

welcome you all to iit paul program myself murthy from department of chemistry iit gowhati in today's class we will study about alkenes alkenes are hydrocarbons that contain carbon-carbon double bond they have general formula  $C_nH_{2n}$

So examples ethane propane are this is the smallest member of this series and you can go on like this are this compound with the two carbon atoms this with alkene with three carbon atoms and you can go for next one butane if you look at the structure of these compounds let us take ethylene as example and then we will see the structure of that compound this is the structure of ethylene the bond angle between these two C-H bonds is a planar molecule and two carbon atoms and the four hydrogen on the same plane and the bond angle between this is 117 degree the bond angle between this C-H bond and the carbon-carbon double bond is about 122 degree the bond length between the carbon-carbon compound is 1.34 Å the C-H bond length is 1.09 Å

So if you look at this compound it has five sigma bonds you have one carbon-carbon sigma bond four carbon-hydrogen sigma bonds in addition to that we have one pi bond

So the sigma bond formation takes place by overlapping of the  $sp^2$  hybridized orbital of carbon with another carbon  $sp^2$  of this carbon with another  $sp^2$  of this carbon overlapping taking place and give this sigma bond and similarly this  $sp^2$  overlapping of this orbital hybrid orbital with hydrogen s orbital generates the carbon-hydrogen sigma bond

So so the pi bond formation takes place this on the plane the four all the atoms carbon and four hydrogen atoms and perpendicular to that  $p$  orbital you these two  $p$  orbitals overlap and below and above the plane of this are sigma bond and we make the pi bond this overlapping these two orbitals give the pi bond formation and overlapping of this  $sp^2$  hybrid orbital of carbon with another carbon  $sp^2$  orbital generated the sigma bond and

So this also we can write like this you look at this one a bond on the below the plane the  $d$  localisation takes place this two orbital that leads the formation of the pi bond and this carbon-carbon double bond pi bond formation restrict the rotation of the carbon-carbon bond otherwise if we have carbon-carbon single bond the bond can rotate but in this case because of this carbon-carbon double pi bond the rotation is not allowed because of that these molecules can lead to the formation of geometrical isomers just we have seen the structure of ethylene now let us look at nomenclature in the IUPAC system the names of alkenes are derived from the corresponding alkanes by replacing the suffix *ane* with *ene* and *e* for examples this is called ethene if you look at the corresponding alkane already we have studied as ethane and what has been done here this *ane* has been replaced by *ene* and *e* in the case of alkene let us take one more example this is called propene the corresponding alkane is propane this is known as butene one the one refers the position of the double bond the corresponding alkene is butane the other isomer is this is  $C_4H_8$  and if you look at all these alkenes and the suffix *ane* has been replaced by *ene* and *e* now let us look at slightly bigger molecule

So the name of the alkene is and we have to start numbering as we have seen the case of alkane and we have to start from here wherever the double bond is very close to the end here um this is two

So as we have seen the case of alkane the name of the compound will be and we have to first place the substituent and in this case four methyl group at one end this is IUPAC name of this molecule and this is the position of the double bond and the methyl substituent present at the carbon atom four therefore is called four methyl one printing let us take more example

So this case and we have to start numbering and you have to from this side this is the longest chain where the double bond is present and we the double bond is close to this side and therefore we have started numbering like this and the substituent present is methyl group in this case and the position of the methyl substituent carbon number four therefore it is called it is the IUPAC name of this compound is four methyl hex-2-ene in the next is isomerism

So ethylene propane they don't have any structural isomers when you go for butane there are two possible isomers do

So these two are all have the same molecular formula but different structures these two if you look at it the position of the double bond is different place this is the one butane this two butane therefore these are called positional isomers the relationship between them is because this is at the first the double bond present on the first carbon atom one butene these are two butene the position of the double bond present

different places though we call it positional isomers and the relation between these two one and three two and three they are called chain isomers they differ in the chain one has the branch another one is linear therefore these two are called chain isomers and these also called chain isomers but these two are called position isomers but all are called structural isomers they differ in the structures

So you can go on when you go for higher alkene you will have more number of isomers So when we discussed about the structures i mentioned and alkene can exhibit geometrical isomers because of restricted rotation of the carbon-carbon double bonds let us take this example this compound we can write two forms

So in this case we look at it the both  $\text{CH}_3$  on the same side

So this is called cis

So we can also this also can have transform if both on the opposite side we call it as trans

So these are called geometrical isomers in this case under both the methyl group same side therefore is called cis but twin and this is this methyl group the opposite side

So we call it as trans

So now let us look at these compounds

So i have written here three compounds and this one will if you write the season transform there is no c strands in this case

So when you have the same substituent in the carbon atom then they cannot exist cis and transform therefore they cannot do it the geometrical isomers this also will have if you look at it both you have the hydrogen atom

