Introduction to Explosions and Explosion Safety
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Lecture - 33
Condensed Phased Explosives Based on Hydrocarbons

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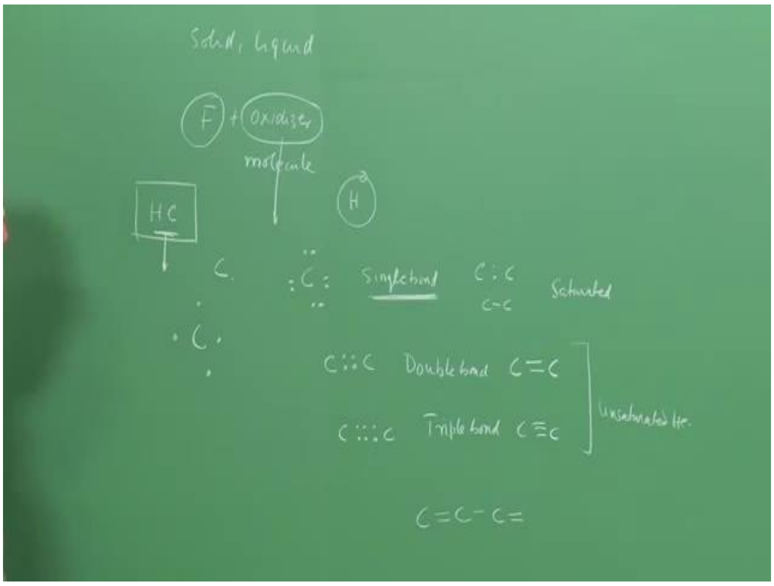

Good morning, in today's class we will consider the case of a Condensed Explosives. When we say condensed explosive, all what we mean is the explosive substance, exist either in a solid face or in a liquid face. We have already considered, like for instance explosives involving fuel gas and air mixtures or fuel gas and oxygen mixtures. We also saw dust with air. And what we do today is solid and liquid explosives, by explosives we it essentially consist of fuel and an oxidizer. And this fuel and an oxidizer could either be mixed together to form a mass of an explosive.

Or else, the fuel and oxidizer could from a compound. Like, it must, it could be as a molecule as a chemical substance. For we consider both these cases and therefore, in order to consider an explosive may be a condensed explosive, which we say being a liquid or solid form as a higher density. And therefore, it is potential for causing damage is much more.

That means, it much more powerful, there may be the dust explosive or the gaseous explosive, which we consider. Therefore, we take a look at what are the fuels and oxidizes, which comprise of the solid explosives. And to be able put things together, I think some clarity must be required on the fuel part of the condensed explosive on the oxidizer part of it. And we recognize, that most of the condensed explosives are derived from organic substances, namely hydrocarbons.

But, we will also consider there are few inorganic explosives, we will also consider them. In today's class we restrict ourselves to those explosives, coming from the hydrocarbon fuels. We will also look at oxidizers. And then we will put both things together. And come out with what are the different types explosives. Let us, take a look at the hydrocarbons. You know, I thing if we can have a classification of different types of hydrocarbons.

And then for these particular classification. If you know, what oxidizer to introduce where, in a we come out with explosives. And it is very easy and the number of such explosives, both organic as well as inorganic are not many. There are just a few of them. Therefore, let us get started with the hydrocarbon fuels. And when I say hydrocarbon fuel, well carbon and hydrogen are central to it, consisting of hydrogen and carbon, when I look at carbon. Well carbon, if you see as an element, it consist so it has an atomic number of 6, it consist of 6 electrons, in the inner cell it has 2 electrons in the outer cell it has 4 electrons. Therefore, for let us say, carbon has let us say 4 electrons on the outer cell. Now, to be able to have a stable cell, it needs 4 more electrons. Such that, on the outer cell you have 8 electrons. And what does it do? It tries to share, may be an electron with some other substance.

Let us say, hydrogen is a substance, which has one electron on the outer cell on the, orbiting around it is nucleus. Therefore, if it can share, this electron which is available in it. And this electron, it could share with another Hydrogen atom, another electron. It could share another hydrogen atom, it could share one more. And it could share one more over here. Well, the outer orbit becomes 8. Therefore, they it is possible for the carbon atom to combine with hydrogen atom by sharing, a pair of electrons.

And when it shares, a pair of electrons, we say it is a single bond. It need not be hydrogen alone. It could also has share, the carbon atom could share an electron with another carbon atom. And this is also we say, this is single bond. When, one pair of electrons are shared, we say well the bond is a single bond. Well, it is not necessary that it is always shares. One carbon atom, sharing one with hydrogen or another one electron from this carbon atom, sharing with this carbon atom one from this, one from this, sharing this forming a single bond.

It is also possible for carbon atoms, two share two that means, a pair of electrons, two pairs of electrons. That means, I have two from this, this is shared between this and this. This shared between this and this, this and this. That means, two pairs of electrons are shared. In which case, we say it is a double bond. In other words, I can show this double bond as carbon sharing two pairs of electrons.

Similarly, I can also thing in terms of may be carbon, we said has something like, we said 4 electrons on the outer cell. It could share with another carbon atom, may be three of the electrons, in which case we say that the bond is a triple bond. In other as the bond number increase as the trip for a triple bond. What is going to happen it, is going to be little unstable, because it is sharing more, where as this is more stable.

And when we say single bond substances are generally, saturated hydrocarbons. Whereas, may be when you go to double bond and triple bond. We call them as being unsaturated hydrocarbons. Now, you know it is not necessary that you have only one double bond. It is possible for you to have two double bonds. And when you have two double bonds, like for instance may be two double bonds, alternating with each other like for instance.

Let us consider, substance over here, where in I have something like a bond like this a single bond, followed let us or a double bond, followed by a single bond, followed by another double bond. Well, you know in this case, I have two double bonds. And such substances also exists. Therefore, let us classify these substances, let us take some example and put these things together.

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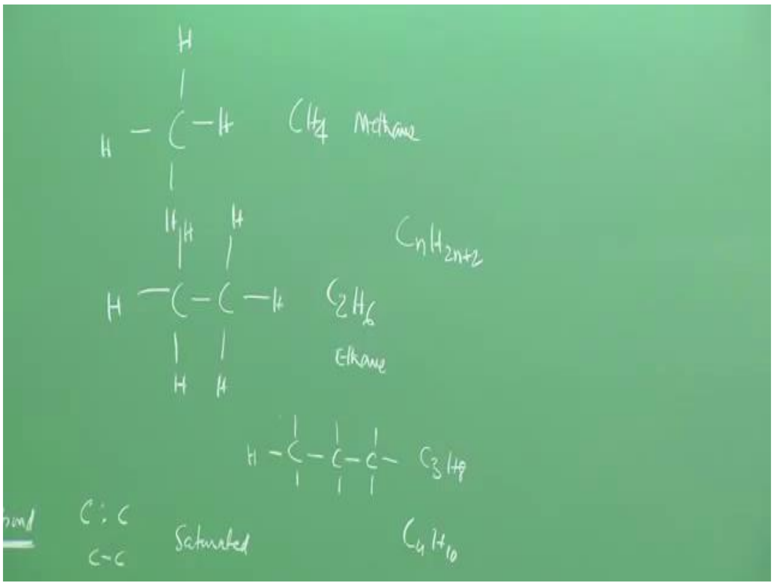

When the carbon atom is has single bonds namely, I have carbon with hydrogen atom over here, H, H, H, H. Well, I form methane or I call it as methane, maybe I could have single bond over here two carbon atoms. Well, linking to the hydrogen over here, hydrogen over here, hydrogen over here, hydrogen over here. Namely, I have something like C 2 have 3 plus 3, 6 over here H 6 and so on.

