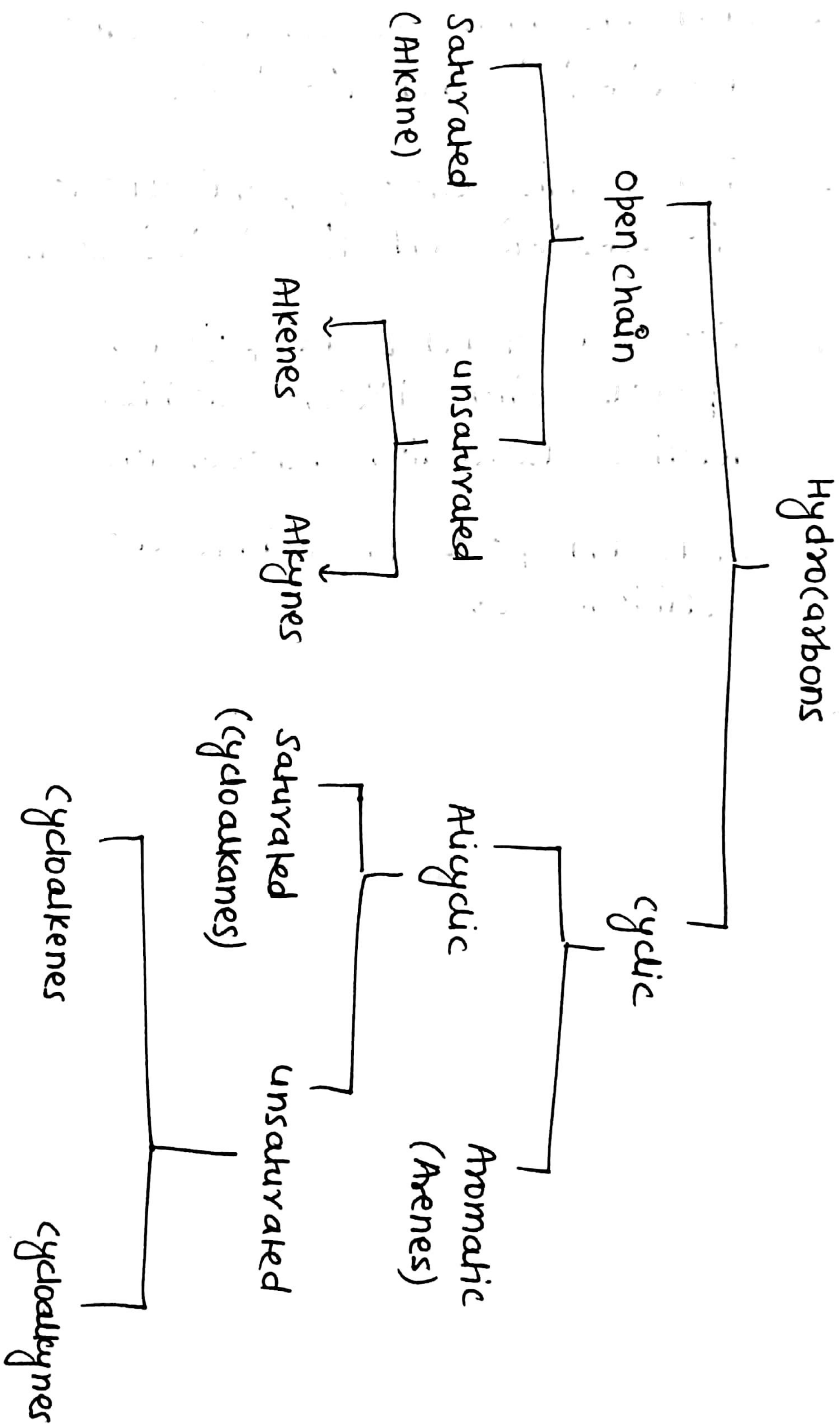
HYDROCARBON

The simplest organic compounds containing carbon and hydrogen only are called hydrocarbons.



Alkanes (C_nH_{2n+2})

① Preparation

→ **from unsaturated hydrocarbons**

$$CH_2 = CH_2 + H_2 \xrightarrow[\text{or Pd}]{\text{Ni}} CH_3 - CH_3$$

this Rx^n is used to prepare Vanaspati Ghee from edible vegetable oils.

→ **Wurtz Reaction**

$$R - \boxed{X + 2Na + X} - R \xrightarrow[\text{ether}]{\text{Dry}} R - R + 2NaX$$

$$CH_3 - \boxed{Cl + 2Na + Cl} - CH_3 \xrightarrow[\text{ether}]{\text{Dry}} CH_3 - CH_3 + 2NaCl.$$

→ It doubles the no of carbon atom in the chain.

→ Used to prepare an even no of carbon atoms chain.

limitation of wurtz

→ Cannot be used to prepare odd no of carbon atom chain. E.g

$$CH_3 - Cl + 2Na + CH_3CH_2Cl \longrightarrow$$

There are 3 possibilities

(i) Two molecules of CH_3-Cl can React with each other

$$CH_3Cl + 2Na + Cl-CH_3 \xrightarrow[ether]{Dry} CH_3-CH_3 + 2NaX$$
(ethane)

(ii) Two molecules of CH_3CH_2Cl can react with each other.

$$CH_3CH_2Cl + 2Na + CH_3CH_2Cl \xrightarrow[ether]{Dry} CH_3-CH_2CH_2CH_3 + 2NaCl$$
(Butane)

(iii) molecule of CH_3Cl can react with molecule of CH_3CH_2Cl.

$$CH_3Cl + Na + CH_3CH_2Cl \xrightarrow[ether]{Dry} CH_3CH_2CH_3 + 2NaCl$$
(propane)

So Here we are getting mixture of three alkanes i.e ethane, propane & butane. The boiling points of these alkanes are very close and hence they cannot be separated by even fractional distillation.

Hence wurtz Rx^n is not used to prepare a carbon chain containing odd no of carbon atoms.

Role of Dry ether in wurtz Rx^n

Wurtz Reaction is carried out with sodium metal which is highly reactive, hence we need to select a solvent which will not react with sodium metal. Thus ether becomes the best choice. Dry ether is a very good solvent and provide medium for the Rx^n.

→ Decarboxylation Rx^n (Removal of COOH Group) (CO_2)

$$R-COOH + NaOH \longrightarrow R-COONa + H_2O$$

$$R-COONa + NaOH \xrightarrow{CaO} R-H + Na_2CO_3$$

E.g

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

$$CH_3COONa + NaOH \xrightarrow{CaO} CH_4 + Na_2CO_3$$

($NaOH + CaO$) is known as soda lime.

→ Kolbe's electrolytic method

$$2RCOONa + H_2O \xrightarrow{Current} R-R + NaOH + H_2 + CO_2$$

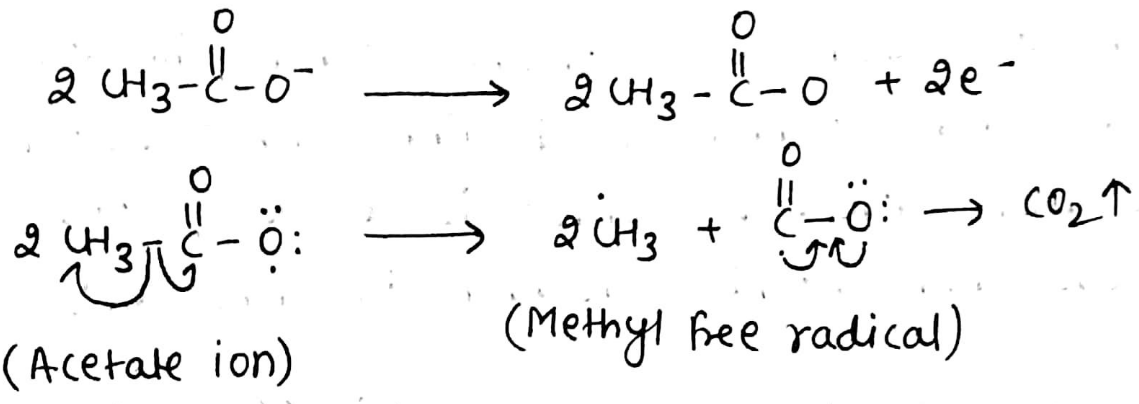
E.g $2CH_3COONa + H_2O \xrightarrow{current} CH_3-CH_3 + NaOH + H_2 + CO_2$

Mechanism: -

i) 

$$2CH_3COO^-Na^+ \rightleftharpoons 2CH_3-\overset{O}{\overset{\|}{C}}-O^- + Na^+$$

At anode:-



$$2CH_3-\overset{O}{\overset{\|}{C}}-O^- \longrightarrow 2CH_3-\overset{O}{\overset{\|}{C}}-O + 2e^-$$

$$2CH_3-\overset{O}{\overset{\|}{C}}-\ddot{\underset{\cdot}{O}}: \longrightarrow 2\dot{C}H_3 + \overset{O}{\overset{\|}{C}}-\ddot{O}: \longrightarrow CO_2\uparrow$$

(Acetate ion)

(Methyl free radical)

$$\dot{C}H_3 + \dot{C}H_3 \longrightarrow CH_3-CH_3$$

At cathode:-

$$H_2O + e^- \longrightarrow OH^- + \dot{H}$$

$$2\dot{H} \longrightarrow H_2\uparrow$$

Limitation:- methane can not be prepared.

→ This Rx^n can not be used to prepare carbon chain of odd no of carbon atoms.

② Physical Properties of alkanes

$$\boxed{\text{No. of Carbon atom} \propto \text{boiling point}}$$

If two compound contain same no C-atom then

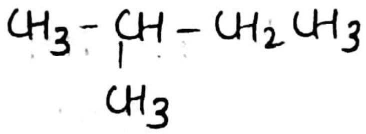
$$\boxed{\text{Boiling point} \propto \frac{1}{\text{no of side chain}}}$$

Q Arrange them in ↑ order of their boiling point.

(i) pentane, Isopentane, Neopentane.

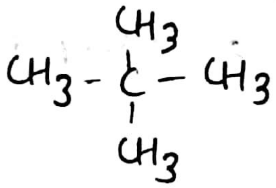
① pentane → $CH_3CH_2CH_2CH_2CH_3$ (No Branch)

Isopentane →



$CH_3-\underset{\underset{CH_3}{|}}{CH}-CH_2CH_3$ (1 Branch)

neopentane →



$CH_3-\overset{CH_3}{\underset{\underset{CH_3}{|}}{C}}-CH_3$ (2 Branch)

so Boiling point order will be

neopentane < isopentane < pentane.

Chemical Properties of alkane

① Chlorination

$$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$$

$$CH_3Cl + Cl_2 \xrightarrow{h\nu} CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \xrightarrow{h\nu} CHCl_3 + HCl$$

(chloroform)

$$CHCl_3 + Cl_2 \xrightarrow{h\nu} CCl_4 + HCl$$

Mechanism:-

→ It follows free radical mechanism which involves 3 steps.

