Reagents in Organic Synthesis
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Lecture 30
Introduction to Lanthanides and Samarium Based Reagents

Welcome again, today we will discuss lanthanides in organic synthesis and today we will discuss samarium and samarium iodide based reagents.

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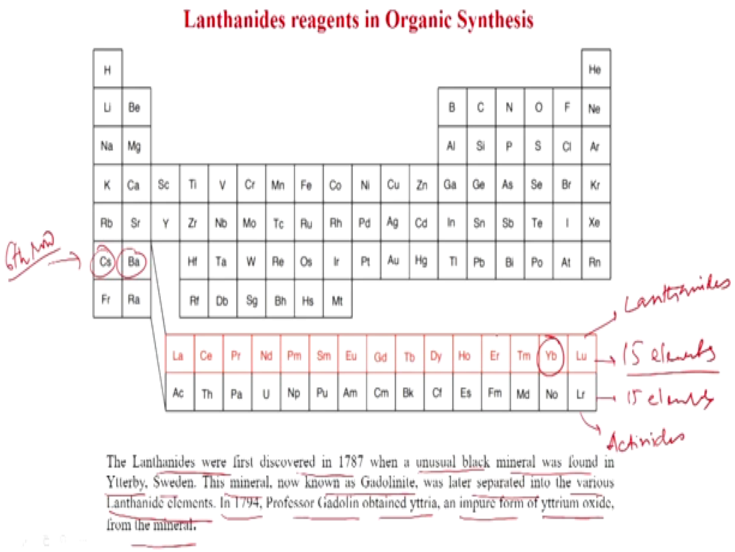

Lanthanides reagents in Organic Synthesis

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt									

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

The Lanthanides were first discovered in 1787 when a unusual black mineral was found in Ytterby, Sweden. This mineral, now known as Gadolinite, was later separated into the various Lanthanide elements. In 1794, Professor Gadolin obtained yttria, an impure form of yttrium oxide, from the mineral.

So lanthanides if you see, this is the sixth row. And after Cesium and Barium these lanthanides are there, they are total 15 elements and they have similar properties that is why they are kept in the same position. And this is the seventh row and here this is the 15 elements also there. And these are called actinides. So this is lanthanides. And these are called actinides. So the lanthanides were first discovered in 1787 when an unusual black mineral was found in Ytterby, Sweden. This mineral now known as gadolinite was later separated into the various lanthanide elements. And 1794, Professor Gadolin obtained yttria, an impure form of yttrium oxide, from the mineral. So you can see this is the yttrium is present here.

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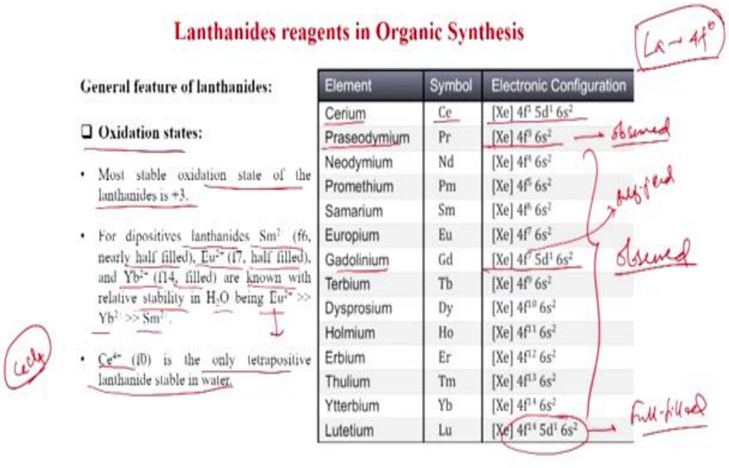

Lanthanides reagents in Organic Synthesis

$La \rightarrow 4f^0$

General feature of lanthanides:

❑ **Oxidation states:**

- Most stable oxidation state of the lanthanides is +3.
- For dipositives lanthanides Sm^{2+} (f6, nearly half filled), Eu^{2+} (f7, half filled), and Yb^{2+} (f14, filled) are known with relative stability in H_2O being $Eu^{2+} >> Yb^{2+} >> Sm^{2+}$.
- Ce^{4+} (f0) is the only tetrapositive lanthanide stable in water.

$CeCl_4$

Element	Symbol	Electronic Configuration
Cerium	Ce	[Xe] $4f^1 5d^1 6s^2$
Praseodymium	Pr	[Xe] $4f^3 6s^2$
Neodymium	Nd	[Xe] $4f^4 6s^2$
Promethium	Pm	[Xe] $4f^5 6s^2$
Samarium	Sm	[Xe] $4f^6 6s^2$
Europium	Eu	[Xe] $4f^7 6s^2$
Gadolinium	Gd	[Xe] $4f^7 5d^1 6s^2$
Terbium	Tb	[Xe] $4f^9 6s^2$
Dysprosium	Dy	[Xe] $4f^{10} 6s^2$
Holmium	Ho	[Xe] $4f^{11} 6s^2$
Erbium	Er	[Xe] $4f^{12} 6s^2$
Thulium	Tm	[Xe] $4f^{13} 6s^2$
Ytterbium	Yb	[Xe] $4f^{14} 6s^2$
Lutetium	Lu	[Xe] $4f^{14} 5d^1 6s^2$

After lanthanum, so lanthanum actually it has 4f0. That is why sometimes it is not called lanthanide but because its property is similar to other lanthanides, so sometimes it is called the lanthanide. So here we see the cerium. This is the symbol and this is the electronic configuration 4f1 5d1 6s2 and Praseodymium and this is the observed. So here you can see this is the observed because accordingly one electron will stay in the 5d but it is coming to 4f and it is becoming 4f3 so this all are observed and the preference for the electron to stay in 4f orbital except gadolinium where this is half filled 4f7, so this is half filled.

That is why one electron going to 5d and this is Lutetium, here also 4f14 5d1, this is full filled. So now we will see the oxidation states, most stable oxidation state of the lanthanide is plus 3. And for di positive lanthanide samarium plus 2 (f6, nearly half filled), Europium plus 2 (f7, hall filled) and Ytterbium plus 2 that is f14 filled are known with relative stability in H2O being Europium plus 2 most stable than equilibrium plus this is much more stable than samarium plus 2. So this is half filled. So half-filled is more stable than full filled. So this is full filled. So half-filled is more stable than full filled because it will be more stable if there is a one electron in each orbital. And cerium plus 4f0, ceric chloride CeCl4 we have seen earlier also. So cerus 4 plus is the only tetra positive lanthanide stable in water.