Therefore, these are all single bond substances. I have something like methane, have ethane. And you find you know I could also have propane C, C, C with hydrogen at the ends of this all places you have, hydrogen it gives me C 3 H 8. I have butane which is C 4 H 10 and so on and in general. When, I have this single bond substances, the general formula could be C H 4, C 2 H 6, C 3 H 8, C 4 H 10 is equal to C n H 2 n plus 2. These single bond substances are known as alkenes. As distinct from these alkenes, whenever I have this double bond substances, well. Let us, take a look at a double bonds substance.

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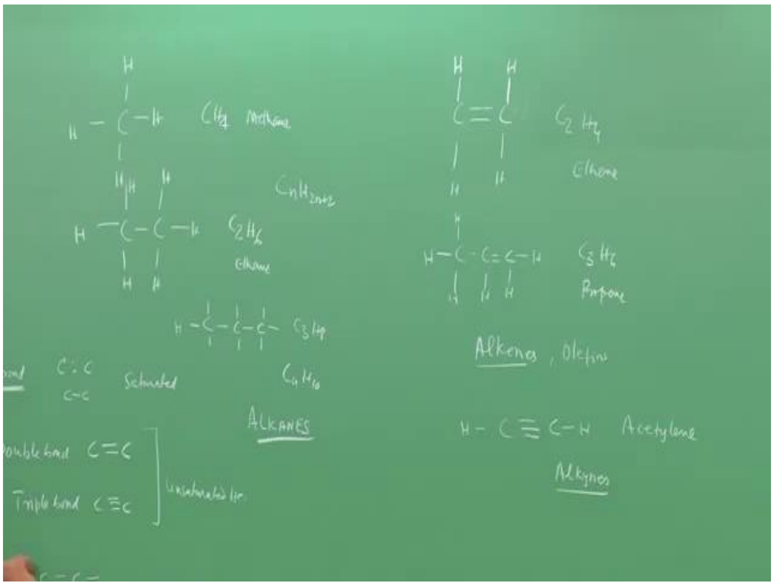

Well, I have the carbon atom over here, it is linked through a double bond with another carbon atom. Well, it has a balance of 4, I need to get the balance of 4. And therefore, well over here have 1, 2, 3, 4, 1, 2, 3, 4. I have something like let us say, C H is it of this I can, draw it over here, H over here, H over here, H over here. I talk in terms of C 2 H 4, which we call as ethane compared to ethane it is ethane, compared to propane, if I have here.

Now, I am talking in terms of may be one double bond. Therefore, if I talk in terms one double bond I have H over here, 1 H over here and 1 H over here and 1 H over here. And may be 1 H over here, have something like C with 4 of them 1, 2, 3, 4 over here. 1, 2, 3, 4 over here. No, 1, 2 and 2, 4 over here, which means it is equal to C 3. 1, 2, 3, 4, 5, 6 C 3 H 6, which is propane. And the general one given for substances having one double bond is what we call as alkenes.

You know these alkenes are not fully saturate. Like, what we said you know it is all single bonds. And these are unsaturated. And it is also known by the name olefins. You know, we can keep going like this I could have alkenes like ethane, propone, butane and so on. And when we come to the third category, namely the triple bond substances, when I say triple bond well I have C, C.

And therefore, I just need 1 H over here, 1 H over here, I have 4 over here. And therefore, this particular substance having a triple bond is known as acetylene. The general formula or the general name for triple bond substances having one triple bond is known as alkynes. And you see, you know the triple bond will not be that stable. And we did C acetylene in our previous study of the gaseous fuels.

And involving with oxygen we found it is ignition energy is very low, it has a higher level of maximum over pressure in a constant volume explosion. We also saw that the d p by d t value or the type of severity of the explosion was higher. And this is what is acetylene may be with that triple bond over here. Therefore, we generally classify hydrocarbons as either, alkanes, alkenes or alkynes. And let us go to the last one, you know when I have two double bonds alternatively occurring. These substances known as alkadiene. You know, what is this alkadiene? You know it is also something, which occurs very frequently. And therefore, we must we very clear about it. And what is an alkadiene?

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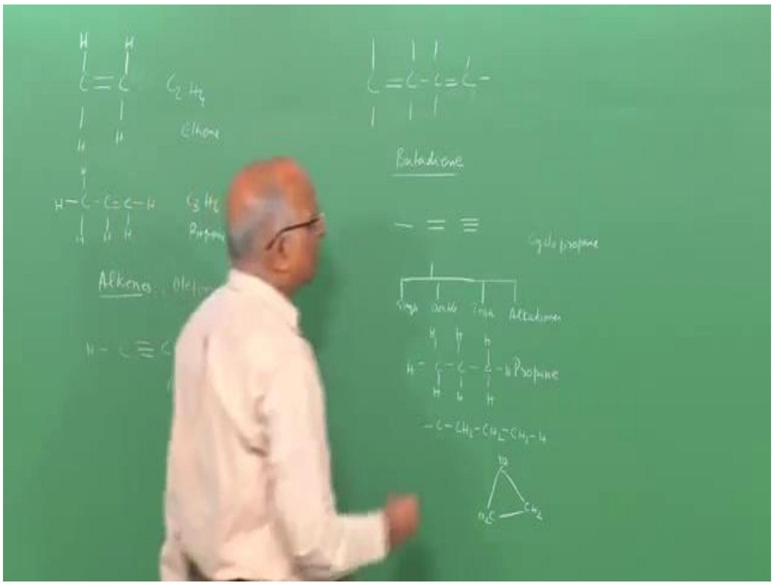

Let us say, I have butane. Butane is something like C, C, C and if say butane**,** well this is the formula of a butane. Now, if instead I have one double bond over here. Well, in this case I do not need this. And I have another double bound over here. Well, I do not need this, well I have something like two double bonds over here, alternate two double bond this is known as butadiene.

You know, it is an alkadiene. That means, a substances having two double bonds is what we call as a butadiene. And typical example of alkadiene is let say, butadiene it could be pentadiene and so on and so forth. Therefore, we say, whenever we are talking of these chains. You know, we are talking of chains, which are straight chains over here, straight chains over here, straight chains.

And whenever we are talking of these hydrocarbon chains, which are essentially single bond, a double bond, a triple bond. And these substances having single, double and are substances, which we can say a hydrocarbon substance, having single bond, giving alkenes, having double bond, giving alkenes, triple bond giving alkynes. And may two double bonds giving alkadienes. These are the typical things and these are all straight chains substances.

But, there is nothing to keep this straight chain always straight. It is also possible for us to have bend chains. Like let us, take an example of propane. We take propane C, C, C have hydrogen here. We are talking of propane, which is an alkenes. You know, in this case, may be you know I can write this as may be 1 H into C, let us put hydrogen 1 to this H, H, H, H, H, H over here, have hydrogen over here. I can put this C, CH 2, I have another CH 2, I have another CH 2 and H over here.

It is quite possible instead of having this as a linear system. I can have it as bend chains something like, chain instead of being straight like this. That means, I have CH 2 over here, I have CH 2 over here, I have CH 2 over here. And this is known as a cyclo that means, I call it as a cyclo of the propane or I call it as cyclo propane. Or since, I am considering alkenes, I could have for alkenes I could have a cyclo alkanes, I could have cyclo alkenes, I could have cyclo alkynes. And I could also have cyclo alkadiene in a different form. Let us, take one more example of a cyclo chain.

