Introductory Organic Chemistry
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Lecture - 26
Reactions of Alkenes Part – 1

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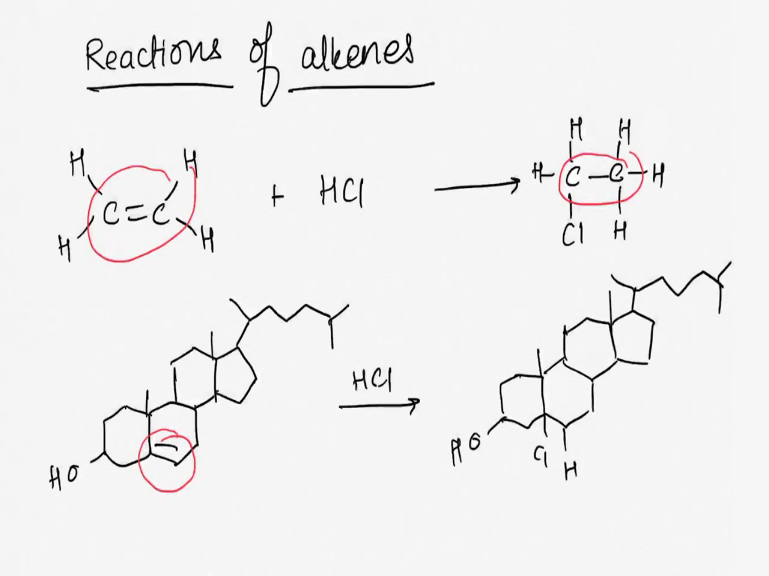

We know that there are millions of organic compounds. So, if we have to memorize how each and every one of them reacts, studying organic chemistry would be a very tough job right. Fortunately, organic compounds can be divided into families and all the members of one family react in a very particular manner. What determines the family of an organic compound is really the functional group. The functional group is a structural unit that acts as a centre of reactivity of that molecule.

We have looked at some of the common functional group in last classes and we are already familiar with various functional groups. So, in this lecture we are gonna study the Reactions of Alkenes, but before I go over reaction of alkenes I want to point out that alkene, which is the Carbon-Carbon double bond, all the alkenes pretty much react in a similar way whether the compound is a really small molecule like ethyl or a really large molecule like cholesterol both these molecule are gonna react the same way in a particular reaction.

So, here in I have an example of an alkene reacting with HCl and it reacts such that the Carbon-Carbon double bond breaks right. So, this bond is broken in the end product and HCl adds on the Carbon-Carbon double bond right. So, Hydrogen adds to one Carbon and Chlorine adds to the other. The same thing will happen if I take cholesterol molecule. So, now, if I look it cholesterol here I have this Carbon-Carbon double bond and when HCl reacts it's gonna do the same reaction. So, it's going to form this right.

So, irrespective of the kind of molecular I have I can determine its reactivity based on the functional group it has. So, this is really key to understand the reactions of organic compounds. One of the key things which we wish to practice before we really start learning organic reactions is not to memorize them. Because remember that even if you want to memorize one of the functional groups and one of its reactions remember that there are multiple reactions of each functional groups.

So, if you really memorize a reaction, organic chemistry becomes really dull and dry and really becomes a memory based subject whereas if we really look at organic chemistry reactions and understand why a particular reaction is taking place then this whole activity of memorizing these vast reaction really is not needed. And, you can really understand the reaction by just looking at the functional group, by just looking at the compounds that are reacting and will be able to predict the product.

So, what we are going to do is we are gonna rather recognise the structure of the functional group and understand their behaviour. So, you can really imagine each functional group to have a characteristic nature. Just like some of our human beings are some are fun loving some are really serious the same way functional groups are also very characteristics. Some of them are acidic, some of them behave in a particular manner, some of them have nucleophilic centres, some of them have electrophilic center.

And, thus instead of remembering each reaction if we understand the chemical logic the structure of the functional group, then it becomes much easier for us to master the reactions in organic chemistry. To further reduce the need of memorization we need to understand why a functional group reacts the way it does. It is not sufficient to know that a compound with a Carbon-Carbon double bond reacts with HBr to form the product wherein Hydrogen goes to one Carbon and Bromine goes to the other Carbon, we really need to focus on why is this compound reacting with HBr, right.

So, henceforth whenever we are studying reactions of any functional group we are gonna focus mainly on why is this really happening. So, anytime you are confronted with any new functional group or any new reaction of a known functional group you should focus on how the nature of the functional group allows it to do that reaction. Then, when you are confronted with the reaction you have never seen before or a molecule that you have never seen before you can still apply the knowledge of how the structure really determines the reactivity of the compound. And, it will really help you to predict the products of the reactions of the compounds that you have never seen before.

Organic chemistry is all about interactions between electron rich atoms and electron deficient atoms or molecules. It is these forces of attraction that make chemical reactions happen. From this follows a very important rule that determines the reactivity of organic compound. Electron rich atoms or molecules are attracted towards electron deficient atoms or molecules right. So, electron rich atoms really want to attack electron poor atoms or molecules, that's what we are going to remember.

Each time we study a new functional group remember that the reactions that it undergoes can be explained by this very simple rule. Therefore, to understand how a functional group reacts we must learn to recognise electron deficient groups and electron rich groups okay.