① Initation

$$Cl-Cl \xrightarrow{h\nu} 2\dot{C}l$$

② chain Propogation

$$CH_3-H + \dot{C}l \longrightarrow \dot{C}H_3 + HCl$$

$$\times\ [\dot{C}H_3Cl + Cl-Cl \longrightarrow$$

$$\dot{C}H_3 + Cl-Cl \longrightarrow CH_3Cl + \dot{C}l$$

③ Chain termination

$$\dot{Cl} + \dot{Cl} \longrightarrow Cl_2$$

$$\dot{C}H_3 + \dot{C}H_3 \longrightarrow CH_3-CH_3$$

$$\dot{C}H_3 + \dot{Cl} \longrightarrow CH_3Cl$$

② Combustion

① Complete combustion

$$CH_4 + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

② Incomplete combustion

$$CH_4 + O_2 \xrightarrow[\text{Limited air}]{\text{absence or}} C(s) + 2H_2O$$

(Carbon Black)

③ Controlled ~~combustion~~ oxidation

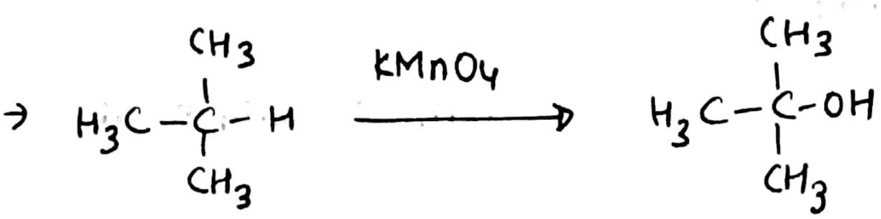
→ $$CH_4 + O_2 \xrightarrow[100\text{ atm}]{Cu/523K} CH_3OH$$

(Methanol)

→ $$CH_4 + O_2 \xrightarrow[\Delta]{Mo_2O_3} HCHO + H_2O$$

(Methanal)

→ $$CH_3CH_3 + O_2 \xrightarrow[\Delta]{(CH_3COO)_2Mn} CH_3COOH$$



→ $$H_3C-\underset{CH_3}{\overset{CH_3}{C}}-H \xrightarrow{KMnO_4} H_3C-\underset{CH_3}{\overset{CH_3}{C}}-OH$$

④ Isomerisation

$CH_3(CH_2)_4CH_3 \xrightarrow{Anh.\ AlCl_3}$ Isomer of Hexane

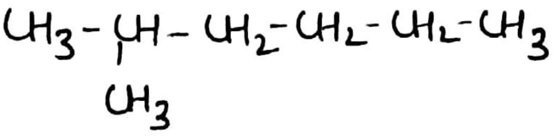
(Hexane)

⑤ Aromatization

$CH_3CH_2CH_2CH_2CH_2CH_3 \xrightarrow[773K \\ 10\text{-}20atm]{V_2O_5/Cr_2O_3}$

(Hexane)

(Benzene)



$CH_3-\underset{CH_3}{CH}-CH_2-CH_2-CH_2-CH_3 \xrightarrow[773K]{V_2O_5}$

(2-Methyl hexane)

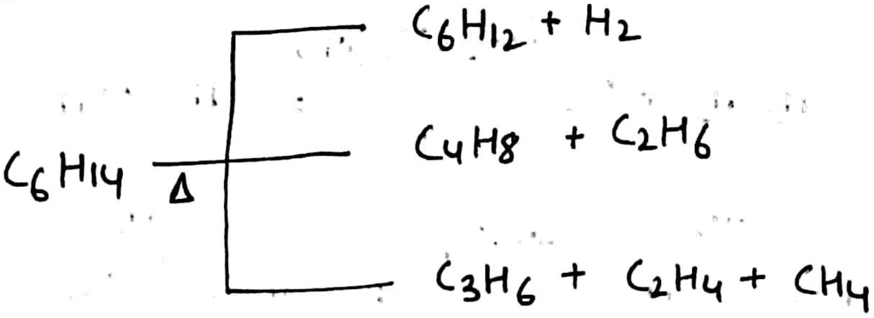
(Towene)

⑥ Reaction with steam

$$CH_4 + H_2O \xrightarrow[Ni]{\Delta} CO + 3H_2$$

This method is used for industrail preparation of dihydrogen gas.

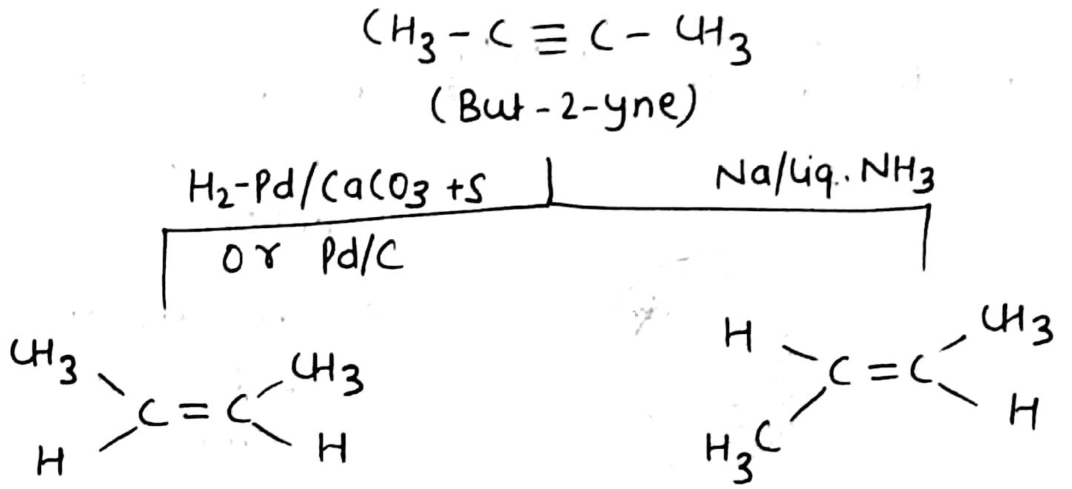
⑦ Pyrolysis (Cracking)



Alkene (C_nH_{2n})

Preparation

① from alkynes



cis-But-2-ene　　　　trans-But-2-ene

② from alkyl halides (β-elimination Rx^n)

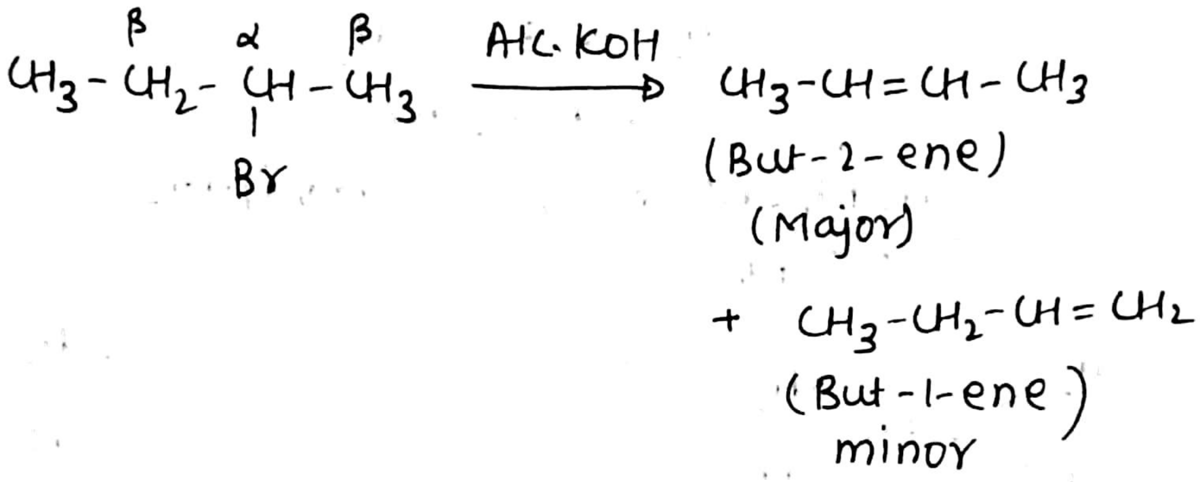
$$\overset{\beta}{CH_3}\overset{\alpha}{CH_2}-Br \xrightarrow{alc.\ KOH} CH_2=CH_2 + HBr$$

from α-carbon there is a removal of Halogen atom & from β-carbon there is a removal of Hydrogen atom.

→ This Rx^n is also known as dehydrohalogenation.

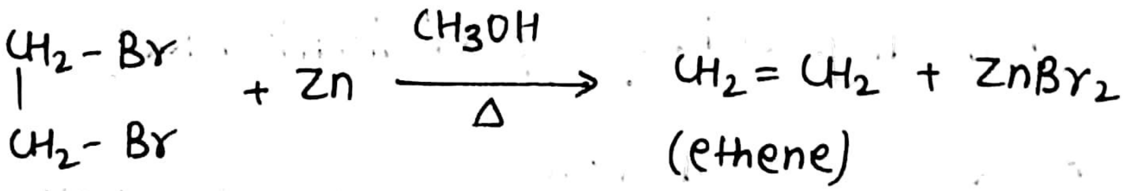
Saytzeff rule :- when there are 2-β carbon then removal of Hydrogen takes place from that β carbon which contains lesser no of hydrogen atoms.

E.g



$$\overset{\beta}{CH_3}-CH_2-\underset{\overset{|}{Br}}{\overset{\alpha}{CH}}-\overset{\beta}{CH_3} \xrightarrow{Alc.\ KOH} CH_3-CH=CH-CH_3 \text{ (But-2-ene) (Major)} + CH_3-CH_2-CH=CH_2 \text{ (But-1-ene) minor}$$

③ From vicinal dihalides



$$\begin{matrix} CH_2-Br \\ | \\ CH_2-Br \end{matrix} + Zn \xrightarrow[\Delta]{CH_3OH} CH_2=CH_2 + ZnBr_2 \text{ (ethene)}$$

④ From alcohols (Dehydration)

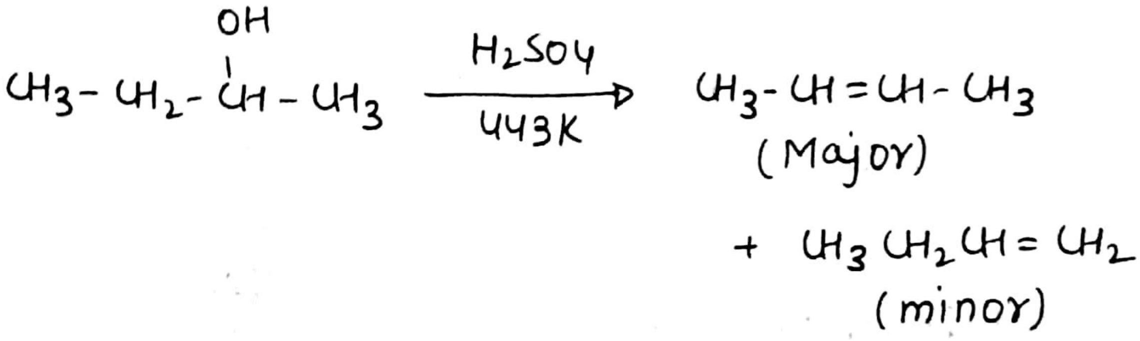
Dehydration :- Removal of H_2O

$$CH_3CH_2OH \xrightarrow[443K]{H_2SO_4} CH_2=CH_2$$

→ Remove OH from α-Carbon and H from β carbon.