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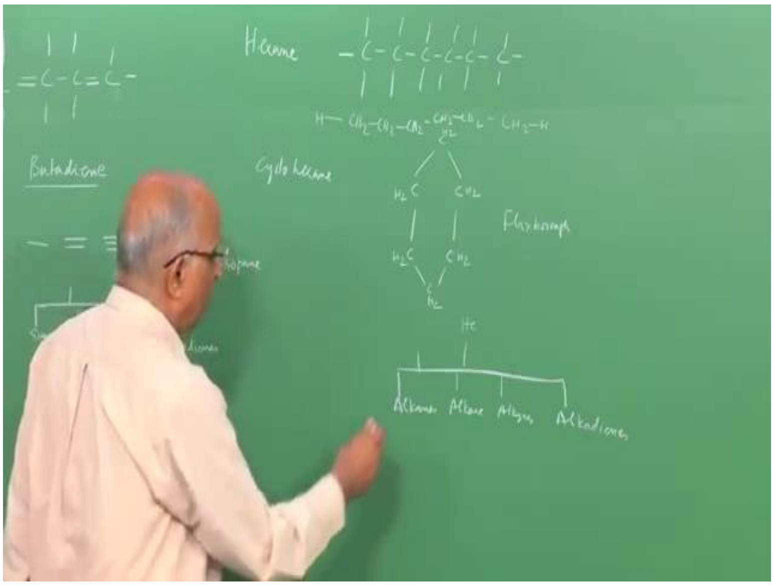

Let us consider hexane, when we say hexane I am thinking in terms of 6, 2, 4, 5 and 6, 6 carbon atoms. That means, 6 corresponding to hexane this is my normal hexane what I have. And if I want form cyclo hexane, what is it we do? We have something like a bend chain. The bend chain consisting of the 6 carbon atoms is going to be C, C, C, C, C, C. And what is it I get, well I can write this as CH 2 with hydrogen over here. CH 2, CH 2, I have CH 2 corresponding to this.

I have another CH 2, 1 2 3 4 5, 1 2 3 4 5 and last one C H 2 and H over here. For this gives me something like this CH 2, CH 2, CH 2, CH 2, CH 2 and CH 2. Well, this is a cyclo form of cyclo hexane. And mind you, you known we did talk of an explosion involving cyclo hexane namely, the flux borough accident in UK. In which we said that the explosion was so strong, involving cyclo hexane. That the entire town shape of flux borough became something like a go city, but in addition to this straight and bend chains involving normal. That is straight chain and the bend chain substances, involving the cyclo radical.

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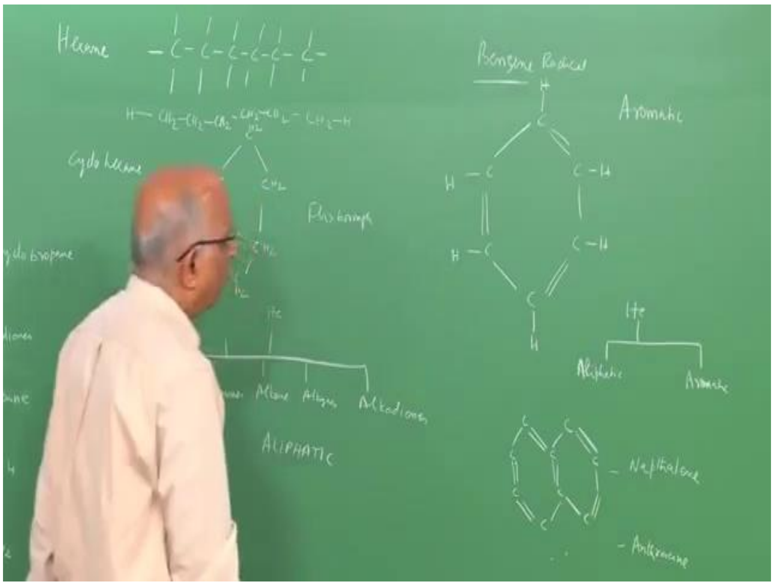

We also have another radical, which is known as a benzene substance, benzene radical. You know, these all these substances are known as aliphatic substances, where as you know compared to this aliphatic substances we also have another form, in which hydrogen and carbon combine together. To give substances known as benzene radical know this benzene radical is somewhat similar to the cyclo hexane in that it has 6 carbon atoms here 1, 2, 3, 4, 5, 6.

And you have CH 2 that is H 2 attached to it give me give you cyclo hexane. Here also, you have something like 6 carbon atoms. Let us, put it together I have 6 of them in a ring compound. But, the difference from cyclo hexanes it has two alternate double bonds I have a single bond, let us say a double bond over here, a single bond over here, a double over here, a single bond over hear, a double over here and a single bond over here. And this is attached to the carbon atoms over here.

This particular radical having 6 carbon atoms with alternative double bonds is known as a benzene, benzene chain or benzene radical. And this particular benzene type of substances are substances having the benzene radical. Have a very strong flavor nice million substances. That means, they have something like an aroma associated with them. And these are known as aromatic substances as compared to these hydrocarbons, which we say are aliphatic substances.

Therefore, we again have a classification we can say the hydrocarbons could either be aliphatic. And these aliphatic substances are known as paraffin's also. It could be substances having the ring type of structure with alternate double bonds with 6 carbon atom those are known as a aromatic substances. And such type of are benzene rings are also associated with hydrocarbon fuels. And they also contribute to forming different types of explosive.

They can also combine with oxygen. Well, it is not that I can have only one benzene radical. It is possible for me, two have two benzene chains together like for instance. I have maybe I have 6 carbons with a double bond this is my benzene radical, double bond over here, I have a single bond over here, have a double bond over here, have another carbon. And now, I could have two such things together, two such benzene chains together like for instance.

I have a another C over here, I have another C over here, I have another C over here, I have C over here, I have a double bond over here. Therefore, I have 2 benzene radical over here combine together and this is known as naphthalene. I could similar have three such things together, which is known as anthracine. You known we would have heard of these things you known some of them are poisonous like anthracine I have three of them together 1, 2, 3.

I have naphthalene you know we use naphthalene in over kaput to protect may be cloths from insects. You know, because it does have strong aroma all these begins substances have strong aroma. Therefore, we talk of hydrocarbon therefore let us, come back to where we got started. We said, well I would like to understand a little bit more about fuels, such that I can talk about the explosives.

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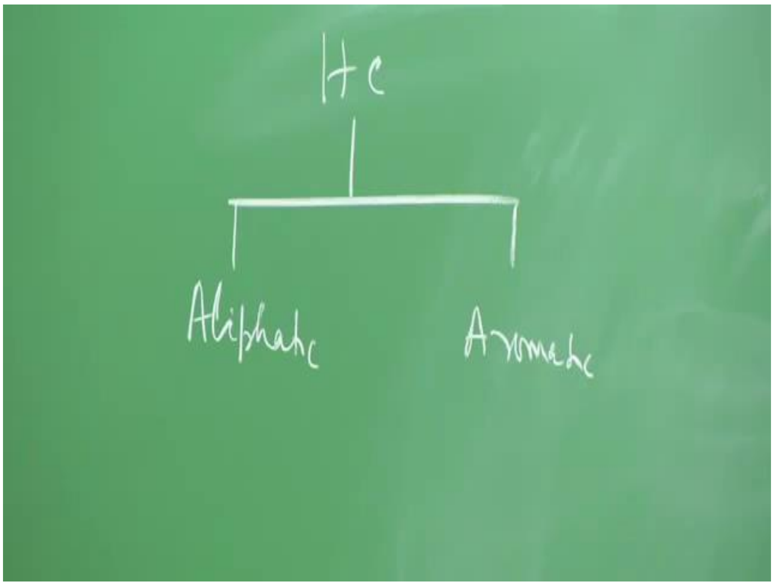

And therefore, we say well a hydrocarbon fuel could either be aliphatic or it could be aromatic. And in aliphatic we had a series of things like we talked in terms of alkanes, alkenes, alkynes and alkadiens in aromatic. We talked in terms of benzene, may be naphthalene, may be anthracine and so on. Therefore, let us quickly summaries this, before we talk in terms of different oxidizers. And how this oxidizers coat combine with these individual substances.