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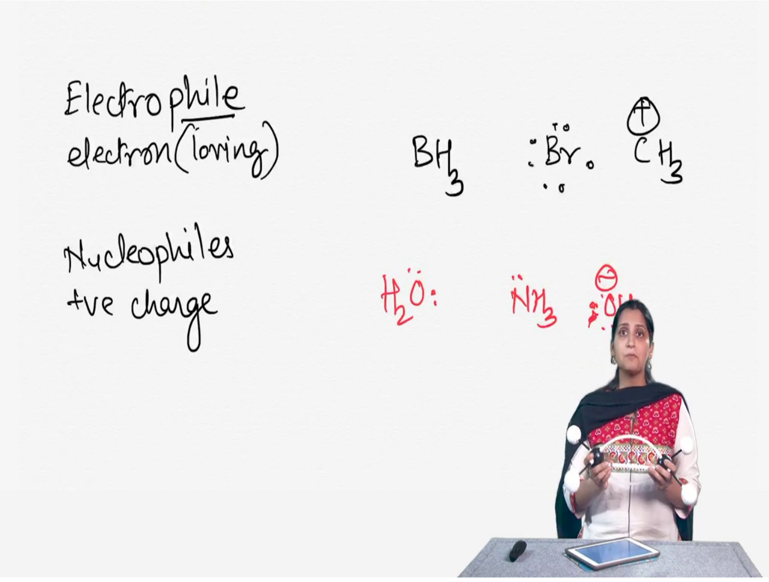

So, we are gonna look at two new terms here. So, the first term that we are going to look at is called as an electrophile. If you look at this particular word the part 'phile' means loving, right. So, this is electron-loving right. So, electrophiles are electron deficient atoms. So, that's why they love electrons, they want to get electrons right. So, they don't have their own electrons. So, an electrophile can have an atom that accepts a pair of electrons or it can have an atom with an unpaired electron and therefore, it is in need of the electron to complete the octet.

So, what are the different electrophiles you have seen before? Really in any acid-base reaction the acid is an electrophile because the base with its lone pair of electrons is attacking the proton to grab the proton from that acid and that proton is really the electrophile here. Other electrophiles that you must have seen are like BH_3. So, we talked about the structure of BH_3 in our first class and we said that Boron has an incomplete octet. So, it becomes an electrophile. Let's take a Bromine with one less electron and that becomes an electrophile or you can also have a carbocation, right, that carbocation is deficient of a pair of electrons and thus it is also an electrophile.

In contrast we have a different terminology for the compounds that really love a positive charge. So, these are nucleophiles. So, remember 'phile' again means loving and nucleophile means the compound that really loves a nucleus; a nucleus that is positively charged. So, a typical nucleophile has a pair of electrons it can share. Some nucleophiles are neutral whereas, some of them are negatively charged and because a nucleophile has electrons to share a nucleophile is typically the compound that will first go and attack a particular electrophile and will try to share its electrons with that electrophile, okay.

And, typically as you can see one of them is electron loving one of them is nucleus loving, so, electrophiles and nucleophiles really are the key players that react with each other since they are attracted to each other, okay. So, most of the organic chemistry reactions can be summarized by just one statement that a nucleophile is reacting with an electrophile in this reaction.

So, now let us look at some of the examples of nucleophile. So, in water the Oxygen atom has a pair of electrons it can attack with. So, Oxygen here becomes a nucleophile or you can think of Ammonia, you can think of hydroxide ion, you can also think of Chloride, Bromide, you can also think of various other nucleophiles. So, negatively charged ions or molecules, that have a potential of attacking in a chemical reaction will be termed as a nucleophile.

So, now let me ask you a question which part of the Carbon-Carbon bond or which part of the alkene moiety is really nucleophillic? Which part of it is really electrophilic, right; that is the question we want to ask because we want to start looking at an alkenes reaction like it’s a reaction between a nucleophile and electrophile?

So, I have the structure of alkene here and if you really see these are the two carbon atoms as we said there is a sigma bond here in between these two; this is the pi bond that exists above and below the plane and rest everything is in the plane of the paper, right. So, where are the electrons in this molecule, which part is really going to get attracted to an electrophile?

As far as I can see in an alkene there is no positive charge so, I don’t see an electrophile directly. But, I can really see that the pi cloud here right so, this is the sigma bond and these are the pi bonds right above and below the plane the pi bonds are really loosely tied to the Carbon atom right. Because sigma bond is stronger pi bond is weaker, the pi bond is easier to break, right; also the pi bond is really rich in electrons. So, if I want to see the reactivity of an alkene molecule I will call it to be a nucleophile, it is a really electron rich molecule. So, the cloud of a pi bond or the cloud of the pi electrons can attack an electrophile in a chemical reaction.

So, we can therefore, predict that an alkene will react with an electrophile and in the process the pi-bond will break. So, for example, if a reagent like hydrogen chloride were to be added to alkene, the alkene will react with the partially positively charged Hydrogen of the hydrogen chloride and a carbocation will be formed. So, what we are going to do is we are now going to look at this particular reaction that we first saw. We are going to look at the reaction between an alkene and HCl.

And, we are going to see how the electrophile and the nucleophile really react in the reaction.

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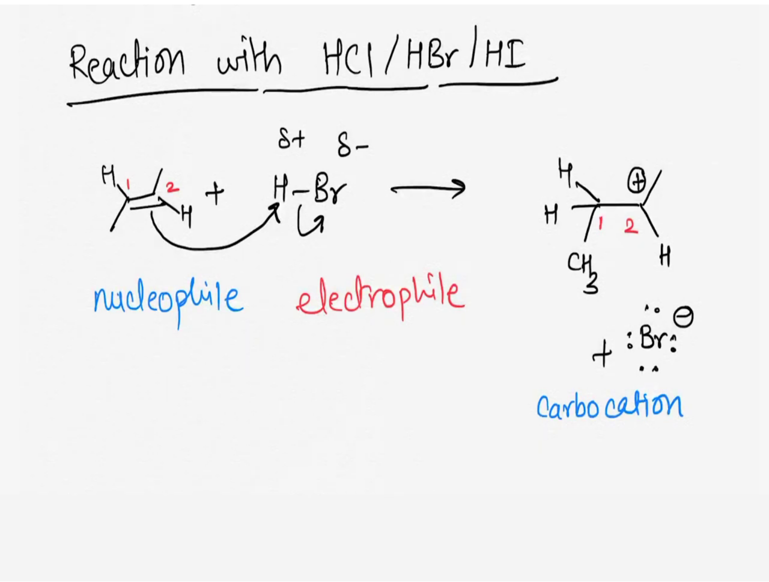