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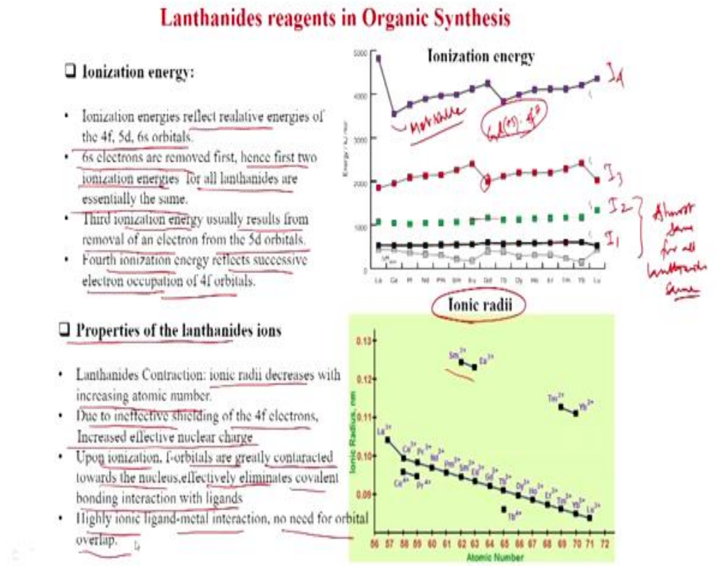

Lanthanides reagents in Organic Synthesis

❑ Ionization energy:

- Ionization energies reflect realative energies of the 4f, 5d, 6s orbitals.
- 6s electrons are removed first, hence first two ionization energies for all lanthanides are essentially the same.
- Third ionization energy usually results from removal of an electron from the 5d orbitals.
- Fourth ionization energy reflects successive electron occupation of 4f orbitals.

❑ Properties of the lanthanides ions

- Lanthanides Contraction: ionic radii decreases with increasing atomic number.
- Due to ineffective shielding of the 4f electrons, Increased effective nuclear charge
- Upon ionization, f-orbitals are greatly contaracted towards the nucleus,effectively eliminates covalent bonding interaction with ligands
- Highly ionic ligand-metal interaction, no need for orbital overlap.

Now we will discuss Ionization energy. So this you can see this black one I1, green is I2, red is I3, this is I4 and you can see this I1 and I2 are almost same for all, means the I1 value for the lanthanide, all lanthanides are same. And similarly the I2 values are same. And Ionization energy reflects relative energies of the f4, 5d, 6s orbitals. 6s electrons are removed first; hence first two ionization energies for all lanthanide are essentially the same. So it is almost similar, because the electrons are removed on the same 6s orbitals. Now third ionization energy usually results from the removal of an electron from the 5d orbitals and you can see there is difference.

So this is not linear and this is more stable because this gadolinium plus 3 this is 4f7, so this is half filled. So it is more above the stability. Stability of the ion that tells the ionization energy, so stability is more means ionization energy will be less. Fourth ionization energy reflects successive electron occupation of 4f orbitals. So here you can see the cerium plus 4 is the most stable. So this is the most stable here and others are very high energy. So cerium plus 4 is most stable and it is stable also in water. Now properties of lanthanide ions, so there is a subtly decrease in the ionic radii value of plus 3. So here we have seen the plus 3 and here plus 4 also.

Here plus 2 also. So all cases if you go along the lanthanides series, the ionic radii subtly decrease so why it is? So, ionic radii decreases with increasing atomic number. Now due to ineffective shielding of the 4f electrons increase effective nuclear charge because shielding by the 4f electrons are not so good. That is why the affecting nuclear charge is very high. However upon ionization f-orbitals are greatly contracted towards the nucleus, effectively eliminates covalent bonding interaction with ligands, highly ironic ligand metal interaction, no need for orbital overlap. This we will also see the properties of lanthanides.

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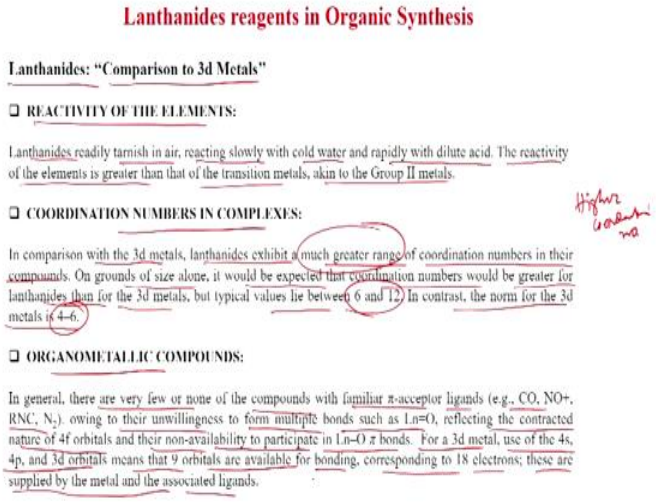

Lanthanides reagents in Organic Synthesis

Lanthanides: "Comparison to 3d Metals"

❑ **REACTIVITY OF THE ELEMENTS:**

Lanthanides readily tarnish in air, reacting slowly with cold water and rapidly with dilute acid. The reactivity of the elements is greater than that of the transition metals, akin to the Group II metals.

❑ **COORDINATION NUMBERS IN COMPLEXES:**

In comparison with the 3d metals, lanthanides exhibit a much greater range of coordination numbers in their compounds. On grounds of size alone, it would be expected that coordination numbers would be greater for lanthanides than for the 3d metals, but typical values lie between 6 and 12. In contrast, the norm for the 3d metals is 4–6.

Higher coordn no

❑ **ORGANOMETALLIC COMPOUNDS:**

In general, there are very few or none of the compounds with familiar π-acceptor ligands (e.g., CO, NO+, RNC, N_2). owing to their unwillingness to form multiple bonds such as Ln=O, reflecting the contracted nature of 4f orbitals and their non-availability to participate in Ln–O π bonds. For a 3d metal, use of the 4s, 4p, and 3d orbitals means that 9 orbitals are available for bonding, corresponding to 18 electrons; these are supplied by the metal and the associated ligands.

Now we will discuss lanthanide comparison to 3d metals. This is the reactivity of the lanthanide elements. They readily tarnish in air, reacting slowly with cold water and rapidly with dilute acid. The reactivity of the elements is greater than that of the transition metal, akin to the group II metals. So they are quite similar to group II metals and their reactivity also sometimes similar to group II metals. Coordination numbers in complexes in comparison with the 3d metals, lanthanides exhibit a much greater range of coordination numbers in their compound. So this is important. They give much greater range.

On grounds of size alone it would be expected that coordination numbers should be greater for lanthanides than for the 3d metals. But typical values lie between 6 and 12. In contrast, the norm for the 3D metals is between 4 to 6, so here higher coordination number. Also organometallic compounds in general there are very few or none of the compounds with familiar Pi acceptor ligands, for example carbon monoxide, NO plus, RNC, N2 owing to their unwillingness to form multiple bonds such as you Ln double bond O, reflecting the contracted nature of the 4f orbitals and their non-availability to participate in Ln O pi bonds.

