when ignited burns with a **yellow sooty** flame in **limited** air to form a mixture of unburnt carbon and carbon(II) oxide and water.

Limited air

Ethyne + Air -> carbon(**II**) oxide + carbon + water

$C_2H_2(g) + O_2(g) \rightarrow 2CO(g) + C + 2H_2O(l/g)$

2.(a) Prop**y**ne when ignited burns with a **yellow sooty** flame in **excess** air to form carbon(IV) oxide and water.

Excess air/oxygen

Prop**y**ne + Air -> carbon(**IV**) oxide + water

$C_3H_4(g) + 4O_2(g) \rightarrow 3CO_2(g) + 2H_2O(l/g)$

(a) Prop**y**ne when ignited burns with a **yellow sooty** flame in **limited** air to form carbon(II) oxide and water.

Limited air

Prop**e**ne + Air -> carbon(**IV**) oxide +water

$2C_3H_4(g) + 5O_2(g) \rightarrow 6CO(g) + 4H_2O(l/g)$

(b)Addition reactions

An addition reaction is one which an unsaturated compound reacts to form a saturated compound.

Addition reactions of alk**y**nes are also named from the reagent used to cause the addition/convert the triple $-C\equiv C-$ to single C- C bond

(i)Hydrogenation

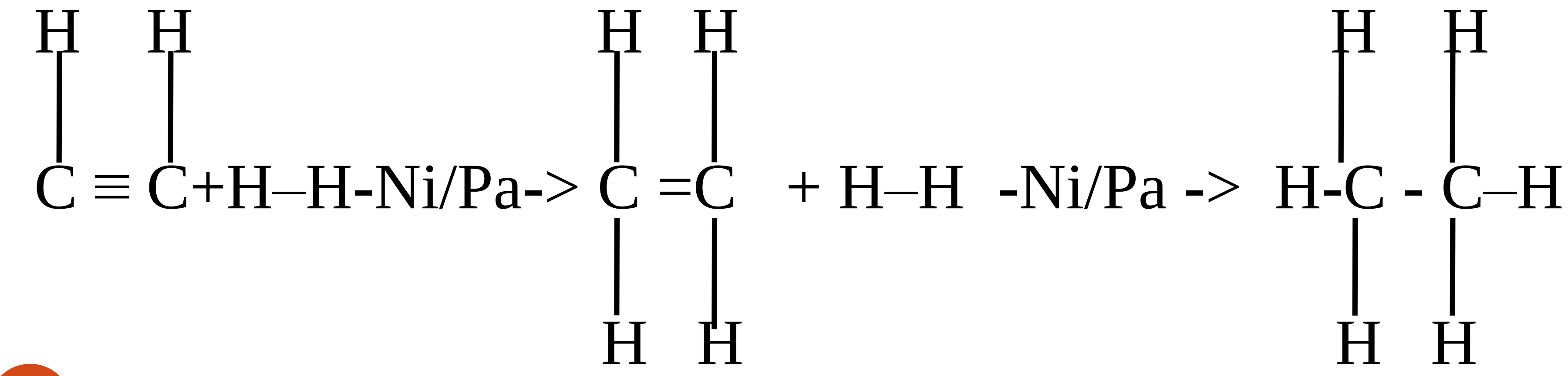
Hydrogenation is an addition reaction in which **hydrogen** in presence of **Palladium/Nickel** catalyst at 150^{o}C temperatures react with alk**y**nes to form alk**e**nes then alk**a**nes.

Examples

1.During hydrogenation, **two** hydrogen atom in the hydrogen molecule attach itself to one carbon and the other **two** hydrogen to the second carbon breaking the **triple** bond to **double** the **single**.

Chemical equation

$$HC \equiv CH + H_2 \text{ -Ni/Pa ->} H_2C = CH_2 + H_2 \text{ -Ni/Pa ->} H_3C\text{-}CH_3$$

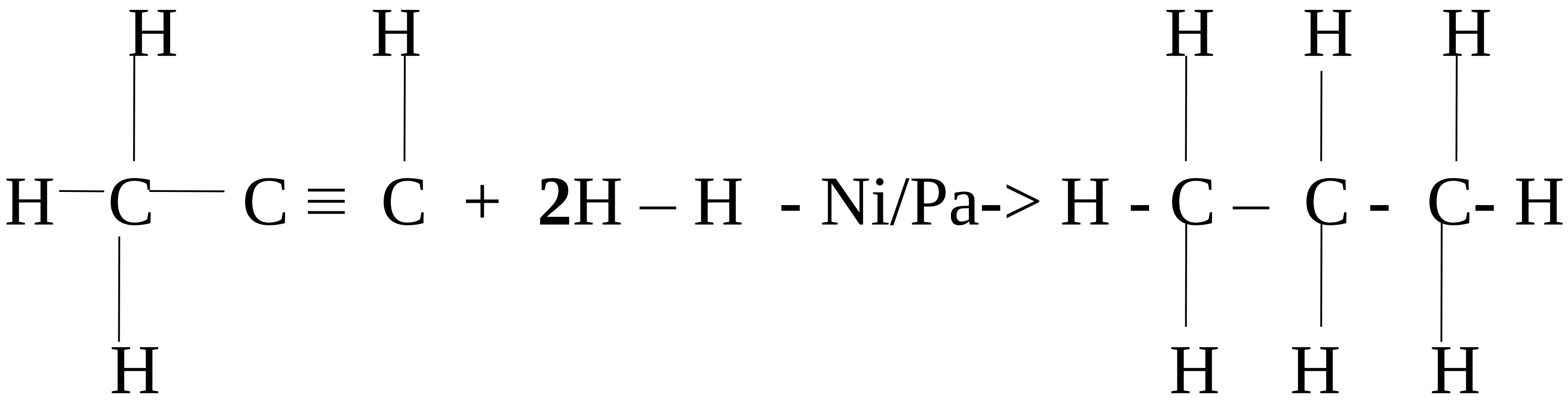


$$\overset{H}{\underset{}{C}} \equiv \overset{H}{\underset{}{C}} + H\text{–}H \text{-Ni/Pa->} \overset{H}{\underset{H}{C}} = \overset{H}{\underset{H}{C}} + H\text{–}H \text{ -Ni/Pa ->} H\text{-}\overset{H}{\underset{H}{C}} - \overset{H}{\underset{H}{C}}\text{–}H$$

2.Prop**y**ne undergo hydrogenation to form Propane

Chemical equation

$H_3C\ CH \equiv CH_2 \quad + \quad \mathbf{2}H_2 \quad \text{-Ni/Pa->} \quad H_3C\ CH - CH_3$



$$\mathrm{H-\underset{H}{\overset{H}{C}}-C\equiv\overset{H}{C}\ +\ \mathbf{2}H-H\ \text{- Ni/Pa->}\ H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H}$$

3.Both But-1-**y**ne and But-2-**y**ne undergo hydrogenation to form Butane

Chemical equation

But-1-**y**ne + Hydrogen –Ni/Pa-> Butane

$H_3C\ CH_2\ C \equiv CH + \mathbf{2}H_2\ \text{-Ni/Pa->}\ H_3C\ CH_2CH_2 - CH_3$

(ii) Halogenation.

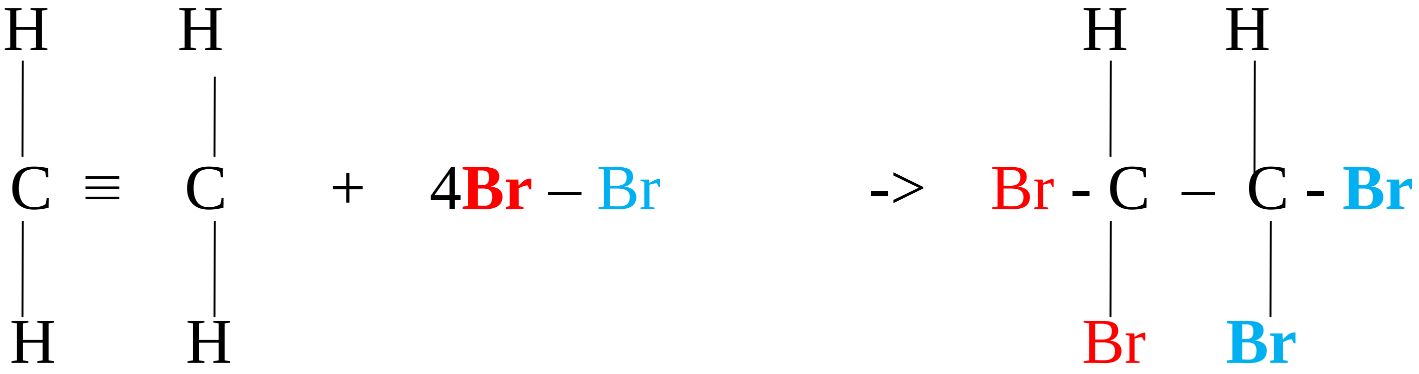
Halogenation is an addition reaction in which a halogen (Fluorine, chlorine, bromine, iodine) reacts with an alk**y**ne to form an halogenoalk**e**ne then halogenoalk**a**ne. The reaction of alkynes with halogens is **faster** than with alkenes.

The triple bond in the alk**y**ne **break** and form a double then single bond.

The colour of the halogen **fades** as the number of **moles** of the halogens **remaining** unreacted decreases.

Two bromine atoms bond at the 1st carbon in the triple bond while the other two goes to the 2nd carbon.

Examples



$$\overset{H}{\underset{H}{C}} \equiv \overset{H}{\underset{H}{C}} + 4Br-Br \rightarrow Br-\overset{H}{\underset{Br}{C}}-\overset{H}{\underset{Br}{C}}-Br$$

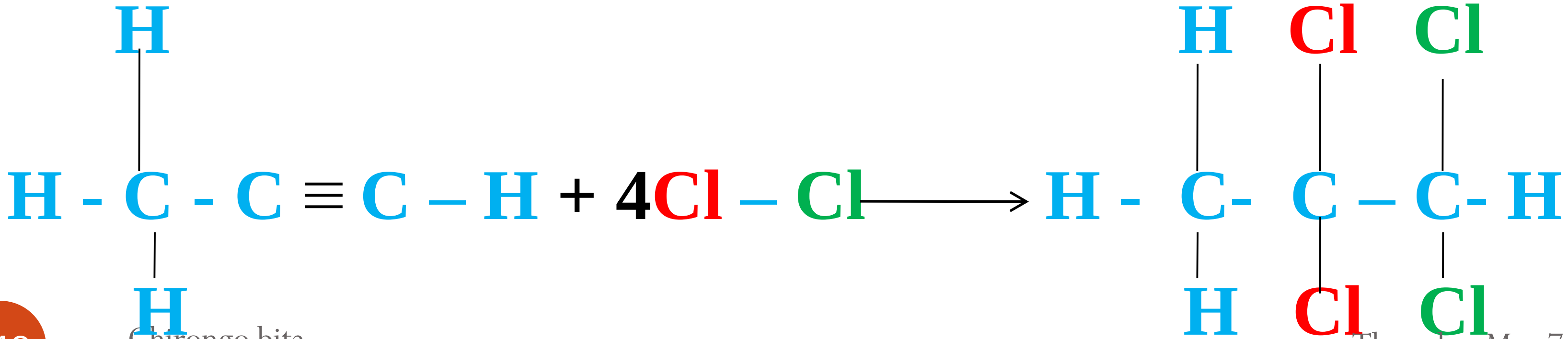
Ethyne + Bromine → 11,2,2-tetrabromoethane

2.Propyne with chlorine forms 1,2-tetrachloropropane.

Chemical equation

$H_3C\ C \equiv CH \quad + \quad 2Cl_2 \quad \rightarrow \quad H_3C\ CCl_2 - CH\ Cl_2$

Propyne + Chlorine 1,1,2,2-terachloropropane



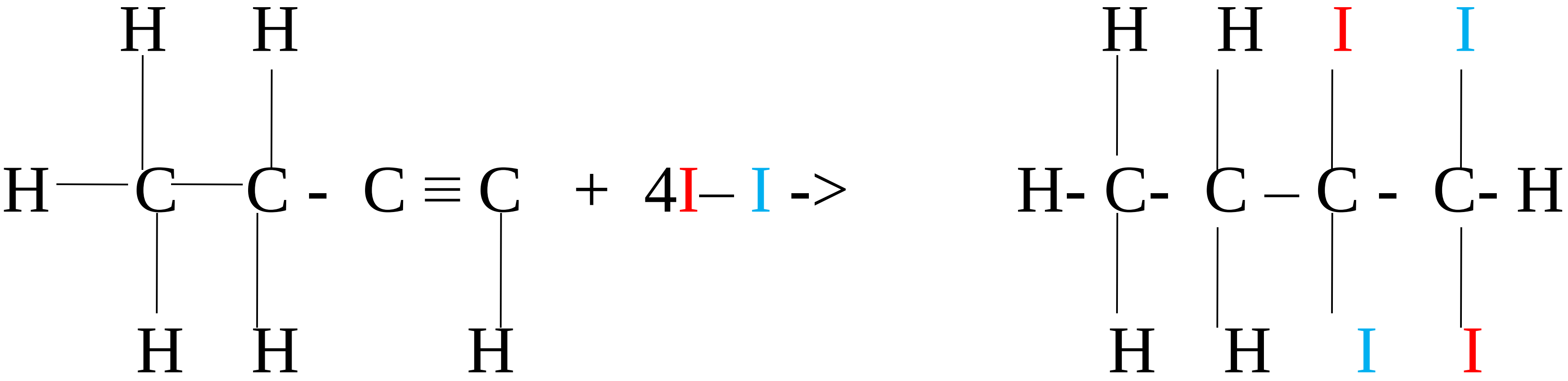
$$H-\overset{H}{\underset{H}{C}}-C \equiv C-H + 4Cl-Cl \longrightarrow H-\overset{H}{\underset{H}{C}}-\overset{Cl}{\underset{Cl}{C}}-\overset{Cl}{\underset{Cl}{C}}-H$$

3.Both But-1-**y**ne and But-2-**y**ne undergo halogenation with iodine to form 1,1,2,2-tetraiodobutane

Chemical equation

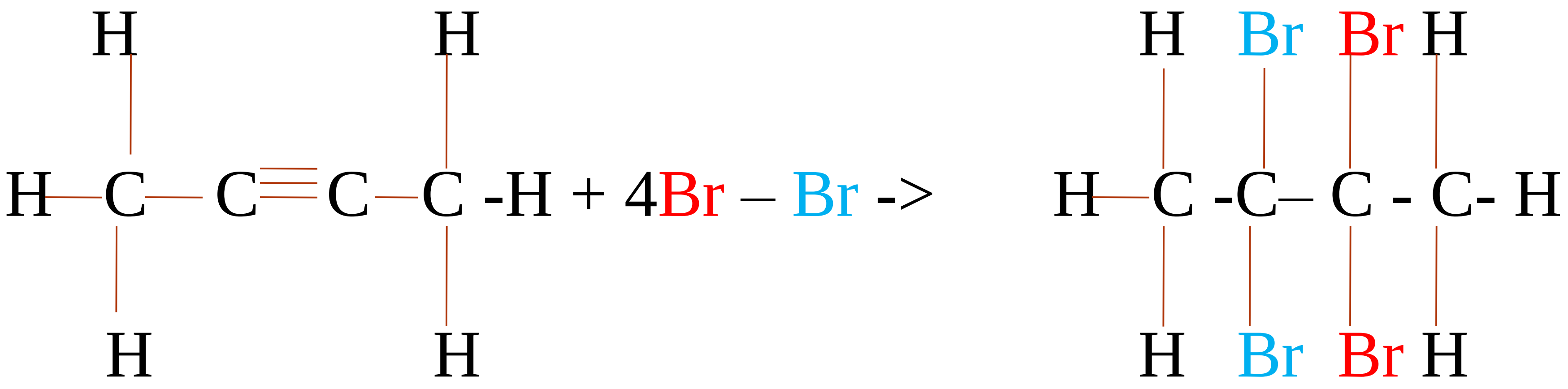
But-1-**y**ne + iodine -> 1,1,2,2-tetraiodobutane

$H_3C\ CH_2\ C \equiv CH \quad + \quad 2I_2 \quad \rightarrow \quad H_3C\ CH_2CI_2 - CH\ I_2$



But-2-**y**ne + Fluorine -> 2,2,3,3-tetrafluorobutane

$H_3C\ C \equiv C\text{-}CH_3 \quad + \quad 2F_2 \quad \rightarrow \quad H_3C\ CF_2CF_2 - CH_3$

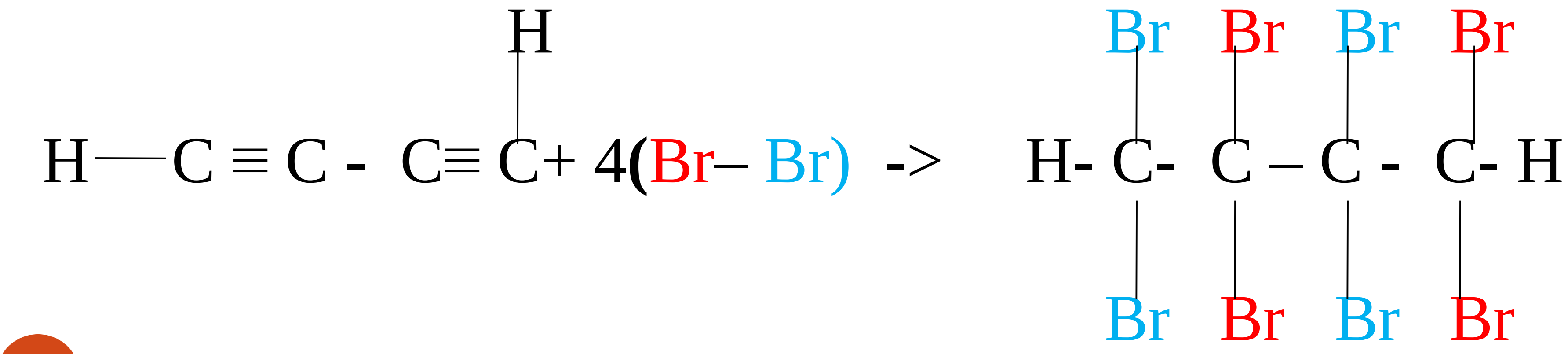


$H-CH_2-C\equiv C-CH_2-H + 4Br-Br \rightarrow H-CH_2-CBr_2-CBr_2-CH_2-H$

But-1,3-diyne should undergo halpgenation using bromine to form 1,1,2,2,3,3,4,4-octabromobutane. The reaction uses **four** moles of bromine molecules / **eight** bromine atoms to break the two triple bonds.

But-1,3-diene + Bromine -> 1,1,2,2,3,3,4,4-octabromobutane.

$H_2C\ CH\ CH=CH_2 + \mathbf{4}Br_2 \rightarrow H_3C\ CH_2CH - CH_3$



$H-C\equiv C-C\equiv CH + 4(Br-Br) \rightarrow H-CBr_2-CBr_2-CBr_2-CBr_2-H$

(iii) Reaction with hydrogen halides/Hydrohalogenation.

Hydrogen halides reacts with alk**y**ne to form a halogenoalk**e**ne then halogenoalk**a**ne.

The triple bond in the alk**y**ne break and form a double then single bond.

The main compound is one which the **hydrogen** atom bond at the carbon with **more** **hydrogen** **(**Markonikoff's rule**)**.

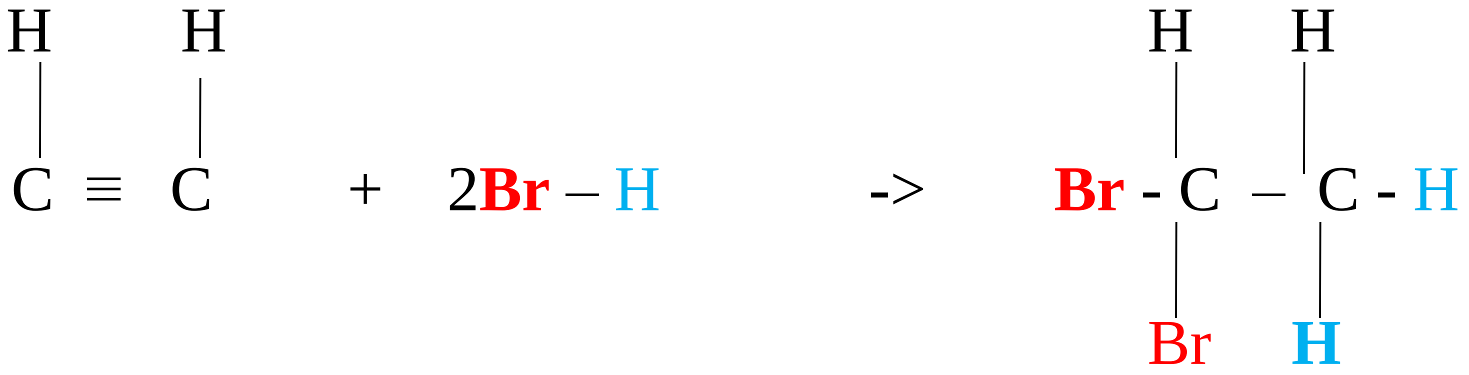
Examples

1. Ethyne reacts with hydrogen bromide to form dibromoethane.

Ethyne + Bromine $\longrightarrow$ dibromoethane

Chemical equation

$HC \equiv CH \quad + \quad 2HBr \longrightarrow H_3C - CHBr_2$



$$\overset{H}{C} \equiv \overset{H}{C} \quad + \quad 2Br-H \quad \rightarrow \quad Br-\overset{H}{\underset{Br}{C}}-\overset{H}{\underset{H}{C}}-H$$

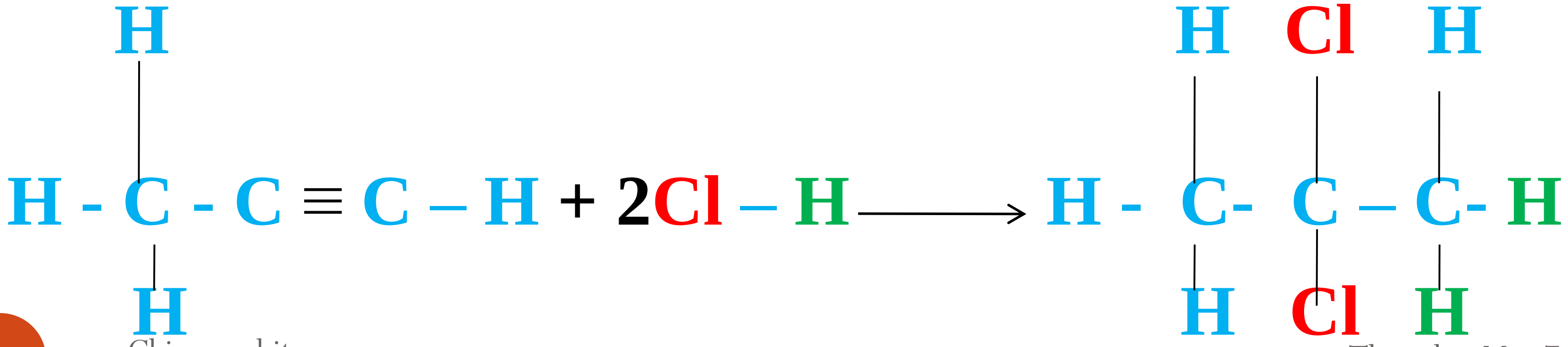
Ethyne + Hydrogen bromide ⟶ 1,1-dibromoethane

2.Propyne with hydrogen chloride forms 2,2-dichloropropane.