So, if I take 2-Butene and I react it with HBr. If you really think we said that our nucleophile is the alkene and the electrophile is HBr, right so, what will happen in the first step is that the double bond of the alkene it's going to be really electron rich, it's gonna go and attack that proton on H-Br because that hydrogen-bromine bond we know is partially polarized bond such that most of the electrons are with Bromine and Hydrogen already has a delta positive.

So, if I want to denote the charges there will be a delta positive on Hydrogen and a delta negative on Bromine right; a partial positive on Hydrogen. So, the electrons are gonna get attracted to the positive charge. So, the way I show it is that I draw an arrow from the middle of the bond towards that Hydrogen. So, the arrow had has to go from the middle of the bond to the Hydrogen not the other way round. I cannot draw an arrow from the Hydrogen to the double bond that is wrong, okay.

So, when we are looking at the reactions we are also going to focus on how the arrow pushing happens, okay. So, we have to draw an arrow from the two electrons of the pi bond of the alkene towards the positively charged proton. Now, the proton does not want to really form two bonds. It's already forming a bond with the Bromine; it does not want to form a new bond with the Carbon. So, what it does indeed is it breaks its bond and gives the electrons to the Bromine.

So, what do we have here, as a result of which now the Carbon has formed a bond with the Hydrogen, right; so, I am going to give the Hydrogen to the first Carbon and form a Bromide ion. If you think about it if I number my Carbons 1 and 2, as the reaction happened as the

Carbon attack the proton; Carbon number 1 got the proton, right; Carbon number 1 got the Hydrogen to form bonds with whereas Carbon number 2 really lost the bond in the reaction, right. So, it had the double bond electrons, now it no longer has the double bonded electrons. So, thus as this reaction happens what we give rise to is a carbocation and a Bromide ion right. So, this is our carbocation.

Now, in the next step what is going to happen, think about it. The Bromide ion is right there, right and you have formed something positively charged. So, what will happen? The positively charged carbocation is going to be attracted towards the negatively charged Bromine and in fact, Bromine with it is electrons is going to attack on that positively charged carbocation. So, what we are going to do is we are going to see the next arrow pushing such that let me just redraw my carbocation here.

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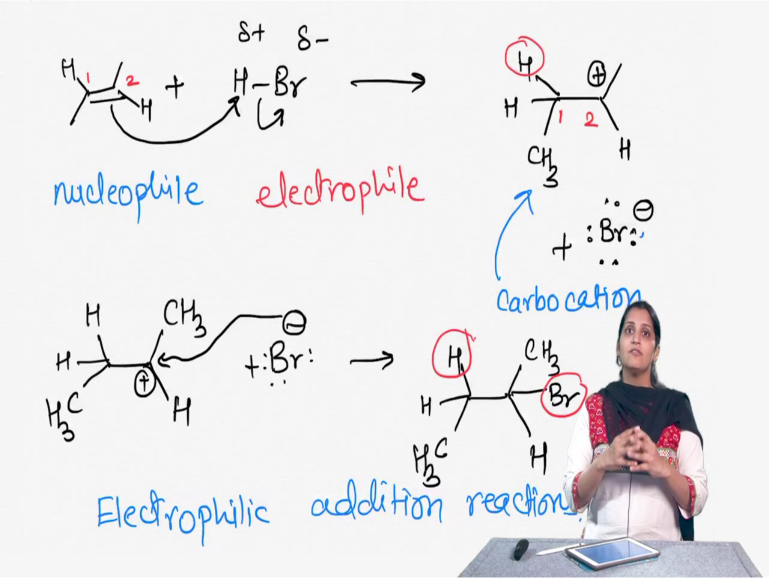

So, the Bromide with its electrons is going to attack on this carbocation to give you addition of Bromine on one of the carbons, right. If I really think about it, one of the Hydrogen's got added in the first step and the Bromine got added in the second step of the reaction. So, what I have done here is that throughout the reaction what we are doing is we are adding a Hydrogen and a Bromine across the double bond right. So, this is an addition reaction; addition reaction wherein 1 mole of H-Br when it reacts with 1 mole of alkene will add across the Carbon-Carbon double bond and form 1 mole of the final product that is the alkyl bromide.

Since we have added an electrophile to the Carbon-Carbon double bond in our case the addition of electrophilic H^+ happens towards the alkene in the first step, right. So, our first step which was the addition of an electrophile so, this whole reaction is termed as in electrophilic addition reaction. So, we are going to call this as Electrophilic-addition reactions and remember that we have added H-Br right now, but HCl reacts the same way, H-I reacts the same way, H_3O^+ will react the same way. So, really addition of any acid will really be termed as an electrophilic addition reaction with the alkene.