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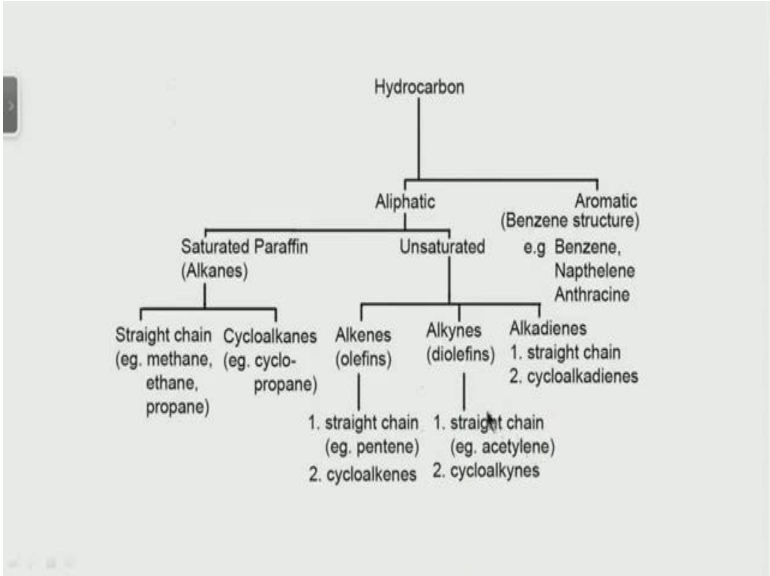

Therefore, I shown this particular classification in the slide. And what I show well the hydrocarbons. Could either be aliphatic substances or aromatic substances, aromatic substances are very strong flavor or smell. And they have the benzene structure and it could either be a benzene, it could be a naphthalene in which case have two of the bezenes, I could have anthracine. When we talk of aliphatic substances, it could either be saturated, in which case I have only straight chain substances.

And these straight chain are some things like methane, ethane, propane I have cyclo chains, in which I could talk terms cyclo propane, cyclo hexane, cyclo butane. I have things, which have a single double bond are alkenes, which are also known as olefins. And these olefins could be straight chain like a I have ethane, propane, pentene and so on.

I could also have cyclo just like I had cyclo in the saturated one. I could have straight chain and cyclo I could have alkynes, alkynes we said is acetylene, I could also have cyclo alkynes. And we could also have alkadienes, in which case I have 2 double bonds. And in which case, again I could have straight chain alkadienes and cyclo alkadienes. This is about all the fuels we have.

And therefore, now I would like to have some understanding of what are the oxidizers. And in how does an oxidizer combine with the hydrocarbon and what are the type of explosives what you get.

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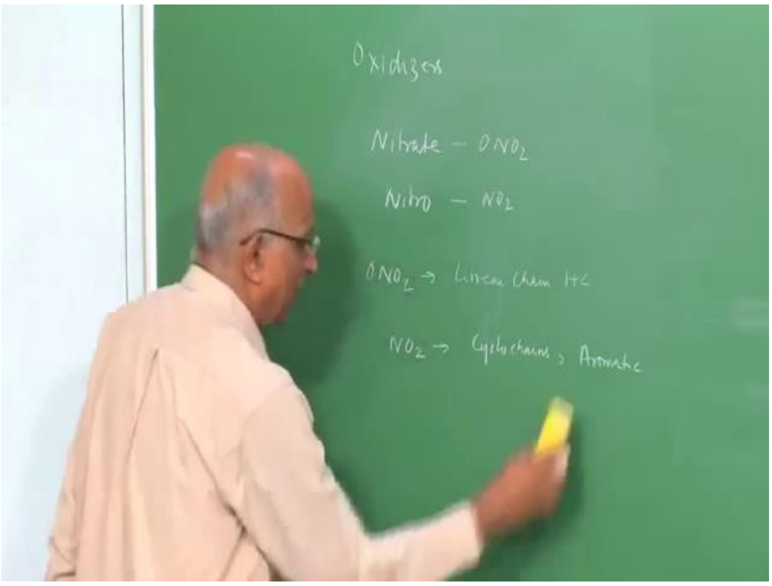

Therefore, let us go to the oxidizers. And the type of oxidizers what we have are but we find the oxidizers which are used with condensed explosives or either nitrate or nitro compounds. What do you mean by nitrate? By nitrate we mean ONO 2 radical, by nitro compound we mean NO 2 radical. Therefore, we normally combine this and for the particular case with which we are talking today namely the organic substance, involving hydrocarbon fuels. Namely, the explosives derived from hydrocarbon fuels.

We are talking in terms may be either nitrate or nitro compound combing with any of the substances, which we just talk just now, may be alkenes alkynes, alkadienes and so on. Normally, what happens is ONO 2 is used or combines with linear chain hydrocarbons. That means, we are talking may be of alkenes, alkynes and alkadienes in the straight chain, where as NO 2 oxidizer combines with cyclo chain involving alkenes, alkynes and alkenes and also alkadienes.

And also the with those having let say we called it as a aromatic chains. That means, those involving benzene. Therefore, we will try see, how ONO 2 and NO 2 combine. And therefore, let over on the bases of what we discussed for the different hydrocarbon fuels. Namely, the aliphatic and aromatic, let us find out how the explosive is found.

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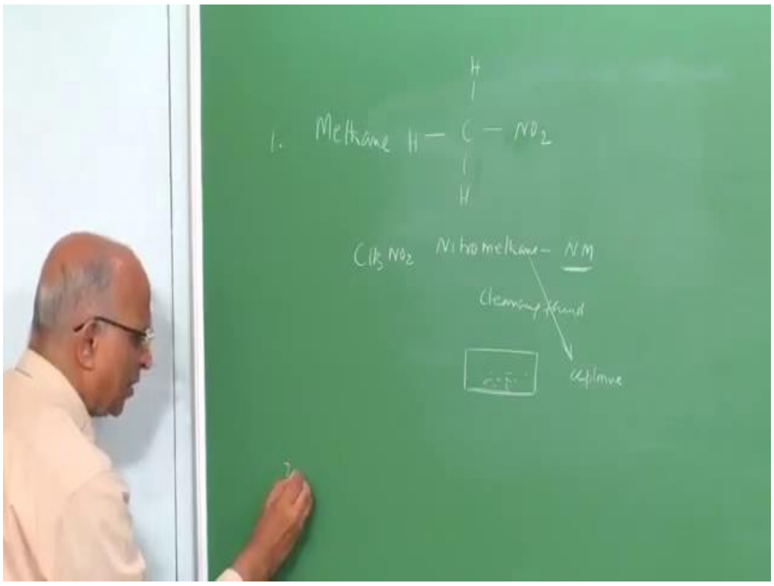

Let us begin with methane, methane we said is CH 4 or what we do is maybe we take one of the hydrogen out, substitute it by NO 2 radical. And what is it I get nitro, which I have added 2 methane, which is known as nitro methane N M, nitro methane. Therefore, the formula for nitro methane is CH 3 NO 2. And this has been used, but originally nitro methane was originally used only as a cleansing fluid.