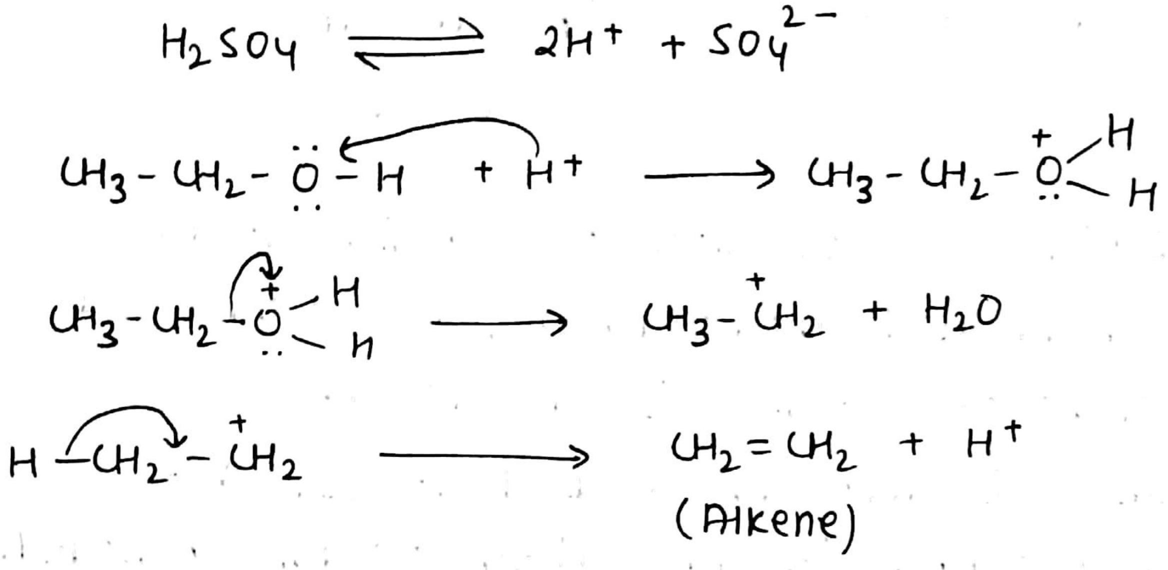
→ If there are more than one β-Carbon then follow Saytzeff rule.

E.g



$$CH_3-CH_2-\overset{OH}{\overset{|}{CH}}-CH_3 \xrightarrow[443K]{H_2SO_4} \underset{(Major)}{CH_3-CH=CH-CH_3} + \underset{(minor)}{CH_3CH_2CH=CH_2}$$

Mechanism: -



$$H_2SO_4 \rightleftharpoons 2H^+ + SO_4^{2-}$$

$$CH_3-CH_2-\ddot{\underset{..}{O}}-H + H^+ \longrightarrow CH_3-CH_2-\overset{+}{\underset{..}{O}}\begin{smallmatrix}H\\H\end{smallmatrix}$$

$$CH_3-CH_2-\overset{+}{\underset{..}{O}}\begin{smallmatrix}H\\H\end{smallmatrix} \longrightarrow CH_3-\overset{+}{C}H_2 + H_2O$$

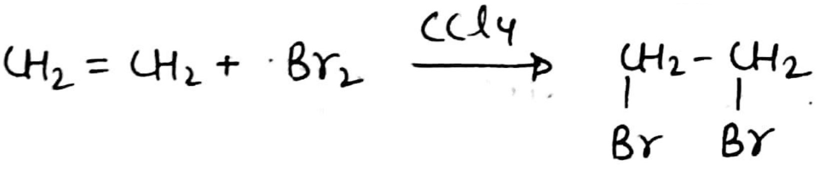
$$H-CH_2-\overset{+}{C}H_2 \longrightarrow \underset{(Alkene)}{CH_2=CH_2} + H^+$$

Chemical Properties of Alkenes

① Addition of H_2

$$\underset{\text{(ethene)}}{CH_2=CH_2} + H_2 \xrightarrow{Ni} \underset{\text{(ethane)}}{CH_3-CH_3}$$

② Addition of Halogens



$$CH_2=CH_2 + Br_2 \xrightarrow{CCl_4} \underset{Br}{\underset{|}{CH_2}}-\underset{Br}{\underset{|}{CH_2}}$$

★ During the addition of bromine to the unsaturated hydrocarbons, the orange red colour of bromine is discharged.

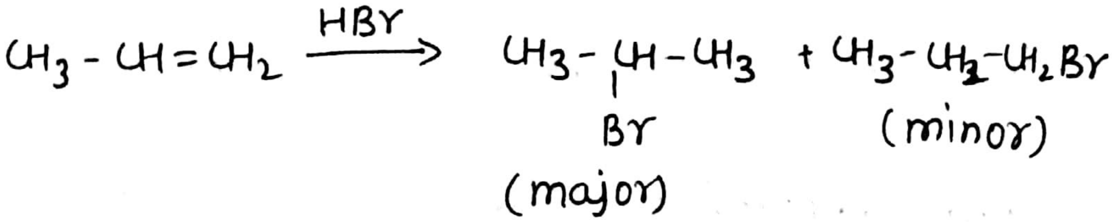
Hence this Rx^n can be used to test for unsaturation in the given organic compound.

③ Addition of Hydrogen halide (HX)

$$CH_2=CH_2 + HBr \longrightarrow CH_3-CH_2Br$$

Markovnikov's Rule :- Halogen atom goes to that double bonded carbon atom which contain lesser no. of hydrogen.

E.g



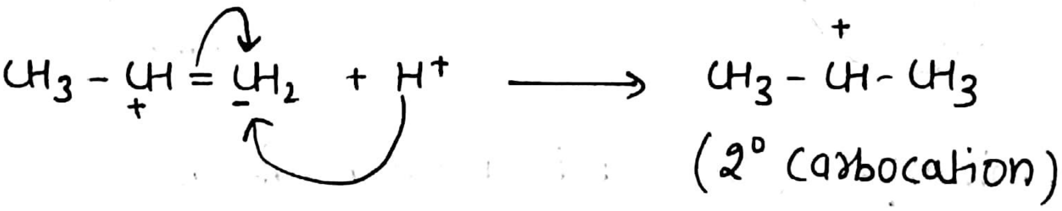
$$CH_3-CH=CH_2 \xrightarrow{HBr} \underset{\text{(major)}}{CH_3-\underset{Br}{CH}-CH_3} + \underset{\text{(minor)}}{CH_3-CH_2-CH_2Br}$$

Mechanism: -

$$HBr \longrightarrow H^+ + Br^-$$

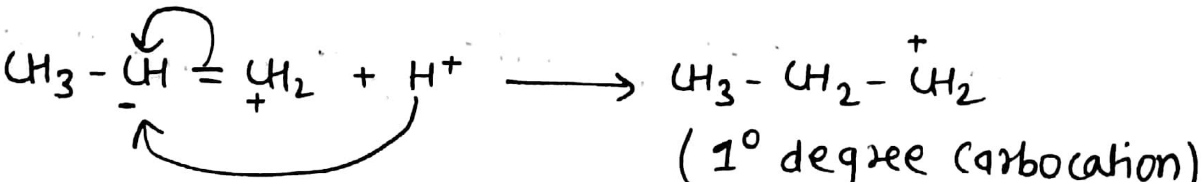
$$CH_3-\underset{②}{CH}=\underset{①}{CH_2} + H^+ \longrightarrow$$

There ~~is~~ are two cases i) when double bond is shifted to ① carbon.



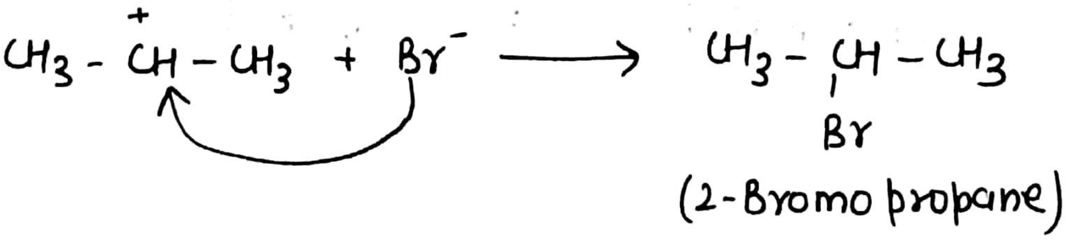
$$CH_3-\underset{+}{CH}=\underset{-}{CH_2} + H^+ \longrightarrow \underset{(2^\circ \text{ carbocation})}{CH_3-\overset{+}{CH}-CH_3}$$

(ii) when double bond is shifted to ② carbon.



$$CH_3-\underset{-}{CH}=\underset{+}{CH_2} + H^+ \longrightarrow \underset{(1^\circ \text{ degree carbocation})}{CH_3-CH_2-\overset{+}{CH_2}}$$

we know that 2° Carbocation is more stable than 1°. So further attacks will take place on 2° carbocation.



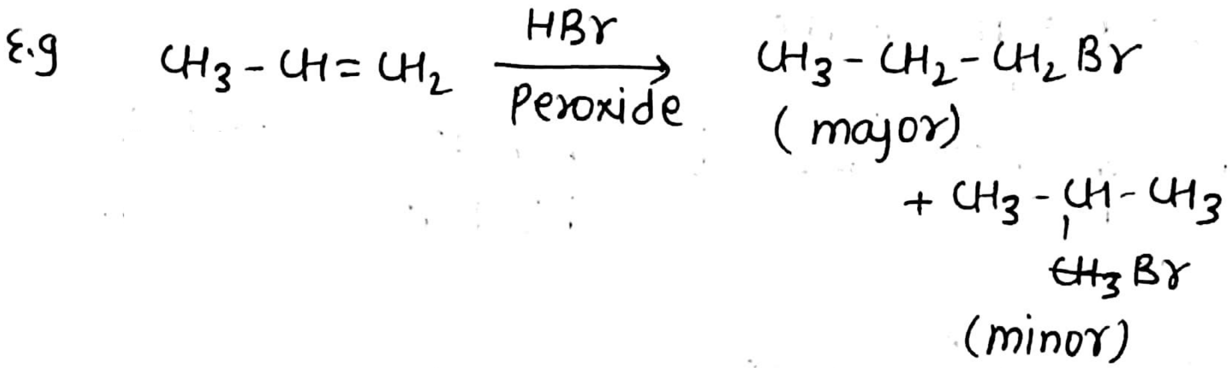
$$CH_3-\overset{+}{CH}-CH_3 + Br^- \longrightarrow CH_3-\underset{Br}{CH}-CH_3$$

(2-Bromo propane)

④ Addition of HX in presence of peroxide

anti-markownikov's Rule / kharasch effect :-

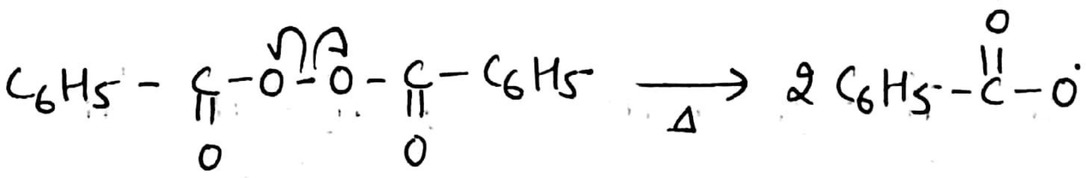
Halogen atom goes to that double bonded carbon atom which contains more no of hydrogen. atoms.