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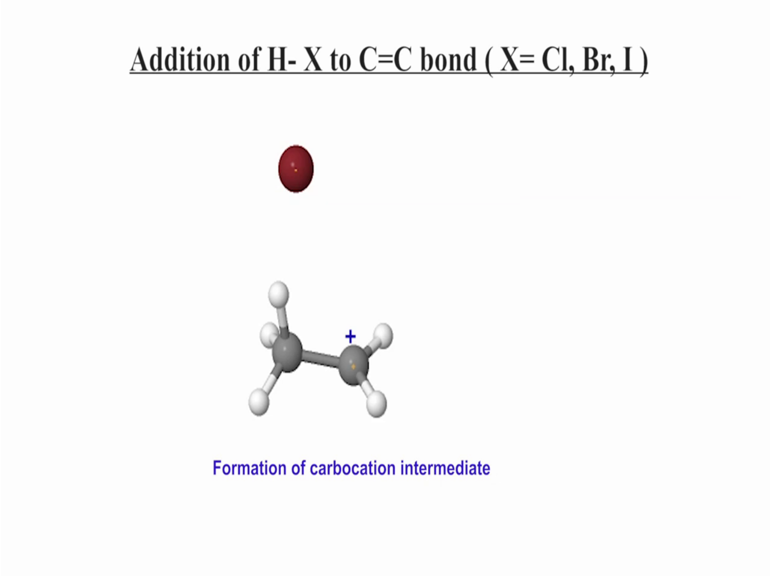
Addition of H- X to C=C bond (X= Cl, Br, I)

Formation of carbocation intermediate

So, now we will look at the animation of this reaction.

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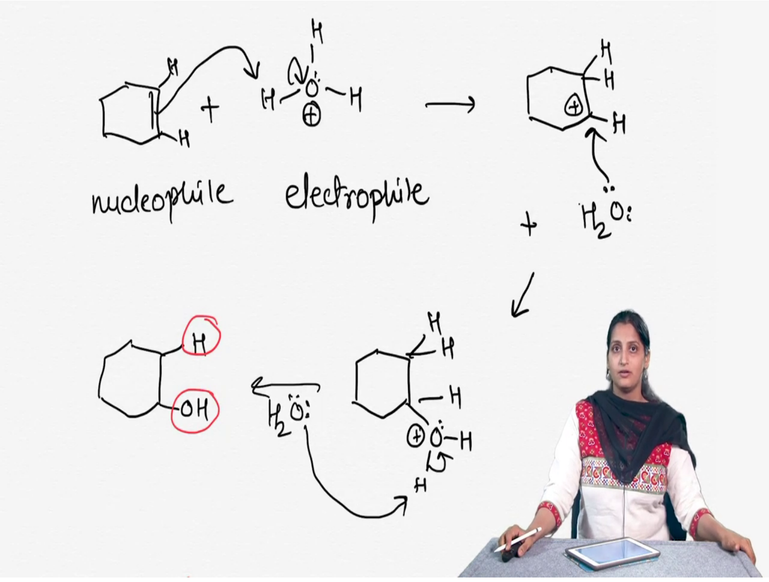

Electrophilic addition reactions are one of the characteristic reactions of the alkenes. So, what I am going to go over is now we are gonna write down two more reactions of various alkenes reacting with HCl, HI, H_3O^+, right.

So, let's take the example of cyclohexene reacting with H_3O^+. Again, the first thing I think about is that where are the electrons and where is the electrophile, right? So, electrons are present on the Carbon-Carbon double bond. So, that is my nucleophile and a positive charge or an H^+ really exists in H_3O^+. So, that is the electrophile right. So, what we are going to do is, we are going to take the Carbon-Carbon double bond. It's going to really take its electrons in attack that proton and the proton does want to form two bonds at the same time. So, what it's going to do is it's going to put those electrons back on that Oxygen, right.

As a result of which what happens is you give rise to a carbocation, okay. Remember there were two protons to begin with here so you give rise to a carbocation and water molecule, right. Now, what happens? Now, you have a carbocation that is formed, positively charged carbon and you have a water molecule where the Oxygen has the pair of electrons right. So, what we are going to do next is that Oxygen is going to attack here. As a result of which what happens is we are going to form this particular species.

Now, you may wonder is this the end of the reaction right because we have done the two steps. In the first step the nucleophile attack the electrophile, in the other case the ion or some moiety that had electrons has now come and attacked on the carbocation. But, remember our 5-star principal, the very first class we said that nature hate charges right.

So, what we have right now is a charged molecule, it has a positive charge. So, it’s not gonna remain like that. In fact, when we are working with water or when we are working with hydronium ion compounds like this we have a lot of other water molecules in the reaction. And, one of the water molecules really is going to come and grab that proton and put the electrons back on that Oxygen.

So, what do we form? We form addition of an OH and H across the Carbon-Carbon double bond. So, if you really see we have done nothing, but addition of hydronium ion across the Carbon-carbon double bond right.

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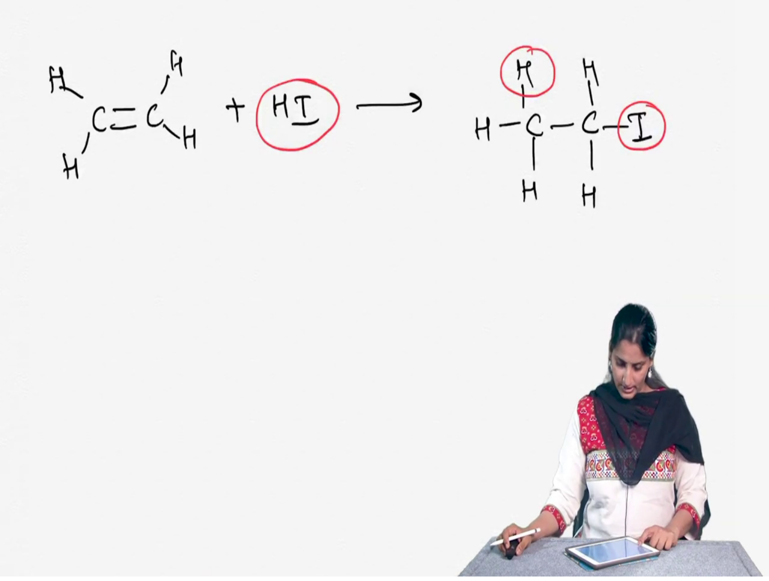

Okay, so, let’s take one more example I am going to take the reaction of an alkene, Ethene and reacted with HI okay. Now, one thing I want to do here is I want to write down the product directly without going through the mechanism. Remember, the mechanism is vitally important and it will allow me to write down the product of any reaction, as long as I know the mechanism I can predict the reaction product. So, in this case I know the mechanism.