Chemical equation

$$H_3C\ CH \equiv CH_2 \quad + 2HCl \quad -> \quad H_3C\ CHCl - \ CH_3$$

Propyne + Chlorine -> 2,2-dichloropropane



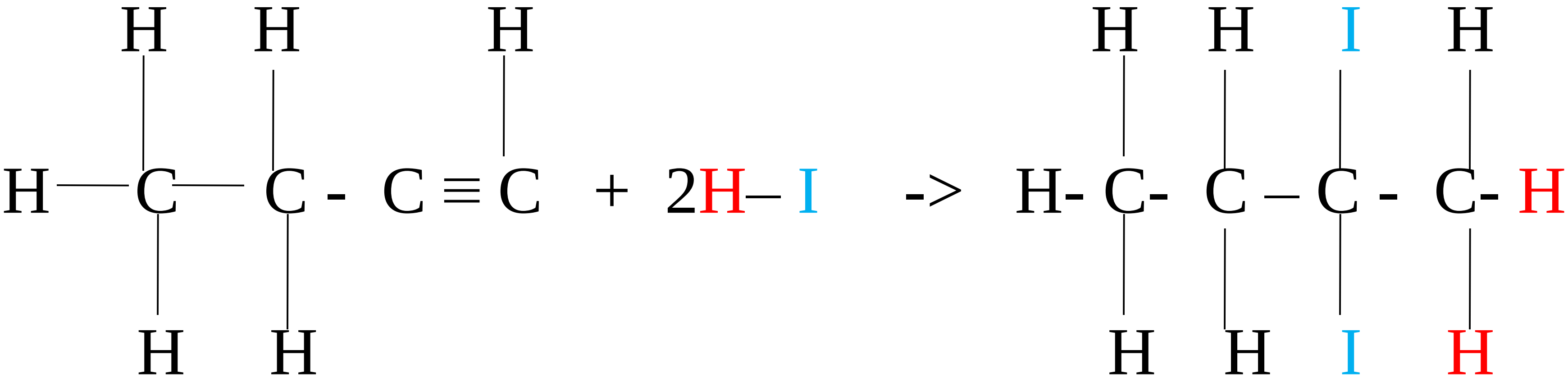
$$H-\overset{H}{\underset{H}{C}}-C \equiv C-H + 2Cl-H \longrightarrow H-\overset{H}{\underset{H}{C}}-\overset{Cl}{\underset{Cl}{C}}-\overset{H}{\underset{H}{C}}-H$$

3.Both But-1-yne and But-2-yne react with hydrogen iodide to form 2-iodobutane

Chemical equation

But-1-yne + hydrogen iodide -> 2,2-diiodobutane

$H_3C\ CH_2\ C \equiv CH$ + 2HI ->$H_3C\ CH_2C\ I_2$ - CH_3



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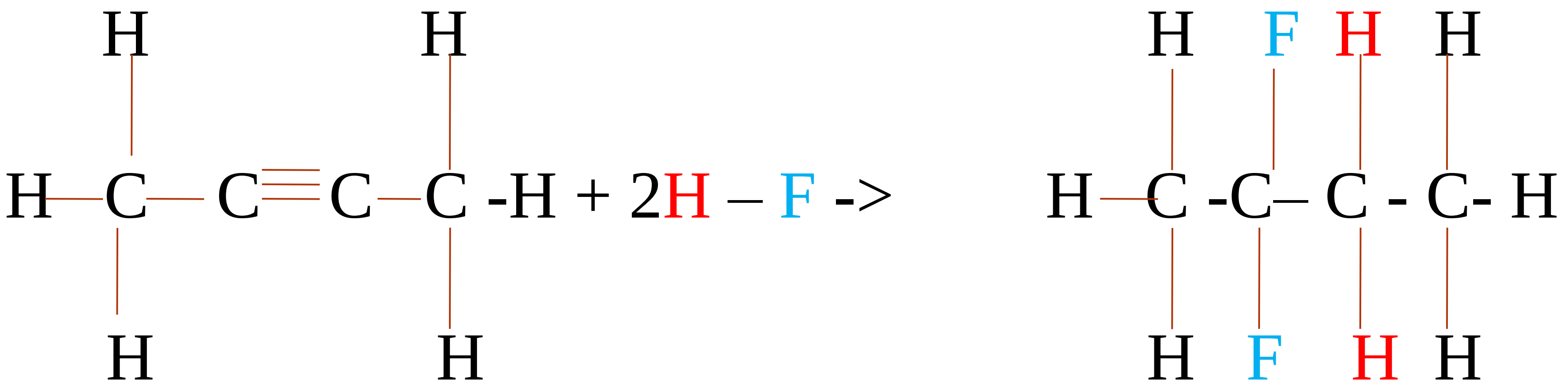
 & & | & & | & & & & | & & & & & | & & | & & | & & | & & \\
H & — & C & — & C & - & C & \equiv & C & + & 2H–I & -> & H- & C & - & C & – & C & - & C & - & H \\
 & & | & & | & & & & & & & & & | & & | & & | & & | & & \\
 & & H & & H & & & & & & & & & H & & H & & I & & H & &
\end{array}$$

But-2-yne + hydrogen fluorine -> 2,2-difluorobutane

$H_3CC \equiv C\text{-}CH_3$ + 2HF -> $H_3C\ CHF_2CH_2$ - CH_3

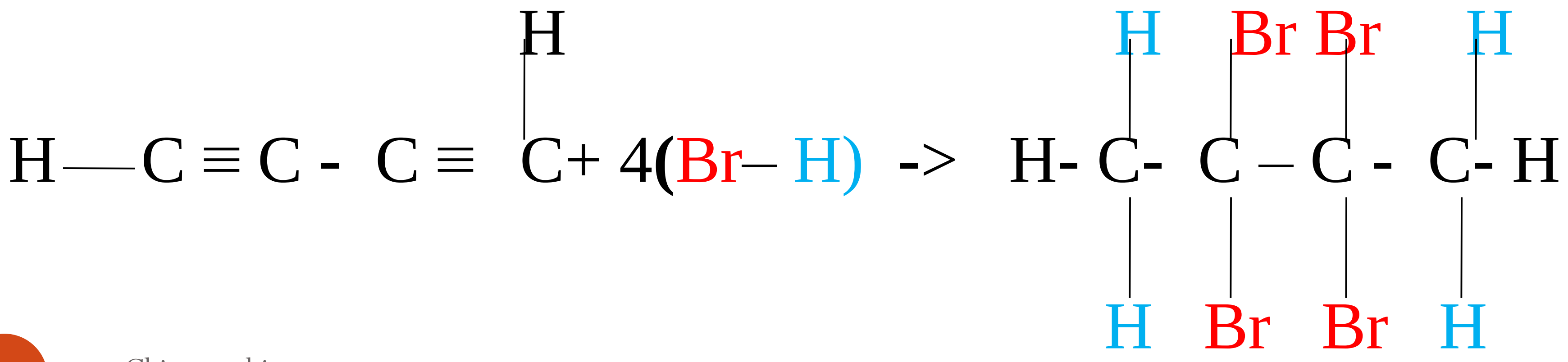


$$H-\overset{H}{\underset{H}{C}}-C\equiv C-\overset{H}{\underset{H}{C}}-H + 2H-F \rightarrow H-\overset{H}{\underset{H}{C}}-\overset{F}{\underset{F}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$$

But-1,3-di**e**ne react with hydrogen bromide to form (as the main product) 2,2,3,3-tetrabromobutane. The reaction uses **four** moles of hydrogen bromide molecules to break the two triple bonds.

But-1,3-di**e**ne + Bromine -> 2,2,3,3-tetrabromobutane

$H_2C\ CH\ CH \equiv CH_2$ + **4**HBr -> $H_3C\ CBr_2CBr_2CH_3$



$$H-C\equiv C-C\equiv \overset{H}{C} + 4(Br-H) \rightarrow H-\overset{H}{\underset{H}{C}}-\overset{Br}{\underset{Br}{C}}-\overset{Br}{\underset{Br}{C}}-\overset{H}{\underset{H}{C}}-H$$

(c)Test for the presence of – C ≡ C –triple bond.

(i)Burning/combustion

Alkynes like alkenes are unsaturated. They have the **– C ≡ C– triple** bond burn with a yellow sooty flame.

<u>Experiment</u>

Scoop a sample of the substance provided in a clean metallic spatula. Introduce it on a Bunsen burner.

Observation	Inference
Solid melt then burns with a yellow sooty flame	**– C = C –** **– C ≡ C –** bond

(ii)Oxidation by acidified $KMnO_4/K_2Cr_2O_7$

Bromine water ,Chlorine water and Oxidizing agents acidified $KMnO_4/K_2Cr_2O_7$ change to **unique** colour in presence of **– C ≡ C -**

Experiment

Scoop a sample of the substance provided into a clean test tube.

Add 10cm3 of distilled water. Shake.

Take a portion of the solution mixture.

Add three drops of acidified $KMnO_4/K_2Cr_2O_7$.

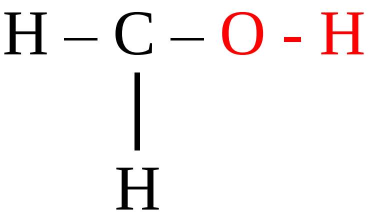
Observation	Inference
Acidified $KMnO_4$ decolorized **orange** colour of acidified $K_2Cr_2O_7$ turns **green** Bromine water is decolorized Chlorine water is decolorized	$-\overset{\vert}{\mathbf{C}}=\overset{\vert}{\mathbf{C}}-$ $-\mathbf{C}\equiv\mathbf{C}-$ bond

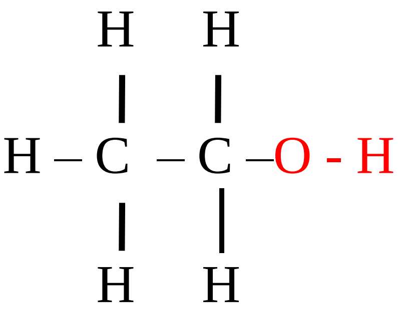
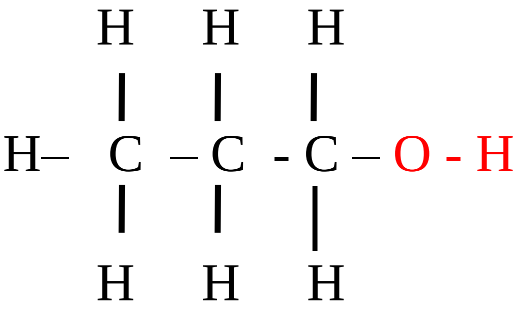
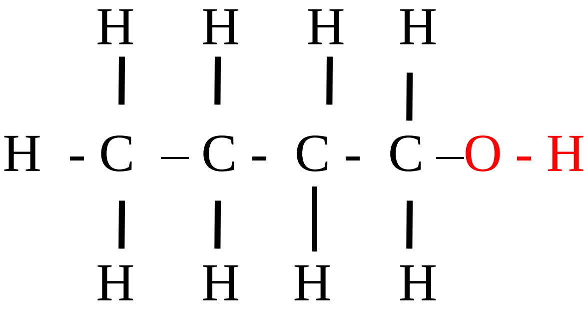
B.ALCOHOLS

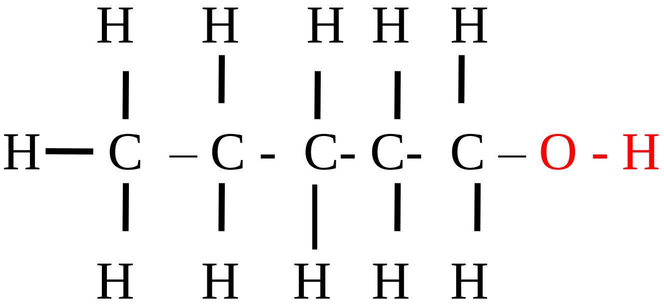
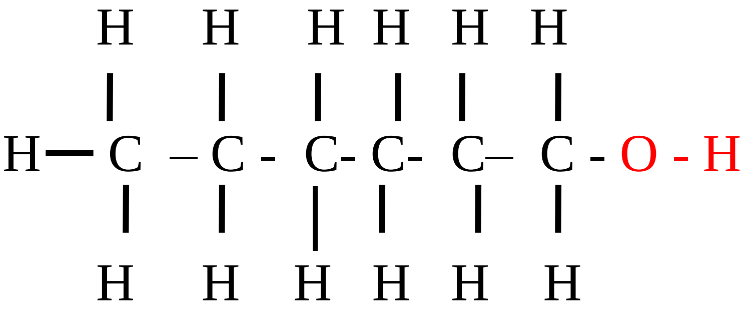
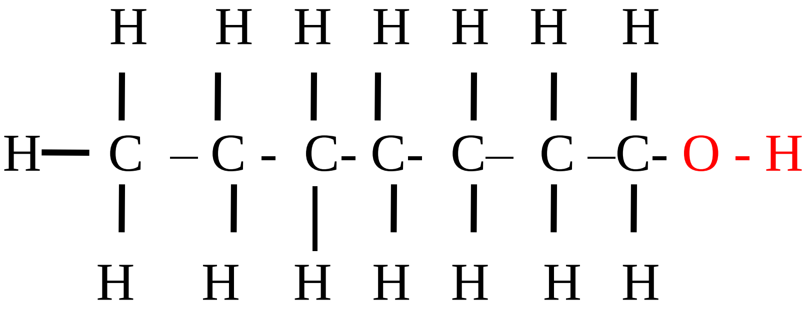
(A) INTRODUCTION.

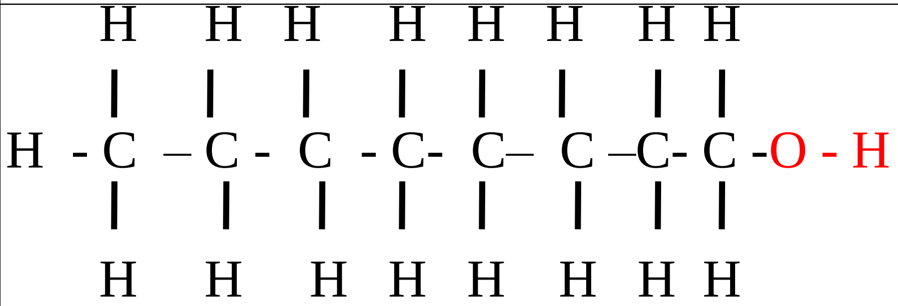
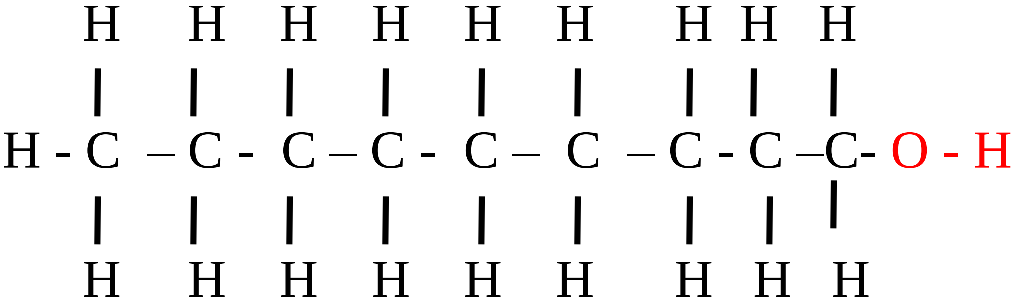
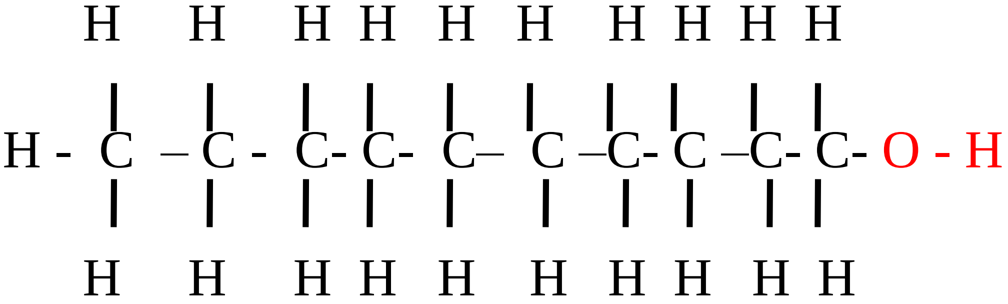
Alkahols belong to a homologous series of organic compounds with a general formula $C_nH_{2n\ +1}$ **OH** and thus **-OH** as the functional group .

The 1st ten alkanols include

n	General /molecular formular	Structural formula	IUPAC name
1	CH_3OH	 $H - \underset{\substack{\vert \\ H}}{C} - O - H$	Methan**ol**

2	$CH_3\ CH_2OH$ $C_2H_5\ OH$	 $\begin{array}{ccccccccc} & & H & & H & & & & \\ & & \vert & & \vert & & & & \\ H & - & C & - & C & - & O & - & H \\ & & \vert & & \vert & & & & \\ & & H & & H & & & & \end{array}$	Ethan**ol**
3	$CH_3\ (CH_2)_2OH$ $C_3H_7\ OH$	 $\begin{array}{ccccccccccc} & & H & & H & & H & & & & \\ & & \vert & & \vert & & \vert & & & & \\ H & - & C & - & C & - & C & - & O & - & H \\ & & \vert & & \vert & & \vert & & & & \\ & & H & & H & & H & & & & \end{array}$	Propan**ol**
4	$CH_3\ (CH_2)_3OH$ $C_4H_9\ OH$	 $\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & & & \\ & & \vert & & \vert & & \vert & & \vert & & & & \\ H & - & C & - & C & - & C & - & C & - & O & - & H \\ & & \vert & & \vert & & \vert & & \vert & & & & \\ & & H & & H & & H & & H & & & & \end{array}$	Butan**ol**

5	$CH_3(CH_2)_4OH$ $C_5H_{11}\ OH$	 $H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-H$	Pentan**ol**
6	$CH_3(CH_2)_5OH$ $C_6H_{13}\ OH$	 $H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-H$	Hexan**ol**
7	$CH_3(CH_2)_6OH$ $C_7H_{15}\ OH$	 $H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-H$	Heptan**ol**

8	$CH_3(CH_2)_7OH$ $C_8H_{17}\ OH$	 $H-C-C-C-C-C-C-C-C-O-H$	Octan**ol**
9	$CH_3(CH_2)_8OH$ $C_9H_{19}\ OH$	 $H-C-C-C-C-C-C-C-C-C-O-H$	Nonan**ol**
10	$CH_3(CH_2)_9OH$ $C_{10}H_{21}\ OH$	 $H-C-C-C-C-C-C-C-C-C-C-O-H$	Decan**ol**

Alkanols like Hydrocarbons(alkanes/alkenes/alkynes) form a homologous series where:

(i)general name is derived from the alkane name then ending with “**-ol**”

(ii)the members have **–OH** as the **functional** group

(iii)they have the same general formula represented by R-OH where R is an **alkyl** group.

(iv) each member differ by $–CH_2$ group from the next/previous.

(v)they show a similar and gradual change in their physical properties e.g. boiling and melting points.

(vi)they show similar and gradual change in their chemical properties.

B. ISOMERS OF ALCOHOLS.

Alkanols exhibit both structural and position isomerism.

The isomers are named by using the following basic guidelines:

(i)Like alkanes , identify the **longest** carbon chain to be the parent name.

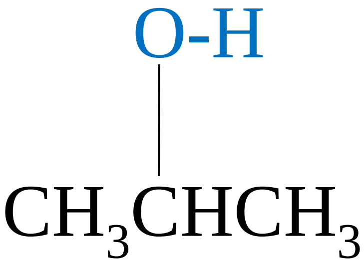
(ii)Identify the position of the **-OH** functional group to give it the **smallest /lowest** position.