So 4f orbitals are very buried inside, so they are not available for bonding that is why this pi acceptor ligand complexes are not there. On the other hand for a 3d metal use of the 4s, 4p and 3d orbitals means that 9 orbitals are available for bonding, corresponding to 18 electrons, these are supplied by the metals and their associated ligands. And we are already seen there are a lot of transition metals, carbon monoxide complexes so they easily form the complexes with pi acceptor ligands, on the other hand lanthanides do not.

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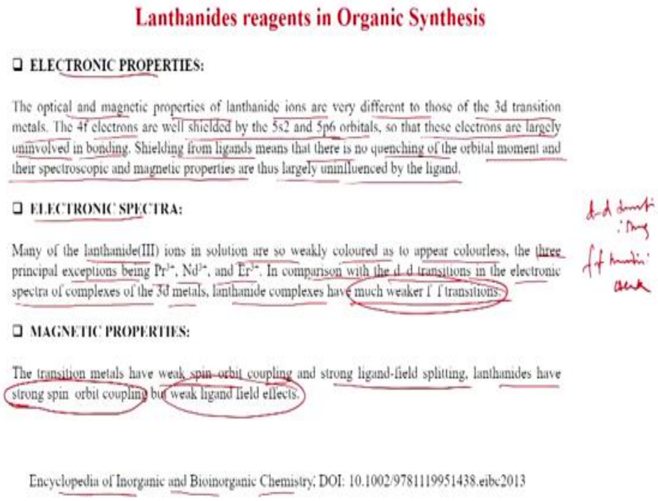

Lanthanides reagents in Organic Synthesis

❑ **ELECTRONIC PROPERTIES:**

The optical and magnetic properties of lanthanide ions are very different to those of the 3d transition metals. The 4f electrons are well shielded by the 5s2 and 5p6 orbitals, so that these electrons are largely uninvolved in bonding. Shielding from ligands means that there is no quenching of the orbital moment and their spectroscopic and magnetic properties are thus largely uninfluenced by the ligand.

❑ **ELECTRONIC SPECTRA:**

Many of the lanthanide(III) ions in solution are so weakly coloured as to appear colourless, the three principal exceptions being Pr^{3+}, Nd^{3+}, and Er^{3+}. In comparison with the d d transitions in the electronic spectra of complexes of the 3d metals, lanthanide complexes have much weaker f f transitions.

d-d transi :strng

f-f transi: weak

❑ **MAGNETIC PROPERTIES:**

The transition metals have weak spin-orbit coupling and strong ligand-field splitting, lanthanides have strong spin orbit coupling but weak ligand field effects.

Encyclopedia of Inorganic and Bioinorganic Chemistry; DOI: 10.1002/9781119951438.eibc2013

Electronic properties, the optical and magnetic properties of lanthanide ions are very different to those of the 3D transition metals. The 4f electrons are well shielded by the 5s2 5p6 orbitals, so that these electrons are largely uninvolved in bonding. Shielding from ligands means that there is no quenching of the orbital moment and their spectroscopic and magnetic properties are thus largely uninfluenced by the ligands.

Now electronic spectra, many of the lanthanides III ions in solution are so weakly colored as to appear colorless. The 3 principle exceptions being Pr 3 plus Nd 3 plus and Er 3 plus in comparison with the d d transition in the electronic spectrum of the complexes of the 3d metals lanthanide complexes have much weaker f f interaction. So this d d transition is very strong, transitions strong. On the other hand, f f transition is very weak. Magnetic properties the transition metals have weak spin orbit coupling and strong ligand-field splitting. Lanthanides have opposite actually. They have strong spin orbit coupling but so weak ligand-field effect but transition metals have strong ligand-field effect. This was the reviewed Encyclopedia of inorganic and bioinorganic chemistry.

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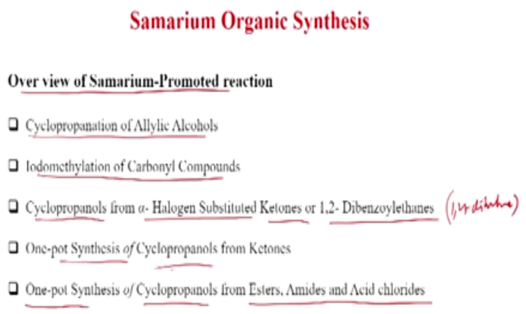

Samarium Organic Synthesis

Over view of Samarium-Promoted reaction

❑ Cyclopropanation of Allylic Alcohols

❑ Iodomethylation of Carbonyl Compounds

❑ Cyclopropanols from α- Halogen Substituted Ketones or 1,2- Dibenzoylethanes (1,4-diketone)

❑ One-pot Synthesis *of* Cyclopropanols from Ketones

❑ One-pot Synthesis *of* Cyclopropanols from Esters, Amides and Acid chlorides

Now will discuss overview of samarium-promoted reaction, Cyclopropanation of Allylic alcohol, Iodomethylation of carbonyl compounds, cyclopropanols from alpha halogen substituted ketones or 1, 2 dibenzoylethanes. This is actually 1 4 diketone that we will see. And one pot synthesis of cyclopropanols from ketones, Also one pot synthesis of cyclopropanols from Esters, Amides and acid chlorides. So samarium this chemistry is very much rich to generate cyclopropane as well as the cyclopropanol that we will see.

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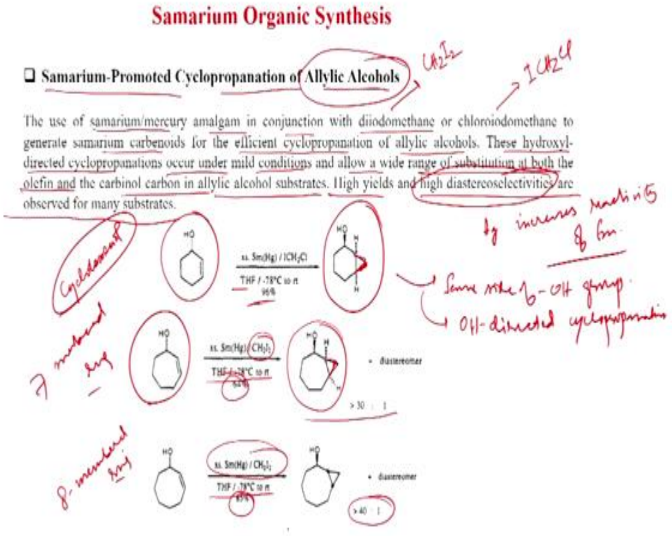

Samarium Organic Synthesis

❑ Samarium-Promoted Cyclopropanation of Allylic Alcohols

The use of samarium/mercury amalgam in conjunction with diiodomethane or chloroiodomethane to generate samarium carbenoids for the efficient cyclopropanation of allylic alcohols. These hydroxyl-directed cyclopropanations occur under mild conditions and allow a wide range of substitution at both the olefin and the carbinol carbon in allylic alcohol substrates. High yields and high diastereoselectivities are observed for many substrates.