What happens when an alkene reacts with an electrophile like this? The double bond breaks and one of the Carbon will form bond with a Hydrogen, the other Carbon will form a carbocation and the I^- is going to go and attack that other Carbon. So, what are we going to form here? Addition of Iodide on one of the Carbons and addition of Hydrogen on one of the Carbons right, in all we end up adding this HI on the Carbon-Carbon double bond, right.

Okay, so, we have covered the first reaction which is the addition of HCl, HI, HBr, H_3O^+ on the Carbon-Carbon double bond. But, remember because the alkenes in the earlier reactions have the same substituents on both of the sp^2 hybridised Carbons it is really easy to determine the product of the reaction right. It did not matter where I put the Iodide, it did not matter where I put the Hydrogen, which Carbon gets the hydrogen it really did not matter.

So, it was very easy to determine the product; but what happens when the alkene does not have the same substituents on both the sp^2 hybridized carbons; which sp^2 hybridized carbon will really get the Hydrogen, right. So, that is one question. So, what I am going to do is I am going to really react 2-Methylpropene and we are going to add HCl to it right.

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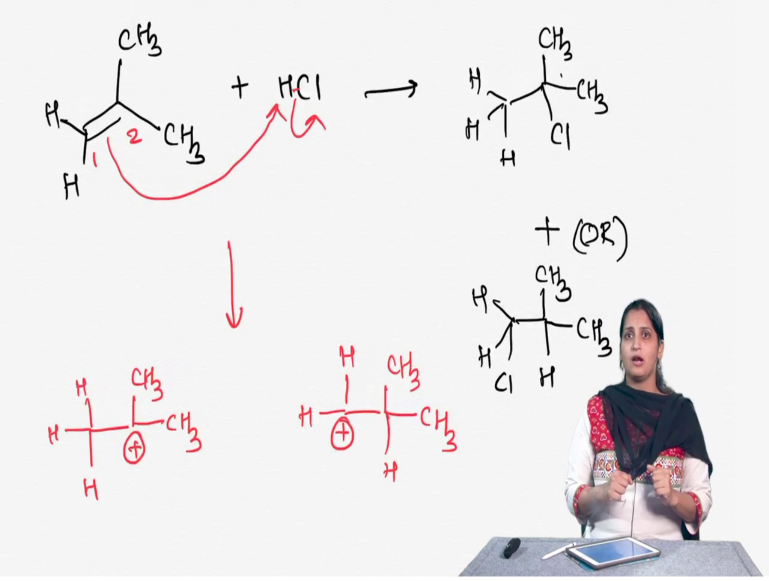

So, let’s take 2-Methylpropene. So, this is propene and this is 2-Methylpropene, right. So, if I really see this is my starting molecule. Now, the question is if this molecule reacts with HCl what is going to happen, okay. Remember, that how I said that each alkene will react in a very particular manner, the answer is yes, it will still do the same reaction. But, now the question is which of these Carbons 1 or 2 will get Hydrogen or which of the Carbons will get the Chlorine?

So, if I really give the Hydrogen to the first Carbon, I form this product or if I give the Hydrogen to the other Carbon I form this product, right. Remember these are two different molecules – one of them is tertiary butyl chloride and one of them is iso-butyl chloride. So, now, the question arises that if this molecule reacts which one will it form, okay.

So, we are going to now look at reactions where in the alkene is asymmetric to begin with. Now, let us think about the first step of the reaction. The first step of the reaction is when the double bonded Carbon goes and attacks the proton right. Now, remember the question is which of these Carbons will prefer to have a Hydrogen attached to it. In order to really understand the logic behind what is happening we need to understand the product that it forms.

So, let us first try to attack this double bonded Carbon on the Hydrogen and kick off the Chlorine, right. If Carbon number 1 gets the Hydrogen this is how the molecule will look like right, the end product of the first reaction; whereas if Carbon number 2 gets the Hydrogen this is what the product looks like right. So, what we have here really are two different molecules, two different carbocations. Which carbocation will form, will be determined by the energy of these carbocations.

Remember, nature hate charges, right. So, if I have a charge that is really unstable, nature is not going to favour the formation of that charge, right. So, between these two charges which one is really stable, right; the answer to this question is that we have to look at what really governs the carbocation stability and before we even go and look at the stability of carbocations, let us first look at the structure of carbocations, right.

