University of Al-Mustaqbal
College of Engineering and
Engineering Techniques
Engineering Techniques of
Fuel and Energy department

Organic Chemistry

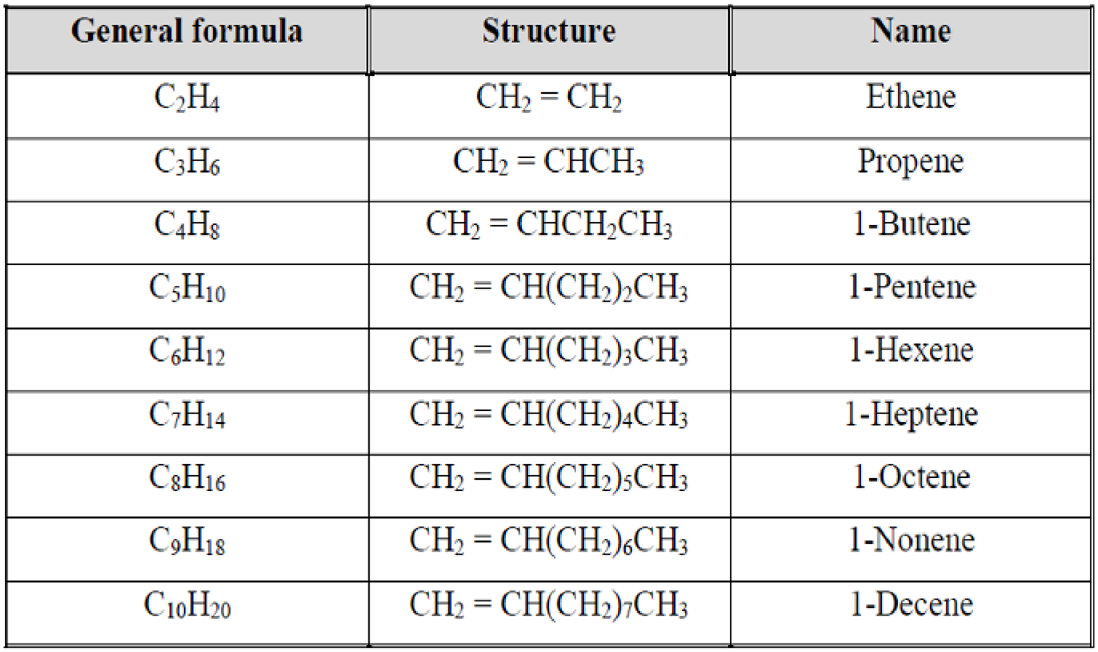
Lecture Four

Alkenes

1. Alkenes

Alkenes are a homologous series of hydrocarbons that contain a carbon carbon double bond. The number of hydrogen atoms in an alkene is double the number of carbon atoms, so they have the general formula C_nH_{2n}.

The carbon-carbon double bond is unsaturated and hence highly reactive toward a wide variety of reagents. The first nine member of the alkenes:



General formula	Structure	Name
C_2H_4	$CH_2 = CH_2$	Ethene
C_3H_6	$CH_2 = CHCH_3$	Propene
C_4H_8	$CH_2 = CHCH_2CH_3$	1-Butene
C_5H_{10}	$CH_2 = CH(CH_2)_2CH_3$	1-Pentene
C_6H_{12}	$CH_2 = CH(CH_2)_3CH_3$	1-Hexene
C_7H_{14}	$CH_2 = CH(CH_2)_4CH_3$	1-Heptene
C_8H_{16}	$CH_2 = CH(CH_2)_5CH_3$	1-Octene
C_9H_{18}	$CH_2 = CH(CH_2)_6CH_3$	1-Nonene
$C_{10}H_{20}$	$CH_2 = CH(CH_2)_7CH_3$	1-Decene

1.2. Naming of alkenes

Common names are seldom used except for three simple alkene; ethylene, propylene, and isobutylene. Most alkene are named by IUPAC system.

1- The longest continuous chain of carbon atoms containing the double bond serves as the parent compound.
2- The ending –ane of the corresponding alkane hydrocarbon name is replaced by the ending –ene.

3- The position of the double bond is indicated by the lower number of the numbers of the carbon atoms to which it is attached. The number that represents this position is placed before the parent compound name. Alkyl groups attached to the parent compound are designated as is done for the alkane.