(iii) Identify the type and position of the **side** branches.

Practice examples of isomers of alkanols

(i)Isomers of propanol C_3H_7OH

$CH_3CH_2CH_2O\text{-}H$ - Propan-1-ol

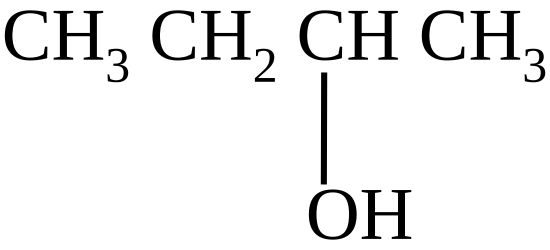


$CH_3\overset{O\text{-}H}{\overset{|}{C}}HCH_3$ - Propan-2-ol

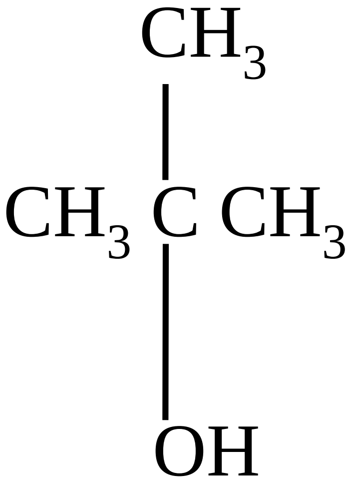
Propan-2-ol and Propan-1-ol are <u>position</u> isomers because only the position of the –OH functional group changes.

(ii)Isomers of Butanol C_4H_9OH

1. $CH_3\ CH_2\ CH_3\ CH_2\ OH$ Butan-1-ol

2.

$CH_3\ CH_2\ \underset{\underset{\displaystyle OH}{|}}{CH}\ CH_3$

Butan-2-ol

3.

$CH_3\ \overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle OH}{|}}{C}}\ CH_3$

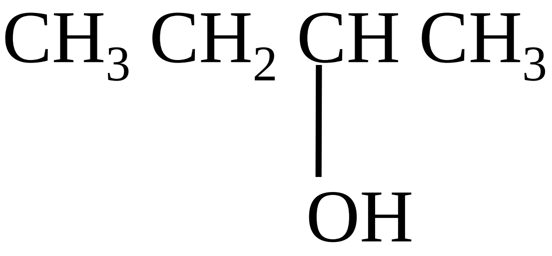
2-methylpropan-2-ol

Butan-2-ol and Butan-1-ol are position isomers because only the position of the -OH functional group changes.

2-methylpropan-2-ol is **both** a structural and position isomers because both the position of the functional group and the arrangement of the atoms in the molecule changes.

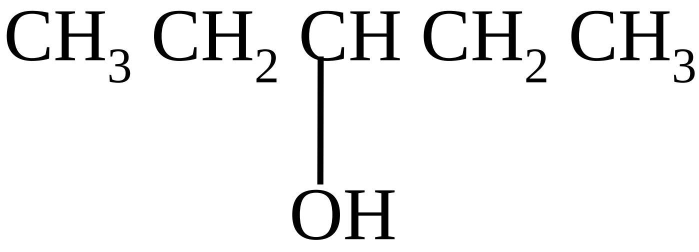
(iii)Isomers of Pentanol $C_5H_{11}OH$

$CH_3\ CH_2\ CH_2CH_2CH_2\ OH$ Pentan-1-ol (Position isomer)



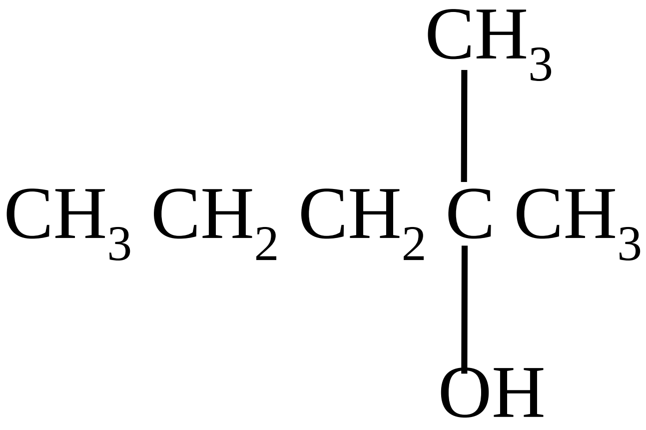
$CH_3\ CH_2\ \underset{\underset{OH}{|}}{CH}\ CH_3$

Pentan-2-ol (Position isomer)



$$CH_3CH_2\underset{\displaystyle OH}{\underset{|}{C}H}CH_2CH_3$$

Pentan-3-ol
(Position isomer)



$$CH_3CH_2CH_2\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle OH}{\underset{|}{C}}}}CH_3$$

2-methylbutan-2-ol
(Position /structural isomer)

C. LABORATORY PREPARATION OF ALCOHOLS.

For decades the world over, people have been fermenting grapes juice, sugar, carbohydrates and starch to produce ethanol as a social drug for relaxation.

In large amount, drinking of ethanol by mammals /human beings causes mental and physical lack of coordination.

Prolonged intake of ethanol causes permanent **mental** and **physical** lack of coordination because it damages vital organs like the liver.

Fermentation is the reaction where sugar is converted to alcohol/alkanol using biological catalyst/enzymes in **yeast.**

It involves **three** processes:

(i)Conversion of **starch** to **maltose** using the enzyme **diastase**

$(C_6H_{10}O_5)n$ (s)+H_2O(l)- -diastase --> $C_{12}H_{22}O_{11}$(aq)
(Starch) (Maltose)

(ii)Hydrolysis of **Maltose** to **glucose** using the enzyme **maltase.**

$C_{12}H_{22}O_{11}$(aq)+ H_2O(l)--maltase-->2 $C_6H_{12}O_6$(aq)
(Maltose) (glucose)

(iii)Conversion of **glucose** to **ethanol** and carbon(IV)oxide gas using the enzyme **zymase.**

$C_6H_{12}O_6$(aq) --zymase-->2C_2H_5OH(aq) + 2CO_2(g)
(glucose) (Ethanol)

At concentration greater than 15% by volume, the ethanol produced **kills** the yeast enzyme stopping the reaction.

To increase the concentration, **fractional** distillation is done to produce spirits (e.g. Brandy=40% ethanol).

Methanol is much more poisonous /toxic than ethanol.

Taken in large quantity it causes **instant** blindness and liver damage, killing the consumer victim within hours.

School laboratory preparation of ethanol from fermentation of glucose

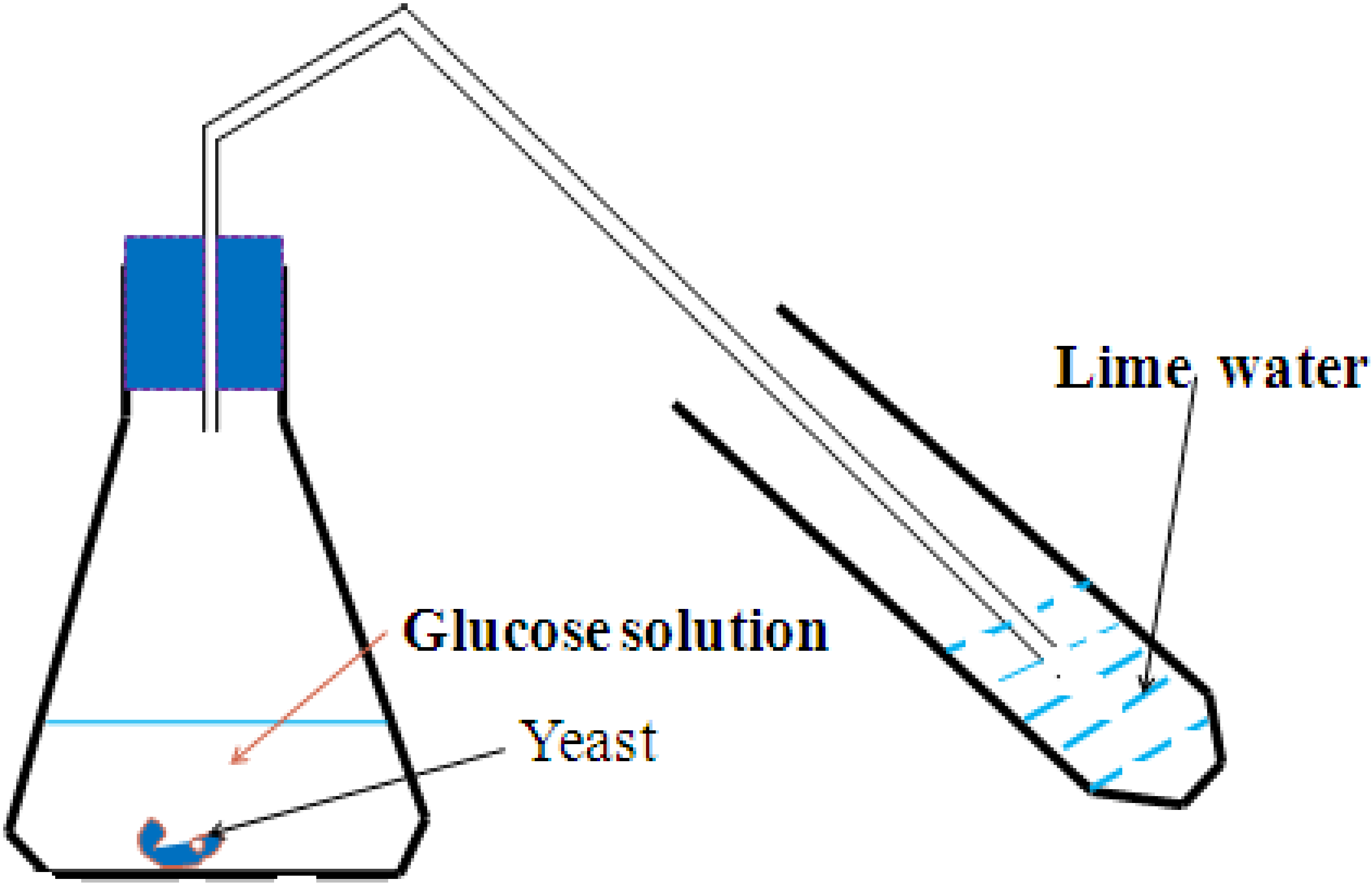
Measure 100cm3 of pure water into a conical flask.

Add about five spatula end full of glucose.

Stir the mixture to dissolve.

Add about one spatula end full of yeast.

Set up the apparatus as below.


Lime water
Glucose solution
Yeast

Preserve the mixture for about **three** days.

D.PHYSICAL AND CHEMICAL PROPERTIES OF ALCOHOLS

Characteristic properties of alkanols

(i)Role of yeast

Yeast is a single cell fungus which contains the enzyme maltase and zymase that catalyse the fermentation process.

(ii)Observations in lime water.

A white precipitate is formed that dissolve to a colourless solution later.

Lime water/Calcium hydroxide reacts with carbon(IV)0xide produced during the fermentation to form insoluble calcium carbonate and water.

More carbon (IV)0xide produced during fermentation react with the insoluble calcium carbonate and water to form soluble calcium hydrogen carbonate.

$Ca(OH)_2(aq) + CO_2 (g) \rightarrow CaCO_3(s)$

$H_2O(l) + CO_2 (g) + CaCO_3(s) \rightarrow Ca(HCO_3)_2 (aq)$

(c)Effects on litmus paper

Experiment

Take the prepared sample and test with both blue and red litmus papers.

Repeat the same with pure ethanol and methylated spirit.

Sample Observation table

Substance/alkanol	**Effect on litmus paper**
Prepared sample	Blue litmus paper remain blue Red litmus paper remain red
Absolute ethanol	Blue litmus paper remain blue Red litmus paper remain red
Methylated spirit	Blue litmus paper remain blue Red litmus paper remain red

Explanation

Alkanols are neutral compounds/solution that have characteristic sweet smell and taste.

They have no effect on both blue and red litmus papers.

(d)Solubility in water.

Experiment

Place about 5cm3 of prepared sample into a clean test tube
Add equal amount of distilled water.
Repeat the same with pure ethanol and methylated spirit.

Observation

No layers formed between the two liquids.

Explanation

Ethanol is **miscible** in water.
Both ethanol and water are **polar** compounds .

The solubility of alkanols **decrease** with **increase** in the alkyl chain/molecular mass.

The alkyl group is insoluble in water while **–OH** functional group is soluble in water.

As the molecular chain becomes **longer** ,the effect of the **alkyl** group **increases** as the effect of the functional group **decreases**.

e)Melting/boiling point.

Experiment

Place pure ethanol in a long boiling tube .Determine its boiling point.

Observation

Pure ethanol has a boiling point of **78°C** at sea level/one atmosphere pressure.

Explanation

The melting and boiling point of alkanols increase with increase in molecular chain/mass .

This is because the intermolecular/van-der-waals forces of attraction between the molecules increase.

More heat energy is thus required to **weaken** the longer chain during melting and **break** during boiling.

f)Density

Density of alkanols increase with increase in the intermolecular/van-der-waals forces of attraction between the molecule, making it very close to each other.

This reduces the volume occupied by the molecule and thus increase the their mass per unit volume (density).

Summary table showing the trend in physical properties of alkanols

Alkanol	**Melting point (°C)**	**Boiling point (°C)**	**Density gcm^{-3}**	**Solubility in water**
Methan**ol**	-98	65	0.791	soluble
Ethan**ol**	-117	78	0.789	soluble
Propan**ol**	-103	97	0.803	soluble
Butan**ol**	-89	117	0.810	Slightly soluble
Pentan**ol**	-78	138	0.814	Slightly soluble
Hexan**ol**	-52	157	0.815	Slightly soluble
Heptan**ol**	-34	176	0.822	Slightly soluble
Octan**ol**	-15	195	0.824	Slightly soluble
Nonan**ol**	-7	212	0.827	Slightly soluble
Decan**ol**	6	228	0.827	Slightly soluble

g)Burning

Experiment

Place the prepared sample in a watch glass. Ignite. Repeat with pure ethanol and methylated spirit.

Observation/Explanation

Fermentation produce ethanol with a lot of water(about a ratio of 1:3)which prevent the alcohol from igniting.

Pure ethanol and methylated spirit easily catch fire / highly flammable.

They burn with an almost colourless non-sooty/non-smoky **blue** flame to form **carbon(IV) oxide** (in excess air /oxygen) or **carbon(II) oxide** (limited air) and **water**.

Ethanol is thus a saturated compound like alkanes.

$C_2H_5OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)$ (excess air)
$C_2H_5OH(l) + 2O_2(g) \rightarrow 3H_2O(l) + 2CO(g)$ (limited air)

$2CH_3OH(l) + 3O_2(g) \rightarrow 4H_2O(l) + 2CO_2(g)$ (excess air)
$CH_3OH(l) + O_2(g) \rightarrow 2H_2O(l) + CO(g)$ (limited air)

$2C_3H_7OH(l) + 9O_2(g) \rightarrow 8H_2O(l) + 6CO_2(g)$ (excess air)
$C_3H_7OH(l) + 3O_2(g) \rightarrow 4H_2O(l) + 3CO(g)$ (limited air)

$2C_4H_9OH(l) + 13O_2(g) \rightarrow 20H_2O(l) + 8CO_2(g)$ (excess air)
$C_4H_9OH(l) + 3O_2(g) \rightarrow 4H_2O(l) + 3CO(g)$ (limited air)

Due to its flammability, ethanol is used;

(i)as a **fuel** in spirit lamps
(ii)as **gasohol** when blended with gasoline

(h)Formation of alkoxides

Experiment

Cut a very small piece of sodium.

Put it in a beaker containing about 20cm3 of the prepared sample in a beaker.

Test the products with litmus papers.

Repeat with absolute ethanol and methylated spirit.

Sample observations

Substance/alkanol	Effect of adding sodium
Fermentation prepared sample	(i)effervescence/fizzing/bubbles (ii)colourless gas that extinguish burning splint with “Pop” sound (iii)colourless solution formed (iv)blue litmus papers remain blue (v)red litmus papers turn blue
Pure/absolute ethanol/methylated spirit	(i)**slow** effervescence/fizzing/bubbles (ii)colourless gas **slowly** that extinguish burning splint with “Pop” sound (iii)colourless solution formed (iv)blue litmus papers remain blue (v)red litmus papers turn blue

Explanations

Sodium/potassium reacts slowly with alkanols to form basic solution called **alkoxides** and producing **hydrogen** gas.

If the alkanol has some water the metals react faster with the water to form **soluble hydroxides/alkalis** i.e.

Sodium + Alkanol -> Sodium **alk**oxides + Hydrogen gas

Potassium+Alkanol->Potassium **alk**oxides+Hydrogen gas

Sodium +Water ->Sodium **hydr**oxides + Hydrogen gas

Potassium+Water->Potassium **hydr**oxides+ Hydrogen gas

Examples

1.Sodium metal reacts with ethanol to form sodium **eth**oxide
Sodium metal reacts with water to form sodium **Hydr**oxide

$2CH_3CH_2O\mathbf{H}(l) + 2Na(s)$ -> $2CH_3CH_2ONa\ (aq) + H_2\ (s)$
$2H_2O(l) + 2Na(s)$ -> $2NaOH\ (aq) + H_2\ (s)$

2.Potassium metal reacts with ethanol to form Potassium **eth**oxide
Potassium metal reacts with water to form Potassium **Hydr**oxide

$2CH_3CH_2O\mathbf{H}(l) + 2K(s)$ -> $2CH_3CH_2OK\ (aq) + H_2\ (s)$
$2H_2O(l) + 2K(s)$ -> $2KOH\ (aq) + H_2\ (s)$

3.Sodium metal reacts with propanol to form sodium **prop**oxide

Sodium metal reacts with water to form sodium **hydr**oxide

$2CH_3CH_2\ CH_2OH(l) + 2Na(s)$

$\rightarrow 2CH_3CH_2\ CH_2ONa\ (aq) \quad + H_2\ (s)$

$2H_2O(l) + 2Na(s) \quad \rightarrow \quad 2NaOH\ (aq) \quad + H_2\ (s)$

4.Potassium metal reacts with propanol to form Potassium **prop**oxide

Potassium metal reacts with water to form Potassium **hydr**oxide

$2CH_3CH_2\ CH_2OH(l) + 2K(s)$

$\rightarrow 2CH_3CH_2\ CH_2OK\ (aq) \quad + H_2\ (s)$

$2H_2O(l) + 2K(s) \quad \rightarrow \quad 2KOH\ (aq) \quad + H_2\ (s)$

5.Sodium metal reacts with butanol to form sodium **but**oxide

Sodium metal reacts with water to form sodium **hydr**oxide

$2CH_3CH_2\ CH_2\ CH_2OH(l)\ +\ 2Na(s)$

$\rightarrow\ 2CH_3CH_2\ CH_2\ CH_2ONa\ (aq)\ \ +\ H_2\ (s)$

$2H_2O(l)\ +\ \ 2Na(s)\ \ \rightarrow\ \ 2NaOH\ (aq)\ \ +\ H_2\ (s)$

(i)Formation of Esters/Esterification

Experiment

Place 2cm3 of ethanol in a boiling tube. Add equal amount of ethanoic acid.

To the mixture add carefully 2drops of concentrated sulphuric(VI)acid.

Warm/Heat gently.

Pour the mixture into a beaker containing about 50cm3 of cold water. Smell the products. Repeat with methanol

Sample observations

Substance/alkanol	**Effect on adding equal amount of ethanol/concentrated sulphuric (VI) acid**
Absolute ethanol	Sweet fruity smell
Methanol	Sweet fruity smell

Explanation

Alkanols react with alkanoic acids to form a group of homologous series of **sweet** smelling compounds called **esters** and **water**.

This reaction is catalyzed by **concentrated** sulphuric(VI) acid in the laboratory.

Esters derive their names from the alkanol first then alkanoic acids. The alkanol “becomes” an **alkyl** group and the alkanoic acid “becomes” **alkanoate** hence **alkylalkanoate**.

e.g.

Ethanol + Ethanoic acid -> Ethylethanoate + Water
Ethanol + Propanoic acid -> Ethylpropanoate + Water
Ethanol + Methanoic acid -> Ethylmethanoate + Water
Ethanol + butanoic acid -> Ethylbutanoate + Water
Propanol + Ethanoic acid -> Propylethanoate + Water
Methanol+Ethanoic acid -> Methyethanoate + Water
Methanol+Decanoic acid -> Methyldecanoate + Water
Decanol +Methanoic acid -> Decylmethanoate + Water

During the formation of the ester, the “O” joining the alkanol and alkanoic acid comes from the alkanol.

$$\mathbf{R_1\text{ -COOH} + R_2 - OH \text{ -> } R_1\text{ -COO} - R_2 + H_2O}$$

Alkanol + Alkanoic acid–Conc. H_2SO_4-> Ester + water

Naturally esterification is catalyzed by **sunlight**.

Each ester has a characteristic sweet **unique** smell derived from the many possible combinations of alkanols and alkanoic acids that create a variety of known natural(mostly in fruits) and synthetic(mostly in juices) esters . e.g.

1. **Eth**anol reacts with ethanoic acid to form the ester **ethyl**ethanoate and water.