Samarium promoted cyclopropanation of Allylic alcohols. First we will discuss the use of samarium mercury amalgam in conjunction with diiodomethane. So this is this and this is chloroiodomethane this is ICH2Cl. To generate samarium carbenoids for the efficient cyclopropanation of allylic alcohols. These hydroxyl directed cyclopropanations occur under mild conditions and allow a wide range of substitution at both the olefin and carbinol carbon in allylic alcohol substrates. High yields and high diastereoselectivities are observed for many substrates. So, this also very important. The high diastereoselectivity that has been obtained for this cyclopropanation of allylic alcohols. So that we will see also.

So this is example, here you can see secondary alcohol is there. So this is cyclohexenol. This is allylic alcohol and with samarium mercury, so this samarium mercury what is that, Hg increases reactivity of samarium. So if you do not put mercury then the reactivity is less. And here samarium amalgam ICH2Cl is there, THF minus 78 degree centigrade to room temperature; you get 96 percent yield of this product. And here you can see the cyclopropyl group is the same side of OH group. So that means this is OH directed cyclopropanation that we will see in the mechanism later. Here also this is 7 member ring, here also you get high diastereoselectivity and under the same condition here diiodomethane is used minus 78 degree centigrade to room temperature THF solvent.

However the yield is little less 64 percent but the diastereoselectivity is still high, greater than 30 is to 1. So this is the major diastereomer. Here also the cyclopropyl group is in the same site of the hydroxy group. And this is 8 member ring with same condition samarium amalgam, CH2I2, THF minus 78 degree centigrade to room temperature. Here you get good yield of 85 percent and here the diastereoselectivity also is very high greater than 40:1. So this means the secondary allylic alcohols can give high diastereoselectivity for the cyclopropanation with samarium amalgam and CH2I2 or ICH2Cl.

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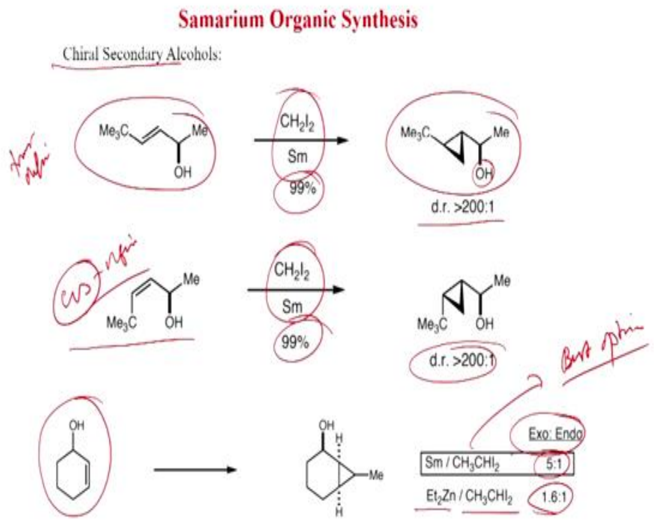

Samarium Organic Synthesis

Chiral Secondary Alcohols:

So this is very important and with chiral secondary alcohols like this one, you put samarium CH2I2 you get 99 percent yield of this product and you can see the diastereoselectivity is greater than 200 is to 1. So this hydroxy and cyclopropyl is in the same side. If you put now cis one so this is trans olefin, cis olefin. Cis olefin also with CH2I2 samarium you get high yield 99 percent. And here also the diastereomeric ratio is very high. The cyclopropyl group is the same side of hydroxy group. And this one we have already seen, cyclohexenol and here thus with samarium CH3CHI2 you get 5:1 diastereomeric ratio exo is to endo. On the other hand, if you put diethylzinc CH3CHI2, the diastereomeric ratio is 1.6 is to 1. Therefore, this is the best option if you want the diastereoselective cyclopropanation of allylic alcohol then this samarium CH2I2 or CH3CHI2 is the best option.

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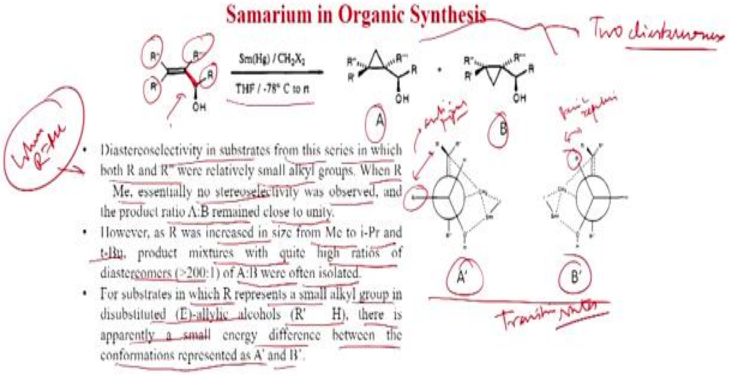

Samarium in Organic Synthesis

- Diastereoselectivity in substrates from this series in which both R and R''' were relatively small alkyl groups. When R Me, essentially no stereoselectivity was observed, and the product ratio A:B remained close to unity.
- However, as R was increased in size from Me to i-Pr and t-Bu, product mixtures with quite high ratios of diastereomers (>200:1) of A:B were often isolated.
- For substrates in which R represents a small alkyl group in disubstituted (E)-allylic alcohols (R' H), there is apparently a small energy difference between the conformations represented as A' and B'.

Now we will see the mechanisms, so here we can see R dash is there, R double dash, R triple dash, there is another R is present and this is the chiral center and with samarium amalgam CH2X2 THF minus 78 degree centigrade you get 2 diastereomer A B. Here this has been drawn in the plane. So there can be two diastereomer either this is that side or it is other side because this is in the plane, then you can draw the other diastereomer like this. So there are two diastereomers. And this diastereoselectivity can be explained by this transition states. In substrates, diastereoselectivity in substrates forms this series in which both R and R double dash were relatively small alkyl groups.

When R is equal to methyl, essentially no stereoselectivity was observed and the product ratio A is to B remained close to unity. So earlier we have seen earlier slide if there is a tertiary butyl group then if you have methyl group you can get. Otherwise the diastereoselectivity is very low when R is equal to, that can be explained because R is here, you can see and here R is here. So here R is in the steric repulsion in the other transition state. But here it is antiperiplanar. So here it is antiperiplanar, so the size of R is important for the energy difference between these two transition state A dash and B dash. However as R was increased in size from methyl to isopropyl and tertiary butyl product mixes with quite high ratio of diastereomers greater than 200 is to 1 of A is to B were often isolated. So this is important if R is becoming tertiary butyl then you can get high diastereomeric ratio because then the steric repulsion here will be more.

So this is R dash and this is R double dash and this is R triple dash, here R is there. And if you see carefully we are looking at this carbon-carbon bond. So this carbon-carbon bond we are looking and then we have drawn this Newmann projection and here also you can see this OH has been binding with samarium also CH2I2 that CH2 is connected with samarium as well this I and now this carbenoid that is the making the cyclopropanation, so reactivity will be double one. For Substrates in which R represents a small alkyl group in disubstituted E-allylic alcohols, R dash is equal to hydrogen, there is apparently a small energy difference between the conformations represented as A dash and B dash.