E.g $CH_3-CH=CH_2 \xrightarrow[\text{Peroxide}]{HBr} \underset{\text{(major)}}{CH_3-CH_2-CH_2Br} + \underset{\text{(minor)}}{CH_3-\underset{\substack{|\\ \cancel{CH_3}\,Br}}{CH}-CH_3}$

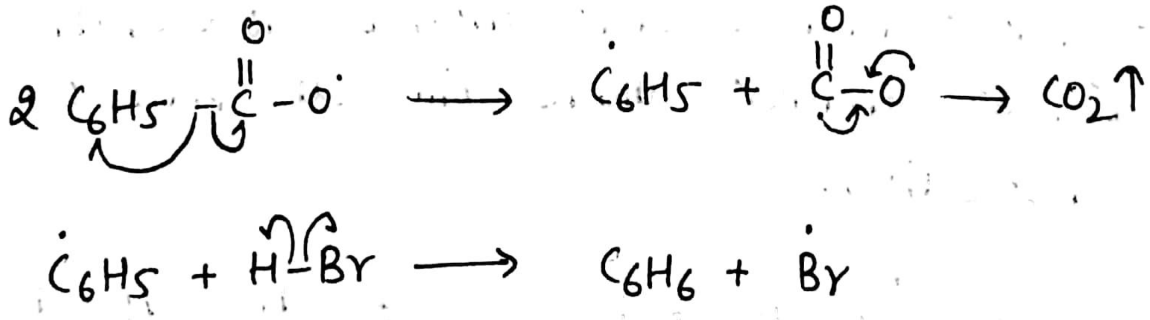
Mechanism:- (free radical mechanism)

① Initation



$$C_6H_5-\underset{\substack{\|\\ O}}{C}-O-O-\underset{\substack{\|\\ O}}{C}-C_6H_5 \xrightarrow[\Delta]{} 2\,C_6H_5-\overset{\substack{O\\ \|}}{C}-\dot{O}$$

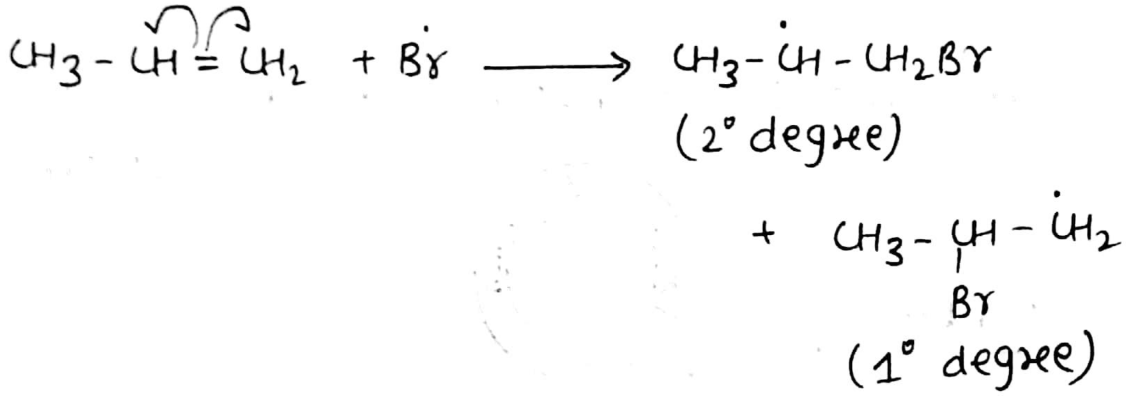
(Benzoyl peroxide)



$$2\,C_6H_5-\overset{\substack{O\\ \|}}{C}-\dot{O} \longrightarrow \dot{C}_6H_5 + \overset{\substack{O\\ \|}}{\dot{C}}-\dot{O} \longrightarrow CO_2\uparrow$$

$$\dot{C}_6H_5 + H-Br \longrightarrow C_6H_6 + \dot{B}r$$

2) Propogation



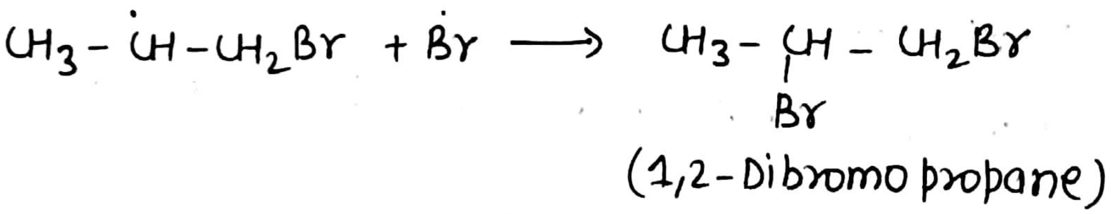
$$CH_3-\overset{\frown\frown}{CH=CH_2} + \dot{B}r \longrightarrow \underset{(2^\circ \text{ degree})}{CH_3-\dot{C}H-CH_2Br} + \underset{(1^\circ \text{ degree})}{CH_3-\underset{|}{\underset{Br}{CH}}-\dot{C}H_2}$$

we know that 2° radical is more stable.

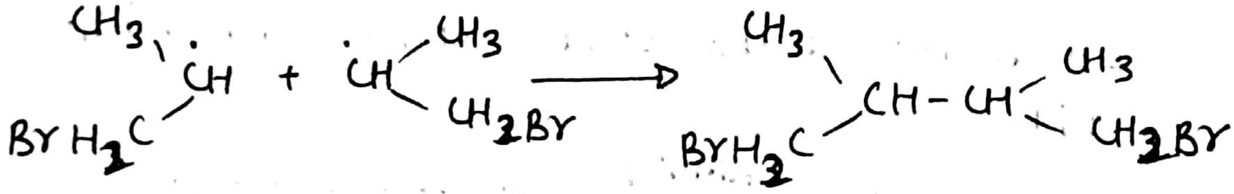
$$CH_3-\dot{C}H-CH_2Br + \overset{\frown}{H-}\overset{\frown}{Br} \longrightarrow \underset{(\text{Bromopropane})}{CH_3-CH_2-CH_2Br} + \dot{B}r$$

3) Termination

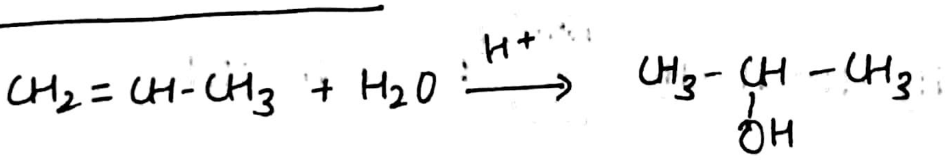
$$\dot{B}r + \dot{B}r \longrightarrow Br_2$$



$$CH_3-\dot{C}H-CH_2Br + \dot{B}r \longrightarrow \underset{(1,2\text{-Dibromo propane})}{CH_3-\underset{|}{\underset{Br}{CH}}-CH_2Br}$$



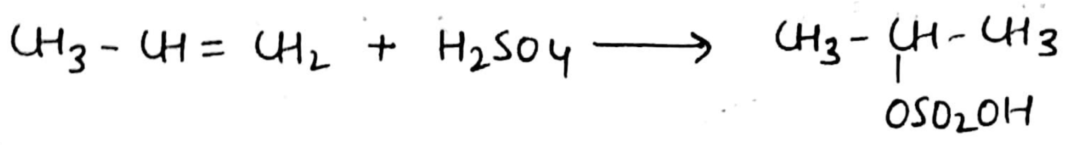
⑤ Addition of water



$$CH_2=CH-CH_3 + H_2O \xrightarrow{H^+} CH_3-\underset{|}{\underset{OH}{CH}}-CH_3$$

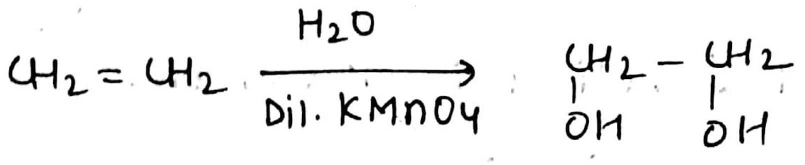
Add OH & H acc. to Markovnikov's rule.

⑥ Addition of H_2SO_4



$$CH_3-CH=CH_2 + H_2SO_4 \longrightarrow CH_3-\underset{OSO_2OH}{\underset{|}{CH}}-CH_3$$

⑦ oxidation



$$CH_2=CH_2 \xrightarrow[\text{Dil. } KMnO_4]{H_2O} \underset{OH}{\underset{|}{CH_2}}-\underset{OH}{\underset{|}{CH_2}}$$

(Glycol)

- ★ During this Reaction the pink colour of $KMnO_4$ solⁿ is discharged and a brown ppt is obtained. Hence this Rxⁿ can be used to test unsaturation in the organic compound.
- ★ $KMnO_4$ is known as Baeyer's Reagent.

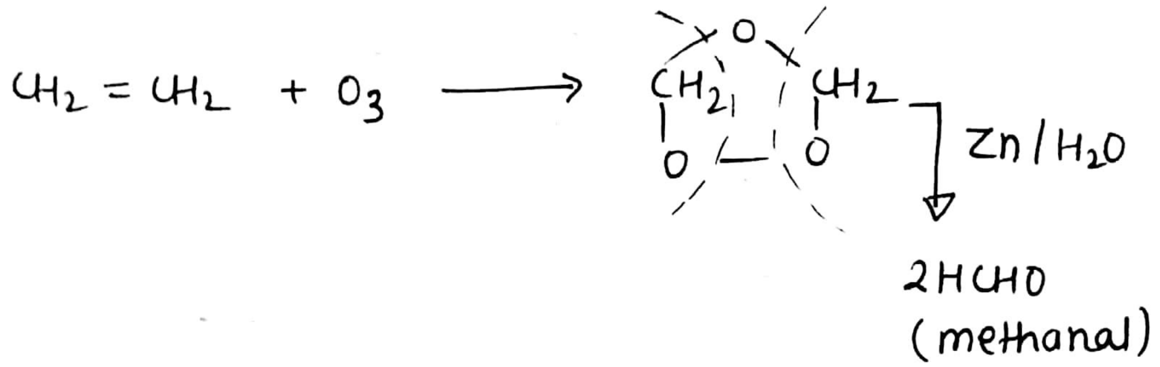
Oxidation with Hot $KMnO_4$

→ Break the double bond & converts them into acid

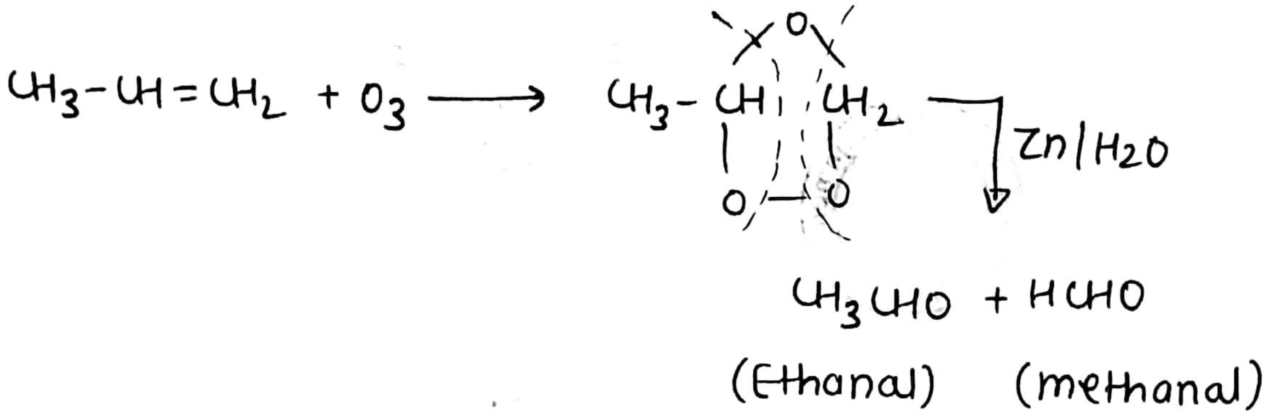
$$CH_3-CH=CH_2 \xrightarrow[KOH]{KMnO_4} CH_3COOH + HCOOH$$

$$CH_3-CH=CH-CH_3 \xrightarrow[KOH]{KMnO_4} 2\,CH_3COOH$$

⑧ Ozonolysis (Addition of ozone)