Ethanol + Ethanoic acid --Conc. H_2SO_4 -->

Ethylethanoate + Water

C_2H_5OH (l)+ CH_3COOH(l) --Conc. H_2SO_4 -->

$CH_3COO\ C_2H_5$(**aq**) +H_2O(l)

CH_3CH_2OH (l)+ CH_3COOH(l) --Conc. H_2SO_4 -->

$CH_3COOCH_2CH_3$(**aq**) +H_2O(l)

2. Ethanol reacts with propanoic acid to form the ester ethylpropanoate and water.

Ethanol + Propanoic acid --Conc. H_2SO_4 -->
Ethylethanoate + Water

C_2H_5OH (l)+ CH_3 CH_2COOH(l) --Conc. H_2SO_4 -->
$CH_3CH_2COO\ C_2H_5$(**aq**) +H_2O(l)

CH_3CH_2OH (l)+ CH_3 CH_2COOH(l)--Conc. H_2SO_4 -->
CH_3 $CH_2COOCH_2CH_3$(**aq**) +H_2O(l)

3. Methanol reacts with ethanoic acid to form the ester methyl ethanoate and water.

Methanol + Ethanoic acid --Conc. H_2SO_4 -->
Methylethanoate + Water

CH_3OH (l) + CH_3COOH(l) --Conc. H_2SO_4 -->
$CH_3COO\ CH_3$(**aq**) +H_2O(l)

4. Methanol reacts with propanoic acid to form the ester methyl propanoate and water.

Methanol + propanoic acid --Conc. H_2SO_4 -->
Methylpropanoate + Water

CH_3OH (l)+ $CH_3\ CH_2COOH$(l) --Conc. H_2SO_4 -->
$CH_3\ CH_2COO\ CH_3$(**aq**) +H_2O(l)

5. Propanol reacts with propanoic acid to form the ester propylpropanoate and water.

C_3H_7OH (l)+ $CH_3\ CH_2COOH$(l) --Conc. H_2SO_4 -->
$CH_3CH_2COO\ C_3H_7$(**aq**) +H_2O(l)

$CH_3CH_2\ CH_2OH$ (l)+ $CH_3\ CH_2COOH$(l) -Conc. H_2SO_4 ->
$CH_3\ CH_2COOCH_2\ CH_2CH_3$(**aq**) +$H_2O$(l)

(j)Oxidation

Experiment

Place 5cm3 of absolute ethanol in a test tube.

Add three drops of acidified potassium manganate(VII).Shake thoroughly for one minute/warm.

Test the solution mixture using pH paper.

Repeat by adding acidified potassium dichromate(VII).

Sample observation table

Substance/ alkanol	Adding acidified $KMnO_4/K_2Cr_2O_7$	pH of resulting solution/mixture	Nature of resulting solution/mixture
Pure ethanol	(i)Purple colour of $KMnO_4$ decolorized (ii) Orange colour of $K_2Cr_2O_7$turns green.	pH= 4/5/6 pH = 4/5/6	Weakly acidic Weakly acidic

Explanation

Both acidified $KMnO_4$ and $K_2Cr_2O_7$ are oxidizing agents(add oxygen to other compounds.

They oxidize alkan**o**ls to a group of homologous series called alkan**a**ls then further oxidize them to alkan**oic** acids.The oxidizing agents are themselves reduced hence changing their colour:

(i) **Purple** $KMnO_4$ is reduced to colourless Mn^{2+}

(ii)**Orange** $K_2Cr_2O_7$is reduced to **green** Cr^{3+}

The pH of alkanoic acids show they have few H^+ because they are **weak** acids i.e

Alkanol + [O] ->Alkanal +[O] -> alkanoic acid

NB The [O] comes from the oxidizing agents acidified $KMnO_4$ or $K_2Cr_2O_7$

Examples

1.When ethanol is warmed with three drops of acidified $KMnO_4$ there is decolorization of $KMnO_4$

Ethanol + [O] -> Ethanal + [O] -> Ethanoic acid

CH_3CH_2OH + [O] -> CH_3CH_2O + [O] -> CH_3COOH

2.When methanol is warmed with three drops of acidified $K_2Cr_2O_7$,the orange colour of acidified $K_2Cr_2O_7$ changes to green.

methanol + [O] -> methanal + [O] -> methanoic acid

CH_3OH +[O] -> CH_3O + [O] -> HCOOH

3.When propanol is warmed with three drops of acidified $K_2Cr_2O_7$,the orange colour of acidified $K_2Cr_2O_7$ changes to green.

Propanol + [O] -> Propanal + [O] -> Propanoic acid

$CH_3CH_2\,CH_2OH + [O] \rightarrow CH_3CH_2\,CH_2O + [O] \rightarrow$

$CH_3\,CH_2COOH$

4.When butanol is warmed with three drops of acidified $K_2Cr_2O_7$,the orange colour of acidified $K_2Cr_2O_7$ changes to green.

Butanol + [O] -> Butanal + [O] -> Butanoic acid

$CH_3CH_2\,CH_2\,CH_2OH + [O] \rightarrow CH_3CH_2\,CH_2CH_2O + [O] \rightarrow$

$CH_3\,CH_2COOH$

Air slowly oxidizes ethanol to dilute ethanoic acid commonly called **vinegar.**

If beer is not tightly corked, a lot of carbon(IV)oxide escapes and there is slow oxidation of the beer making it "flat".

(k)Hydrolysis /Hydration and Dehydration

I. Hydrolysis/Hydration is the reaction of a compound/substance with water.

Alkenes react with water vapour/steam at high temperatures and high pressures in presence of phosphoric acid catalyst to form alkanols. i.e.

Alkenes+ Water - H_3PO_4 catalyst-> Alkanol

Examples

(i)Ethene is mixed with steam over a phosphoric acid catalyst at 300°C temperature and 60 atmosphere pressure to form ethanol

Ethene + water ---60 atm/300°C/ H_3PO_4 --> Ethanol

H_2C =CH_2 (g) + **H_2O**(l) --60 atm/300°C/ H_3PO_4 --> CH_3 C**H_2O**H(l)

This is the main method of producing large quantities of ethanol instead of fermentation

(ii) Propene + water ---60 atm/300°C/ H_3PO_4 --> Propanol

CH_3C =CH_2(g) + **H_2O**(l) -- H_3PO_4 --> CH_3 CH_2C**H_2O**H(l)

(iii) Butene+ water ---60 atm/300°C/ H_3PO_4 --> Butanol

CH_3 CH_2 C=CH_2 (g)+**H_2O**(l) -->$CH_3CH_2CH_2$C**H_2O**H(l)

II. Dehydration is the process which concentrated sulphuric(VI)acid (**dehydrating agent**) removes water from a compound/substances.

Concentrated sulphuric(VI)acid dehydrates alkanols to the corresponding alkenes at about 180°C. i.e

Alkanol --Conc. $H_2\ SO_4$/180°C--> Alkene + Water

Examples

1. At 180°C and in presence of Concentrated sulphuric(VI)acid, ethanol undergoes dehydration to form ethene.

Ethanol --180°C/ H_2SO_4 --> Ethene + Water

$CH_3\ C\mathbf{H_2O}H(l)$ -180°C/ H_2SO_4 ->$H_2C=CH_2$ (g) + $\mathbf{H_2O}(l)$

2. Propanol undergoes dehydration to form propene.

Propanol ---$180^{o}C$/ H_2SO_4 --> Propene + Water

$CH_3\ CH_2\ C\mathbf{H_2O}H(l)$ --$180^{o}C$/ H_2SO_4 -->

$CH_3CH=CH_2\ (g)\ +\ \mathbf{H_2O}(l)$

3. Butanol undergoes dehydration to form Butene.

Butanol ---$180^{o}C$/ H_2SO_4 --> Butene + Water

$CH_3\ CH_2\ CH_2C\mathbf{H_2O}H(l)$ --$180^{o}C$/ H_2SO_4 -->

$CH_3\ CH_2C=CH_2\ (g)\ +\ \mathbf{H_2O}(l)$

3. Pentanol undergoes dehydration to form Pentene.

Pentanol ---$180^{o}C$/ H_2SO_4 --> Pentene + Water

$CH_3\ CH_2\ CH_2\ CH_2\ C\mathbf{H_2O}H(l)$--$180^{o}C$/ H_2SO_4-->

$CH_3\ CH_2\ CH_2C=CH_2\ (g)+\mathbf{H_2O}(l)$

(l)Similarities of alkanols with Hydrocarbons

I. Similarity with alkanes

Both alkanols and alkanes burn with a **blue non-sooty flame** to form carbon(IV)oxide(in excess air /oxygen) /carbon(II)oxide(in limited air) and water.

This shows they are saturated with high C:H ratio. e.g.

Both ethanol and ethane ignite and burns in air with a **blue non-sooty flame** to form carbon(IV)oxide(in excess air/oxygen)/carbon(II)oxide(in limited air) and water.

$CH_2\ CH_2OH(l)+3O_2(g)$ -Excess air-> $2CO_2\ (g) + 3H_2\ O(l)$

$CH_2\ CH_2OH(l)+2O_2(g)$ -Limited air-> $2CO\ (g) + 3H_2\ O(l)$

$CH_3\ CH_3(g)+3O_2(g)$ -Excess air-> $2CO_2\ (g) + 3H_2\ O(l)$

$2CH_3\ CH_3(g) + 5O_2(g)$ -Limited air-> $4CO\ (g) + 6H_2\ O(l)$

Both alkanols(R-OH) and alkenes/alkynes (with = C = C = double and – C $\equiv$ C- triple) bond:

(i)decolorize acidified $KMnO_4$

(ii)turns **Orange** acidified $K_2Cr_2O_7$ to **green**.

Alkan**o**ls(R-**OH**) are oxidized to alkan**a**ls(R-**O**) and then alkan**oic** acids(R-**OOH**).

Alkenes are oxidized to alkanols with duo / double functional groups.

Examples

1.When ethanol is warmed with three drops of acidified $K_2Cr_2O_7$,the orange colour of acidified $K_2Cr_2O_7$ turns to green.

Ethanol is oxidized to ethan**a**l and then to ethanoic acid.

Ethan**ol** + [O] -> Ethan**al** + [O] -> Ethan**oic** acid

CH_3CH_2OH + [O] -> CH_3CH_2O +[O]-> CH_3COOH

2.When ethene is bubbled in a test tube containing acidified $K_2Cr_2O_7$,the orange colour of acidified $K_2Cr_2O_7$ turns to green.

Ethene is oxidized to ethan-1,2-diol.

Ethene + [O] -> Ethan-1,2-diol.

$H_2C=CH_2$ + [O] -> $HOCH_2$ -CH_2OH

III. Differences with alkenes/alkynes

Alkanols do not decolorize bromine and chlorine water.

Alkenes decolorizes bromine and chlorine water to form halogenoalkanols

Example

When ethene is bubbled in a test tube containing bromine water,the bromine water is decolorized. Ethene is oxidized to bromoethanol.

Ethene + Bromine water -> Bromoethanol.

$H_2C=CH_2$ + HOBr -> $BrCH_2$ -CH_2OH

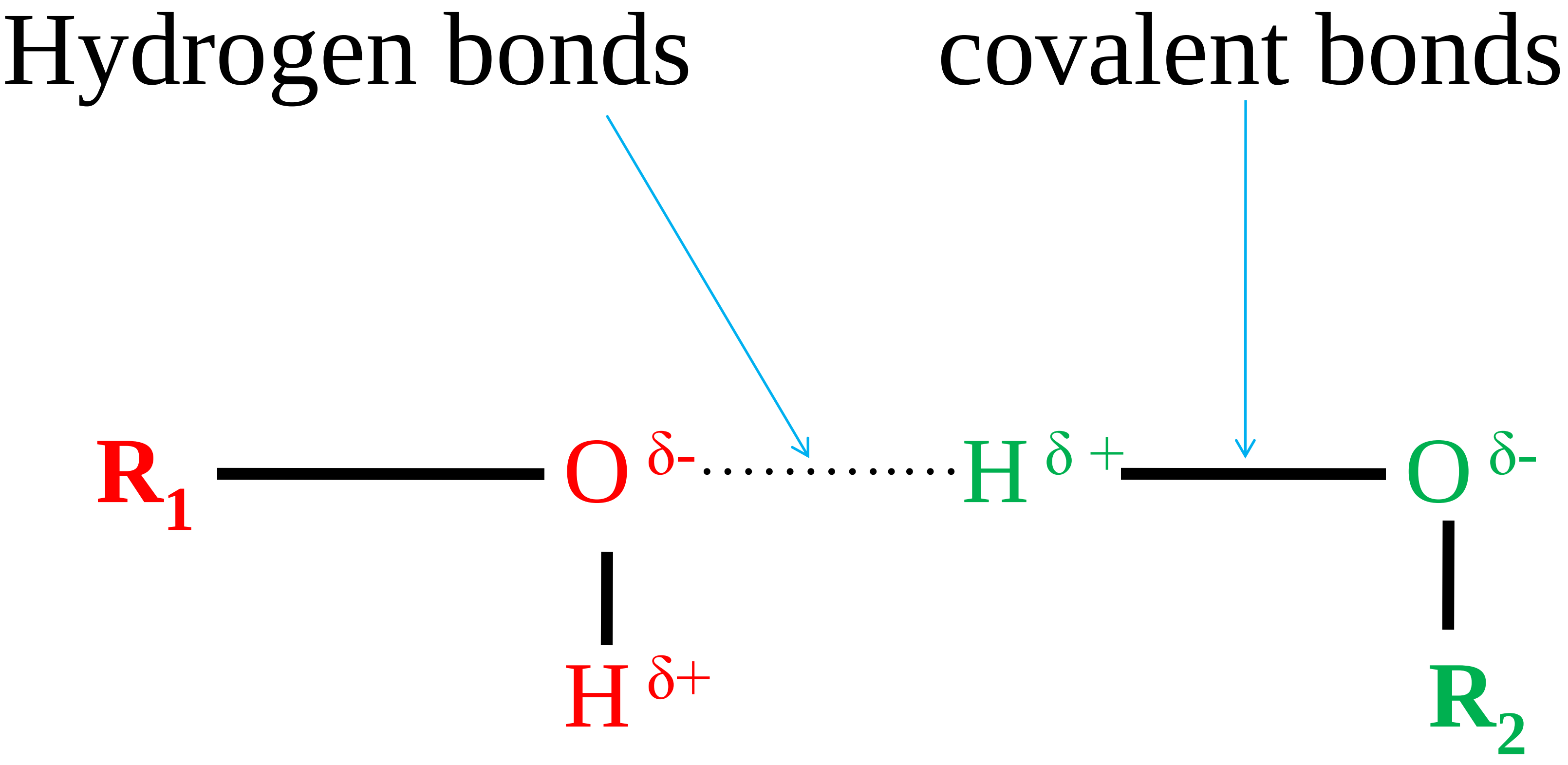
IV. Differences in melting and boiling point with Hydrocarbons

Alkanols have higher melting point than the corresponding hydrocarbon (alkane /alkene/ alkyne)

This is because most alkanols exist as **dimer.**

A dimer is a molecule made up of two molecules joined usually by van-der-waals forces/hydrogen bond or dative bonding.

Two alkanol molecules form a dimer joined by hydrogen bonding.



Hydrogen bonds

covalent bonds

R_1 and R_2 are extensions of the molecule.

Example

In Ethanol the oxygen atom attracts/pulls the shared electrons in the covalent bond more to itself than Hydrogen.

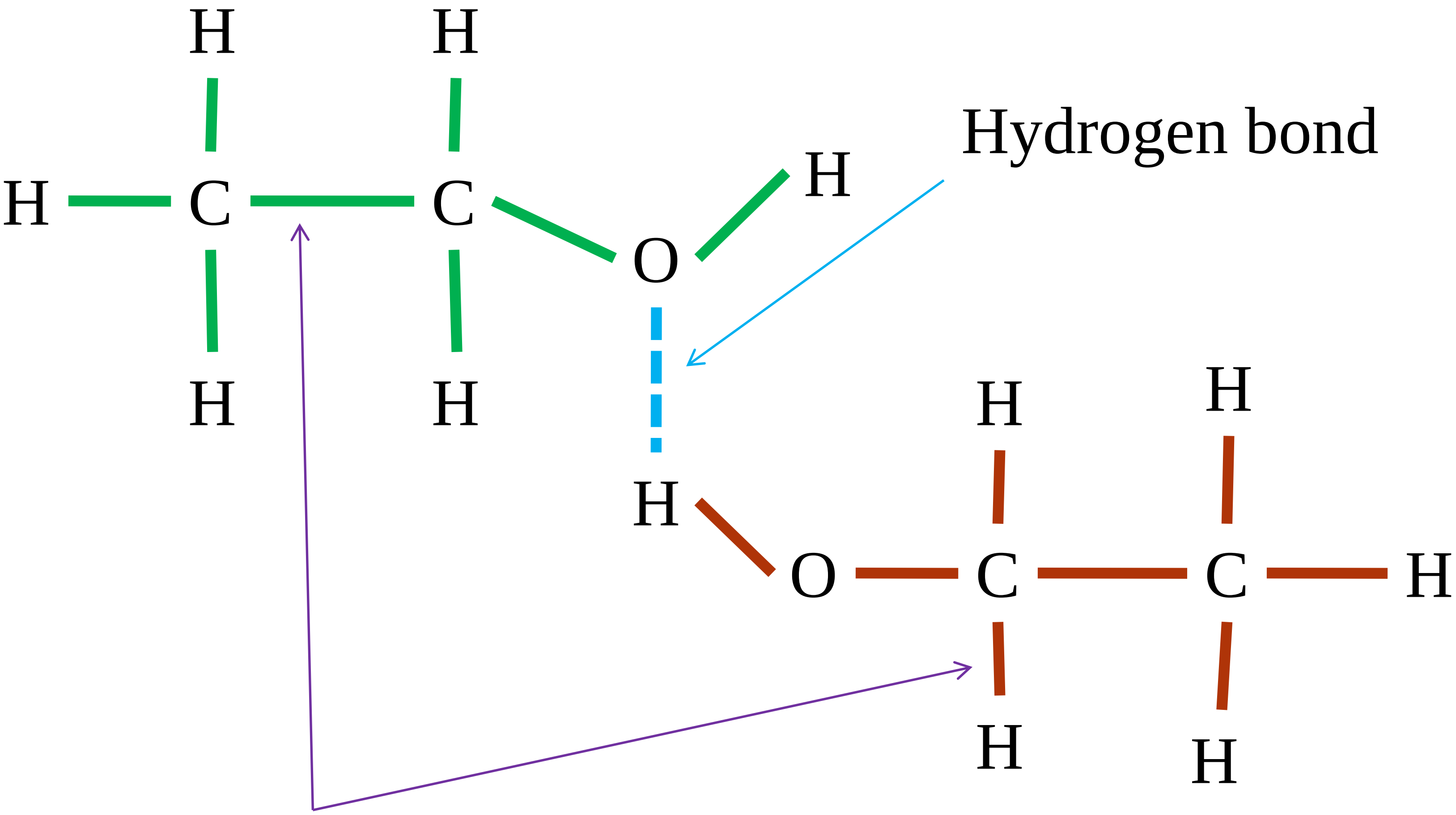
This creates a partial negative charge ($^{\delta-}$) on oxygen and partial positive charge($^{\delta+}$) on hydrogen.

Two ethanol molecules attract each other at the partial charges through Hydrogen bonding forming a **dimme**r.

Dimerization of alkanols means more energy is needed to break/weaken the Hydrogen bonds .This increases/raises the bpt/mpt

All organic compounds require to break /weaken the intermolecular forces attraction joining the molecules before boiling/melting.

An ethanol dimer from hydrogen bonding



Hydrogen bond

Covalent bonds

E.USES OF SOME ALCOHOLS

(a)**Methanol** is used

1.as industrial alcohol

2.making methylated spirit

(b)**Ethanol** is used:

1. as alcohol in alcoholic drinks e.g Beer, wines and spirits.

2.as antiseptic to wash wounds

3.in manufacture of vanishes, ink ,glue and paint because it is volatile and thus easily evaporate

4.as a fuel when blended with petrol to make gasohol.

C. CARBOXYLIC ACIDS

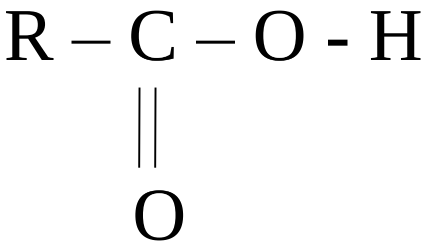
(A) INTRODUCTION.

Alkanoic acids belong to a homologous series of organic compounds with a general formula **C_nH_{2n+1} COOH** and thus **-COOH** as the functional group .

Alkanoic acids like alkanols /alkanes/alkenes/alkynes form a homologous series where:

(i)the general name of an alkanoic acids is derived from the alkane name then ending with **"–oic"** acid.

(ii) the members have R-**COOH**/ R – C – O - H as the functional group.



$$R-\underset{\underset{O}{\|}}{C}-O-H$$

(iii)they have the same general formula represented by R-COOH where R is an alkyl group.

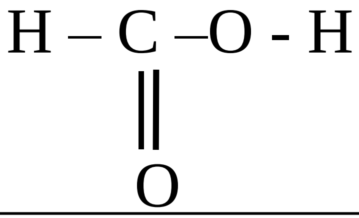
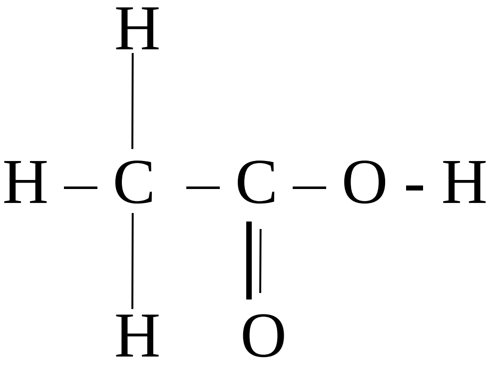
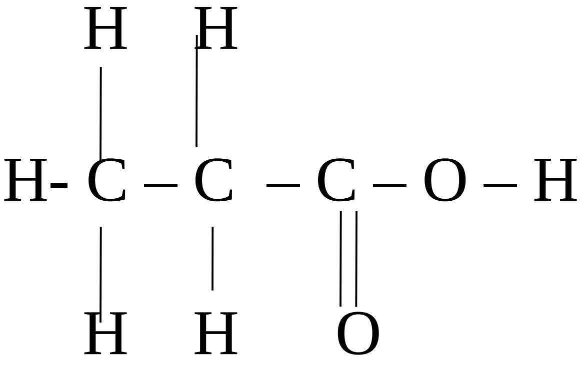
(iv)each member differ by –CH_2- group from the next/previous.