Mind you, since the methane is a gas, when you nitrated, it is a liquid, it is a volatile liquid and has been used as a cleansing fluid. But, you know in one particular accident, which occurred in ((Refer Time: 26:15)) in a place known as Pollachi. This was around 1958. You know the huge wagons which had this nitro methane stored in them. And what happened when the wagon was being shunted. You had bubbles of air formed in the nitro methane.

And you known whenever we have bubble of air in a liquid, and it is being trends to get compressed. And when it gets compressed it is gets heated. And this heat sought of detonated the whole nitro methane. And ever since you know, we are very careful in handling nitro methane and it is an explosive. That means, we are talking of the first alkenes, which is methane which could form an explosive and this is known as nitro methane. Let us take the second one, let us again restrict ourselves to alkenes.

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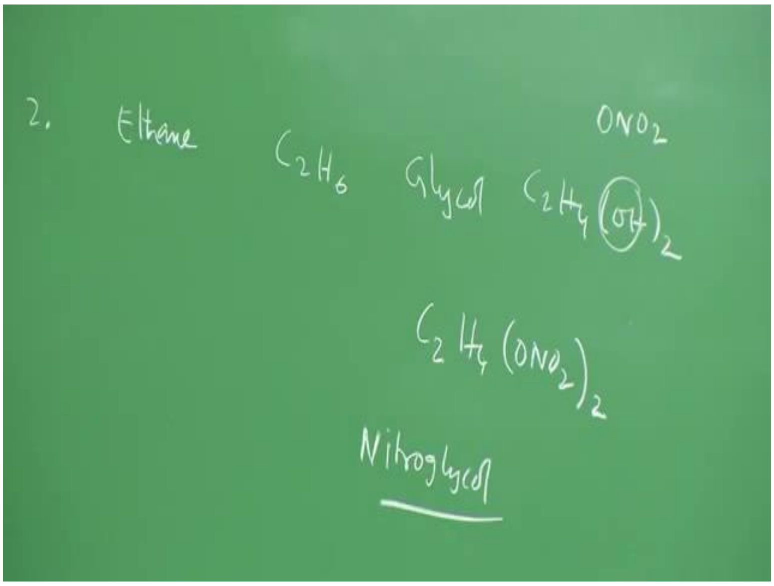

Let us, take the next one which is ethane. When we say ethane well, we know it is C 2 H 4 that is H 4 plus 2, H 6. And you know, what we do is you know when we say ethane may be reform, we hydrolyze it to form an alcohol. And this alcohol is known as glycol. And the when we are hydrolyze it form C 2 H 4 OH 2. And what you do is you essentially, replace OH by ON of 2 that is nitrate radical. And you get a substance known as OC 2 H 4, ONO 2 twice.

That means, I replace this OH by the nitrate radical and this is known as nitro glycol. It is not a very popular explosives. But, well it also contains oxygen, it contains fuel and it can do the job. Let us, go to one or two more substances. let us come to propane. Why I am going this example is you know the even though sometimes the formula for a particular explosive ((Refer Time: 28:28)) whether, it is liquid explosive or a solid explosive may look difficult or may look some of unfamiliar to a trained person in explosives. You know, it is all very simple. It is all derivate from basics and it is not necessary for you to really remember a formula for explosive. It can be just like that written from the structure. Let us take an example, let us take propane.

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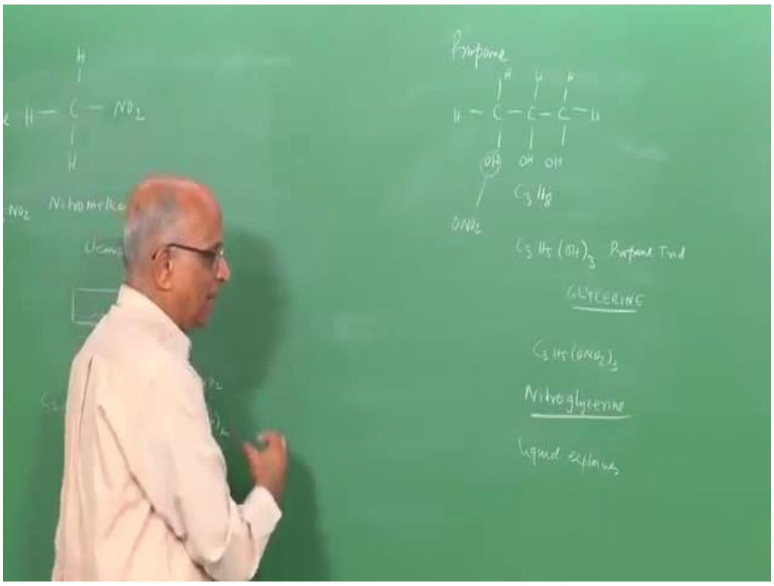

It is also an alkenes saturated hydrocarbon. You have C, C, C H over here. We saw this equal to C 3 H 8. And what you do is when you have propane like this. You again a you could hydrolyze. And you could have something like C 3 H 5 I take 3 of the H atoms substituted by OH atom. And I form something known as propane trial. And this is propane trial is what is known as glycerin. It has medicinal value and in fact, you know mean people get as a up stake stomach ache go and try to take substances involving glycerin.

And what you do is you take the OH substitute the OH by nitrate ONO 2. And you get a substance C 3 H 5 ONO 2, 3 times which is nitro of glycerin. And this particular substance which is an explosive is known as nitro glycerin. This particular explosive has been used for a long time, it continued to be used. And we will take a look at this some of these properties. But, we must remember that when we talk of nitro methane, we talk of nitro glycol from ethane.

We talk of nitroglycerin from propane. All these three are essentially liquids, these are liquid explosives. You know, we could keep on going like this. Let us go to one more substance. Because, it is a very popular explosive and quite powerful explosive. May be I go to let say pentane.

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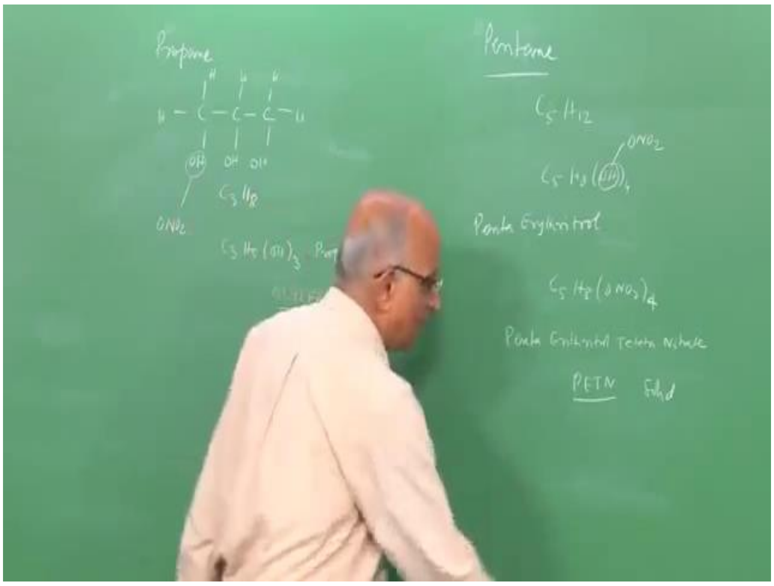

Well, pentane is let us not write the structure any more. We know, how to do this structure C 5 H 12. You know, when I have pentane I could also hydrolyze it to form alcohol of pentane very sweet alcoholic drink, which is say C 5 H 8 into OH 4. This is known as penta erythritrol. You know, what we do is may be from pentane you get penta erythritrol I substitute OH by ONO 2 to give me C 5 H 8 ONO 2, 4. And what is it we have done.