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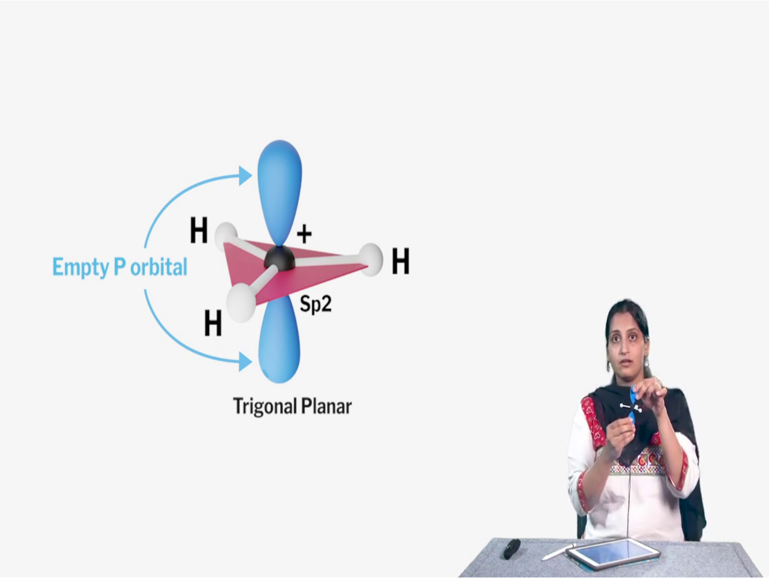

So, here in I have a model of a methyl carbocation okay. A carbocation is sp^2 hybridized. So, methyl carbocation which is CH_3^+ has three bonds with the 3 Hydrogens and they are all in the same plane. So, this is a flat and a planar Carbon-Hydrogen bond molecule, right; Trigonal planar geometry. What really happen is that above and below the plane the carbocation has a empty p-orbital right. So, this is where the vacancy is, right.

So, remember the second step where the Bromide ion came and attack the carbocation this is the position where the Bromide ion is going to come and put its electrons right. So, a carbocation is really sp^2 hybridized, trigonal planar and has an vacant p-orbital here right. So, now, for such a molecule what will really govern its stability; if you think about it anything that can put electrons into the, into this empty p-orbital that can make the Carbon more electron rich because right now it does not have a complete octet right.

So, if it can gain electrons in any way that particular species is gonna be really stable right. So, now, between these two carbocation compounds we want to figure out which one is really more stable based on which carbocation which positive charge can gain electrons from the surroundings.

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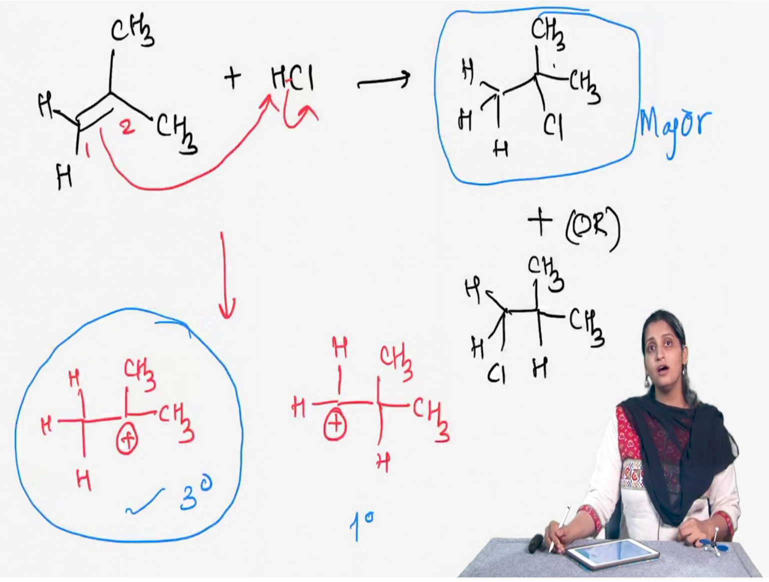

So, carbocations are classified according to the number of alkyl substitutes that are bonded to the positively charged Carbon. A primary carbocation, so for example, this one here has one substituent, one alkyl group attached; a secondary carbocation will have two alkyl groups attached and a tertiary carbocation will have three alkyl groups attached. In fact, I have also drawn a methyl carbocaion which is no alkyl groups attached, only Hydrogen’s attached to it.

The stability of a carbocation increases as the number of alkyl groups that are attached to the positively charged Carbon increase. So, tertiary carbocation is going to be most stable and methyl carbocation is gonna be least stable and the stability is going to increase as we go towards tertiary carbocation. Here we are talking about the relative stabilities; carbocations are really not stable species. So, even in the tertiary carbocation when we say it is stable it is not really stable to isolate from a reaction medium right. There are very few carbocations which are stable enough such that they can be isolated and stored in the bottle.

But, remember when I say that tertiary carbocation is really stable what I mean is amongst all the carbocations, a tertiary carboncation will be more stable. So, we are all talking about relative stabilities here. So, why does the stability of a carbocation increase as the number of alkyl substituents bonded to it really increase? Alkyl groups decrease the concentration of positive charge on the Carbon. Remember, what we said that the middle Carbon here is electron deficient; it has a positive charge, it has an empty p-orbital, right.

So, anything that can put electrons into the system such that they decrease this charge because nature hates charges, right. So, anything that decreases the charge on that Carbon we are going to have a favourable stabilizing interaction, right. So, how do alkyl groups decrease the concentration of positive charge on the Carbon? For this we need to recall that the positive charge on a Carbon signifies the empty p-orbital.