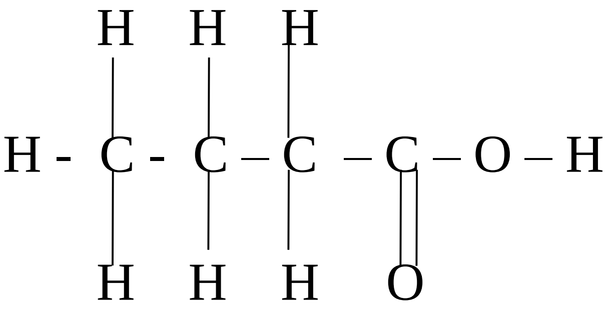
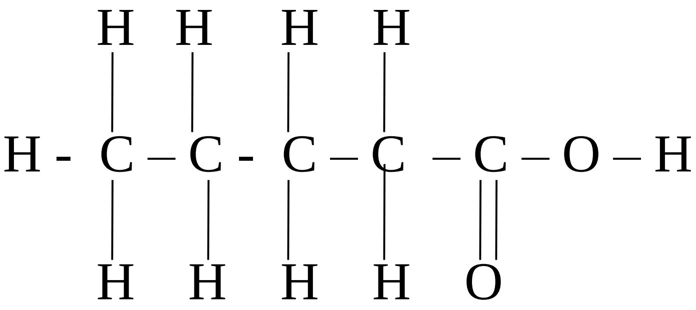
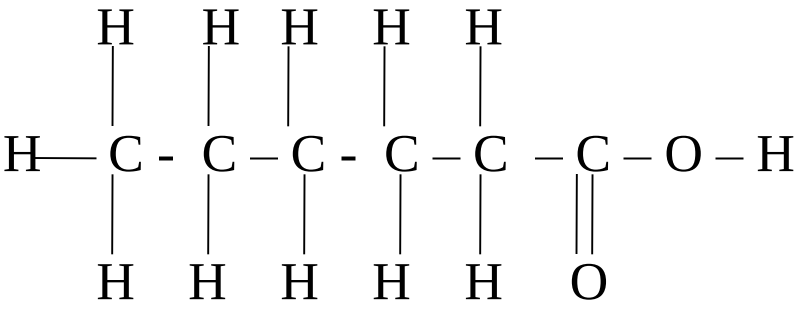
(v)they show a similar and gradual change in their physical properties e.g. boiling and melting point.

(vi)they show similar and gradual change in their chemical properties.

(vii) since they are acids they show similar properties with mineral acids

The 1st ten alkanoic acids include:

n	General /molecular formular	Structural formula	IUPAC name
0	$HCOOH$	 $H-\underset{\underset{O}{\|}}{C}-O-H$	Methanoic acid
1	$CH_3\,COOH$	 $H-\underset{\underset{H}{\vert}}{\overset{\overset{H}{\vert}}{C}}-\underset{\underset{O}{\|}}{C}-O-H$	Ethanoic acid
2	$CH_3\,CH_2\,COOH$ $C_2\,H_5\,COOH$	 $H-\underset{\underset{H}{\vert}}{\overset{\overset{H}{\vert}}{C}}-\underset{\underset{H}{\vert}}{\overset{\overset{H}{\vert}}{C}}-\underset{\underset{O}{\|}}{C}-O-H$	Propanoic acid

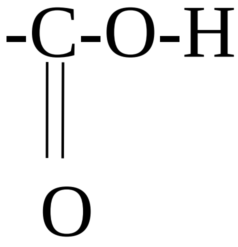
3	$CH_3\ CH_2\ CH_2\ COOH$ $C_3\ H_7\ COOH$	 $H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{\underset{O}{\|}}{C}-O-H$	Butanoic acid
4	$CH_3CH_2CH_2CH_2$ $COOH$ $C_4\ H_9\ COOH$	 $H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{\underset{O}{\|}}{C}-O-H$	Pentanoic acid
5	$CH_3CH_2\ CH_2CH_2CH_2$ $COOH$ $C_5\ H_{11}\ COOH$	 $H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{\underset{O}{\|}}{C}-O-H$	Hexanoic acid

(B) ISOMERS OF CARBOXYLIC ACIDS.

Alkanoic acids exhibit both structural and position isomerism.

The isomers are named by using the following basic guidelines

(i)Like alkanes. identify the longest carbon chain to be the parent name.

(ii)Identify the position of the  $-\underset{\underset{O}{\|}}{C}-O-H$ functional group to give it the smallest /lowest position.

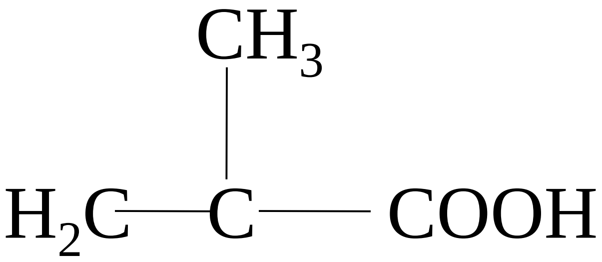
(iii)Identify the type and position of the side group branches.

Practice examples on isomers of alkanoic acids

1.Isomers of butanoic acid C_3H_7COOH

$CH_3\ CH_2\ CH_2\ COOH$

Butan-1-oic acid



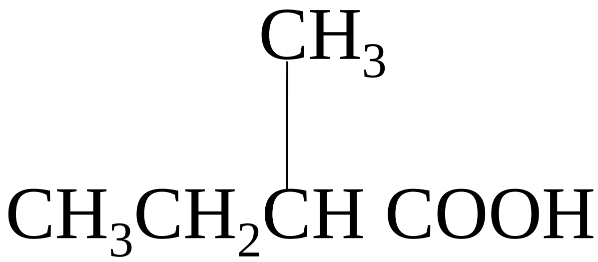
$$H_2C-\overset{\overset{CH_3}{|}}{C}-COOH$$

2-methylpropan-1-oic acid

2-methylpropan-1-oic acid and Butan-1-oic acid are structural isomers because the position of the functional group does not change but the arrangement of the atoms in the molecule does.

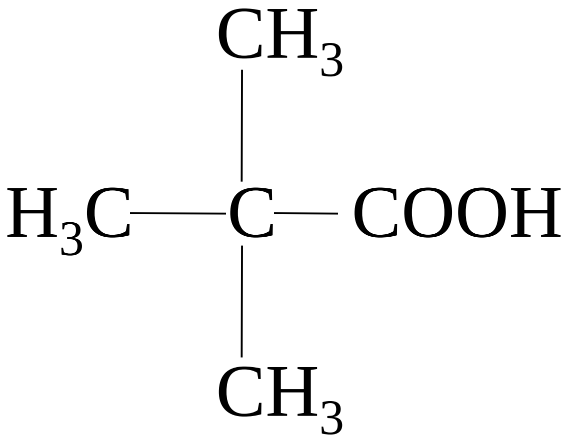
2.Isomers of pentanoic acid C_4H_9COOH

$CH_3CH_2CH_2CH_2\ COOH$ pentan-1-oic acid



$$CH_3CH_2\overset{\overset{CH_3}{|}}{C}H\ COOH$$

2-methylbutan-1-oic acid

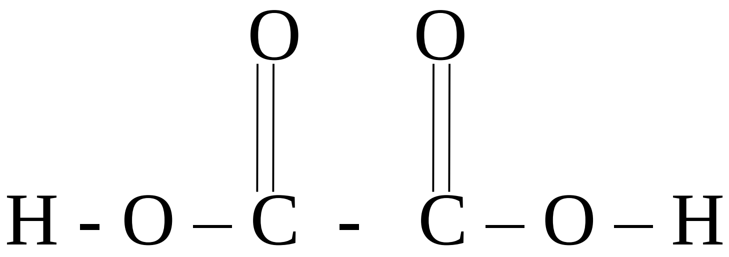


$$H_3C-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-COOH$$

2,2-dimethylpropan-1-oic acid

3.Ethan-1,2-dioic acid

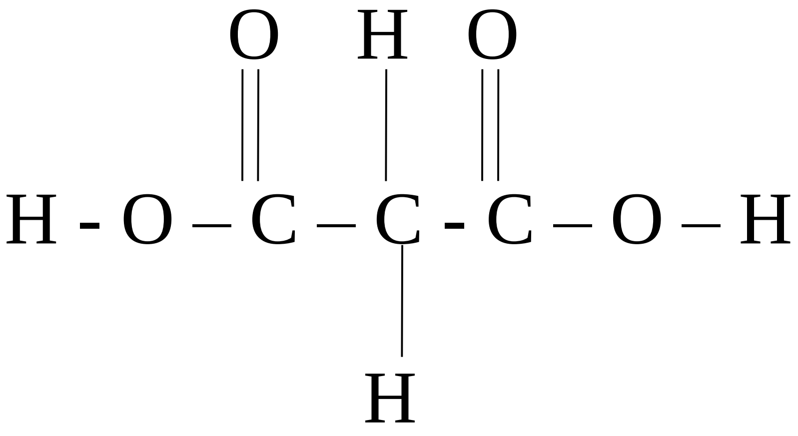
HOOC- COOH ->



$$H-O-\overset{\overset{O}{\|}}{C}-\overset{\overset{O}{\|}}{C}-O-H$$

4.Propan-1,3-dioic acid

HOOC-CH$_2$ COOH ->



$$H-O-\overset{\overset{O}{\|}}{C}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{O}{\|}}{C}-O-H$$

5.Butan-1,4-dioic acid

(C) LABORATORY AND INDUSTRIAL PREPARATION OF ALKANOIC ACIDS.

In a school laboratory, alkanoic acids can be prepared by adding an oxidizing agent ($H^+/KMnO_4$ or $H^+ / K_2Cr_2O_7$) to the corresponding **alkanol** then warming.

The oxidation converts the alkanol first to an alkanal the alkanoic acid.

NB Acidified $KMnO_4$ is a stronger oxidizing agent than acidified $K_2Cr_2O_7$

General equation:

R- CH_2 – **OH** + [O]--$H^+/KMnO_4$--> R- CH –**O** + $H_2O(l)$

(alkan**o**l) (alkan**a**l)

R- CH – **O** + [O]--$H^+/KMnO_4$--> R- C –**OOH**

(alkanal) (alkan**oic** acid)

Examples

1.Ethan**ol** on warming in acidified $KMnO_4$ is oxidized to ethan**al** then ethan**oic** acid .

CH_3- CH_2– **OH**+[O] -H^+/$KMnO_4$-->CH_3- CH–**O** + H_2O(l)

(ethan**ol**) (ethan**al**)

CH_3- CH – **O** + [O]--H^+/$KMnO_4$--> CH_3- C –**OOH**

(ethan**al**) (ethan**oic** acid)

2Propan**ol** on warming in acidified $KMnO_4$ is oxidized to propan**al** then propan**oic** acid

CH_3- CH_2 CH_2–**OH**+[O]--H^+/$KMnO_4$-->

CH_3- CH_2 CH –**O** + H_2O(l)

(propan**ol**) (propan**al**)

CH_3- CH – **O** + [O]--H^+/$KMnO_4$--> CH_3- C –**OOH**

(propan**al**) (propan**oic** acid)

Industrially,large scale manufacture of alkanoic acid like ethanoic acid is obtained from:

(a)Alk**e**nes reacting with steam at high temperatures and pressure in presence of phosphoric(V)acid catalyst and undergo hydrolysis to form alkanols. i.e.

Alkenes + Steam/water -- H_2PO_4 Catalyst--> Alkanol

The alkanol is then oxidized by air at 5 atmosphere pressure with Manganese (II)sulphate(VI) catalyst to form the alkanoic acid.

Alkanol+Air--$MnSO_4$ Catalyst/5atm pressure->alkanoic acid

Example

Ethene is mixed with steam over a **phosphoric(V)acid** catalyst,300oC temperature and 60 atmosphere pressure to form ethanol.

$CH_2=CH_2$ + H_2O -> CH_3 CH_2OH

(Ethene) (Ethanol)

This is the industrial large scale method of manufacturing ethanol

Ethanol is then oxidized by air at 5 atmosphere pressure with **Manganese (II)sulphate(VI)** catalyst to form the ethanoic acid.

CH_3 CH_2OH + [O]-- $MnSO_4$ Catalyst/5 atm pressure--> CH_3 COOH

(Ethanol) (Ethanoic acid)

(b)Alk**y**nes react with liquid water at high temperatures and pressure in presence of Mercury (II) sulphate(VI) catalyst and 30% concentrated sulphuric(VI)acid to form alkan**a**ls.

Alk**y**ne + Water -- **Mercury**(II)sulphate(VI) -->
Alkan**a**l

The alkan**a**l is then oxidized by air at 5 atmosphere pressure with Manganese (II) sulphate(VI) catalyst to form the alkan**oic** acid.

Alkan**a**l + air/oxygen --
Manganese(II)sulphate(VI)catalyst-->
Alkan**oic acid**

Example

Eth**y**ne react with liquid water at high temperature and pressure with Mercury (II) sulphate (VI)catalyst and 30% concentrated sulphuric (VI)acid to form ethan**a**l.

CH = CH + H_2O --$HgSO_4$--> CH_3 CH_2O
(Ethyne) (Ethan**a**l)

This is another industrial large scale method of manufacturing ethanol from large quantities of ethyne found in natural gas.

Ethan**a**l is then oxidized by air at 5 atmosphere pressure with Manganese (II)sulphate(VI) catalyst to form the ethanoic acid.

CH_3 CH_2O +[O] -- $MnSO_4$ Catalyst/5 atm pressure--> CH_3 COOH
(Ethan**a**l) (Oxygen from air) (Ethanoic acid)

(D) PHYSICAL AND CHEMICAL PROPERTIES OF ALKANOIC ACIDS.

I.Physical properties of alkanoic acids

The table below shows some physical properties of alkanoic acids

Alkanol	Melting point(°C)	Boiling point(°C)	Density (gcm^{-3})	Solubility in water
Methanoic acid	18.4	101	1.22	soluble
Ethanoic acid	16.6	118	1.05	soluble
Propanoic acid	-2.8	141	0.992	soluble
Butanoic acid	-8.0	164	0.964	soluble

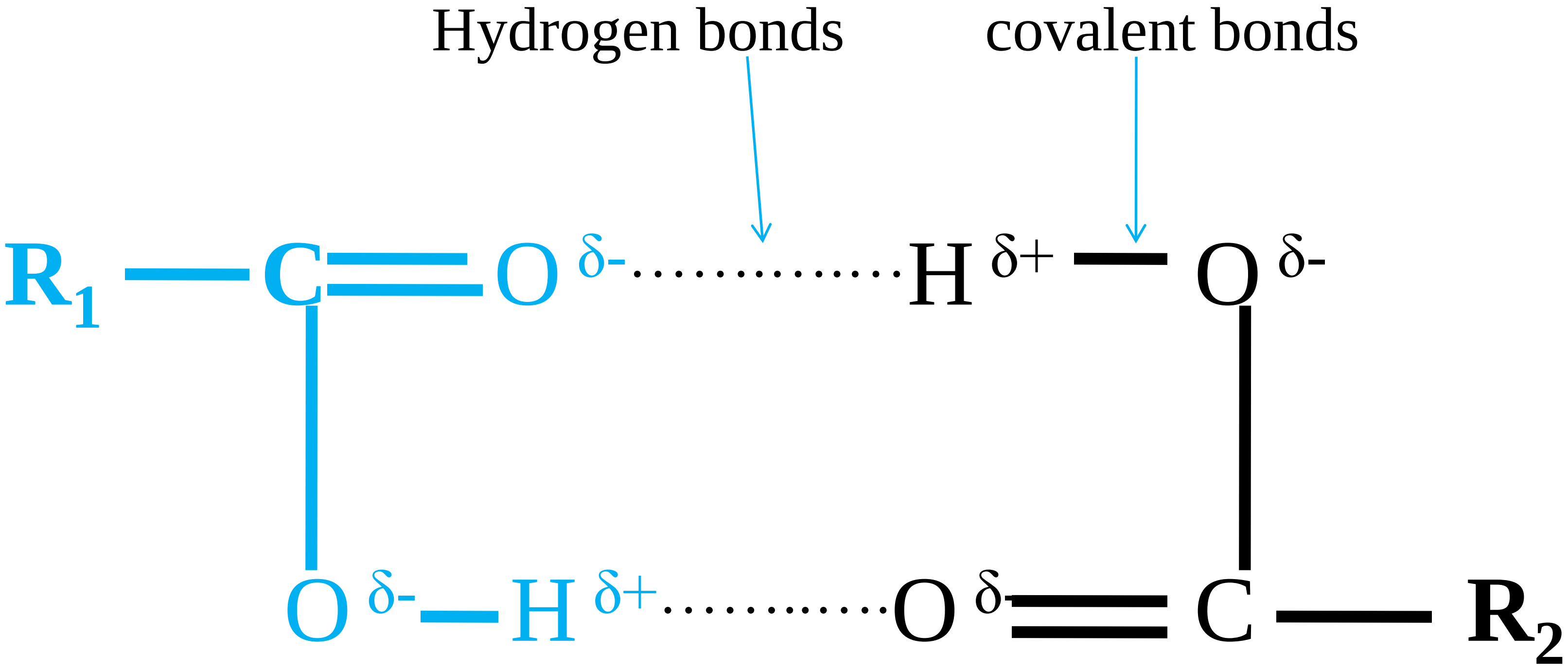
Pentanoic acid	-9.0	187	0.939	Slightly soluble
Hexanoic acid	-11	205	0.927	Slightly soluble
Heptanoic acid	-3	223	0.920	Slightly soluble
Octanoic acid	11	239	0.910	Slightly soluble
Nonanoic acid	16	253	0.907	Slightly soluble
Decanoic acid	31	269	0.905	Slightly soluble

From the table note the following:

- Melting and boiling point decrease as the carbon chain increases due to increase in intermolecular forces of attraction between the molecules requiring more energy to separate the molecules.
- The density decreases as the carbon chain increases as the intermolecular forces of attraction increases between the molecules making the molecule very close reducing their volume in unit mass.

- Solubility decreases as the carbon chain increases as the soluble –COOH end is shielded by increasing insoluble alkyl/hydrocarbon chain.

Like alkanols ,alkanoic acids exist as dimmers due to the hydrogen bonds within the molecule. i.e..



Hydrogen bonds

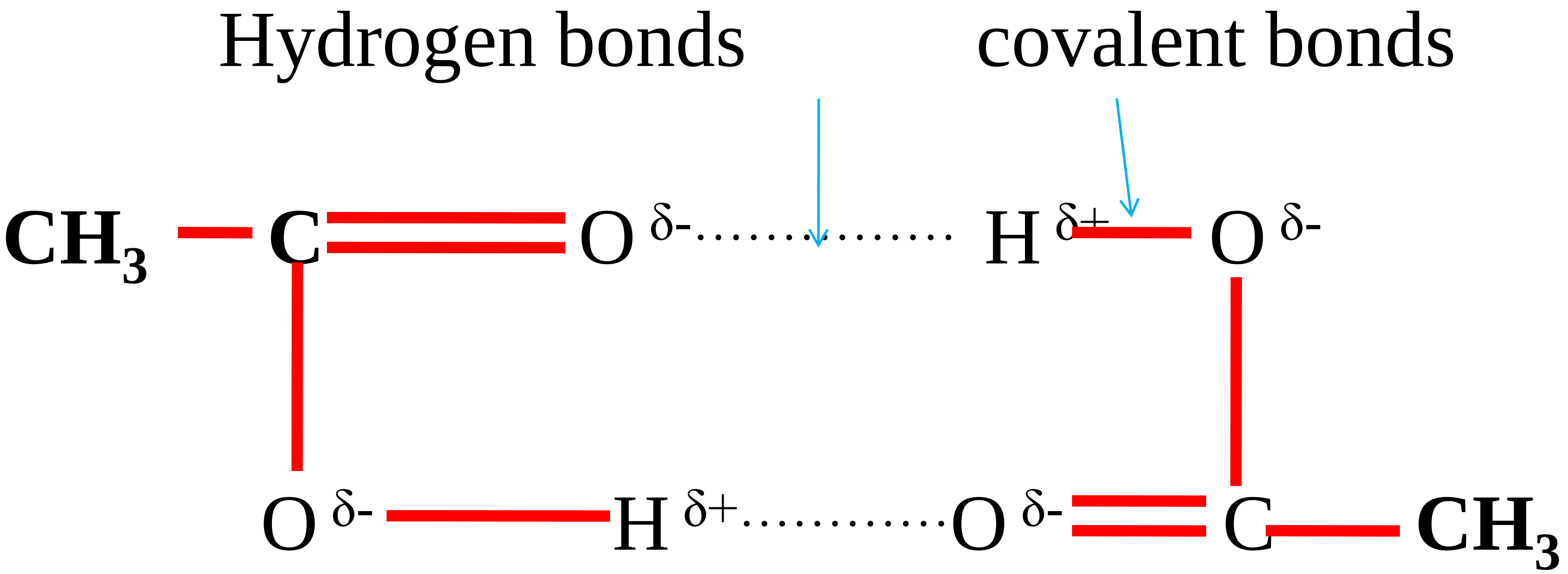
covalent bonds

R_1 and R_2 are **extensions** of the molecule.