4- If a geometric isomer is designated, the name begins with cis- or trans-.

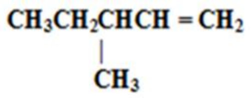
Examples:

$CH_3CH_2CH_2CH_2CH{=}CH_2$

1- Hexene

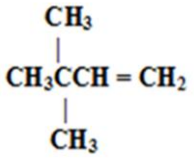
$CH_2{=}CHCH_2CH_3$

1-Butene



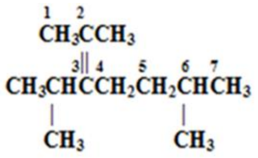
$$CH_3CH_2\underset{\substack{|\\ CH_3}}{C}HCH = CH_2$$

3-Methyl-1-pentene



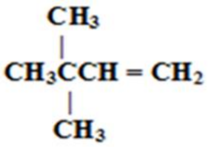
$$CH_3\overset{\substack{CH_3\\ |}}{\underset{\substack{|\\ CH_3}}{C}}CH = CH_2$$

3,3-Dimethyl-1-butene



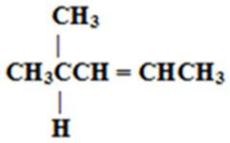
$$\begin{array}{l}\qquad\quad \overset{1}{C}H_3\overset{2}{C}CH_3\\ \qquad\qquad\ \|\\ CH_3\underset{\substack{|\\ CH_3}}{C}H\overset{3}{C}\overset{4}{C}H_2\overset{5}{C}H_2\underset{\substack{|\\ CH_3}}{\overset{6}{C}}H\overset{7}{C}H_3\end{array}$$

3-Isopropyl-2,6-dimethyl-2-heptene



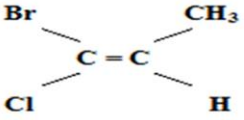
$$CH_3\overset{\substack{CH_3\\ |}}{\underset{\substack{|\\ CH_3}}{C}}CH = CH_2$$

3,3-Dimethyl-1-butene

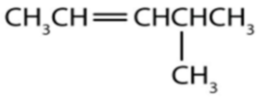


$$CH_3\overset{\substack{CH_3\\ |}}{\underset{\substack{|\\ H}}{C}}CH = CHCH_3$$

4-Methyl-2-pentene

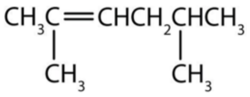


1-Bromo-1-chloropropene



$$CH_3CH{=}CH\underset{\substack{|\\ CH_3}}{C}HCH_3$$

4-methyl-2-pentene



$$CH_3\underset{\substack{|\\ CH_3}}{C}{=}CHCH_2\underset{\substack{|\\ CH_3}}{C}HCH_3$$

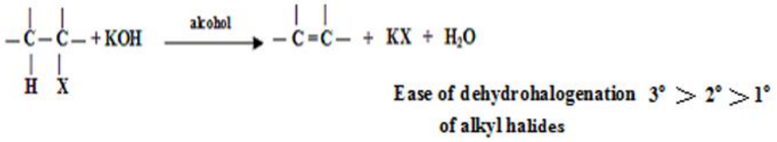
2,5 di methyl hexene

1.3. Preparation of Alkenes

There are four ways to prepare alkenes:

1.3.1. Dehydrohalogenation of alkyl halides

Dehydrohalogenation involves loss of the halogen atom and of hydrogen atom from a carbon adjacent to the one losing the halogen (1,2 elimination).



$$-\underset{H}{C}-\underset{X}{C}- + KOH \xrightarrow{alkohol} -C=C- + KX + H_2O$$

Ease of dehydrohalogenation of alkyl halides 3° > 2° > 1°

$$CH_3CH_2CH_2CH_2Cl \xrightarrow{KOH,\ alcohol} CH_3CH_2CH=CH_2 + KCl + H_2O$$

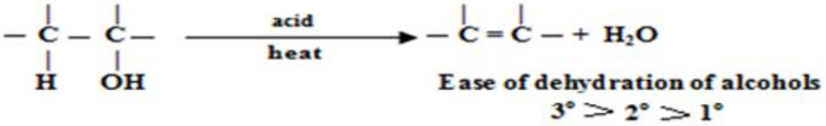
n-Butyl chloride 1-Butene

Example : prepare 2-hexene by using KOH ?