We are having penta erythritrol, in which I have nitrate over here that is tetetra nitrate. Therefore, I have penta erythritrol, tetetra 4 of nitrate, which we call as PETN. And this PETN has been used extensively for blasting may be in the wars. And this is something derived from pentane. Therefore, we seen this is a solid, PETN is solid. And therefore, you known as we increase the initial molecular mass of the fuel or make this structure more larger. It is more possible that it get a solid out.

And therefore, what is it we have considered. We have considered from alkenes four types of explosives namely, we talk of nitro methane, we talk of nitro glycol, we talk of nitroglycerin and now we talk of PETN namely penta erythritrol tetetra nitrate. You know, let us go to the next one. See, this is from alkenes, let us take a few from cyclo alkenes. When we talk of cyclo alkenes, we are talking of cyclo chains. Let us, just take an example.

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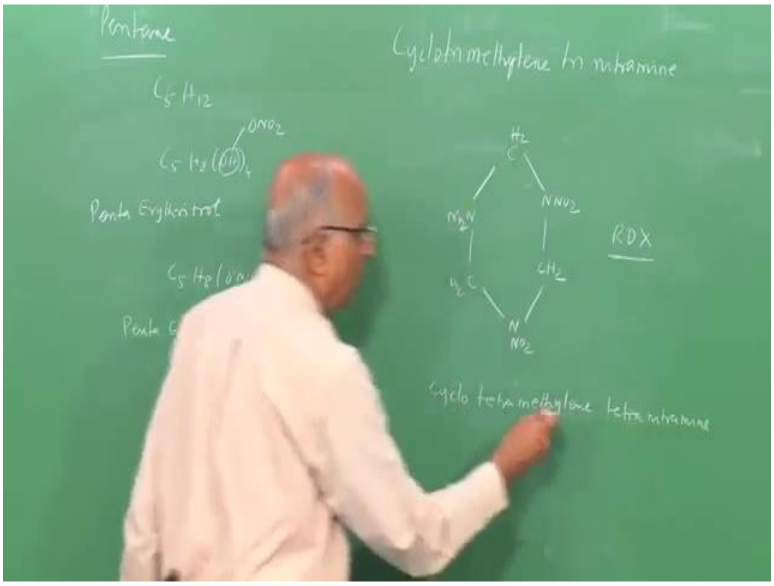

We talk of cyclo, let us take an example trimethylene, trinitramine. That means, we are talking of a structure, which involves may be a cyclo chain. That means, I am talking of cyclo chain. I am talking of may be chain like this methylene CH 2, nitro mean NO 2. I am talking of CH 2, I am talking of N NO 2, I am talking of CH 2, I am talking of N NO2. And therefore, this is 1, 2, 3 tri, 1 2 3 nitramine, trinitramine this is known, this is an explosive.

And this explosive is extensively used in the explosive industry it is known as a RDX, research and development explosive. Quite powerful it does not initiate that easily, we will consider how to make it even more powerful .And also, consider how to make it less sensitive. But, this is what we call as a research and development explosive. It is widely known by the name RDX. Let us consider one more example in the cyclo chain. And this is something, which is very popular.

We talk of cyclo, tetetra, methylene cyclo, tetetramethylene, tetetranitramine. You known, when we look at this particular structure it is have four of them. it is something like a box like structure again a cyclo chain. That means, we are talking of bend chains.

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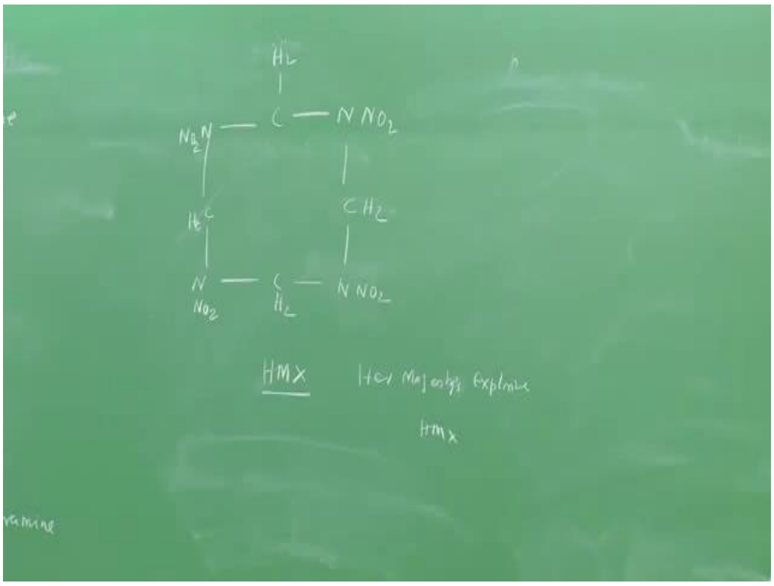

And therefore, the type of substance that you have is maybe you talk of C CH 2. You talk of N NO2. You again have C CH 2. That means, no it should have been CH 2 over here. the methylene, you have CH 2 over here, you have N NO 2, you have CH 2 methylene, you have N NO2, you have CH 2, you have N NO 2 and this becomes this. And this particular explosive, which is in a cycle chain with four methylene and 4 NNO 2 for 4 nitro minericals is what is known as HMX explosive, you all would heard of it.

And the abbreviation stands for her majesty's explosive. This was this is from UK and that is why the name her majesty's explosive, which is HMX. HMX and RDX are very commonly used explosives. We look at that properties, we look at that definitions properties. And well, it belongs to the cyclo chain of the substances.

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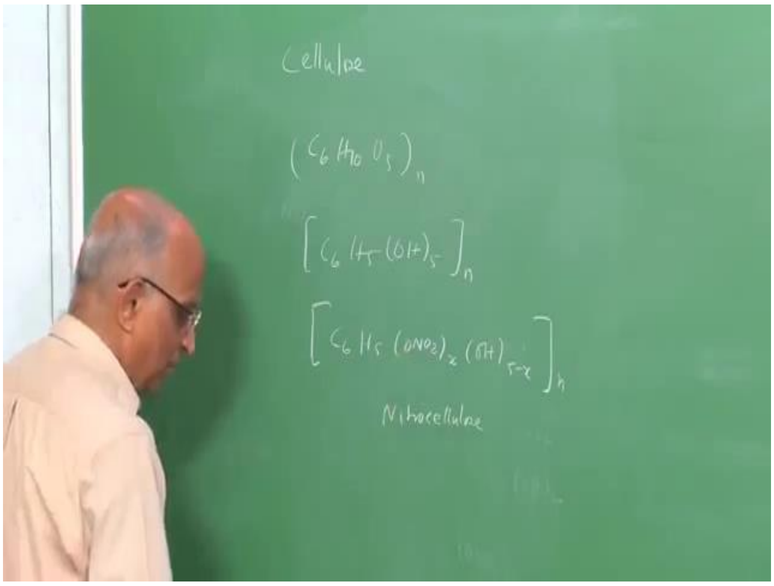

Let us, take one or two more example. Cellulose let us take an example of cellulose. You known cellulose is something like paper. The formula for cellulose is C 6 H 10 O 5, it is a long type of chain, it could be it n could be a large number. You just have a chain like cellulose like this. It could also be written as C 6 H 5 OH 5 to the power n. What you do to cellulose nitrated. And you have instead of OH, you replace part of the OH by ONO 2, in which you have C 6 H 5 ONO 2 replacing part of it let us say, x of it is getting replaced.