For ethanoic acid the extension is made up of

CH_3 – to make the structure;

For ethanoic acid the extension is made up of CH_3 – to make the structure;



Hydrogen bonds

covalent bonds

Ethanoic acid has a **higher** melting/boiling point than ethanol .

This is because ethanoic acid has **two/more** hydrogen bond than ethanol.

II Chemical properties of carboxylic acids

The following experiments shows the main chemical properties of ethanoic(alkanoic) acid.

(a)Effect on litmus papers

Experiment

Dip both blue and red litmus papers in ethanoic acid.

Repeat with a solution of succinic acid, citric acid, oxalic acid, tartaric acid and dilute nitric (V)acid.

Sample observations

Solution/acid	Observations/effect on litmus papers	Inference
Ethanoic acid	Blue litmus paper turn red Red litmus paper remain red	H_3O^+/H^+(aq)ion
Succinic acid	Blue litmus paper turn red Red litmus paper remain red	H_3O^+/H^+(aq)ion
Citric acid	Blue litmus paper turn red Red litmus paper remain red	H_3O^+/H^+(aq)ion
Oxalic acid	Blue litmus paper turn red Red litmus paper remain red	H_3O^+/H^+(aq)ion
Tartaric acid	Blue litmus paper turn red Red litmus paper remain red	H_3O^+/H^+(aq)ion
Nitric(V)acid	Blue litmus paper turn red Red litmus paper remain red	H_3O^+/H^+(aq)ion

Explanation

All acidic solutions contains $H^+/H_3O^+(aq)$ ions. The $H^+/H_3O^+(aq)$ ions is responsible for turning blue litmus paper/solution to red

(b)pH

Experiment

Add 2 drops of universal indicator solution to 2cm3 of ethanoic acid and determine its pH.

Repeat with a solution of succinic acid, citric acid, oxalic acid, tartaric acid and dilute sulphuric (VI)acid.

Sample observations

Solution/acid	pH	Inference
Ethanoic acid	4/5/6	Weakly acidic
Succinic acid	4/5/6	Weakly acidic
Citric acid	4/5/6	Weakly acidic
Oxalic acid	4/5/6	Weakly acidic
Tartaric acid	4/5/6	Weakly acidic
Sulphuric(VI)acid	**1/2/3**	**Strongly acidic**

Explanations

Alkanoic acids are weak acids that partially/partly dissociate to release few H^+ ions in solution.

The pH of their solution is thus 4/5/6 showing they form weakly acidic solutions when dissolved in water.

All alkanoic acid dissociate to releases the **"H"** at the functional group in -COO**H** to form the **alkanoate ion;**
$–COO^-$

Mineral acids(Sulphuric(VI)acid, Nitric(V)acid and Hydrochloric acid) are strong acids that wholly/fully dissociate to release many H^+ ions in solution.

The pH of their solution is thus 1/2/3 showing they form strongly acidic solutions when dissolved in water.i.e

Examples

$CH_3COO\mathbf{H}(aq) \rightleftharpoons CH_3COO^-(aq) + \mathbf{H}^+(aq)$

(ethanoic acid) (ethanoate ion) (few H^+ ion)

$CH_3\,CH_2COO\mathbf{H}(aq) \rightleftharpoons CH_3\,CH_2COO^-(aq) + \mathbf{H}^+(aq)$

(propanoic acid) (propanoate ion) (few H^+ ion)

$HOO\mathbf{H}(aq) \rightleftharpoons HOO^-(aq) + \mathbf{H}^+(aq)$

(methanoic acid) (methanoate ion) (few H^+ ion)

$\mathbf{H_2}\,SO_4\,(aq) \rightleftharpoons SO_4^{2-}\,(aq) + \mathbf{2H}^+(aq)$

(sulphuric(VI) acid) (sulphate(VI) ion) (**many** H^+ ion)

$\mathbf{H}NO_3\,(aq) \rightleftharpoons NO_3^-\,(aq) + \mathbf{H}^+(aq)$

(nitric(V) acid) (nitrate(V) ion) (**many** H^+ ion)

(c)Reaction with metals

Experiment

Place about 4cm3 of ethanoic acid in a test tube.

Put about 1cm length of polished magnesium ribbon.

Test any gas produced using a burning splint.

Repeat with a solution of succinic acid, citric acid, oxalic acid, tartaric acid and dilute sulphuric (VI) acid.

Sample observations

Solution/acid	**Observations**	**Inference**
Ethanoic acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that burn with “pop” sound/explosion	H_3O^+/H^+(aq)ion
Citric acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that burn with “pop” sound/explosion	H_3O^+/H^+(aq)ion
Oxalic acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that burn with “pop” sound/explosion	H_3O^+/H^+(aq)ion
Nitric(V)acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that burn with “pop” sound/explosion	H_3O^+/H^+(aq)ion

Explanation

Metals higher in the reactivity series displace the hydrogen in **all** acids to evolve/produce hydrogen gas and form a salt.

Alkanoic acids react with metals to form alkanoates salt and produce/evolve hydrogen gas.

.Hydrogen extinguishes a burning splint with a pop sound/explosion.

Only the “H”in the functional group -COO**H** is /are displaced and not in the alkyl hydrocarbon chain.

Alkanoic acid + Metal -> Alkanoate + Hydrogen i.e.

Examples

1. For a monovalent metal with monobasic acid

$$2R - COO\mathbf{H} \quad + \quad 2M \quad \rightarrow \quad 2R\text{-}\ COO\mathbf{M} \quad + \quad H_2(g)$$

2.For a divalent metal with monobasic acid

$$2R - COO\mathbf{H} \quad + \quad M \quad \rightarrow \quad (R\text{-}\ COO)_2\mathbf{M} \quad + \quad H_2(g)$$

3.For a divalent metal with dibasic acid

$$\mathbf{H}OOC\text{-}R\text{-}COO\mathbf{H} + \quad 2M \quad \rightarrow \quad \mathbf{M}OOC\text{-}R\text{-}COO\mathbf{M} \quad + \quad H_2(g)$$

4.For a monovalent metal with dibasic acid

$$\mathbf{H}OOC\text{-}R\text{-}COO\mathbf{H} + \quad 2M \quad \rightarrow \quad \mathbf{M}OOC\text{-}R\text{-}COO\mathbf{M} \quad + \quad H_2(g)$$

5 (i)Sulphuric(VI)acid is a dibasic acid

$H_2SO_4(aq) + 2M \rightarrow M_2SO_4(aq) + H_2(g)$

$H_2SO_4(aq) + M \rightarrow MSO_4(aq) + H_2(g)$

(ii)Nitric(V) is a monobasic acid

$2HNO_3(aq) + 2M \rightarrow 2MNO_3(aq) + H_2(g)$

$2HNO_3(aq) + M \rightarrow M(NO_3)_2(aq) + H_2(g)$

(iii)hydrochloric acid is a monobasic acid

$2HCl(aq) + 2M \rightarrow 2MCl(aq) + H_2(g)$

$2HCl(aq) + M \rightarrow MCl_2(aq) + H_2(g)$

Examples

1.Sodium reacts with ethanoic acid to form sodium ethanoate and produce. hydrogen gas.

Caution: This reaction is explosive.

$CH_3COO\mathbf{H}$ (aq)+ Na(s) -> $CH_3COO\mathbf{Na}$ (aq) + H_2(g)
(Ethanoic acid) (Sodium ethanoate)

2.Calcium reacts with ethanoic acid to form calcium ethanoate and produce. hydrogen gas.

$2CH_3COO\mathbf{H}$ (aq)+ Ca(s) ->$(CH_3COO)_2\mathbf{Ca}$ (aq) + H_2(g)
(Ethanoic acid) (Calcium ethanoate)

3.Sodium reacts with ethan-1,2-dioic acid to form sodium ethan-1,2-dioate and produce. hydrogen gas.

HOOC-R-COO**H**+ 2Na -> **Na**OOC - COO**Na** + H_2(g)
(ethan-1,2-dioic acid) (sodium ethan-1,2-dioate)

Commercial name of ethan-1,2-dioic acid is oxalic acid. The salt is sodium oxalate/sodium ethan-1,2-dioate.

4.Magnesium reacts with ethan-1,2-dioic acid to form magnesium ethan-1,2-dioate and produce. hydrogen gas.

$\mathbf{H}OOC\text{-}R\text{-}COO\mathbf{H} + Mg \rightarrow (OOC - COO)\mathbf{Mg} + H_2(g)$

(ethan-1,2-dioic acid) (magnesium ethan-1,2-dioate)

5.Magnesium reacts with

(i)Sulphuric(VI)acid to form Magnesium sulphate(VI)

$\mathbf{H_2}SO_4(aq) + Mg \rightarrow MgSO_4(aq) + H_2(g)$

(ii)Nitric(V) and hydrochloric acid are monobasic acid

$2\mathbf{H}NO_3(aq) + Mg \rightarrow M(NO_3)_2(aq) + H_2(g)$

(d)Reaction with hydrogen carbonates and carbonates

Experiment

Place about 3cm3 of ethanoic acid in a test tube.

Add about 0.5g/ ½ spatula end full of sodium hydrogen carbonate/sodium carbonate.

Test the gas produced using lime water.

Repeat with a solution of succinic acid, citric acid, oxalic acid, tartaric acid and dilute sulphuric (VI) acid.

Sample observations

Solution/acid	Observations	Inference
Ethanoic acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that forms a white precipitate with lime water	H_3O^+/H^+(aq)ion
Succinic acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that forms a white precipitate with lime water	H_3O^+/H^+(aq)ion
Citric acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that forms a white precipitate with lime water	H_3O^+/H^+(aq)ion
Nitric(V)acid	(i)effervescence, fizzing, bubbles (ii)colourless gas produced that forms a white precipitate with lime water	H_3O^+/H^+(aq)ion

All acids react with hydrogen carbonate/carbonate to form salt ,water and evolve/produce bubbles of carbon(IV) oxide and water.

Carbon(IV)oxide forms a white precipitate when bubbled in lime water/extinguishes a burning splint.

Alkanoic acids react with hydrogen carbonate/carbonate to form alkanoates ,water and evolve/produce bubbles of carbon(IV)oxide and water.

Alkanoic acid + hydrogen carbonate -> alkanoate + water
+ carbon(IV)oxide

Alkanoic acid + carbonate -> alkanoate + water
+ carbon(IV)oxide

Examples

1.**Sodium hydrogen carbonate** reacts with **ethanoic acid** to form sodium ethanoate ,water and carbon(IV)oxide gas.

$CH_3COO\mathbf{H}\ (aq)+NaHCO_3\ (s)\ {-}{>}CH_3COO\mathbf{Na}(aq)+H_2O(l)+CO_2\ (g)$

(Ethanoic acid) (Sodium ethanoate)

2.**Sodium carbonate** reacts with **ethanoic acid** to form sodium ethanoate ,water and carbon(IV)oxide gas.

$2CH_3COO\mathbf{H}\ (aq)+Na_2CO_3(s){-}{>}2CH_3COO\mathbf{Na}(aq)+H_2O(l)+CO_2\ (g)$

(Ethanoic acid) (Sodium ethanoate)

3.Sodium carbonate reacts with **ethan-1,2-dioic acid** to form sodium ethanoate ,water and carbon(IV)oxide gas.

$\mathbf{H}OOC\text{-}COO\mathbf{H}+Na_2CO_3(s){-}{>}\mathbf{Na}OOC - COO\mathbf{Na}\ +H_2O(l)+CO_2\ (g)$

(ethan-1,2-dioic acid) (sodium ethan-1,2-dioate)

4.**Sodium hydrogen carbonate** reacts with **ethan-1,2-dioic acid** to form sodium ethanoate ,water and carbon(IV)oxide gas.

$\mathbf{H}OOC\text{-}COO\mathbf{H}+2NaHCO_3(s){-}{>}\mathbf{Na}OOC\text{-}COO\mathbf{Na}+H_2O(l)+2CO_2\ (g)$

(ethan-1,2-dioic acid) (sodium ethan-1,2-dioate)

(e)Esterification

Experiment

Place 4cm3 of ethanol acid in a boiling tube.

Add equal volume of ethanoic acid.

To the mixture, add 2 drops of concentrated sulphuric(VI)acid **carefully**.

Warm/heat gently on Bunsen flame.

Pour the mixture into a beaker containing 50cm3 of water.

Smell the products.

Repeat with a solution of succinic acid, citric acid, oxalic acid, tartaric acid and dilute sulphuric (VI) acid.

Sample observations

Solution/acid	Observations
Ethanoic acid	Sweet fruity smell
Succinic acid	Sweet fruity smell
Citric acid	Sweet fruity smell
Oxalic acid	Sweet fruity smell
Tartaric acid	Sweet fruity smell
Dilute sulphuric(VI)acid	**No sweet fruity smell**

Explanation

Alkanols react with alkanoic acid to form the sweet smelling homologous series of esters and water.

The reaction is **catalysed** by concentrated sulphuric(VI)acid in the laboratory but naturally by sunlight /heat.

Each ester has a characteristic smell derived from the many possible combinations of alkanols and alkanoic acids.

Alkanol + Alkanoic acids -> Ester + water

Esters derive their names from the alkanol first then alkanoic acids. The alkanol “becomes” an **alkyl** group and the alkanoic acid “becomes” **alkanoate** hence **alkylalkanoate**. e.g.

Ethanol + Ethanoic acid -> Ethylethanoate + Water
Ethanol + Propanoic acid -> Ethylpropanoate + Water
Ethanol + Methanoic acid -> Ethylmethanoate + Water

Ethanol + butanoic acid -> Ethylbutanoate + Water
Propanol + Ethanoic acid->Propylethanoate + Water
Methanol+Ethanoic acid->Methyethanoate + Water

Methanol+Decanoic acid->Methyldecanoate + Water
Decanol +Methanoic acid->Decylmethanoate + Water

During the formation of the ester, the “O” joining the alkanol and alkanoic acid comes from the alkanol.

R_1 -CO**OH** + R_2 –O**H** -> **R_1 -COO –R_2** + **H_2O**

Examples

1. Ethanol reacts with ethanoic acid to form the ester ethyl ethanoate and water.

Ethanol + Ethanoic acid --Conc. H_2SO_4 --> Ethylethanoate + Water

C_2H_5OH (l) + CH_3COOH(l) --Conc. H_2SO_4 --> $CH_3COO\ C_2H_5$(**aq**) +H_2O(l)

CH_3CH_2OH (l)+ CH_3COOH(l) --Conc. H_2SO_4 --> $CH_3COOCH_2CH_3$(**aq**) +H_2O(l)

C. DETERGENTS

Detergents are cleaning agents that improve the cleaning power /properties of water.

A detergent therefore should be able to:

(i)dissolve substances which water can not e.g grease ,oil, fat

(ii)be washed away after cleaning.

There are **two** types of detergents:

(a)Soapy detergents

(b)Soapless detergents

(a)SOAPY DETERGENTS

Soapy detergents usually called soap is long chain salt of organic alkanoic acids.

Common soap is sodium octadecanoate .

It is derived from reacting concentrated sodium hydroxide solution with octadecanoic acid(18 carbon alkanoic acid)

Sodium hydroxide + octadecanoic acid ->

Sodium octadecanoate + water

$NaOH(aq) + CH_3(CH_2)_{16}COOH(aq) \rightarrow$

$CH_3(CH_2)_{16}COO^- Na^+ (aq) + H_2O(l)$

Commonly ,soap can thus be represented ;

$R\text{-}COO^- Na^+$ where;

R is a long chain alkyl group and $-COO^- Na^+$ is the alkanoate ion.

In a school laboratory and at industrial and domestic level, soap is made by reacting concentrated sodium hydroxide solution with **esters** from (animal) **fat** and **oil**.

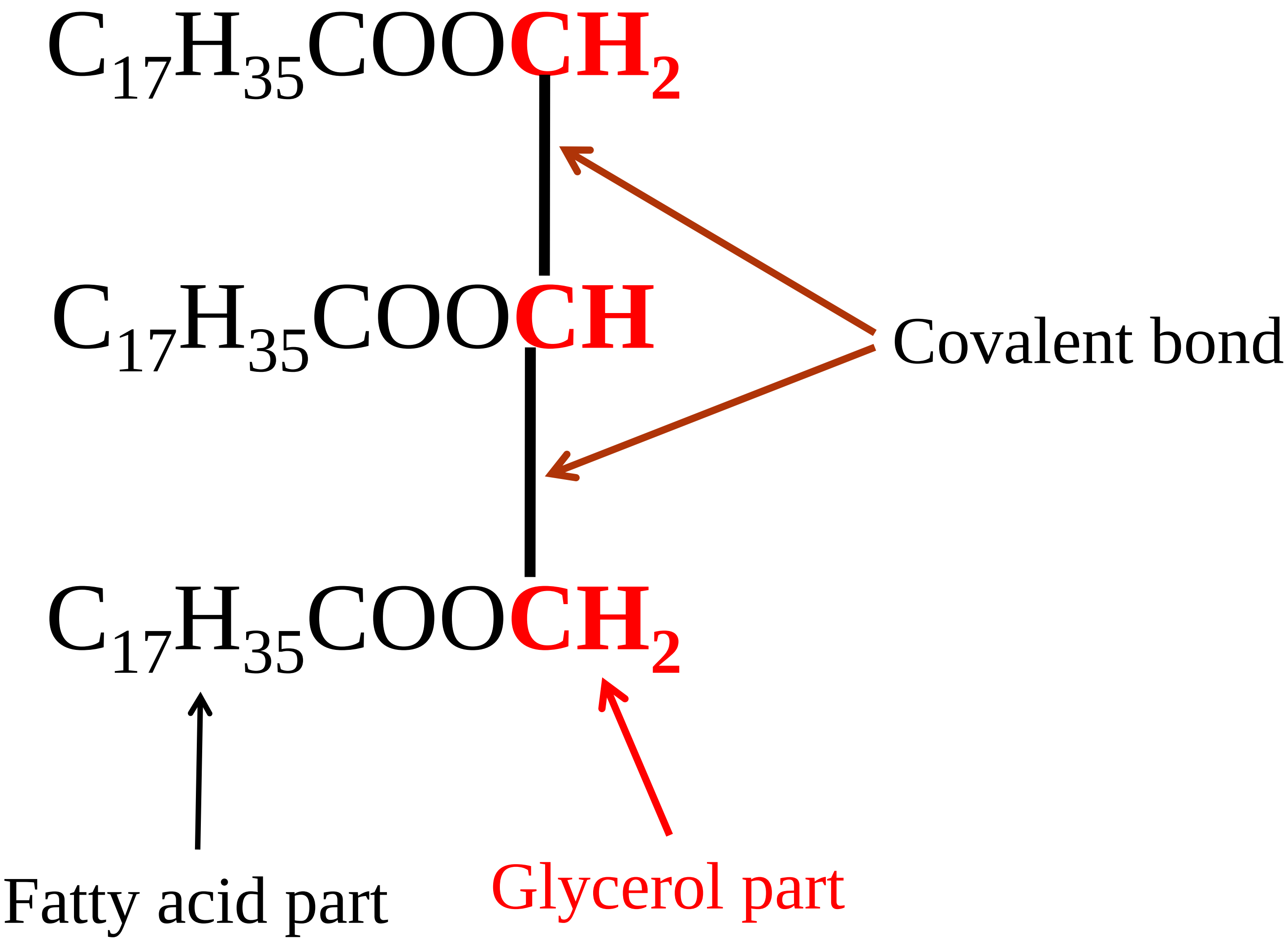
The process of making soap is called **saponification.**

During saponification ,the ester is **hydrolyzed** by the alkali to form sodium salt /soap and **glycerol /propan-1,2,3-triol** is produced.