$$H_3C-\overset{Cl}{HC}-CH_2-CH_2-CH_2-CH_3 + K-OH \xrightarrow{alcohol} K-Cl + H-OH + H_3C-CH=CH-CH_2\cdot CH_2\cdot CH_3$$

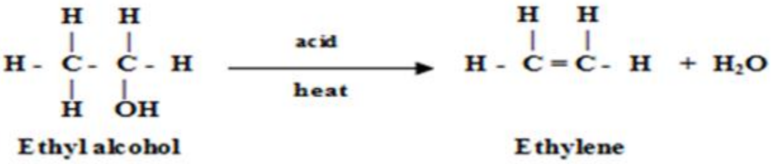
1.3.2. Dehydration of alcohols

In the dehydration of alcohols, the H and OH are lost from adjacent carbons (1,2- elimination). An acid catalyst is necessary and application of heat.



$$-\underset{H}{C}-\underset{OH}{C}- \xrightarrow[heat]{acid} -C=C- + H_2O$$

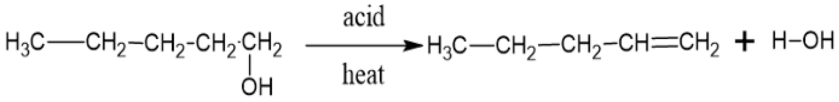
Ease of dehydration of alcohols 3° > 2° > 1°



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-H \xrightarrow[heat]{acid} H-\overset{H}{C}=\overset{H}{C}-H + H_2O$$

Ethyl alcohol Ethylene

Example : prepare 1- pentene from alcohol ?



$$H_3C-CH_2-CH_2-CH_2-\underset{OH}{\underset{|}{CH_2}} \xrightarrow[\text{heat}]{\text{acid}} H_3C-CH_2-CH_2-CH=CH_2 + H-OH$$

1.3.3. Dehalogenation of vicinal dihalides

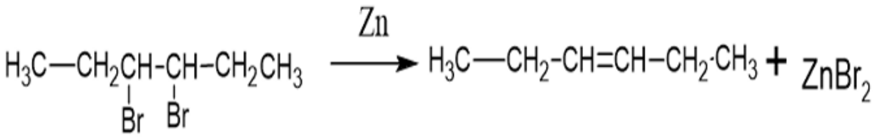
Alkenes can be prepared by elimination of two halide atoms from a vicinal (neighbouring) dihalides.

$$-\underset{X}{\underset{|}{\overset{|}{C}}}-\underset{X}{\underset{|}{\overset{|}{C}}}- + Zn \longrightarrow -\overset{|}{C}=\overset{|}{C}- + ZnX_2$$

$$CH_3CHBrCHBrCH_3 \xrightarrow{Zn} CH_3CH=CHCH_3 + ZnBr_2$$

2,3-Dibromobutane **2-Butene**

Example : prepare 3-hexene by 3- Dehalogenation of vicinal dihalides?



$$H_3C-CH_2\underset{Br}{\underset{|}{CH}}-\underset{Br}{\underset{|}{CH}}-CH_2CH_3 \xrightarrow{Zn} H_3C-CH_2-CH=CH-CH_2-CH_3 + ZnBr_2$$

1.3.4. Cracking of petroleum hydrocarbons

This method usually for commercial alkenes with pd, pt as a catalyst

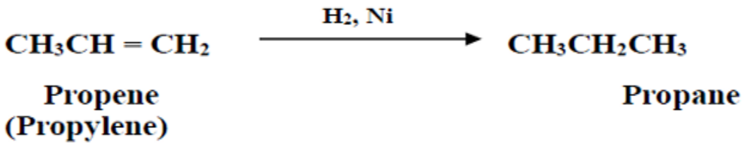
$$CH3CH2CH3 \xrightarrow{pt/pd} CH=CH2CH3 + H2$$

1.4. Reactions of alkenes

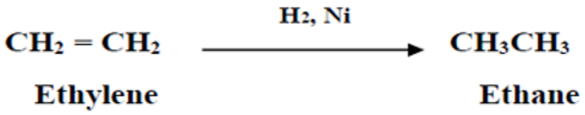
The presence of the carbon-carbon double bond confers very considerable chemical activity on the alkenes and consequently they react with a much wider variety of reagents than do the alkanes. The π-bond component of the double bond is weaker than the σ-bond component and the π-electrons are more easily accessible to attacking reagents.