And you have the remaining OH that means, 5 minus x as OH. In the straight chain n is what forms we are nitrate ting the cellulose it is known as nitrocellulose. This is again an explosive. And so on, you know could keep on adding other substances to it again a straight chain explosive. And therefore, we saw that when we are talking in terms alkenes and cyclo alkenes.

We have explosives like nitro methane, nitroglycerin, nitro glycol we talk in terms of PETN, we talk in terms of RDX HMX, which come from the straight chain. Now, can we from the straight chain and also cyclo chain, because RDX and HMX came from the cyclo chains. Now, let us take a look at some of the aromatic substances. And see, whether we could form some explosives.

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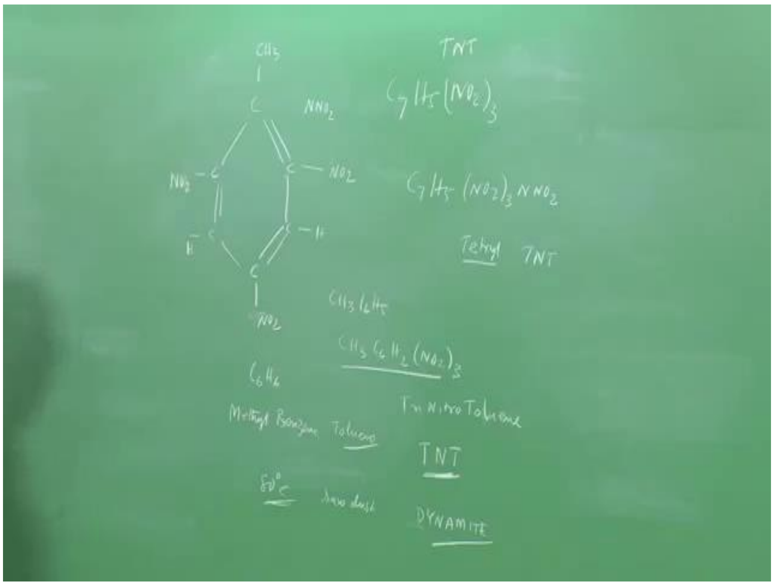

And when we look at aromatic substances, we are talking in terms of may be the benzene chain double bond C over here, double bond single bond over here, double bond C over here. And you know, we can talk in terms of this is hydrogen, hydrogen, hydrogen C over here hydrogen, hydrogen, hydrogen let us put it down H, H, H, H, H, H that means, it C 6 H 6, which is the benzene chain. If I substitute one of the hydrogen atoms by methyl radical I form methylbenzene, which we call as toluene.

You know, you will recall in one of the accidents in a shape, we said to toluene vapor licked and caused an explosion well, this is toluene. And if we can nitrate this and how do we nitrate it add NO 2. And you add something like NO 2, 3 of NO 2, NO 2, NO 2 and replace hydrogen by NO2 here. What is it essentially we are doing we had methylbenzene which is CH 3 C 6 H 5. And then what did I do, I removed 3 of the hydrogen atoms.

And I have CH 3 C 6 H 5 that means now 3 are removed. And into this I put NO 2 3 that means, 3 of the H atoms are replaced by NO 2. What is it I do? We take toluene and in to toluene I put 3. That means, I am having trinitrotoluene and the abbreviation is TNT. This is what is a TNT it is again a solid explosive did I form an aromatic base that is means, a benzene chain. And you have toluene which nitrated to give you trinitrotoluene.

And this is the formula chemical formula for toluene namely, if I put it together well I have C 7 H 5 N 3 O 6, which is the chemical formula. And this is a solid explosive, which melts around 80 degree centigrade. And you known when what we do is to bring down the power. You known it is quite a strong explosive. And it is use as a standard for all explosions and we will be considering about the TNT equivalence after one or two classes. After two classes we will look at TNT equivalence of all explosion.

And this is a standard it has high distention velocity. And it is almost like instantaneously exploding. And therefore, it used as a good reference. Therefore, it melts at 80 degrees and when it melts. You know, I can add some sawdust or some of these things to make it into a less energetic solid explosive. And this is what is known as a dynamite. You form a lower explosive by adding you melt it at 80 degree centigrade.

Mind you this 80 degree centigrade is very, very below the temperature at which it explodes. And therefore, into this liquid I add sawdust make a solid explosive known as dynamite. Well, you know in to this TNT which we said is C 6 well let me write it down again. I have C 7 C 6 plus 1 C 7 have a H 5 NO 2 3, NNO 2 3 times this we said is trinitrotoluene. I want to even make it more, more energetic. Therefore, what we do is I add C 7 H 5 into NO 2 3 times I had n into of NO 2 it. This is what is known as tartly.

More energetic then TNT and this is another explosive. That means, I take the aromatic base form TNT and I add NNO 2 to it. Well, it becomes tartly. Well, these are the different types of explosives. Let us, put down the names of two or three more and then summarize what these organic explosives are like.

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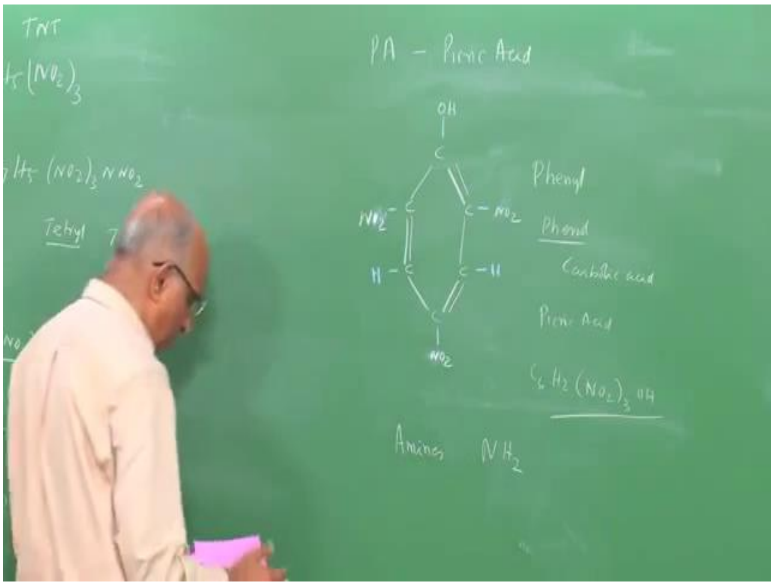

We take the example, an explosive known as P A, which is picric acid. When I say, picric acid you know I am essentially looking again at aromatic substances, which form an explosive I again looking at the benzene ring structure double bond, double bond, double bond C, C, C, C over here. And we said that the benzene ring structure consist or a benzene, consist of hydrogen attached to all the carbon atoms. Well, I should add have a carbon over here.

You know, when I remove one hydrogen atom from this particular benzene ring structure. This substance is known as phenyl radical. If I substitute, instead of H that means, if I remove one it is phenyl radical. If I substitute by OH it is known as phenol. You know we have this smell phenol it is used as to clean the wash rooms, such that it emits smell and that is phenol also known as carbolic acid. In to this phenol, we again add some NO 2. That means, I add NO 2, I add NO 2, 3 NO 2 I add NO 2 over here.