Fat/oil(ester) + sodium/potassium hydroxide->
sodium /potassium salt(soap)+ glycerol

Fats/Oils are esters with **fatty acids** and **glycerol** parts in their structure;

Structure of Fat/oil



$C_{17}H_{35}COO\mathbf{CH_2}$

$C_{17}H_{35}COO\mathbf{CH}$

$C_{17}H_{35}COO\mathbf{CH_2}$

Covalent bond

Fatty acid part

Glycerol part

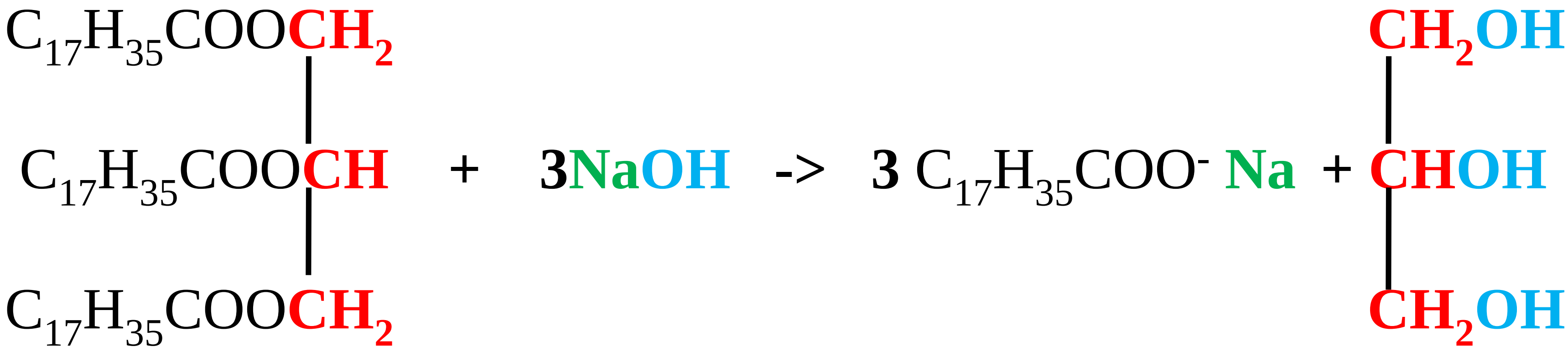
When boiled with concentrated sodium hydroxide solution NaOH;

(i) NaOH ionizes/dissociates into **Na^+** and **OH^-** ions

(ii)fat/oil split into **three** $C_{17}H_{35}COO^-$ and **one** CH_2 CH CH_2

(iii) three **Na^+** combine with the three $C_{17}H_{35}COO^-$ to form the salt $C_{17}H_{35}COO^-$ **Na^+**

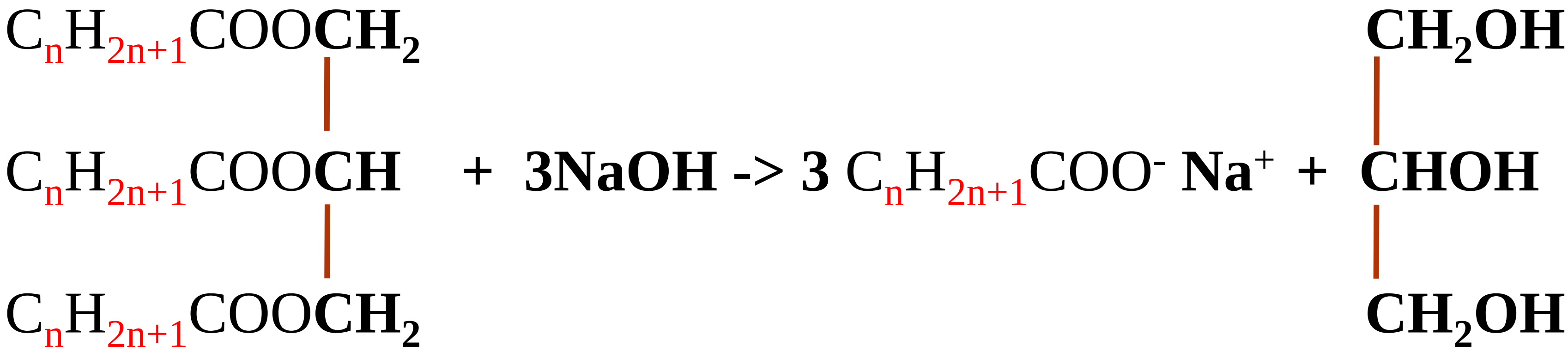
(iv)the three **OH^-**ions combine with the CH_2 CH CH_2 to form an alkanol with three functional groups CH_2 **OH** CH **OH** CH_2 **OH(propan-1,2,3-triol)**



$$\begin{array}{l} \mathrm{C_{17}H_{35}COOCH_2} \\ \qquad\qquad | \\ \mathrm{C_{17}H_{35}COOCH} \\ \qquad\qquad | \\ \mathrm{C_{17}H_{35}COOCH_2} \end{array} + \mathrm{3NaOH} \rightarrow \mathrm{3\,C_{17}H_{35}COO^{-}\,Na} + \begin{array}{l} \mathrm{CH_2OH} \\ | \\ \mathrm{CHOH} \\ | \\ \mathrm{CH_2OH} \end{array}$$

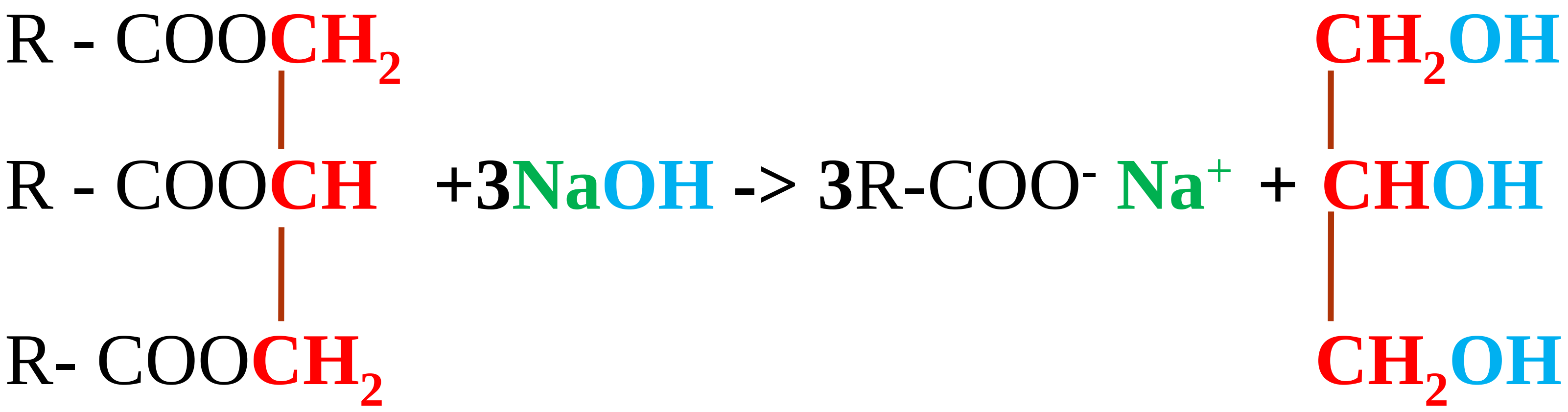
Ester **Alkali** **Soap** **glycerol**

Generally:



$$\begin{array}{l} \mathrm{C_nH_{2n+1}COOCH_2} \\ \qquad\qquad | \\ \mathrm{C_nH_{2n+1}COOCH} \\ \qquad\qquad | \\ \mathrm{C_nH_{2n+1}COOCH_2} \end{array} + \mathrm{3NaOH} \rightarrow \mathrm{3\,C_nH_{2n+1}COO^{-}\,Na^{+}} + \begin{array}{l} \mathrm{CH_2OH} \\ | \\ \mathrm{CHOH} \\ | \\ \mathrm{CH_2OH} \end{array}$$

Ester **Alkali** **Soap** **glycerol**



$$\begin{array}{lcccr} R-COOCH_2 & & & & CH_2OH \\ \quad\quad\quad | & & & & | \\ R-COOCH & +3NaOH & \rightarrow & 3R\text{-}COO^- Na^+ & + \; CHOH \\ \quad\quad\quad | & & & & | \\ R-COOCH_2 & & & & CH_2OH \end{array}$$

Ester **Alkali** **Soap** **glycerol**

During this process a little <u>sodium chloride</u> is added to **precipitate** the soap by reducing its solubility.

This is called **salting out**.

The soap is then added colouring agents ,perfumes and herbs of choice.

School laboratory preparation of soap

Place about 40 g of fatty (animal fat)beef/meat in 100cm3 beaker .

Add about 15cm3 of 4.0M sodium hydroxide solution.

Boil the mixture for about 15minutes.

Stir the mixture .

Add about 5.0cm3 of distilled water as you boil to make up for evaporation.

Boil for about another 15minutes.Add about four spatula end full of pure sodium chloride crystals. Continue stirring for another five minutes. Allow to cool.

Filter of /decant and wash off the residue with distilled water .

Transfer the clean residue into a dry beaker. Preserve.

The action of soap

Soapy detergents:

(i)act by reducing the surface tension of water by forming a thin layer on top of the water.

(ii)is made of a **non-polar** alkyl /hydrocarbon tail and a **polar** $-COO^-Na^+$ head.

The non-polar alkyl /hydrocarbon tail is **hydrophobic** (water hating) and thus does not dissolve in water.

It dissolves in non-polar solvent like grease, oil and fat.

The polar $-COO^-Na^+$ head is **hydrophilic** (water loving)and thus dissolve in water.

When washing with soapy detergent, the non-polar tail of the soapy detergent surround/dissolve in the dirt on the garment /grease/oil while the polar head dissolve in water.

Through **mechanical agitation** /stirring /sqeezing/ rubbing/ beating/kneading, some grease is dislodged /lifted of the surface of the garment.

It is immediately surrounded by more soap molecules.

It float and spread in the water as tiny droplets that scatter light in form of emulsion making the water cloudy and shinny.

It is removed from the garment by rinsing with fresh water.

The repulsion of the soap head prevent /ensure the droplets do not mix.

Once removed, the dirt molecules cannot be redeposited back because it is surrounded by soap molecules.

Advantages and disadvantages of using soapy detergents

Soapy detergents are **biodegradable**.

They are acted upon by bacteria and rot.

They thus do not cause environmental pollution.

Soapy detergents have the disadvantage in that:

(i)they are made from fat and oils which are better eaten as food than make soap.

(ii)forms an insoluble precipitate with hard water called **scum.**

Scum is insoluble calcium octadecanoate and Magnesium octadecanoate formed when soap reacts with **Ca^{2+}** and **Mg^{2+}** present in **hard water**.

Chemical equation

$2C_{17}H_{35}COO^{-}$ **Na^{+}** (aq) **+** Ca^{2+}(aq) **->**

($C_{17}H_{35}COO^{-}$ **)** $_{2}Ca^{2+}$ **(**s**)** + **2Na**$^{+}$(aq)

(insoluble Calcium octadecanote/scum)

$2C_{17}H_{35}COO^{-}$ **Na^{+}** (aq) **+** Mg^{2+}(aq) **->**

($C_{17}H_{35}COO^{-}$ **)** $_{2}Mg^{2+}$ **(**s**)** + **2Na**$^{+}$(aq)

(insoluble Magnesium octadecanote/scum)

This causes wastage of soap.

Potassium soaps are better than Sodium soap.

Potassium is more expensive than sodium and thus its soap is also more expensive.

(b)SOAPLESS DETERGENTS

Soapless detergent usually called detergent is a long chain salt formed from by-products of fractional distillation of crude oil.

Commonly used detergents include:

(i)washing agents

(ii)toothpaste

(iii)emulsifiers/wetting agents/shampoo

Soapless detergents are derived from reacting:

(i)concentrated sulphuric(VI)acid with a long chain alkanol e.g. Octadecanol(18 carbon alkanol) to form alkyl hydrogen sulphate(VI)

Alkanol + Conc. sulphuric(VI)acid ->

alkyl hydrogen sulphate(VI) +Water

$R{-}OH + H_2SO_4 \rightarrow R{-}O{-}SO_3H + H_2O$

(ii)the alkyl hydrogen sulphate(VI) is then **neutralized** with sodium/potassium hydroxide to form sodium / potassium alkyl hydrogen sulphate(VI)

Sodium/potassium alkyl hydrogen sulphate(VI) is the **soapless** detergent.

alkyl hydrogen sulphate(VI) + Potassium/sodium hydroxide -> Sodium/potassium alkyl hydrogen sulphate(VI) + Water

$R{-}O{-}SO_3H + \mathbf{Na}OH \rightarrow R{-}O{-}SO_3^- \, \mathbf{Na}^+ + H_2O$

Example

Step I : Reaction of Octadecanol with Conc.$\mathbf{H}_2SO_4$

$C_{17}H_{35}CH_2OH\ (aq)\ +\ H_2SO_4\ \rightarrow$

$C_{17}H_{35}CH_2\text{-}\mathbf{O}\text{-}\ \mathbf{SO_3}^{-}\ \mathbf{H}^{+}\ (aq)\ +\ H_2O\ (l)$

octadecanol + sulphuric(VI)acid ->

Octadecyl hydrogen sulphate(VI) + water

Step II: Neutralization by an alkali

$C_{17}H_{35}CH_2\text{-}\mathbf{O}\text{-}\ \mathbf{SO_3}^{-}\ \mathbf{H}^{+}\ (aq)\ +\ NaOH\ \rightarrow$

$C_{17}H_{35}CH_2\text{-}\mathbf{O}\text{-}\ \mathbf{SO_3}^{-}\ \mathbf{Na}^{+}\ (aq)\ +\ H_2O\ (l)$

Octadecyl hydrogen sulphate(VI) + sodium/potassium hydroxide ->

sodium/potassium octadecyl hydrogen sulphate(VI) +Water

School laboratory preparation of soapless detergent

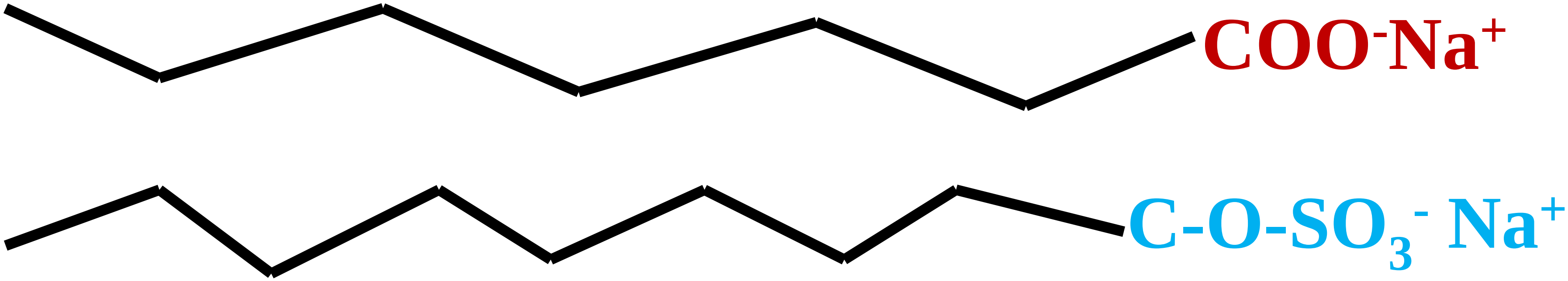
Place about 20g of olive oil in a 100cm3 beaker.
Put it in a trough containing ice cold water.

Add dropwise carefully 18M concentrated sulphuric (VI)acid stirring continuously into the olive oil until the oil turns brown.

Add 30cm3 of 6M sodium hydroxide solution.
Stir.
This is a soapless detergent.

The action of soapless detergents

The action of soapless detergents is similar to that of soapy detergents.
The soapless detergents contain the hydrophilic head and a long hydrophobic tail. i.e.



$COO^{-}Na^{+}$

$C\text{-}O\text{-}SO_3^{-}\ Na^{+}$

(long hydrophobic / non-polar alkyl tail)

(**polar/ionic head hydrophilic**)

The tail dissolves in fat/grease/oil while the ionic/ polar/ ionic head dissolves in water.

The tail stick to the dirt which is removed by the attraction of water molecules and the polar /ionic /hydrophilic head by mechanical agitation /squeezing /kneading / beating/ rubbing/ scrubbing/ scratching.

The suspended dirt is then surrounded by detergent molecules and repulsion of the anion head preventing the dirt from sticking on the material garment.

The tiny droplets of dirt emulsion makes the water cloudy.

On rinsing the cloudy emulsion is washed away.

Advantages and disadvantages of using soapless detergents

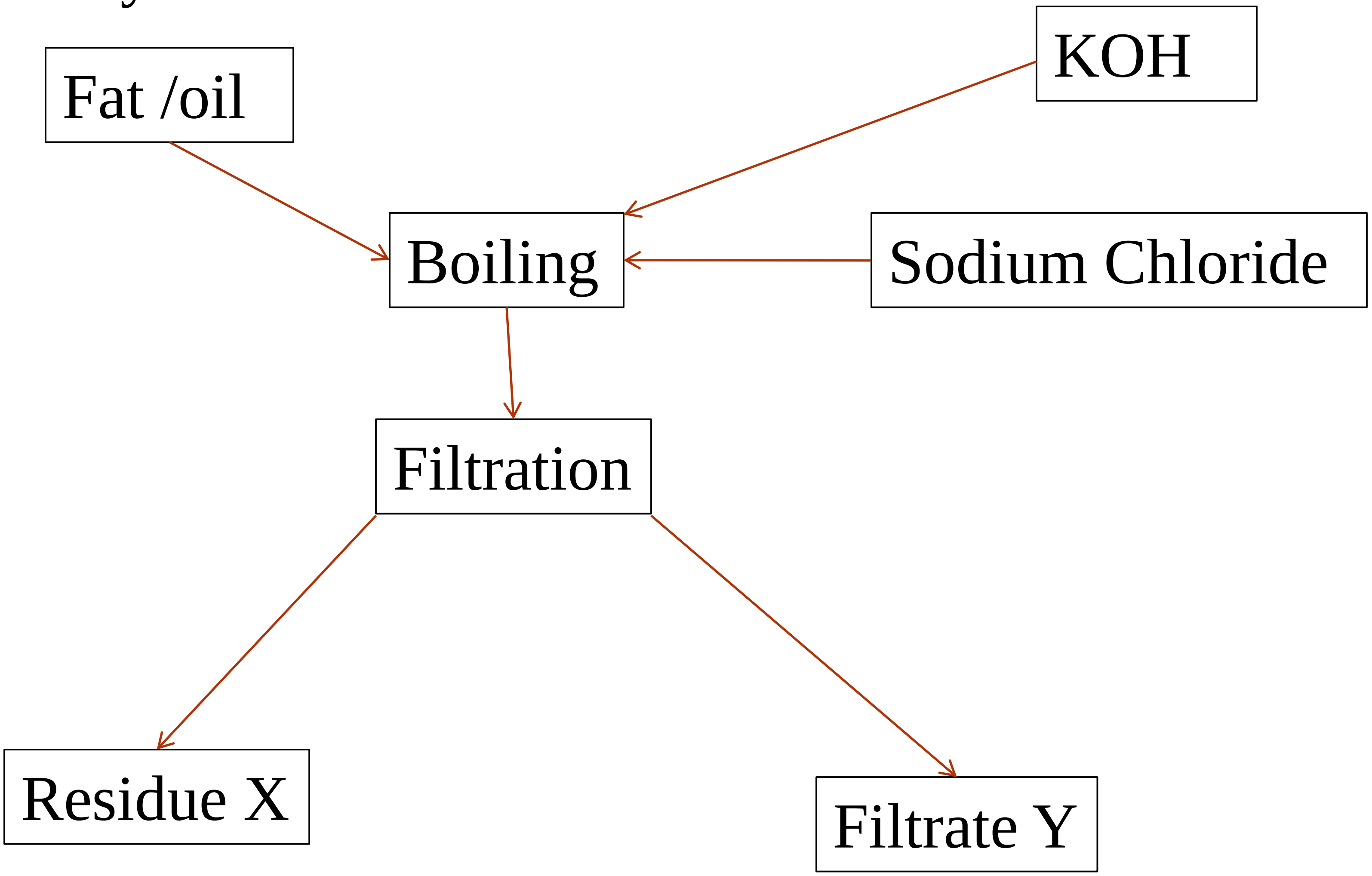
Soapless detergents are non-biodegradable unlike soapy detergents.

They persist in water during sewage treatment by causing **foaming** in rivers ,lakes and streams leading to marine /aquatic death.

Soapless detergents have the advantage in that they:
(i)do not form scum with hard water.
(ii)are cheap to manufacture/buying
(iii)are made from petroleum products but soap is made from fats/oil for human consumption.

Sample revision questions

1. Study the scheme below


Fat /oil

KOH

Boiling

Sodium Chloride

Filtration

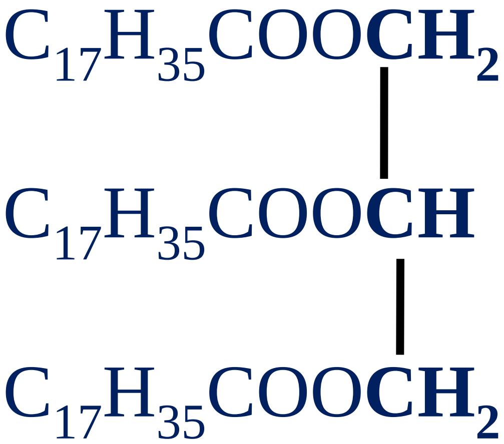
Residue X

Filtrate Y

(a)Identify the process

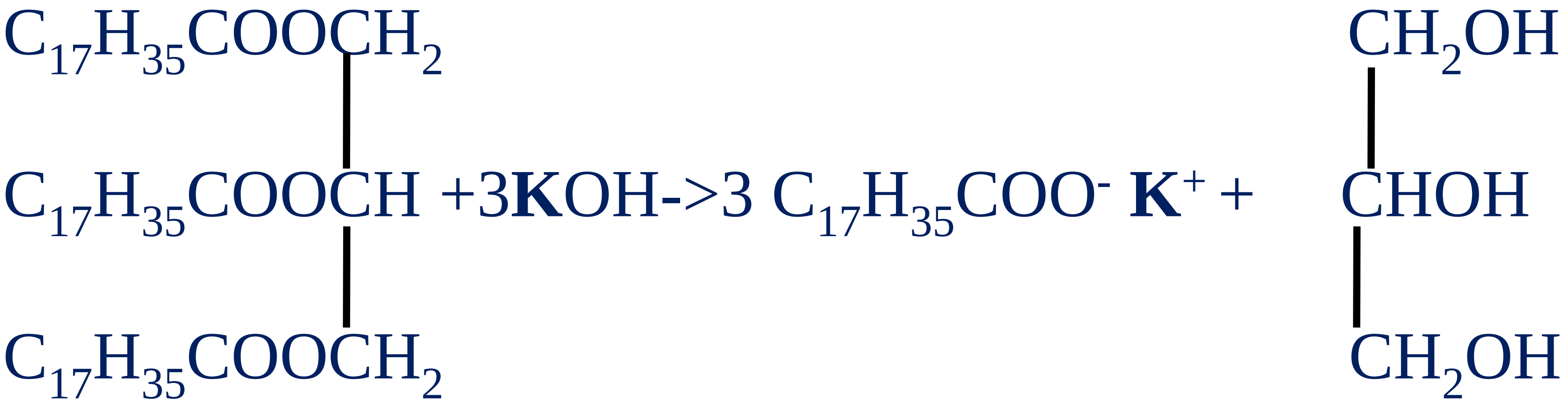
Saponification

(b)Fats and oils are esters. Write the formula of the a common structure of ester



$$\begin{array}{l} C_{17}H_{35}COO\mathbf{CH_2} \\ \qquad\qquad\qquad\quad | \\ C_{17}H_{35}COO\mathbf{CH} \\ \qquad\qquad\qquad\quad | \\ C_{17}H_{35}COO\mathbf{CH_2} \end{array}$$

(c)Write a balanced equation for the reaction taking place during boiling



$$\begin{array}{lr} C_{17}H_{35}COOCH_2 & CH_2OH \\ \quad\quad\quad\quad\quad\; | & | \\ C_{17}H_{35}COOCH + 3\mathbf{K}OH \rightarrow 3\ C_{17}H_{35}COO^{-}\ \mathbf{K}^{+} + & CHOH \\ \quad\quad\quad\quad\quad\; | & | \\ C_{17}H_{35}COOCH_2 & CH_2OH \end{array}$$

(d)Give the IUPAC name of:

(i)Residue X

Potassium octadecanoate

(ii)Filtrate Y

Propan-1,2,3-triol

(e)Give one use of fitrate Y

Making paint

(f)What is the function of sodium chloride

To reduce the solubility of the soap hence helping in precipitating it out

(g)Explain how residue X helps in washing.