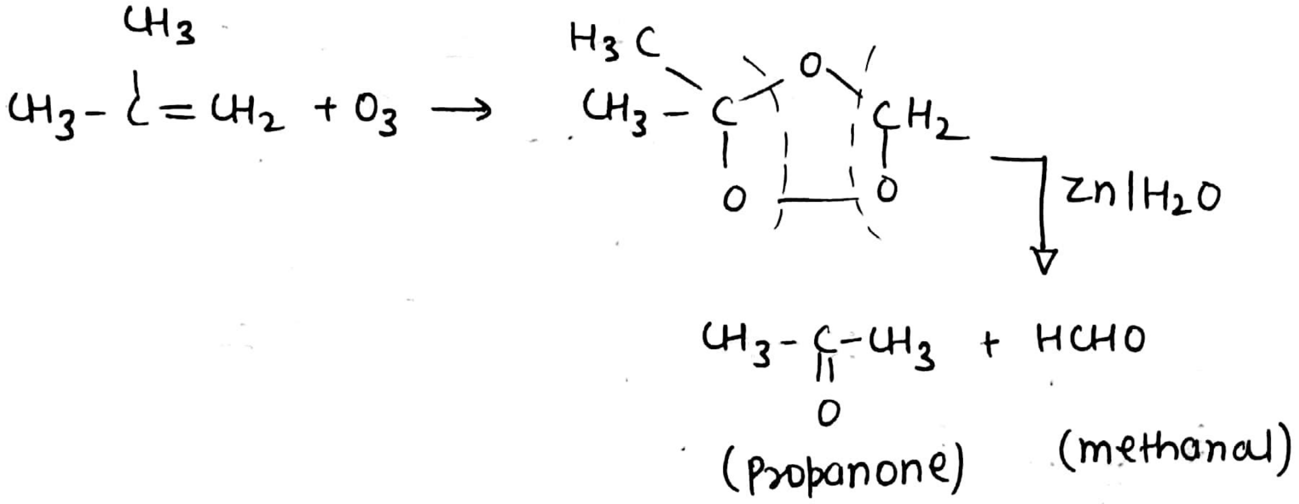


$CH_2=CH_2 + O_3 \longrightarrow$ ozonide $\xrightarrow{Zn/H_2O}$ $2HCHO$ (methanal)



$CH_3-CH=CH_2 + O_3 \longrightarrow$ ozonide $\xrightarrow{Zn/H_2O}$ $CH_3CHO + HCHO$

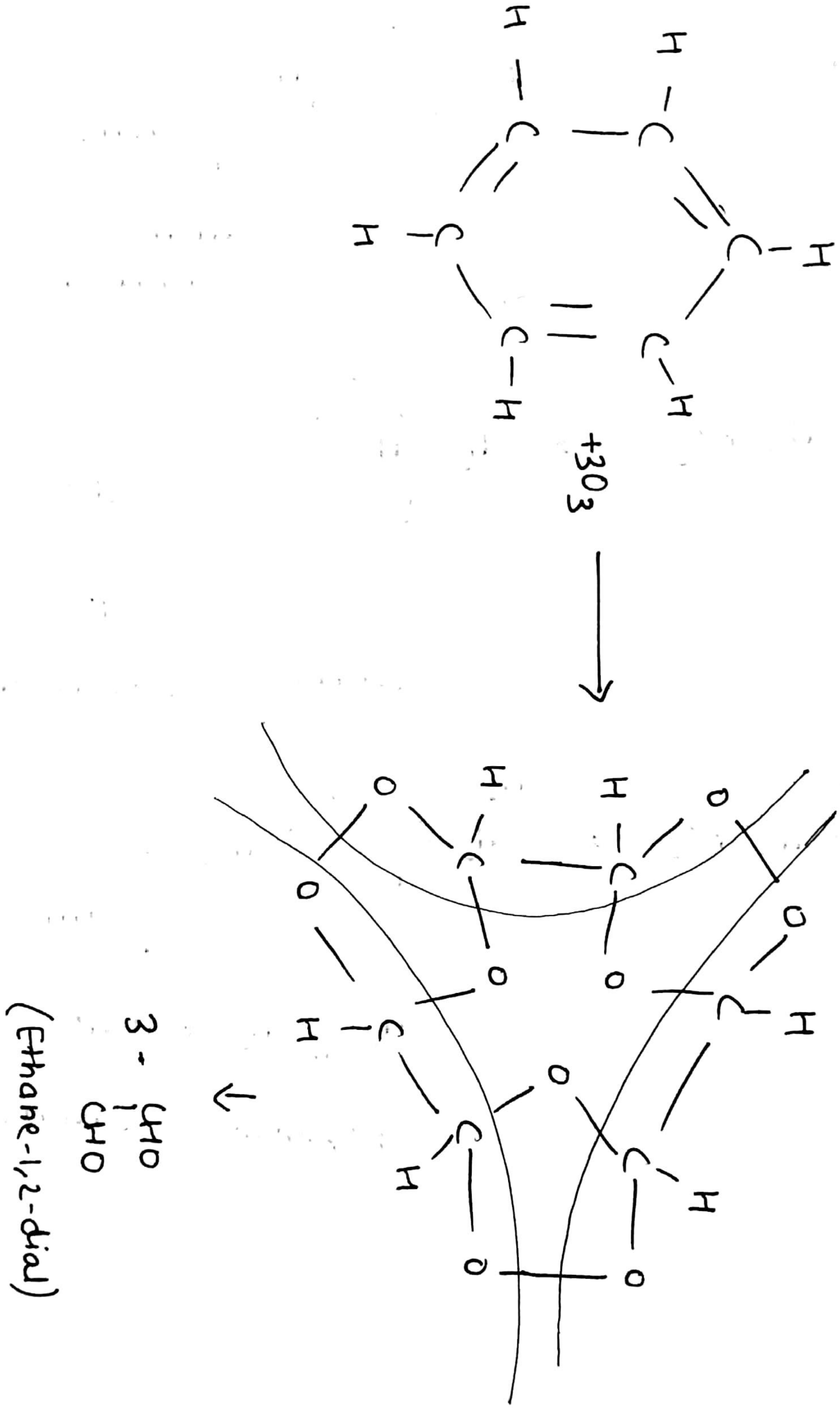
(Ethanal) (methanal)



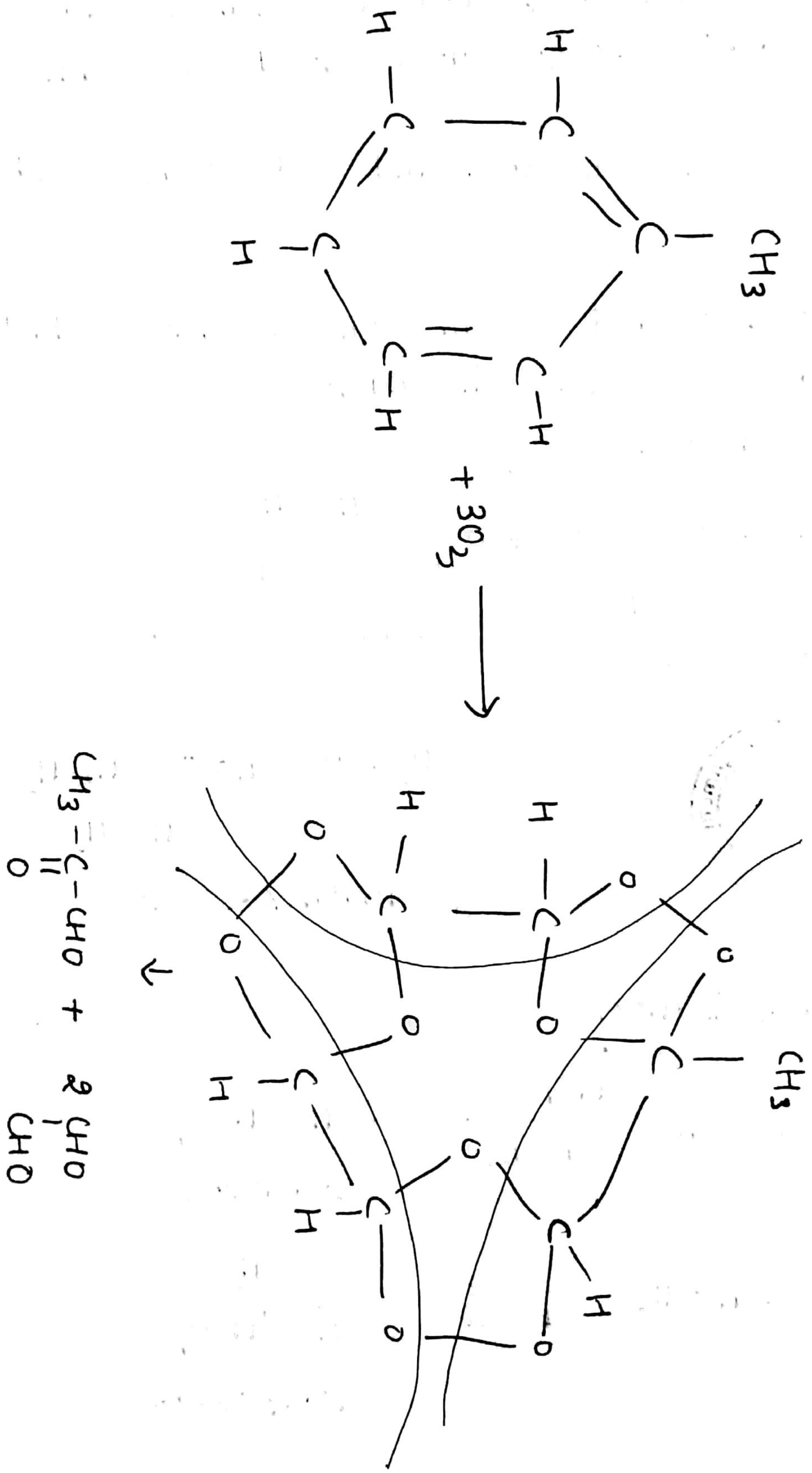
$CH_3-\overset{CH_3}{C}=CH_2 + O_3 \longrightarrow$ ozonide $\xrightarrow{Zn/H_2O}$ $CH_3-\underset{O}{\overset{||}{C}}-CH_3 + HCHO$