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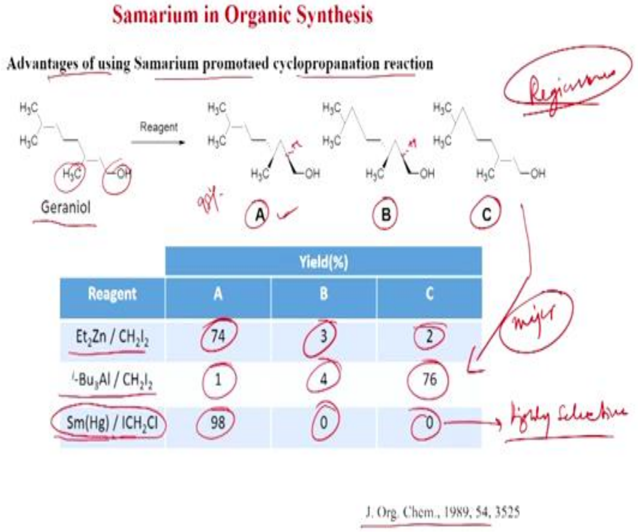

Samarium in Organic Synthesis

Advantages of using Samarium promotaed cyclopropanation reaction

	Yield(%)		
Reagent	A	B	C
Et_2Zn / CH_2I_2	74	3	2
^{i}-Bu_3Al / CH_2I_2	1	4	76
Sm(Hg) / ICH_2Cl	98	0	0

J. Org. Chem., 1989, 54, 3525

Now advantage of using Samarium promoted cyclopropanation reaction that here you can see two double bond present. Of course, one is allylic alcohol this is allylic alcohol and this is simple olefin. And this compound is called geraniol. And now if you put different reagents you can get this is down hydrogen, three kinds of product, one is cyclopropanation here that is A another is cyclopropanation is both double bond then it is equal to B compound and if it is here in the olefin not in the allylic alcohol that is also another possible. So three compounds can be formed so this is actually regioisomers. Now if you put diethylzinc CH2I2 then A is formed 74 percent, A that is the major, but you get some amount of B and C, 3 percent, 2 percent.

On the other hand if triisobutylaluminum with CH2I2 so this is aluminum you get only 1 percent A, 4 percent B and 76 percent C, So this becomes major here with triisobutylaluminum, so this is interesting. And now samarium mercury ICH2Cl whatever we are studying today there you get 98 percent of this one. So this is 98 percent and these two are 0. So this means highly selective. So Samarium Mercury ICH2Cl you get regioselective as well as the stereoselective cyclopropanation, so the high regioisomer as well as the diastereoselectivity obtained. Here this stereochemistry is retained. Here they are cis, here also cis. And this is the journal of organic chemistry 1989.

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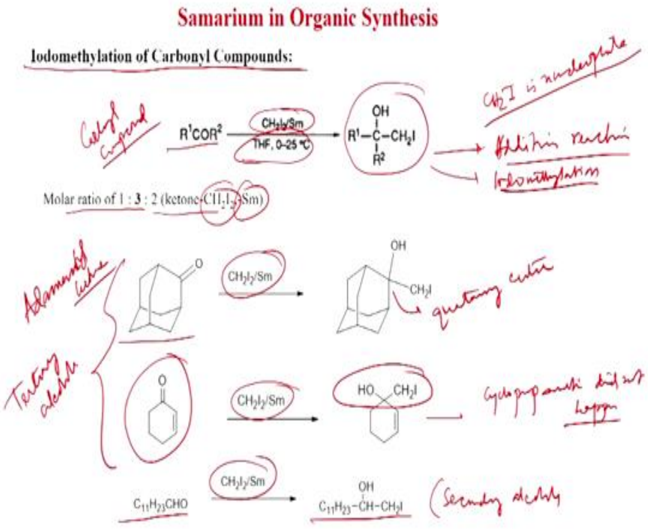

Samarium in Organic Synthesis

Iodomethylation of Carbonyl Compounds:

Molar ratio of 1 : **3** : 2 (ketone:CH_2I_2:Sm)

Now we will discuss another reaction that is Iodomethylation of carbonyl compounds. So in the same ways and we will see what happens in carbonyl compound. Now if you have a carbonyl compound R1COR2 CH2I2 samarium THF, 0 to 25 degree centigrade you get this compound. So what happens the CH2I group added and as a nucleophile. So CH2I is nucleophile. And it added to the carbonyl compounds, so this is simply addition reaction. And that is called iodomethylation also because iodomethyl group has come, that is why it is called iodomethylation of carbonyl compounds.

Now molar ratio will be 1 is to 3 is to 2 ketone will be 1, 3 will be CH2I2 and 2 will be samarium. And then if you keep this adamantyl ketone, so this is adamantyl ketone or adamantone and then with CH2I2 samarium we get this, this is a quaternary center and carbonyl becomes OHCH2I. Similarly cyclohexenone, also if you put CH2I2 samarium, here the cyclopropanation did not happen because we have already seen only allylic alcohol reacts, so simply olefin will not do the cyclopropanation instead it will give reaction with the carbonyl part and you get this hydroxyl CH2I group also aldehyde can be reacted with this reagent CH2I2 samarium and you get this secondary alcohol and in this case with ketone you get tertiary alcohol.

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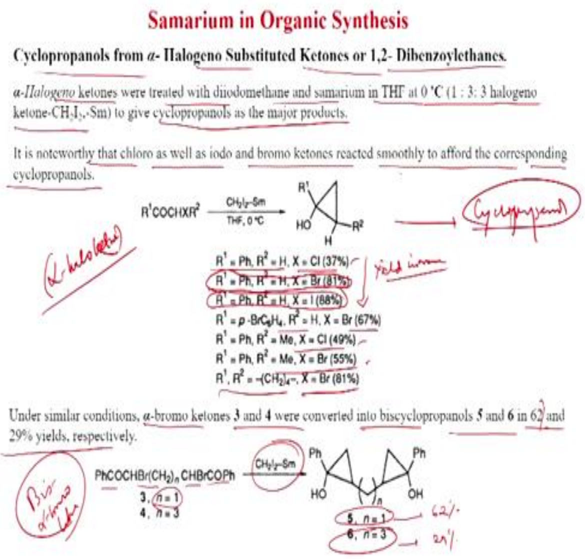

Samarium in Organic Synthesis

Cyclopropanols from *α*- Halogeno Substituted Ketones or 1,2- Dibenzoylethanes.

α-Halogeno ketones were treated with diiodomethane and samarium in THF at 0 °C (1 : 3: 3 halogeno ketone-CH_2I_2-Sm) to give cyclopropanols as the major products.

It is noteworthy that chloro as well as iodo and bromo ketones reacted smoothly to afford the corresponding cyclopropanols.