So it cannot exist there somatic geometrical isomers however in this case

So this is and you can also have another form

So therefore this can exist as geometrical isomers these two cannot exhibit geometrical isomers because you have the same substituent this carbon atom similarly you have the same substituent and this as well as that carbon atom preparation of alkanes the first there are

So many methods are available to make alkanes the first example what we are going to see is acidic dehydration of alcohols

So when you compare the reactivity of alcohols tertiary alcohol is more reactive compared to secondary alcohol secondary alcohol is more reactive compared to primary alcohol for example when you react ethanol to the sulphuric acid and heat under heating you can undergo dehydration to give ethene the byproduct will be water is a elimination reaction and this is a primary alcohol when you treat this alcohol with sulfuric acid under heating and it can undergo dehydration to give alkyl this simple alcohol you get this for example if you take secondary alcohol which is unsymmetrical for example this is a primary alcohol this is a secondary alcohol when you treat this alcohol with sulphuric acid under heating as we have seen here they it also can undergo dehydration to give a mixture of alkenes

So in this case we get a mixture of alkenes and one is an substituted more substitute alkenes another one is terminal alkene we get here and this if you compare the ratio of these compounds this is will be major and this will be minor compound and four times about eighty percent and formation of this alkene takes place and the remaining twenty percent will be this alkene these things we will study later because this is a when you have more substituted double bond will be more stable this formation of this alkene um takes place quite efficiently comparing to that now let me show you the reaction pathway how the formation of these two alkenes takes place this or alcohol when you treat this alcohol with sulphuric acid let us write h plus this for reversible and fast and protonation of this o h takes place you will have this intermediate once you form this intermediate the carbon oxygen bond cleavage takes place to form carbocation plus water So the o h becomes oh<sup>+</sup> this species once you form this this called alkyl oxonium intermediate once you form this intermediate the c o bond cleavage takes place and we generate a carbocation intermediate plus water this is a slow step this is called rare determining step this is fast this is reversible and once you form this one now the cleavage takes place that can lead to the formation of the carbocation that is slow step and now the adjacent to the carbocation carbon you have two hydrogen atoms now this water molecule can act as a base it can remove this proton then you'll get the corresponding alkene for example path a if this water molecule removes this proton So let me write you will get this alkene on the other hand if the water molecule removes this proton this is path b remove this hydrogen then you will get

So this is the double bond less substituted double bond this is a more substituted double bond this more stable comparing to this and if you look at the ratio of this formation of these tolkiens just i mentioned this will be a major compound this will be minor and this ah

So you will get the byproduct will be this one and this auxiliary will be converted into this is called hydronium ion this will be converted into water plus h plus and this if you look at it this one this we are writing of course this is a mixture of geometrical isomers and you can have a mixture of two compounds this plus this is trans two butene this is again among this this will be the measure this will be minor ah these are called the geometrical isomers and this will be the major ah compound this will be minor and if you compare the ratio of these two this will be the major product and if you go for tertiary algal there is also possibility and you will it can the carbocation can undergo rearrangement then ah the double bond formation takes place

So the next reaction is dehydro halogenation reaction for example when you have this ah alkyl halide bromide and instead of o h you have the here uh beer

So when you treat this compound with alcoholic o h um sodium hydroxide potassium hydroxide is a base and this k o h again depends upon the alkyl ah halide in this case you know the hydrogen ah at beta carbon atom to the this carbon and this base the o h minus can remove this proton the elimination takes place you will get alkene you get propane the byproduct will be potassium bromide plus water

So the reaction condition is very important you have to use alcoholic koh then act as a base otherwise it will be a substitution reaction but this must you have to write the alkali akos then the elimination reaction takes place you get alkene

So if you um want to have the rate of the reactivity of alkyl halides the iodide will have more reactive reactivity comparing to the aryl bro alkyl bromide and alkyl bromide will show more reactivity comparing to alkyl chloride the reactivity order of the alkyl halides towards alcohol kos to give alkenes the third type of reaction is dehalogenation if you have vicinal halides you can also convert the dihalo compound into the alkenes for example if you have the dibromo compound which the you can see here the bromine atoms present in the two next this is called vicinal dibromide they are present next carbon atoms when you treat this compound zinc dust in alcohol generally ethyl alcohol is used as solvent when you have treat this compound in ethiopia with the zinc dust and you can convert into the corresponding alkenes you will get one butene plus zinc bromide this is a byproduct this case now how how the reaction takes place the zinc undergoes insertion between this carbon halogen bond you first generate instruction takes place zinc is converted to zinc two and you have the this intermediate once you have this one this can undergo elimination to give the alkenes the next common reaction to make alkanes is hydrogenation its very important reaction and if you have all alkyne alkene can be converted into alkene there are two ways you can make alkanes and one is catalytic hydrogenation for example if you have alkyne for example this alkyne this alkyne can be reduced into corresponding cis alkene any use perium sulphate palliative supported on barium sulfate in the press of quinoline and when you treat ah this compound with hydrogen quinoline and it partially can be reduced into cis2 butane