(Propanone) (methanal)

Ozonolysis of Benzene



Ozonolysis of Toulene

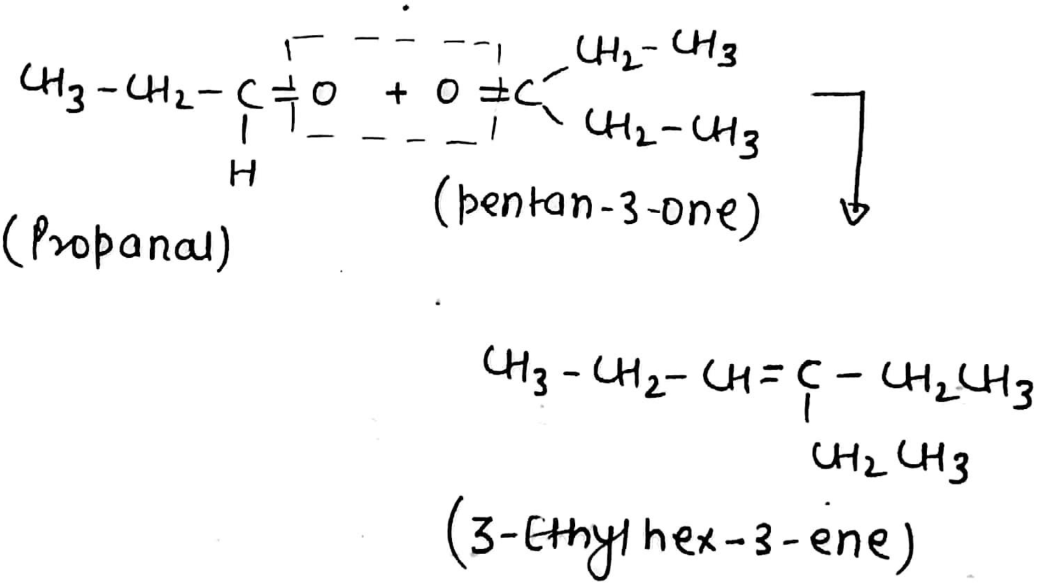


How to ~~Rea~~ write Reactant from the given products of ozonolysis

→ Draw structure of products in such a way that their oxygen atom should face each other.

→ Replace oxygen atom and add double bond there.

E.g Propanal and pentan-3-one are the products of ozonolysis. Write name & structure of the alkene.



$$CH_3-CH_2-\underset{H}{\underset{|}{C}}=O + O=C\begin{matrix} CH_2-CH_3 \\ CH_2-CH_3 \end{matrix} \longrightarrow CH_3-CH_2-CH=\underset{CH_2CH_3}{\underset{|}{C}}-CH_2CH_3$$

(Propanal)

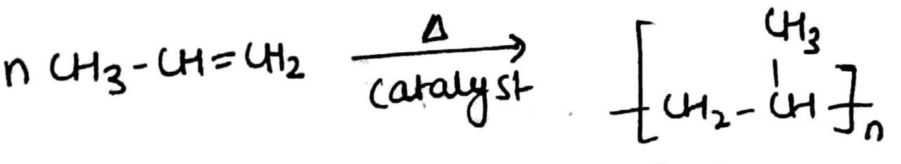
(pentan-3-one)

(3-Ethyl hex-3-ene)

⑨ Polymerisation

$$n\, CH_2=CH_2 \xrightarrow[\text{catalyst}]{473K} +CH_2-CH_2+_n$$

(polyethene)



$$n\, CH_3-CH=CH_2 \xrightarrow[\text{catalyst}]{\Delta} \left[CH_2-\overset{CH_3}{\overset{|}{CH}}\right]_n$$

(polypropene)

Alkynes (C_nH_{2n-2})

① Preparation

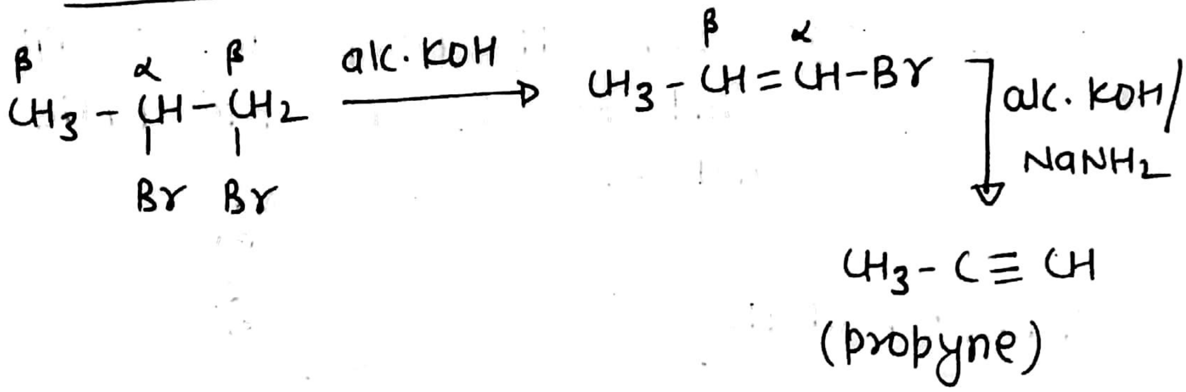
① from calcium carbide

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

$$CaO + 3C \longrightarrow CaC_2 + CO\uparrow$$

$$CaC_2 + H_2O \longrightarrow Ca(OH)_2 + \underset{\text{(Ethyne)}}{CH\equiv CH}$$

② from vicinal dihalides :



$$\overset{\beta'}{CH_3}-\underset{Br}{\overset{\alpha}{CH}}-\underset{Br}{\overset{\beta}{CH_2}} \xrightarrow{alc.\ KOH} CH_3-\overset{\beta}{CH}=\overset{\alpha}{CH}-Br \xrightarrow{alc.\ KOH/NaNH_2} \underset{\text{(propyne)}}{CH_3-C\equiv CH}$$

Chemical Properties of alkynes

① Acidic nature of alkyne

$$CH \equiv CH + Na \longrightarrow HC \equiv C^{-}Na^{+} + \frac{1}{2} H_2 \uparrow$$

almost all metal Reacts with acid and produce H_2 gas. Since alkyne is also producing H_2 with Reactive metal, hence it is acidic in nature.

Q Arrange them in ↑ order of acidic nature

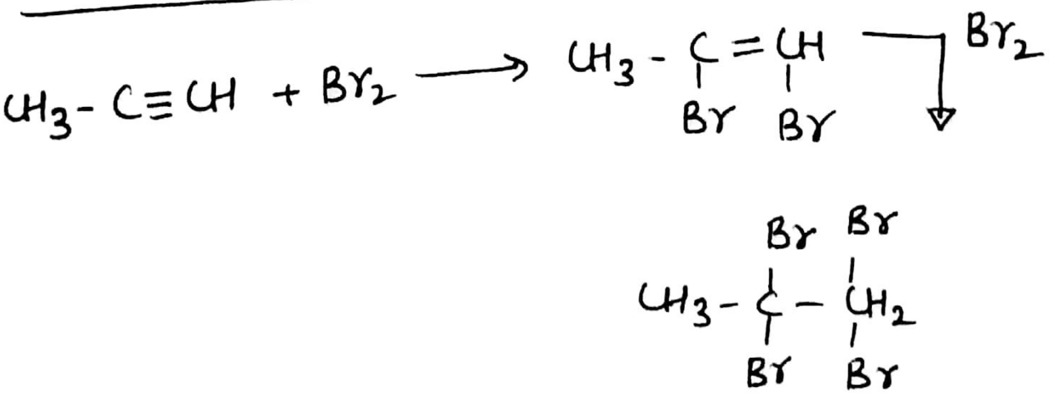
i) $CH \equiv CH$ (ii) $CH_3 - C \equiv CH$ (iii) $CH_3 - C \equiv C - CH_3$

A (3) < (2) < (1) Since CH_3 group has +I effect and +I decreases the acidic nature.

② Addition of H_2

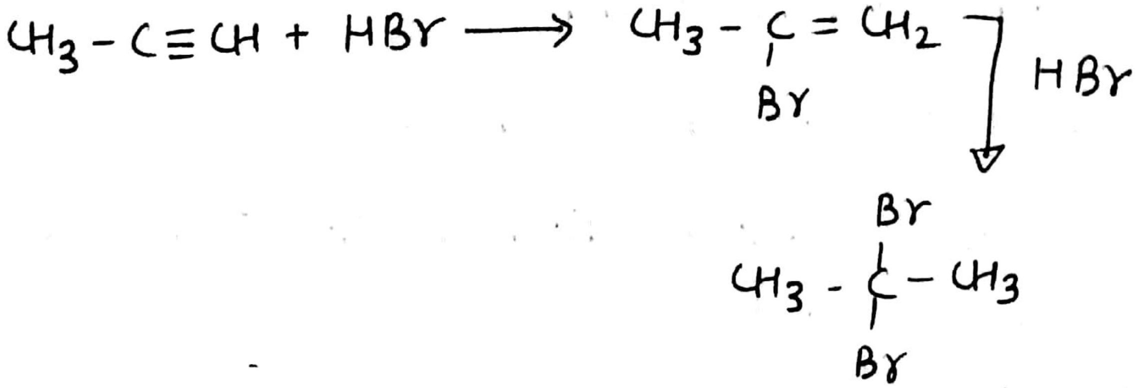
$$CH \equiv CH \xrightarrow{H_2/Ni} CH_2 = CH_2 \xrightarrow{Ni/H_2} CH_3 - CH_3$$

③ Addition of Halogen



$$CH_3 - C \equiv CH + Br_2 \longrightarrow \underset{\quad\ Br\qquad Br}{CH_3 - C = CH} \xrightarrow{Br_2} CH_3 - \overset{Br}{\underset{Br}{C}} - \overset{Br}{\underset{Br}{CH_2}}$$

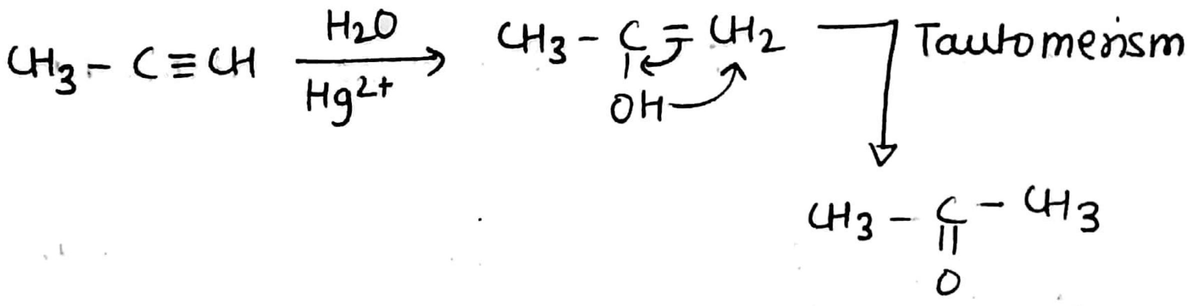
6 ④ Addition of HX



$$CH_3-C\equiv CH + HBr \longrightarrow CH_3-\underset{Br}{C}=CH_2 \xrightarrow{HBr} CH_3-\overset{Br}{\underset{Br}{C}}-CH_3$$

(Geminal dihalide)

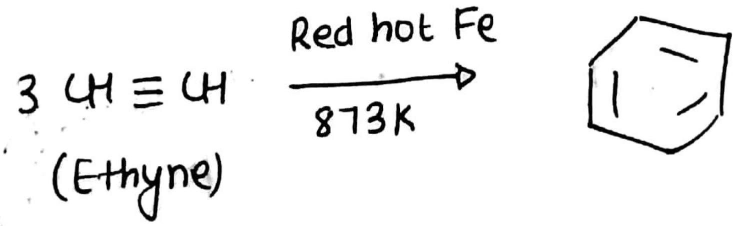
⑤ Addition of water



$$CH_3-C\equiv CH \xrightarrow[Hg^{2+}]{H_2O} CH_3-\underset{OH}{C}=CH_2 \xrightarrow{Tautomerism} CH_3-\underset{\overset{\|}{O}}{C}-CH_3$$

(propanone)

⑥ Polymerisation



$$3\ CH\equiv CH \xrightarrow[873K]{Red\ hot\ Fe}$$

(Ethyne)

Aromatic hydrocarbons

condition for Aromaticity

① Structure should be planar.