And this particular substance is what we call this particular explosive when to added to phenol is what we call as picric acid. Therefore, the formula for picric acid is we have C6 we are left with 1 CH 2, C 6 H 2 in and NO 2 3 times and OHO here this picric acid. It is also a good explosive has a high dissention velocity. And we will we will consider this explosive also, when we talk of characteristics of explosives. You know, we have to look at some more accepts of explosive.

We are just looking at the chemical structure of an explosive. Because, once the chemical structure is there, we can then go ahead look at the formula, look at whether it is fuel rich, oxidizer rich whether it could slightly modified to make its characterizes even superior. And that is what we want to. Therefore, one last explosive, which I will take now is what we call is derived from amines. I think this will complete the organic explosive for explosives derived from hydrocarbons.

When we say amine what we mean is we take ammonia and we have the take the hydrogen of we have NH 2 radical is an amine. And one such explosive again derive from the aromatic structure namely the benzene ring is what we call is TATB explosive.

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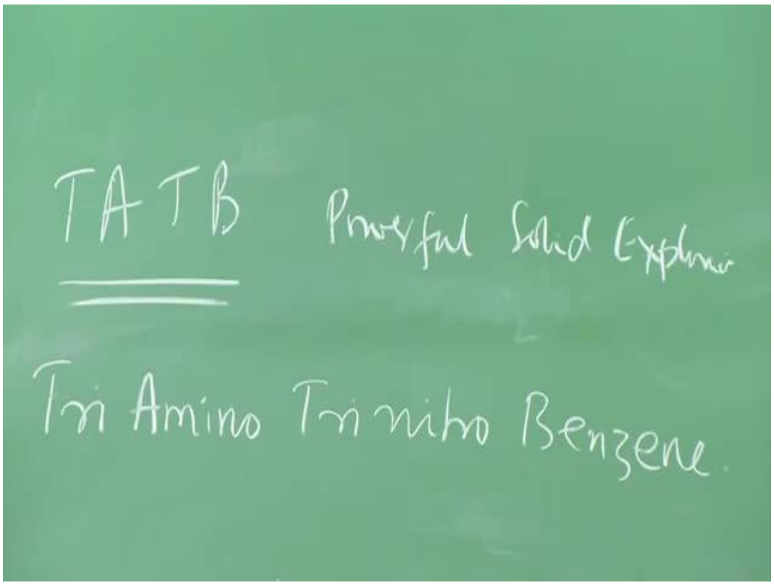

Let us, now put the formula down TATB is tri amino, tri nitro benzene. Therefore, you know, now we know what are benzene molecules? Yes, we can now put it down. I have C over here, double bond C over here, C over here, double bond, C over here, have C over here, C over here 1, 2 double bonds over here. That means, I have tri amino that means, I am talking of instead of this I am talking amino NH 2.

I am talking amino NH 2 over here. I am talking amino the NH2 over here. And what I do is I attach NO 2 3 of them, NO 2 I attach NO 2. That means, I have tri nitro, tri amino that is tri amino, tri nitro in the benzene chain. And this TATB is also a powerful solid explosive. Therefore, what is we have done. You know we started with the with the fuels as at well.

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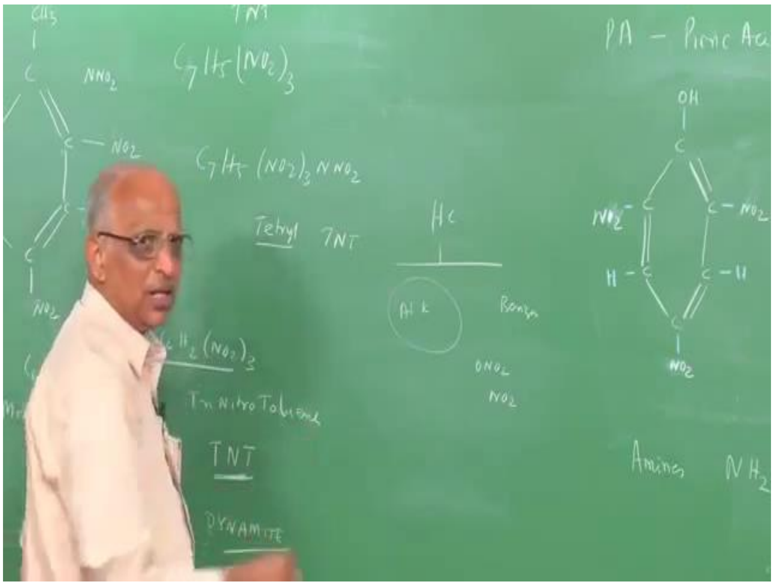

We are able to classify the hydrocarbon fuels into different categories like alkenes, alkenes, alkynes and cyclo of these alkenes, alkenes and alkadienes, which we said. And also we talked about the benzene structure components of these are the hydrocarbons fuels. And when we say, well these things could be could combine with ONO 2 or NO 2, which constitute the oxidizer. We form different explosives substance. Let us, take a look at the different exposure substances which are formed as per this classification.

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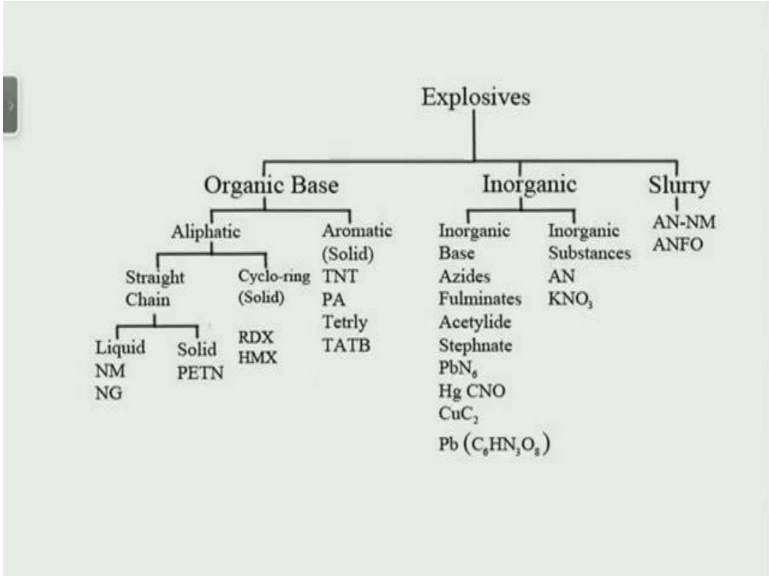

We say, these are the organic base, which could be aliphatic namely the both the straight change and the cyclo change of alkenes, alkenes, alkynes and alkadienes, and also aromatic, corresponding to the benzene family. And in the straight chain substances we form liquid explosives like nitro methane, nitro glycol, nitroglycerin with the solids we form the penta erythritrol tetetro nitrate. When we talked of the cyclo ring of these aliphatic substances we form RDX and HMX.

And when we talk of the benzene ring structure well we from explosives like tri nitro toluene TNT, which we said from which we get the dynamite, we talked in terms of picric acid, from TNT we add NNO 2 to it and form tartly. And lastly we trap of TATB, which is which we said is tri amino tri nitro benzene. Well, these are all the explosives derived from the organic base. But, you know there are also explosives, which are derived from inorganic substances.

And we will deal with this inorganic substances, there are not many. You know, instead of having NNO 2, we talked in terms of substances like asides, fulminates, acetyl ides and stephanotis. These are quite simple and then we will move into inorganic substances. And into slurry explosives and take a look at the exposition characteristics of these substances. We will do the inorganic explosives, slurry explosives and take a summary of the different condensed explosives in the next class.

Well, thank you.