So the reaction stereo specific and it can be you can it is example for addition reaction what you do here you add hydrogen gas to the carbon carbon triple bond is addition reaction the reaction stereo specific you can end up with ah cis 2 butane and selectively and in this case ah the this also called lindler catalyst inline catalyst and this palladium is supported on barium sulphate or calcium sulphate and in the price of quinoline the reactivity of this cattle is reduced

So that then partially you can reduce the carbon carbon triple bond to carbon carbon double bond with syn stereochemistry and how the reaction takes place you need catalytic amount of palladium supported on parium sulfate and first what happens you have the catalyst the catalyst reacts the hydrogen gas the hydrogen is observed on the surface metal surface once the hydrogen is observed on the surface of metal then alkene alkyne approaches the observed hydrogen and the hydrogen transport takes place under those additional same side of the alkyne therefore you end up with syn alkenes the reaction takes place same phase of the bottom face of the alkyne you end up with a cis to butane you can also transform alkyne to trans to butane for example if you take this alkyne react with sodium liquid ammonia

So in this case you end up with trans to butane the stereochemistry is different the previous case the catalytic hydrogenation using linear catalyst we have seen you can end

up with cis alkene and in this case uh when you use ah sodium liquid liquid ammonia you have to use stoichiometric amount of sodium in this case and then you get trans alkene this reaction also stereo specific you get ah trans alkene this is also example for addition reaction you have to use sodium and liquid ammonia

So regarding the reaction mechanism sodium can give is it involves a single electron transfer process it can give one electron to the alkyne

So you can generate the radical anion it generate the radical anion when sodium gives one electron to the alkyne it generated this intermediate once you have a radical anion it can react with your liquid ammonia it can remove a proton from the ammonia once you have this one this again can react the another sodium can give one more electron you generate this anion this anion ah take proton from the ammonia do

So you get transfer butane plus sodium sodamide

So the stereochemistry is decided on this step

So you can see here this you have the ah trans geometry it reacts again with another sodium you have the anion this anion once we have this one this can pick up the proton from the ammonia you can get selectively the trans to butane

So this means you need two equivalent of sodium with respect to alkyne and in this case the alkene does not undergo further reduction using sodium liquid ammonia is a very nice reaction if you want to make trans alkenes and you can use this method it works very well the next reaction is cracking when you heat petroleum around 500 to 800 degree celsius the options of air it can undergo cracking into small alkenes alkane plus hydrogen the example is when you heat propane at 600 degree celsius it can undergo cleavage into is a radical reaction methane hydrogen

So this is used in petrol industries when you make the cracking and of alkanes and you can large amount of alkenes are produced depends upon if you have the larger alkanes you will end up with mixture of alkenes

So far we have seen the structure and preparation of alkenes now let us look at the physical properties of alkenes the first three members of this series 18 propane and butane their gases at room temperature the first three members of this series 18 propane butane their gases and the next 14 members and the colkins that contain c52 c17 carbon atoms sulkins that contain c5 to c17 carbon atoms next 14 members of the series they are generally liquids they are liquids alkenes that contain more than c eighteen carbon atoms they are usually solids

So alkenes can be gas liquid or solid depends upon the ah the molecular weight and for example in this case the first three compound alkenes they are gases and the next protein that alkene that contain c phi two c seventy carbon atoms they are general liquids and the higher homologous the alkenes that contain more than c 18 carbon atoms they are solids alkenes are non polar compounds they are well soluble in organic solvent like chloroform ah they are well soluble ah thf and

So on and less soluble in water

So non polar compounds

So when you talk about melting and boiling points and when you increase the molecular weight of the alkene the melting and boiling point increases

So for example let us take pentene the boiling point is 32 degree celsius therefore when you increase the molecular weight of the alkenes the boiling point and melting melting and boiling points increases

So when you increase the molecular weight of the alkene the boiling and melting points increases and in summary

So in this class we have seen about the first part of alkenes and we first we have seen the structure and bonding of ethylene then we have seen the nomenclature and isomerism then we have seen the preparation of alkenes then the physical properties of alkenes as you can see here the alkenes the first three members of the series is their gases at room temperature the next um the 14 members that alkyne that contains c5 to c17 they are usually liquids and the alkenes that contain more than c 18 carbon atoms they are solids and they are non-polar compounds they are well solved in organic solvents the boiling point and melting point increases with increase of the molecular weight and

So the the next class we will study about the chemical properties of the alkenes with this i conclude you