② Complete delocalisation of the π electrons in the ring.

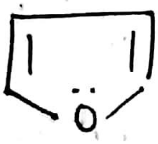
③ Structure should contain $(4n+2)\pi$ electrons where $n = 0, 1, 2 \ldots$ (known as Hükel rule)

Q Which of the following compounds are aromatic

(i)

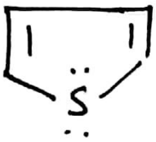
$\pi e^- \Rightarrow 6 \Rightarrow (4(1)+2)$ Hence aromatic

(ii)



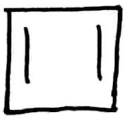
$\pi e^- \Rightarrow 6 \Rightarrow (4(1)+2)$ Hence aromatic

(iii)



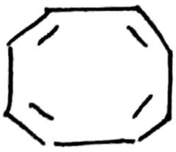
$\pi e^- \Rightarrow 6 \Rightarrow (4(1)+2)$ Hence aromatic

(iv)

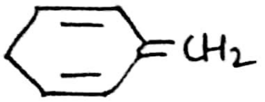


$\pi e^- \Rightarrow 4$ not aromatic

(v)



$\pi e^- \Rightarrow 8$ not aromatic

(vi) 

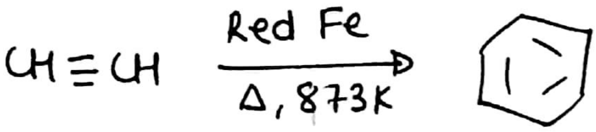
not aromatic (missing of conjugation)

(vii) 

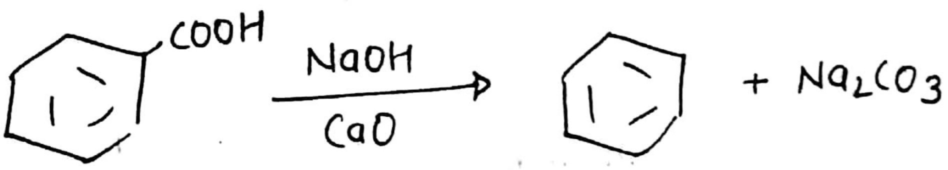
not aromatic (missing conjugation)

Preparation of Benzene

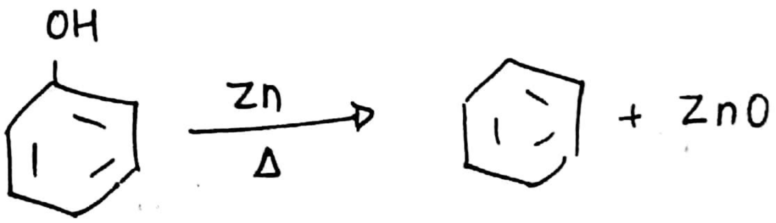
① Polymerisation of ethyne



② from Decarboxylation of benzoic acid



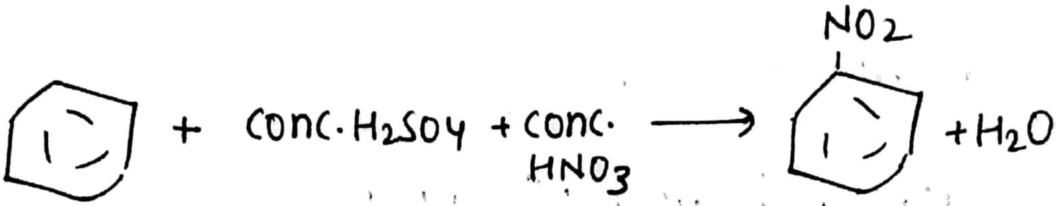
③ from phenol



chemical Properties of Benzene

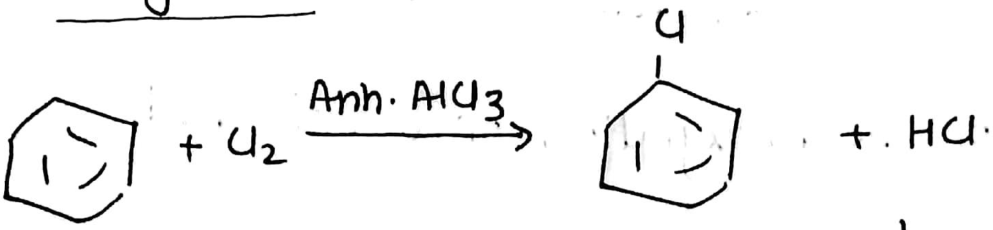
① Electrophilic substitution Rxn

① Nitration

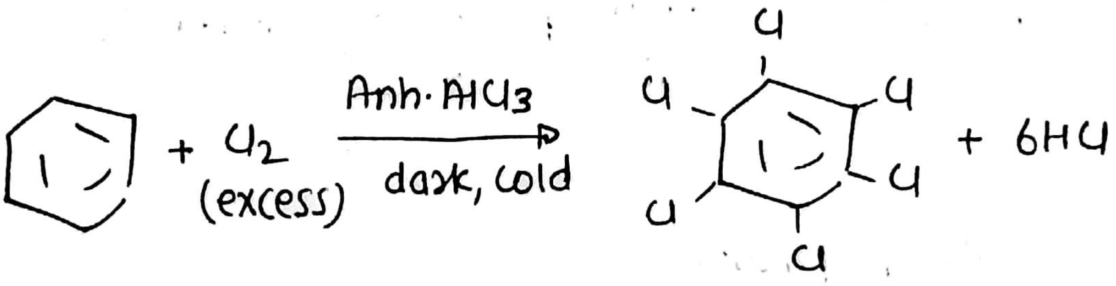


(nitrobenzene)

② Halogenation

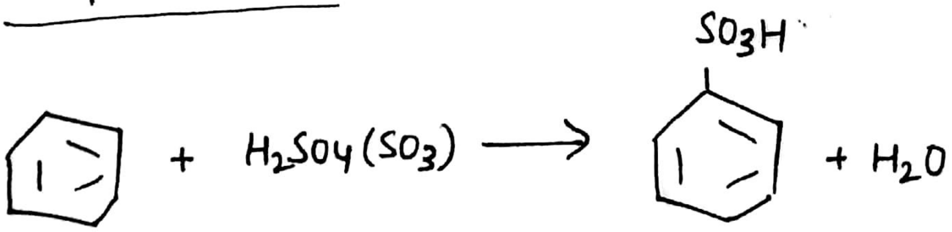


(chlorobenzene)



(Hexa chlorobenzene)

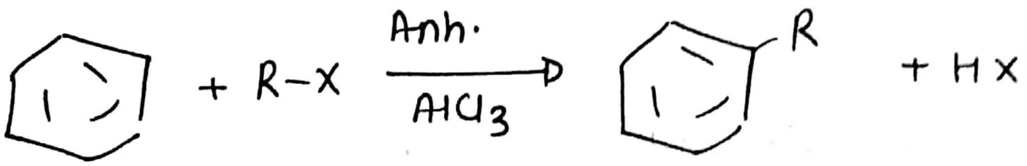
③ Sulphonation



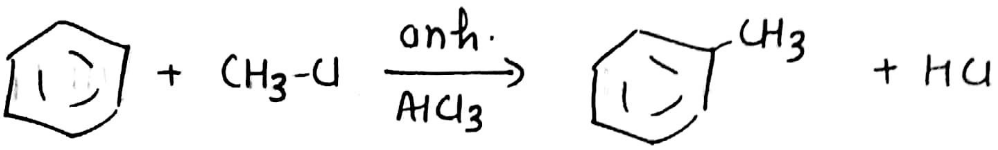
(Benzene sulphonic acid)

④ Friedel Crafts Rx^n

① Alkylation

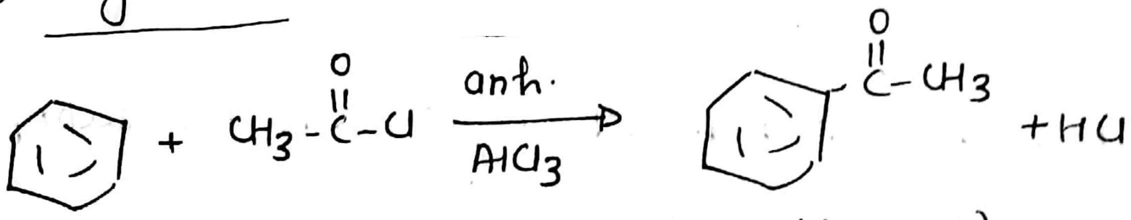


E.g

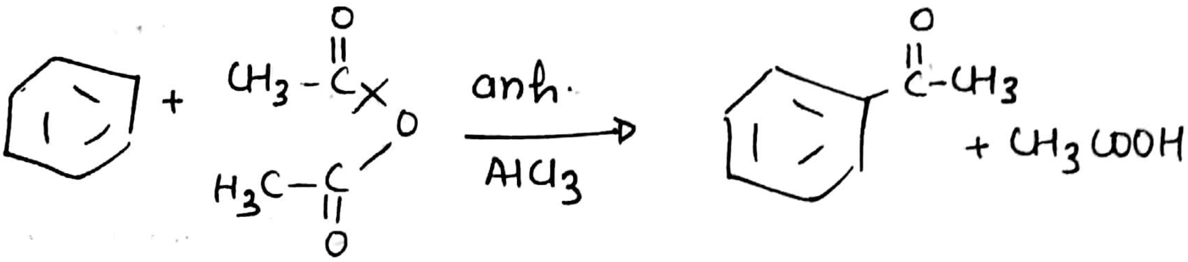


(Towlene)