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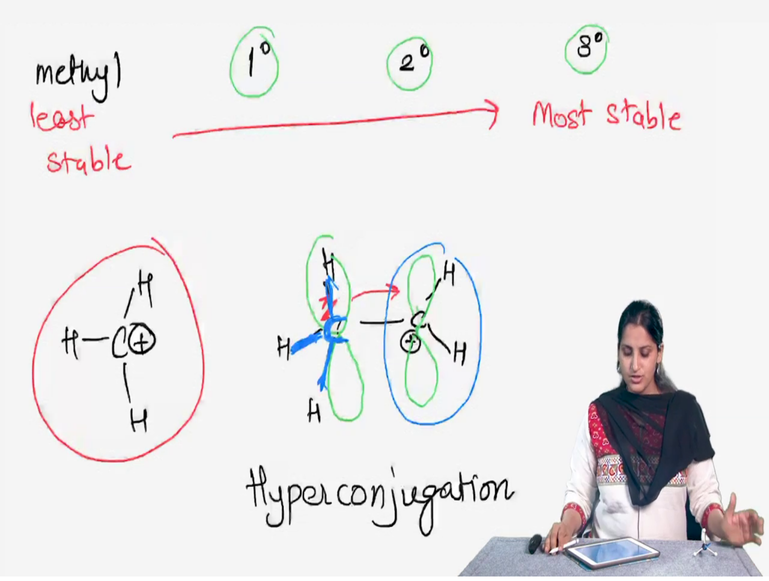

And, for example, in this one the adjacent CH bond right so, let’s take the example of a methyl carbocation versus an ethyl carbocation. So, what I am going to do is, since carbocations are trigonal planar, we now on we are going to show the geometry correctly; we are going to show that they are trigonal planar whereas, if I take an ethyl carbocation that’s how it looks, right. If you think about it the adjacent Carbon-Hydrogen bonds for the ethyl carbocation so, this orbital here, whereas you have the empty p-orbital here on this Carbon that is carbocation.

What happens is the bond electrons of this CH bond get polarized towards this positively charged Carbon, okay. No such overlap is possible here; in methyl carbocation you cannot have that overlap.

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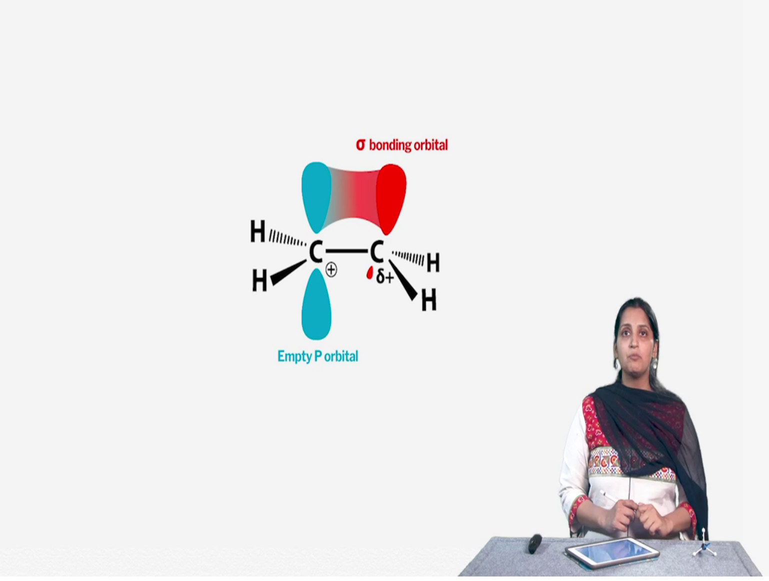

But, in this case what happens is that the CH bond electrons of the adjacent Carbon can overlap slightly with the empty p-orbital. Remember, I am not moving the electrons we are not taking the electrons from the CH bond and putting it on that Carbon. It is just a polarization, it is slight movement towards that positive charge right.

So, this movement of electrons from sigma orbital towards the vacant p-orbital of the ethyl cation really decreases the charge on the sp^2 hybridised Carbon and really this causes a partial positive charge to develop on the Carbon really bonded by the sigma bond right. So, when this particular process happens, what happens is the charge on this Carbon goes down whereas, there happens to be a slight charge, a very slight charge develops on this other Carbon.

As a result of this what has happened a positive charge is no longer localised on that carbocation; a positive charge in now spread out over a greater volume of space and when we were studying acids and bases this is what we talked about, right. Dispersion of charge really helps the molecule to be stable, right. So, in this case the dispersion of the positive charge really stabilizes the carbocation because charged species is more stable if the charge is spread out; nature hate charges; that's what we always remember, all right.

So, delocalisation of electrons by the overlap of this orbitals is really called as a hyperconjugations. So, we are going to learn a new term here, this is called as hyperconjugation. Hyperconjugation does not mean that we move the electrons all the way it is just a slide polarization. Now, really if you see this particular Carbon here has three Carbon-Hydrogen bonds. So, the question is which one will really overlap.

The truth is it has to align in the geometry, if it aligns very nicely in the geometry that particular sigma orbital will overlap its electrons on the positively charged carbon okay. And, hyperconjugation really only occurs if the sigma orbital and the empty p-orbital have the proper orientation, okay. But really the proper orientation is always easily achieved because there is a free rotation between the Carbon-Carbon s-bond; right, that's what we saw in the first class.

If I really see this tertiary butyl carbocation here there are 9 Carbon-Hydrogen bonds that can potentially overlap with the empty p-orbital such that the positive charge of the carbocation gets spread out on the whole molecule, right. So, the reason why, as we go on to the tertiary carbocation it becomes more stable is that just that there are more C-H bonds, there are more of these sigma orbital electrons that can potentially overlap with the empty p-orbital.

So, now let us go back to our question and now answer this question which one amongst these two is more stable, this one or this one? If you really see the carbocations, in this case the carbocation is attached to, this is a tertiary carbocation; whereas, in this case this is a primary carbocation. So, which one is more stable? Of course, the tertiary one. So, what happens is this carbocation will be formed in excess okay. Because it is more stable the formation of that carbocation is much more favoured.

And, thus what will be the product that will be formed? So, the product that will be formed will arise from this particular carbocation and the product of our reaction here that arises from this carbocation is the first one. So, this will be the major product of the reaction and the other product will be the minor product of the reaction. We are gonna see couple of more examples where in we start reacting with the asymmetrical alkenes.