Has a **non-polar** hydrophobic tail that dissolves in **dirt**/grease /oil/fat

Has a **polar** /ionic hydrophilic head that dissolves in **water**.

From **mechanical agitation** ,the dirt is plucked **out** of the garment and **surrounded** by the **tail** end preventing it from being deposited back on the garment.

(h)State one:

(i)advantage of continued use of residue X on the environment

Is biodegradable and thus do not pollute the environment

(ii)disadvantage of using residue X

Uses fat/oil during preparation/manufacture which are better used for human consumption.

(i)Residue X was added dropwise to some water. The number of drops used before lather forms is as in the table below.

	Water sample		
	A	**B**	**C**
Drops of residue X	**15**	**2**	**15**
Drops of residue X in boiled water	**2**	**2**	**15**

(i)State and explain which sample of water is:

I. Soft

Sample B .

Very little soap is used and no effect on amount of soap even on boiling/heating.

II. Permanent hard

Sample C .

A lot of soap is used and no effect on amount of soap even on boiling/heating.

Boiling does not remove permanent hardness of water.

III. Temporary hard

Sample A .

A lot of soap is used before boiling. Very little soap is used on boiling/heating.

Boiling remove temporary hardness of water.

(ii)Write the equation for the reaction at water sample C.

Chemical equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}(aq) + CaSO_4(aq) \rightarrow (C_{17}H_{35}COO^{-})_2Ca^{2+}(\mathbf{s}) + \mathbf{K}_2SO_4(aq)$

Ionic equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}(aq) + Ca^{2+}(aq) \rightarrow (C_{17}H_{35}COO^{-})_2Ca^{2+}(\mathbf{s}) + \mathbf{2K}^{+}(aq)$

Chemical equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}(aq) + MgSO_4(aq) \rightarrow (C_{17}H_{35}COO^{-})_2Mg^{2+}(\mathbf{s}) + \mathbf{K}_2SO_4(aq)$

Ionic equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}(aq) + Mg^{2+}(aq) \rightarrow (C_{17}H_{35}COO^{-})_2Mg^{2+}(\mathbf{s}) + \mathbf{2K}^{+}(aq)$

(iii)Write the equation for the reaction at water sample A before boiling.

Chemical equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}$ (aq) + $Ca(HCO_3)$(aq) ->
$\mathbf{(}C_{17}H_{35}COO^{-}\mathbf{)}_{2}Ca^{2+}$ **(s)** + $2KHCO_3$ (aq)

Ionic equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}$ (aq) + Ca^{2+}(aq) ->
$\mathbf{(}C_{17}H_{35}COO^{-}\mathbf{)}_{2}Ca^{2+}$ **(s)** + $2K^{+}$(aq)

Chemical equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}$ (aq) + $Mg(HCO_3)$(aq) ->
$\mathbf{(}C_{17}H_{35}COO^{-}\mathbf{)}_{2}Mg^{2+}$ **(s)** + $2KHCO_3$
(aq) Ionic equation

$2C_{17}H_{35}COO^{-}\,\mathbf{K}^{+}$ (aq) + Mg^{2+}(aq) ->
$\mathbf{(}C_{17}H_{35}COO^{-}\mathbf{)}_{2}Mg^{2+}$ **(s)** + $2K^{+}$(aq)

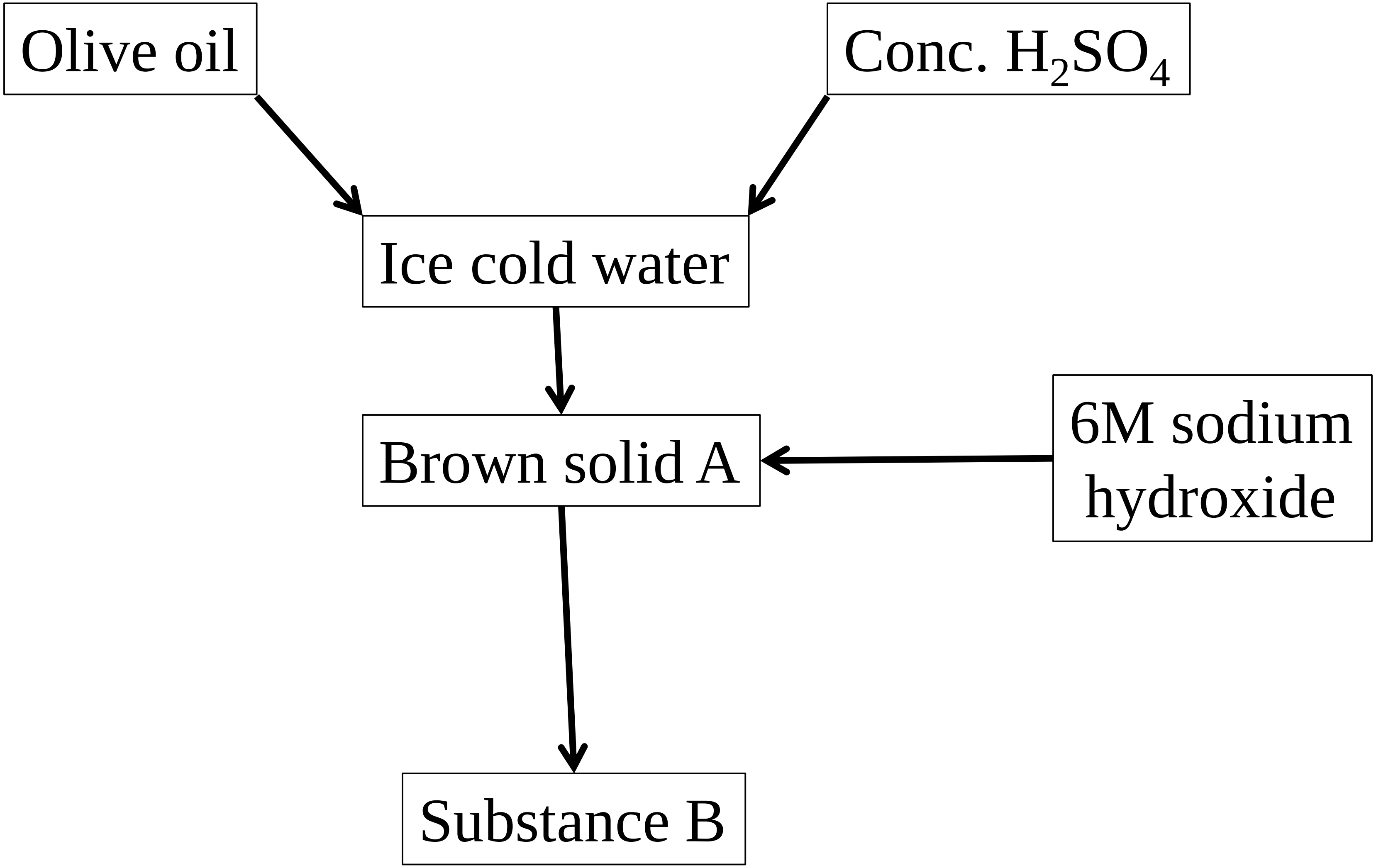
(iv)Explain how water becomes hard

Natural or rain water flowing /passing through rocks containing calcium (chalk, gypsum, limestone)and magnesium compounds (dolomite)dissolve them to form soluble Ca^{2+} and Mg^{2+} ions that causes water hardness.

(v)State two useful benefits of hard water

-Used in bone and teeth formation
-Coral polyps use hard water to form coral reefs
-Snails use hard water to make their shells
-Is sweet

2.Study the scheme below and use it to answer the questions that follow.



Olive oil

Conc. H_2SO_4

Ice cold water

Brown solid A

6M sodium hydroxide

Substance B

(a)Identify :

(i)brown solid A

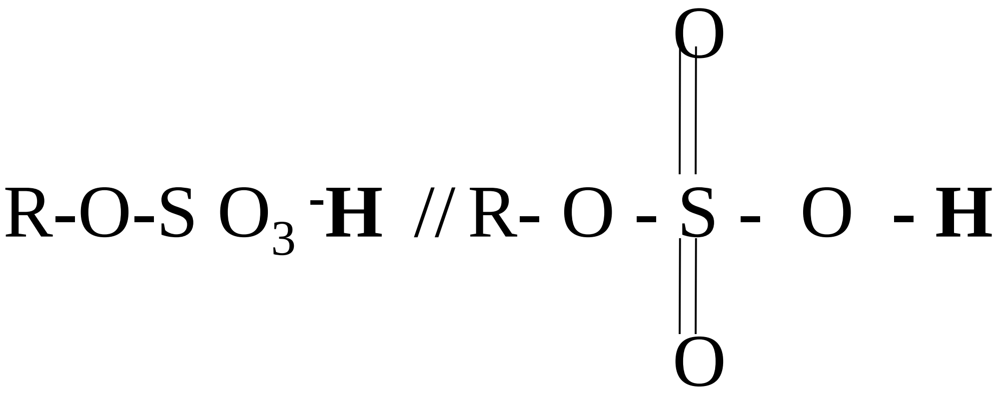
Alkyl hydrogen sulphate(VI)

(ii)substance B

Sodium alkyl hydrogen sulphate(VI)

(b)Write a general formula of:

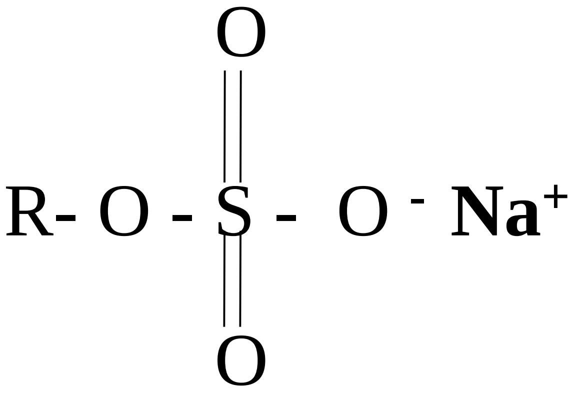
(i)Substance A.



$$R\text{-}O\text{-}S\,O_3{}^{-}\mathbf{H}\ \ //\ R\text{-}\ O\ \text{-}\ \overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O}{\|}}{S}}\ \text{-}\ O\ \text{-}\ \mathbf{H}$$

(ii)Substance B

$\text{R-O-S O}_3{}^{-}\ \mathbf{Na}^{+}$ //



$$\text{R- O -}\ \overset{\displaystyle \text{O} \atop \|}{\underset{\| \atop \displaystyle \text{O}}{\text{S}}}\ \text{- O}^{-}\ \mathbf{Na}^{+}$$

(c)State one

(i) advantage of continued use of substance B

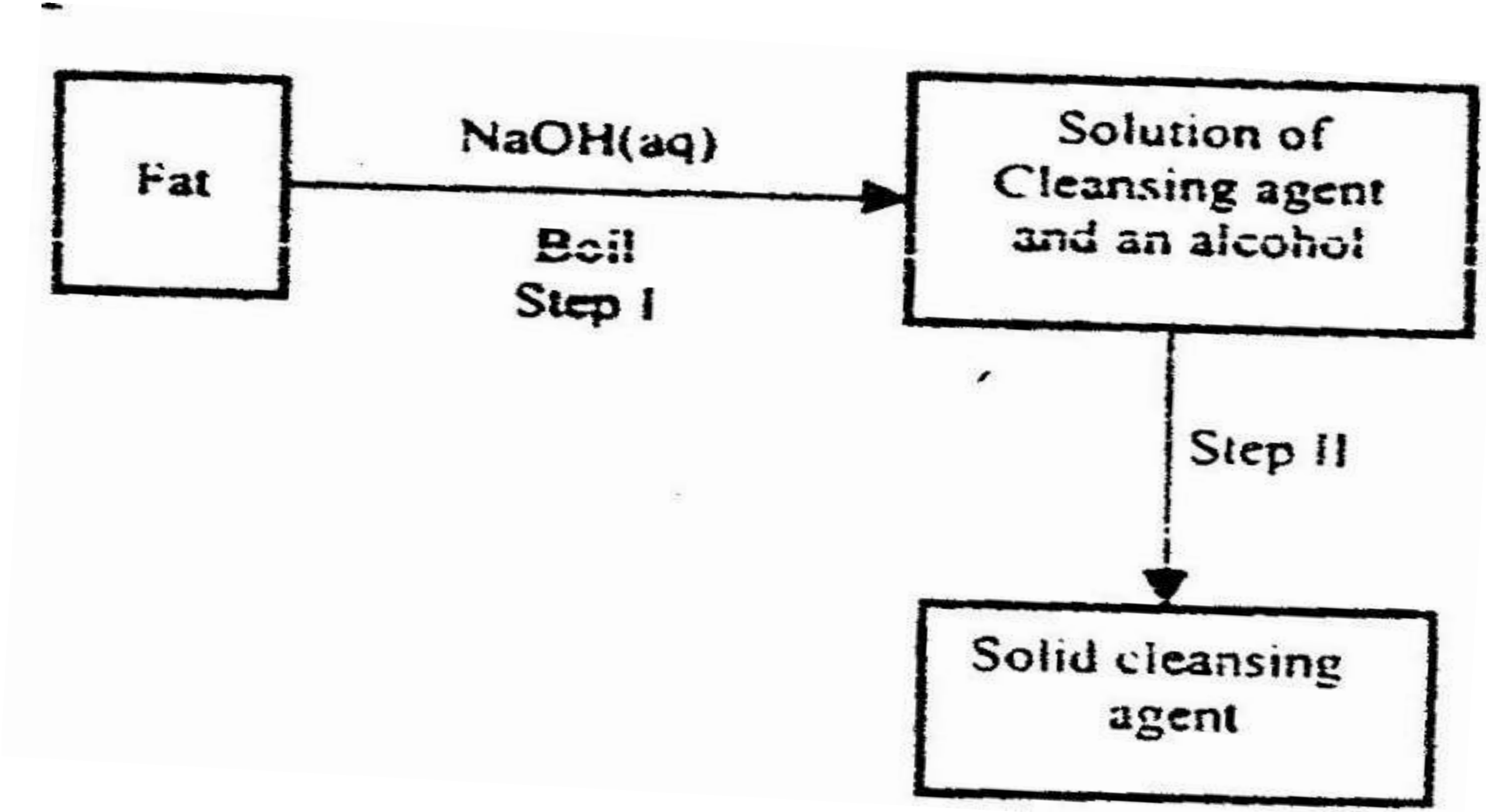
-Does not form scum with hard water

-Is cheap to make

-Does not use food for human as a raw material.

(ii)disadvantage of continued use of substance B.

Is non-biodegradable therefore do not pollute the environment (c)The scheme below was used to prepare a cleaning agent. Study and answer the questions that follow.



What name is given to the type of cleaning agent prepared by the method shown in the scheme?

Soapy detergent

Name one chemical substance added in step II

Sodium chloride

What is the purpose of adding the elements substance names in C(ii) above.

Reduce solubility of soap/for salting out the soap.

Draw the structure of

(i)solid cleansing agent

$R\text{-}COO^- \mathbf{Na}^+$

(ii)Alcohol formed in step 1

$CH_2OHCHOH\ CH_2OH$(Ethan-1,2,3-triol)

Explain how an aqueous solution of the cleansing removes oil from utensils during washing.

Has a non-polar hydrocarbon long tail that dissolves in dirt / grease /oil/fat.

Has a polar/ionic hydrophilic head that dissolves in water

Through mechanical agitation the dirt is plucked /removed from the garment and surrounded by the tail end preventing it from being deposited back on the garment.

(d)Explain the action of B during washing.

Has a non-polar hydrocarbon long tail that dissolves in dirt / grease /oil/fat.

Has a polar/ionic hydrophilic head that dissolves in water

Through mechanical agitation the dirt is plucked /removed from the garment and surrounded by the tail end preventing it from being deposited back on the garment.

(e) Ethene was substituted for olive oil in the above process. Write the equation and name of the new products A and B.

Product A

Ethene + Sulphuric(VI)acid ->Ethyl hydrogensulphate(VI)

$$H_2C{=}CH_2 \ +H_2SO_4 \quad \rightarrow \quad H_3C - CH_2 - O\text{-}SO_3H$$

Product B

Ethyl hydrogen sulphate(VI) + sodium hydroxide ->
sodium ethyl hydrogen sulphate(VI) + Water

$H_3C – CH_2 –O\text{-}SO_3H$ + $NaOH$ ->
$H_3C – CH_2 –O\text{-}SO_3^-Na^+$ + H_2O

(f)Ethanol can also undergo similar reactions forming new products A and B. Show this using a chemical equation.

Product A

Ethanol +Sulphuric(VI)acid ->Ethyl hydrogen sulphate(VI) + water

$$\mathbf{H_3C\text{-}CH_2OH + H_2SO_4 \rightarrow H_3C – CH_2 –O\text{-}SO_3H + H_2O}$$

Product B

Ethyl hydrogen sulphate(VI) + sodium hydroxide ->
sodium ethylhydrogen sulphate(VI) + Water

$H_3C - CH_2 - O\text{-}SO_3H$ +**Na**OH -> $H_3C - CH_2 - O\text{-}SO_3^{-}$**Na**$^{+}$ + H_2O

3.Below is part of a detergent

$\mathbf{H_3C\ -(CH_2)_{16}\ -\ O\ -\ SO_3^{\ -}\ K^{+}}$

(a)Write the formula of the polar and non-polar end

Polar end

$\mathbf{H_3C\ -(CH_2)_{16}\ -}$

Non-polar end

$\mathbf{-\ O\ -\ SO_3^{\ -}\ K^{+}}$

(b)Is the molecule a soapy or soapless detergent?

Soapless detergent

(c)State one advantage of using the above detergent

-does not form scum with hard water

-is cheap to manufacture

The structures below represents two cleansing agents:

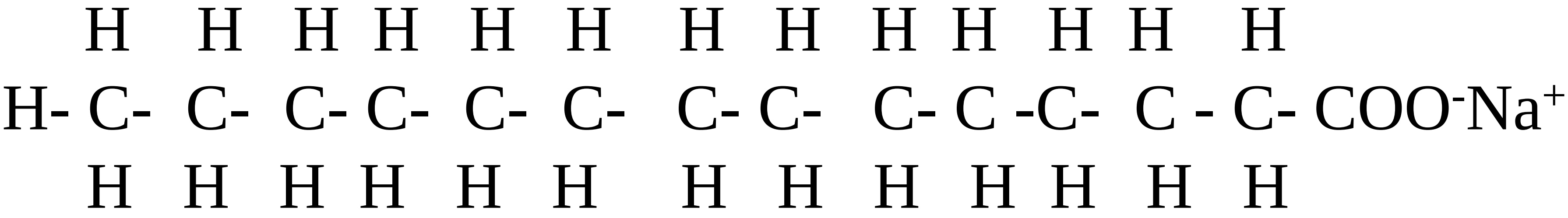
$R – COO^- Na^+$

$R – OSO_3^- Na^+$

In the table below, give one advantage and one disadvantage of using each one of them

	Advantage	Disadvantage
$R – COO- Na^+$	**Is biodegradable**	**-Is expensive-uses oil/fat which are better used as food** **-A lot is used with hard water**
$R - OSO_3 – Na^+$	**Is cheap.** **Can be used with hard water**	**Is non-biodegradable**

4.The structure of a detergent is



$$\begin{array}{cccccccccccccccc} & H & H & H & H & H & H & H & H & H & H & H & H & H & \\ H- & C- & C- & C- & C- & C- & C- & C- & C- & C- & C & -C- & C\ - & C- & COO^{-}Na^{+} \\ & H & H & H & H & H & H & H & H & H & H & H & H & H & \end{array}$$

a) Write the molecular formula of the detergent. (1mk)

$CH_3(CH_2)_{12}COO^-Na^+$

b)What type of detergent is represented by the formula?

Soapy detergent

c) When this type of detergent is used to wash linen in hard water, spots (marks) are left on the linen.

Write the formula of the substance responsible for the spots

$(CH_3(CH_2)_{12}COO^-)_2Ca^{2+}$ / $CH_3(CH_2)_{12}COO^-)_2Mg^{2+}$

Write the formula of the detergent that would not leave the spots

$CH_3(CH_2)_{12}\ CH_2\text{-}O\text{-}SO_3^-Na^+$

THE END

THANK YOU

Prepared by Chirongo bita
0752394969