1.4.1. Addition of hydrogen

When an alkene is mixed with hydrogen, there is no appreciable reaction, but in the presence of certain metal catalysts such as nickel, platinum or palladium, a fairly rapid reaction occurs leading to the uptake of hydrogen.

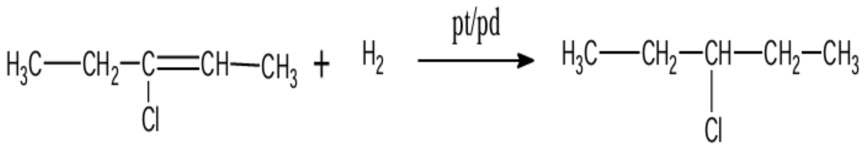


$$CH_3CH=CH_2 \xrightarrow{H_2,\ Ni} CH_3CH_2CH_3$$



$$CH_2=CH_2 \xrightarrow{H_2,\ Ni} CH_3CH_3$$

Example : give a productions of 3-chloro-2-pentene hydrogenation?



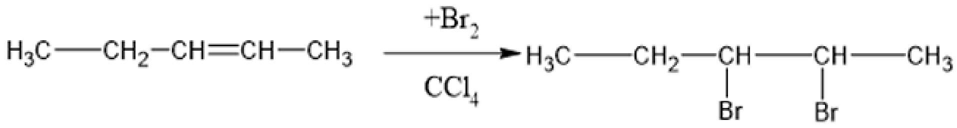
$$H_3C-CH_2-\underset{Cl}{C}=CH-CH_3 + H_2 \xrightarrow{pt/pd} H_3C-CH_2-\underset{Cl}{CH}-CH_2-CH_3$$

1.4.2 Addition of halogen

Chlorine and bromine react readily with alkenes, in the liquid or vapour states, to form dihalogeno addition products, the two halogen atoms are attached to adjacent carbons. Iodine generally fails to react.

$$CH_3CH = CH_2 \xrightarrow{Br_2 \text{ in } CCl_4} CH_3CHBrCH_2Br$$

Example : complete this reaction :



$$H_3C-CH_2-CH=CH-CH_3 \xrightarrow[CCl_4]{+Br_2} H_3C-CH_2-\underset{\displaystyle Br}{\underset{|}{CH}}-\underset{\displaystyle Br}{\underset{|}{CH}}-CH_3$$

1.4.3. Addition of hydrogen halides

The reaction of alkyl halide with alkenes is subjected to Markovnikov's rule.

Markovnikov's rule: the rule states that with the addition of HX other polar reagent to an unsymmetrical alkene, the acid hydrogen (H) or electropositive part gets attached to the carbon with more hydrogen substituents, and the halide (X) group gets attached to the carbon with more alkyl substituents. in which the rule is stated that the X component is added to the carbon with the fewest hydrogen atoms while the hydrogen atom is added to the carbon with the greatest number of hydrogen atoms.

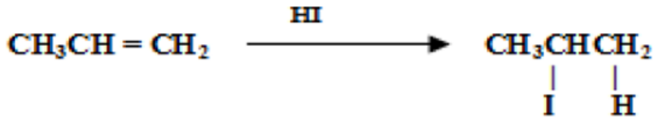
Symmetrical alkenes have the same number of hydrogen atoms on both sides of the double bond...

ethene... CH2=CH2

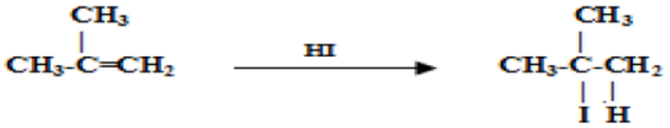
Unsymmetrical alkenes have different number of hydrogen atoms on each side of double bond.