So, now let us look at some more reactions, okay

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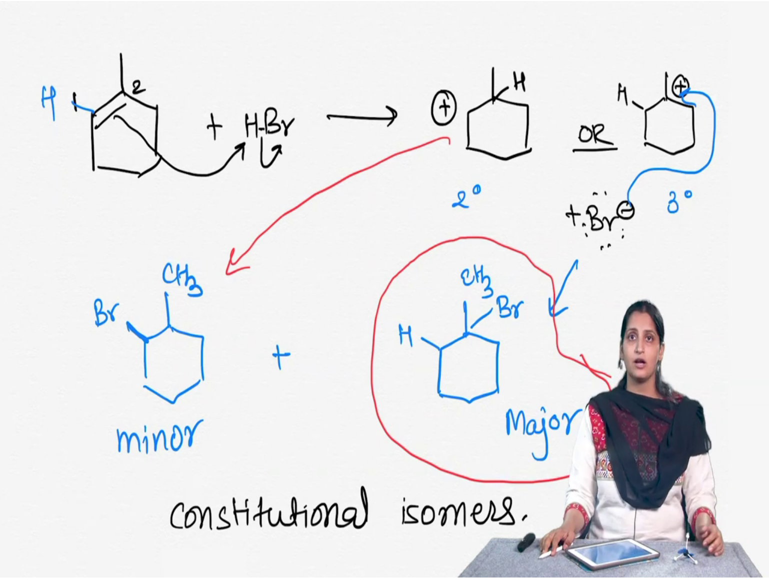

So, I am going to take this example right and we are going to react it with HBr. So, this is Methylcyclohexene and we are reacting with HBr. Again, if I see the two possible carbocations that could be formed first on Carbon number 1, such that the Hydrogen goes to Carbon number 2 in the first step, again focus on the arrow pushing; the double bond attacks the proton, the bond between Hydrogen and Bromine breaks. Arrows have to be pushed from the electrons towards the positive charge right.

So, you can either form this or you could form the other carbocation and give the Hydrogen to the first Carbon right and of course, you are forming a Bromide ion. Now, the question is which one amongst these two really forms right. If I see this clearly this is a secondary carbocation and this one is a tertiary carbocation. So, the tertiary carbocation will be formed in excess, will be formed faster.

So, what we are going to do is, we are going to attack the Bromide onto this tertiary carbocation giving rise to our major product which looks like this, right; whereas the other product which arises from the other carbocation is really the minor product right. So, let me draw the minor product as well. So, the minor product is going to arise from this carbocation. So, when the Bromine will attack here on this carbocation I will give rise to the minor product right, but the reaction is predominantly going to give me this particular alkyl halide, okay.

So, the major product obtained from reaction of addition of HBr to 1-methylcyclohexene is 1-Bromo-1-methylcyclohexane. So, in both cases the more stable tertiary carbocation is formed that's what we saw. It is found much more rapidly than the less stable secondary carbocation. So, the major product of each reaction is the one that we are forming from the tertiary carbocation.

If you really see these two products the major and the minor product here, these are constitutional isomers of each other. So, we have looked at different isomers, what is the relationship? They are constitutional isomers. Why are they constitutional isomers because they have the same molecular formula, but different structural formula; their connectivity is different right. So, the constitutional isomers they differ in the way their atoms are connected.

A reaction such as this one in which two or more constitutional isomers can be obtained as products, but one of them is predominant; so, in this case the major product is predominant is called as a regioselective reaction. The reaction is selective in the region that it operates. There are degrees of regioselectivity, a reaction can be moderately regioselective, highly regioselective or completely regioselective.

So, completely regioselective reactions does not form the minor product at all, it only forms one type of product. In this case addition of alkene with HI, HBr, hydronium ion or electrophilic addition on the alkene, it is highly regioselective meaning the major product really predominant; 80 percent-20 percent, right that will be the ratio between the major and the minor products. Moderately regioselective reactions are like 60:40 whereas, there are reactions that are not regioselective at all. So, they will form both the products in equal distribution, but this one is highly regioselective okay.

We have now seen that if we want to predict the major product of an electrophilic addition reaction we must first determine the relative stabilities of the two positive carbocation intermediates. Around 1865, when the carbocations or existence of carbocations, the relative stabilities were still not proven Vladimir Markovnikov published a paper in which he described the way to predict the major product obtained from the addition of hydrogen halide to an asymmetrical alkene.

So, he used a shortcut which is also called as Markovnikov's Rule. In his rule what he states is that when hydrogen halide adds to an asymmetric alkene the addition occurs in such a manner that the Hydrogen attaches itself to the double bonded Carbon atom of the alkene bearing the lesser number of Hydrogen atoms because H^+ is the first species that adds to the alkene. So, if I have to really think about Markovnikov's rule; Markovnikov rule is nothing, but it is talking about the stability of the carbocation.

If I have to now state the Markovnikov's rule again knowing that the carbocation exists and knowing that their relative stabilities are such that I would always say that the Hydrogen adds to the Carbon-Carbon double bond such that a more stable carbocation is formed, right; that is more substituted carbocation is formed. That is how I would remember the Markovnikov's rule because not always you will have Hydrogen's attached to the Carbon-Carbon double bond. Sometimes you may have a Carbon-Carbon double bond that does not have any Hydrogens.

So, the right way to remember this rule would be such that the double bond attacks on the hydrogen halide such that the Hydrogen goes to the Carbon such that the carbocation that is hence formed is much more stable, right. Okay, so, we will continue with the Reactions of alkenes in the next class.