$R^1COCHXR^2 \xrightarrow[\text{THF, 0 °C}]{CH_2I_2\text{-Sm}}$

R^1 = Ph, R^2 = H, X = Cl (37%)
R^1 = Ph, R^2 = H, X = Br (81%)
R^1 = Ph, R^2 = H, X = I (88%)
R^1 = *p*-BrC_6H_4, R^2 = H, X = Br (67%)
R^1 = Ph, R^2 = Me, X = Cl (49%)
R^1 = Ph, R^2 = Me, X = Br (55%)
R^1, R^2 = $-(CH_2)_4-$, X = Br (81%)

Under similar conditions, *α*-bromo ketones **3** and **4** were converted into biscyclopropanols **5** and **6** in 62 and 29% yields, respectively.

$PhCOCHBr(CH_2)_nCHBrCOPh \xrightarrow{CH_2I_2\text{-Sm}}$

3, *n* = 1
4, *n* = 3

5, *n* = 1
6, *n* = 3

Now we will see cyclopropanols from alpha halogens substituted ketones or 1, 2 benzoylethane. So if you have a alpha bromo or alpha halo substitution of the ketone, then you get different product. Alpha halogen ketones were treated with diiodomethane and samarium in THF at 0 degree centigrade, 1 is to 3 is to 3 halogen ketone CH2I2 samarium to give cyclopropanols as the major product. It is noteworthy that chloro as well as iodo and bromo ketones reacted smoothly to afford the corresponding cyclopropanols. You can see this is the alpha halo ketone, so with alpha halo ketone you get cyclopropanol. So here, that means or halo reacted first and then you get enolate and then only this possible. We will see this mechanism in details, so here you can see R1 is equal to PH, R2 is equal to H, X is equal to Cl you get 37 percent.

And if it is Bromide then you get 81 percent. And if it is iodide then you get 88 percent. So yield increase. So iodides are the better so that means the halo group is important and here the other groups are there, 67 percent, X is equal to Chlorine 49, X is equal to Br 55, if R2 is equal to methyl and this is cyclic ketone also 81 percent yield you can get. Similar conditions alpha bromo ketones 3 and 4 were converted into biscyclopropanols 5 and 6 in 62 percent and 29 percent yields, respectively. This alpha bromo ketone like here PHCOCHBR(CH2) and CHBRCOPH, here CH2I2 samarium of course more equivalent you have to use and if n is equal to 1, then it is 5 that case you get 62 percent yield. So this will give 62 percent and n is equal to 3 then you get 29 percent. So this means this reaction is quite general for alpha bromo ketones.

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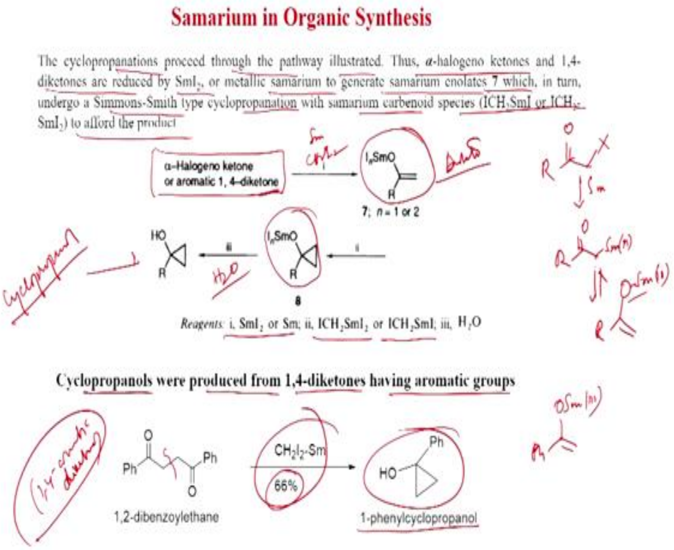

Samarium in Organic Synthesis

The cyclopropanations proceed through the pathway illustrated. Thus, α-halogeno ketones and 1,4-diketones are reduced by SmI_2, or metallic samarium to generate samarium enolates 7 which, in turn, undergo a Simmons-Smith type cyclopropanation with samarium carbenoid species (ICH_2SmI or ICH_2SmI_2) to afford the product

Reagents: i, SmI_2 or Sm; ii, ICH_2SmI_2 or ICH_2SmI; iii, H_2O

Cyclopropanols were produced from 1,4-diketones having aromatic groups

So the cyclopropanations proceed through the pathway illustrated. The alpha halogen ketones and 1, 4 diketones are reduced by samarium Iodide or metallic samarium to generate samarium enolate 7. So this is the samarium enolate, this is important which in turn undergoes a Simmons-Smith type cyclopropanation with samarium carbenoid species to afford the product. So alpha halogeno ketone, or aromatic 1, 4 diketone that also we will see. When you treat with samarium and CH2I2 then you get this enolate or you simply if you start with samarium iodide here, this enolate will form so enolate. So what is happening here, that means when you put samarium then samarium inserts this CX bond.

So here, you get samarium and now this will be enolate and when enolate the samarium will go with the enolate, so it will be like this, that is happening here and after that if you put ICH2 SMI2 or ICH2 SMI so this will give the cyclopropanation that is this. And after hydrolysis so this is water then you get the cyclopropanol. So this is very important that means this enolate is very important and enolate after cyclopropanation, giving the cyclopropyl samarium species and then after hydrolysis you get the cyclopropanol.

Cyclopropanols were produced from 1, 4 diketones having aromatic groups, this is also special. So this is 1, 4 aromatic diketone and here if you see this product that means this bond has been broken. So samarium has been able to break this bond and making this enolate. And after that enolate formation, with CH2I2 samarium you get the cyclopropanation and you are getting this 1-phencyclopropanol in 66 percent yield. So this is very important, either alpha halogeno ketone or 1, 4 diketone aromatic can give this kind of product.

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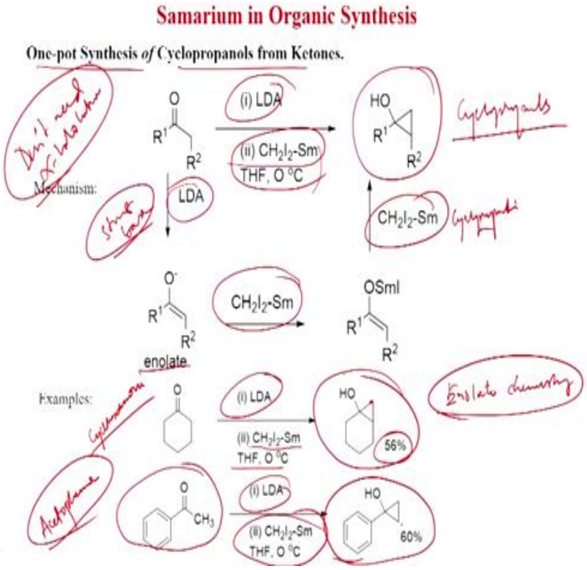

Samarium in Organic Synthesis

One-pot Synthesis of Cyclopropanols from Ketones.