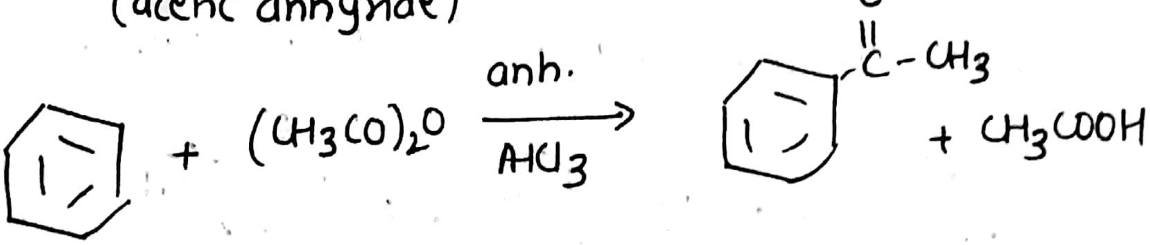
② Acylation



(Acetophenone)



(acetic anhyride)



Mechanism of Electrophilic substitution

① Generation of electrophile (E^+)
② Formation of Carbocation intermediate
③ Removal of proton (H^+)

① Generation of electrophile (E^+)

→ $Cl-Cl + AlCl_3 \longrightarrow \overset{+}{Cl} + [AlCl_4]^-$

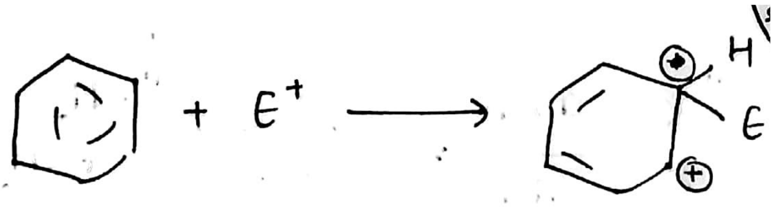
→ $CH_3-Cl + AlCl_3 \longrightarrow \overset{+}{C}H_3 + [AlCl_4]^-$

→ 

$CH_3-\underset{\underset{O}{\|}}{C}-Cl + AlCl_3 \longrightarrow CH_3-\underset{\underset{O}{\|}}{\overset{+}{C}} + [AlCl_4]^-$

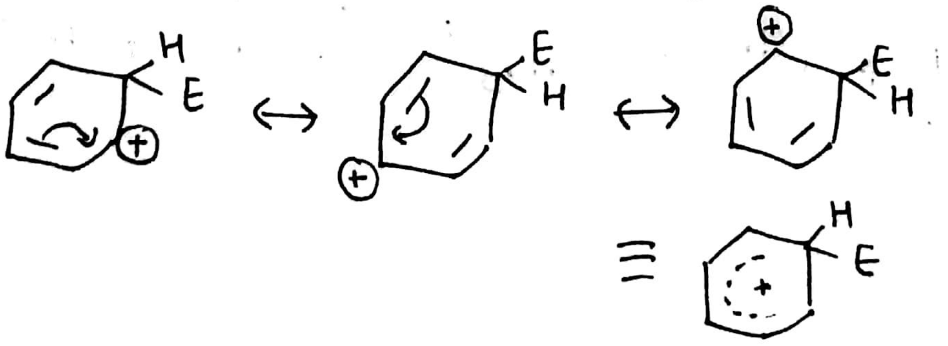
Here role of anh. $AlCl_3$ is to generate electrophile.

② Formation of Carbocation

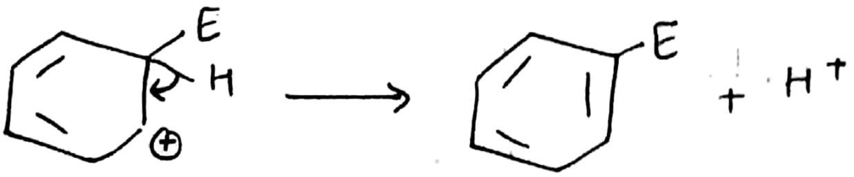


(σ complex/ Arenium ion)

Arenium ion gets stabilised by resonance.

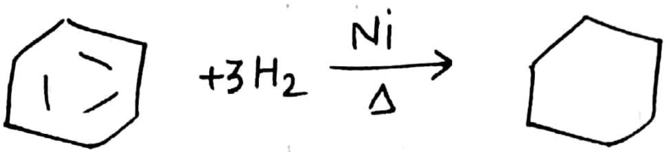


③ Removal of proton (H^+)



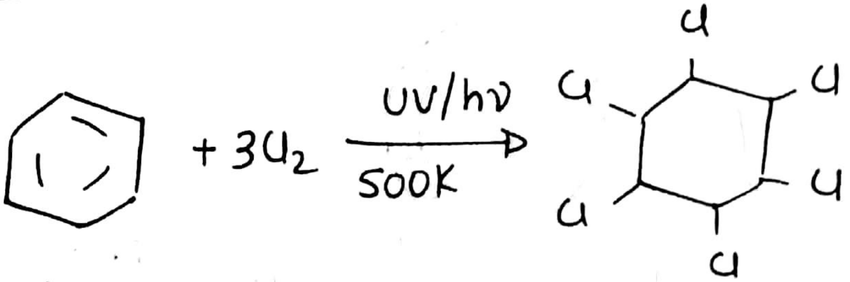
Addition Reaction

① Addition of H_2



(Benzene) (cyclohexane)

② Addition of Cl_2



(Benzene Hexa chloride)
(BHC)

Combustion of Benzene

$$C_6H_6 + \frac{15}{2}O_2 \xrightarrow[\Delta]{} 6CO_2 + 3H_2O$$

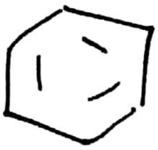
Q Convert following into benzene

(i) hexane ii) ethene (iii) ethyne

(iv) ethanoic acid.

A (i) $CH_3CH_2CH_2CH_2CH_2CH_3 \xrightarrow[773K]{V_2O_5}$

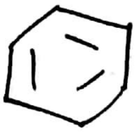
(Hexane)



(Benzene)

(iii) $CH \equiv CH \xrightarrow[873K]{\text{Red hot Fe}}$

(Ethyne)

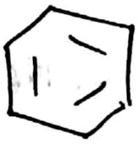


(Benzene)

(ii) $CH_2=CH_2 \xrightarrow{Br_2} \underset{Br}{\overset{\beta}{CH_2}}-\underset{Br}{\overset{\alpha}{CH_2}} \xrightarrow{alc.\,KOH} \underset{Br}{\overset{\alpha}{CH}}=\overset{\beta}{CH_2} \xrightarrow{alc.\,KOH} CH \equiv CH \xrightarrow[873K]{\text{Red hot Fe}}$

(iv) $CH_3COOH \xrightarrow[CaO]{NaOH} CH_4 \xrightarrow[h\nu]{Cl_2} CH_3Cl \xrightarrow[(wurtz)]{Na} CH_3-CH_3 \xrightarrow[h\nu]{Cl_2} \overset{\beta}{CH_3}\overset{\alpha}{CH_2}Cl \xrightarrow{alc.\,KOH} CH_2=CH_2 \xrightarrow{Br_2} \underset{Br}{CH_2}-\underset{Br}{CH_2} \xrightarrow{Alc.\,KOH} CH \equiv CH \xrightarrow[\text{hot Fe}]{Red}$

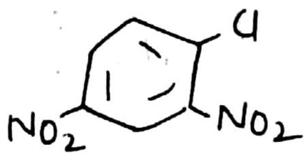
(ethanoic acid)



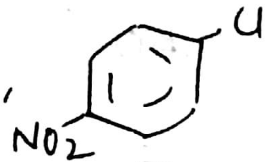
Q Arrange the following set in order of their decreasing reactivity with an electrophile E^+

(i) chlorobenzene, 2,4-dinitrochlorobenzene, p-nitrochlorobenzene

①



②



③

Intermediate is carbocation and we know that -I effect decreases the stability of carbocation. (NO_2 has -I effect).

So order is :- ① > ③ > ②

(ii) Toluene, $p-CH_3-C_6H_4-NO_2$, $p-NO_2-C_6H_4-NO_2$

①

②

③

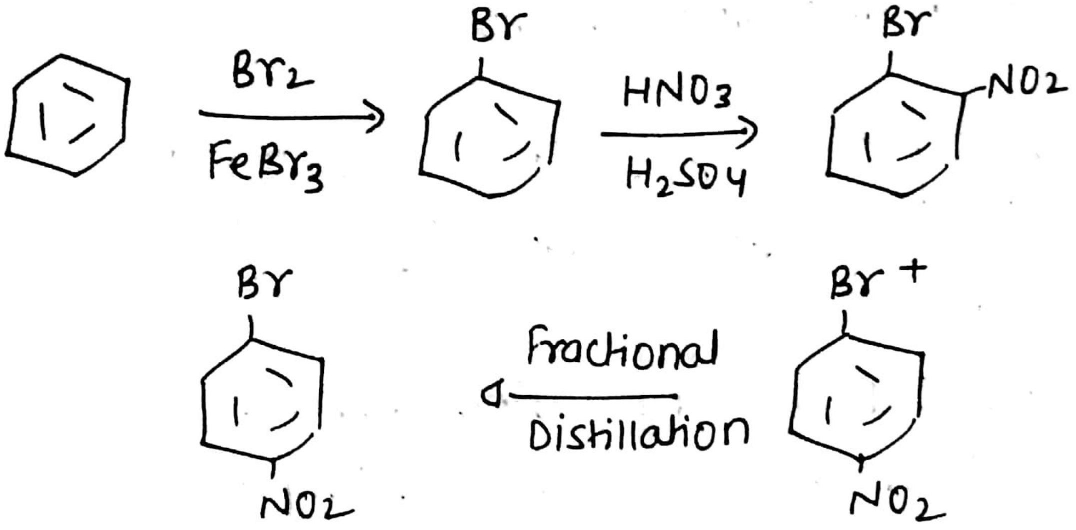
Since NO_2 has -I effect. Hence order will be

① > ② > ③.

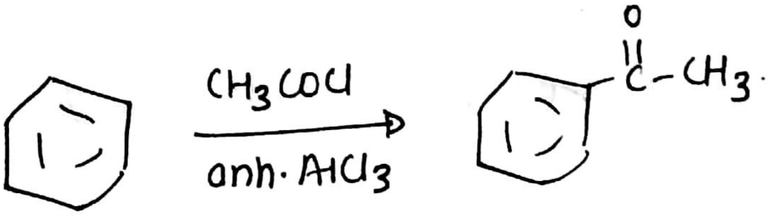
Q. Convert Benzene into

(i) p-nitro bromo benzene
(ii) acetophenone
(iii) m-nitro chlorobenzene
(iv) p-nitro toluene

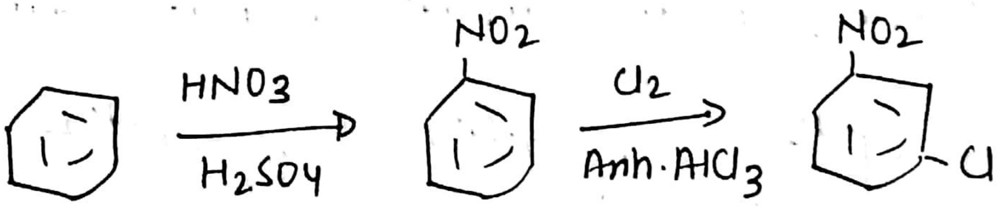
A (i)



(ii)



(iii)



(iv)