but-1-ene.... CH3 =CH-CH2-CH3

Examples of Unsymmetrical alkenes reaction with HX

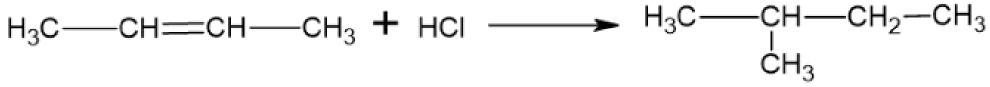


$$CH_3CH=CH_2 \xrightarrow{HI} CH_3\underset{I}{\underset{|}{CH}}\underset{H}{\underset{|}{CH_2}}$$



$$CH_3\text{-}\overset{CH_3}{\overset{|}{C}}{=}CH_2 \xrightarrow{HI} CH_3\text{-}\underset{I}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}\text{-}\underset{H}{\underset{|}{CH_2}}$$

Examples of symmetrical alkene reaction with HX

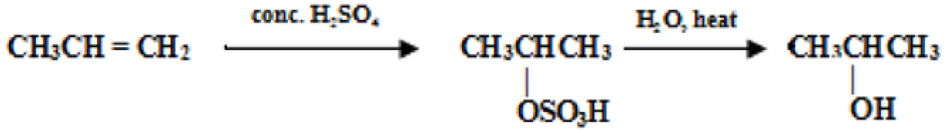


$$H_3C-CH=CH-CH_3 + HCl \longrightarrow H_3C-\underset{CH_3}{\underset{|}{CH}}-CH_2-CH_3$$

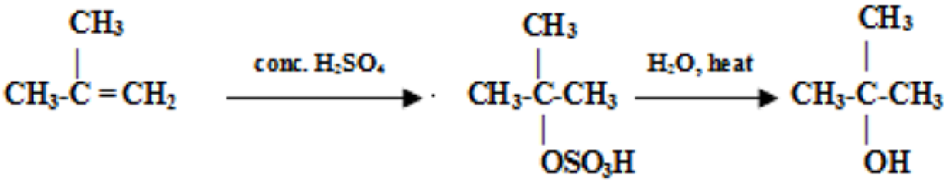
1.4.4. Addition of sulphuric acid

Alkenes are slowly absorbed when they are bubbled through, or shaken with, cold concentrated sulphuric acid. The reaction involves the addition of H and HSO4 groups across the double bond, to form alkyl hydrogen sulphates, which is on dilution with water and heating yield alcohol.

Examples



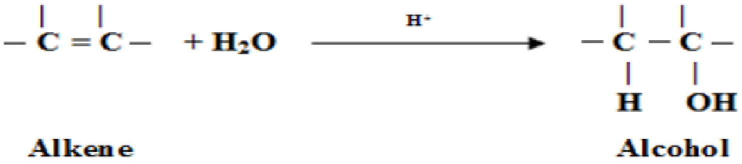
$$CH_3CH=CH_2 \xrightarrow{\text{conc. } H_2SO_4} CH_3\underset{OSO_3H}{\underset{|}{CH}}CH_3 \xrightarrow{H_2O\text{, heat}} CH_3\underset{OH}{\underset{|}{CH}}CH_3$$



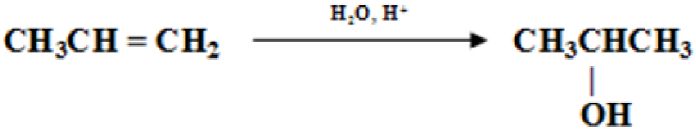
$$CH_3\text{-}\overset{CH_3}{\overset{|}{C}}=CH_2 \xrightarrow{\text{conc. } H_2SO_4} CH_3\text{-}\underset{OSO_3H}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}\text{-}CH_3 \xrightarrow{H_2O\text{, heat}} CH_3\text{-}\underset{OH}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}\text{-}CH_3$$

1.4.5. Addition of water. Hydration

Alkenes are also reacting with water, and this reaction is carried out in a dilute acid medium. The reaction follows Markovnikov's rule.



Example



$$CH_3CH=CH_2 \xrightarrow{H_2O,\ H^+} CH_3\underset{\displaystyle OH}{\underset{|}{C}}HCH_3$$

1.4.6. Polymerization

In the presence of a certain catalyst, alkene molecule can add on to each other in a head-to-tail fashion to form long-chain molecules of a very high relative molecular mass.

$$n\ CH_2=CH_2 \xrightarrow[\text{pressure}]{O_2,\ \text{heat}} -CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$$

$$\text{or}\ \ (-CH_2-CH_2-)_n$$

Ethylene **Polyethylene**