And one-pot synthesis of cyclopropanols from ketones is possible. So here you do not need alpha halo ketone because we have seen that halogen is there only to make an enolate and now if you have external base if the enolate can be formed from the ketone and then if you put this second step samarium CH2I2 THF 0 degree centigrade whether you can get this product or not. In fact, this is yes and you put LDA this is very strong base, so strong base LDA and then you can get this enolate and this enolate then reacting with CH2I2 samarium plus this one samarium takes this and after that the cyclopropanation will happen.

Cyclopropanation of the double bond will give this cyclopropanol after hydrolysis. Therefore, this is cyclopropanol. And different ketones can be made enolates like here cyclohexanone, cyclohexanone if you treat with first LDA, LDA will make the enolate and then react with CH2I2 samarium THF 0 degree centigrade then you get this product. So this comes from the CH2 group here. So this is the enolate chemistry. Enolate chemistry and that enolate is reacting with the carbenoid to generate the cyclopropanol in 56 percent yield. Also if you have a acetophenone, this is acetophenone and acetophenone with LDA also makes the enolate and after that CH2I2 samarium you get this cyclopropanol in 60 percent yield.

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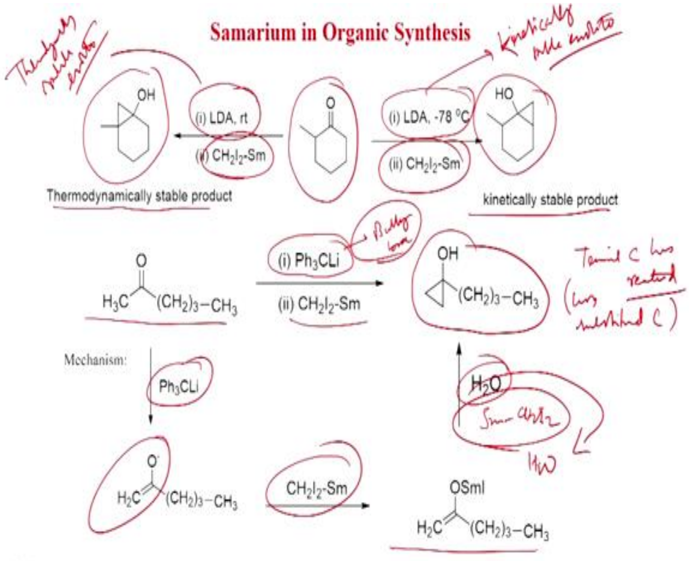

Now we will discuss two kinds of enolates can be formed we know one is kinetic enolate another is thermodynamic enolate and depending on the reaction condition we can get two different kind of products like two methyl cyclohexanone, if you treat with LDA minus 78 degree centigrade and then you put CH2I2 samarium you get the kinetically stable product. In fact before that LDA minus 78 degree centigrade you get the kinetically stable enolate or kinetic enolate.

And kinetic enolate will be this side because this side is substituted and after that you get this product. On the other hand at room temperature because you allowed the reaction to equilibrate and after that only thermodynamically stable enolate will form. So this will give thermodynamically stable enolate and after that with CH2I2 samarium you get this. So one case the enolate from this side another case enolate from this side that is why this side is the cyclopropanol happened.

Also if you put unsymmetrical ketone like this one side methyl another side butyl and with PH3Cli, this is a bulky. Bulky base also and then you put this CH2I2 samarium you get this. So what does this means, the terminal carbon H reacted that is the less substituted, less substituted carbon H reacted. So here you can see this is methyl and this is butyl so with strong base bulky base here you get this one enolate formation because this is the kinetic enolate and after CH2I2 samarium you get this. And after hydrolysis and of course the samarium is there CH2I2, plus cyclopropanation will happen and after hydrolysis water will be later, then you get this cyclopropanol.

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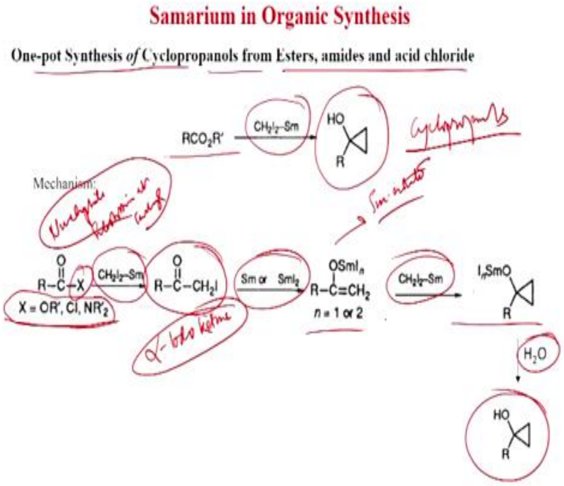

Samarium in Organic Synthesis

One-pot Synthesis *of* Cyclopropanols from Esters, amides and acid chloride

Mechanism:

Also one-pot synthesis of cyclopropanols from esters, amides and acid chloride is possible. So we have seen that this is the enolate chemistry, so enolate chemistry we have seen it for the alpha bromo ketone as well as the ketone with base. And now if you put esters, amides or acid chloride that case also you get this cyclopropanols. So what is happening here that if you have a leaving group X is equal to 1, Cl NR2 that is the tertiary amide and then if you put CH2I2 samarium then nucleophilic substitution reaction happens.

So this is nucleophilic substitution at carbonyl because this is a leaving group and this CH2I we have already seen that come here and you get this. And this is in fact now alpha iodo ketone. So we know that alpha halo ketone will generate the enolate with samarium or samarium I2 that is what has been done here. This is the enolate, so this is samarium, enolate and after that the cyclopropanation will happen CH2I2 samarium and after hydrolysis you get the cyclopropanol. So this is very important that when you have a ester, acid chloride, tertiary amide then this substitution reaction at the carbonyl carbon is happening and you get this alpha iodo ketone. And after that enolate is forming and then the remaining steps are similar.

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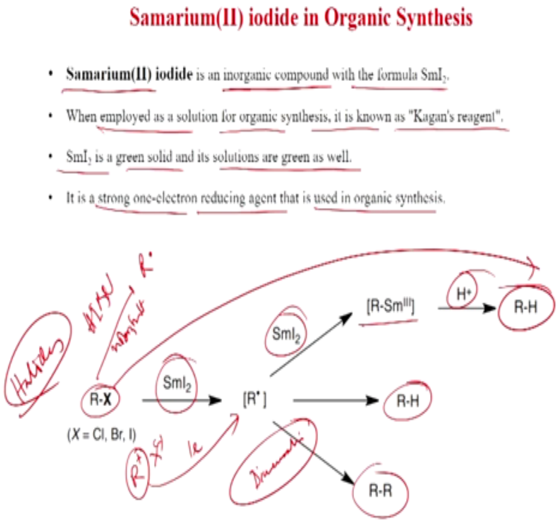

Samarium(II) iodide in Organic Synthesis

- **Samarium(II) iodide** is an inorganic compound with the formula SmI_2.
- When employed as a solution for organic synthesis, it is known as "Kagan's reagent".
- SmI_2 is a green solid and its solutions are green as well.
- It is a strong one-electron reducing agent that is used in organic synthesis.

Now we will discuss samarium iodide. So samarium iodide is an useful reagent in inorganic synthesis and many transformations has been carried out which samarium iodide. So samarium iodide is an inorganic compound with the formula SmI2, when employed as a solution for organic synthesis it is known as Kagan's reagent. As samarium I2 is green solid and its solutions are green as well. It is a strong one-electron reducing agent that is used in organic synthesis and this is a general reaction which halides and AIBN and tributyl hydride also can generate a radical that is common.

And here we will see the samarium iodide can do the similar radical generation. Is ionic so R gets plus X minus and that R plus is reduced by samarium to generate the radical to 1 electron goes to R plus then it becomes radical and this radical can be going to its samarium I2 to get this R minus, samarium 3 then after proton source you get RX. So RX can be converted to RH also others can go to RH also radical. And this is the dimerization. So radical forms then it can carry out many kind of reaction that also we will see later where R dash can be used for different carbon-carbon as well as carbon heteroatom bond formations.

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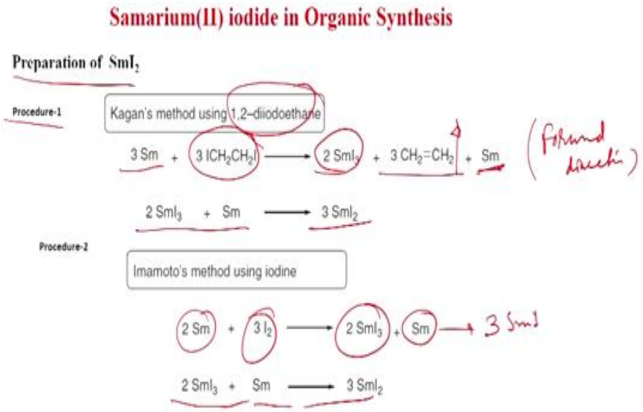

Samarium(II) iodide in Organic Synthesis

Preparation of SmI_2

Procedure-1

Kagan's method using 1,2–diiodoethane

$$3\,Sm + 3\,ICH_2CH_2I \longrightarrow 2\,SmI_3 + 3\,CH_2{=}CH_2\uparrow + Sm$$

(Forward direction)

$$2\,SmI_3 + Sm \longrightarrow 3\,SmI_2$$

Procedure-2

Imamoto's method using iodine

$$2\,Sm + 3\,I_2 \longrightarrow 2\,SmI_3 + Sm \longrightarrow 3\,SmI$$

$$2\,SmI_3 + Sm \longrightarrow 3\,SmI_2$$

So first we will discuss preparation of samarium iodide. First procedure 1, this is Kagan's method using 1, 2 diiodethane. So this is 1, 2 diiodethane and this is interesting, here you get the ethylene gas, so this gas will be out, so the reaction will go to the forward direction. Forward direction you get the reaction to be quite fast, 3 equivalent of samarium metal and then 3 equivalent this you will give 2 equivalent of samarium I3, 3 equivalent ethylene and samarium. This samarium I3 and samarium again will react to generate the samarium I2. Imamoto method here use iodine actually, So samarium plus 3 I2, 2 SmI3 plus samarium. Similarly the second step is same, 2 SmI3 plus (sam) Sm is 3 SmI2. So this is actually same 3 SmI2 is formed here.

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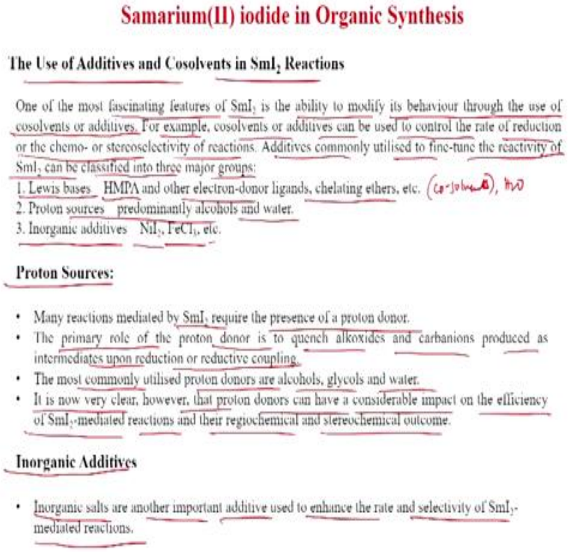

Samarium(II) iodide in Organic Synthesis

The Use of Additives and Cosolvents in SmI_2 Reactions

One of the most fascinating features of SmI_2 is the ability to modify its behaviour through the use of cosolvents or additives. For example, cosolvents or additives can be used to control the rate of reduction or the chemo- or stereoselectivity of reactions. Additives commonly utilised to fine-tune the reactivity of SmI_2 can be classified into three major groups:

1. Lewis bases HMPA and other electron-donor ligands, chelating ethers, etc. (co-solvent), H_2O
2. Proton sources predominantly alcohols and water.
3. Inorganic additives NiI_2, $FeCl_3$, etc.

Proton Sources:

- Many reactions mediated by SmI_2 require the presence of a proton donor.
- The primary role of the proton donor is to quench alkoxides and carbanions produced as intermediates upon reduction or reductive coupling.
- The most commonly utilised proton donors are alcohols, glycols and water.
- It is now very clear, however, that proton donors can have a considerable impact on the efficiency of SmI_2-mediated reactions and their regiochemical and stereochemical outcome.

Inorganic Additives

- Inorganic salts are another important additive used to enhance the rate and selectivity of SmI_2-mediated reactions.

Now we will see that use of additives and co-solvents also important in samarium iodide reactions. One of the most fascinating feature of the samarium iodide is the ability to modify its behavior through the use of co-solvents or additives. So this is very important it can be more reactive if you put sometimes co-solvents like HMPA and also water. For example, co-solvents or additives can be used to control the rate of reduction or the chemo or stereoselectivity of reactions. Additives commonly utilize to fine-tune the reactivity of samarium iodide and it can be classified into 3 major groups.

One is the Lewis bases. These are actually co-solvents, Lewis basic co-solvent like HMPA and other electron-donor ligands, chelating ethers also water. Proton sources here it is predominantly alcohol and water. And inorganic additives nickel iodide, ferric chloride etc. So proton sources we will first discuss, many reactions mediated by samarium iodide requires the presence of a proton donor. The primary role of the proton donor is to quench alkoxide and carbanions produced as intermediates upon reduction or reductive coupling. This we have seen in the halide reaction with samarium iodide that you need a proton source to quench the alkoxide or carbanion.

The most commonly utilized proton donors are alcohols, glycols and water. It is now very clear, however that proton donors can have a considerable impact on the efficiency of samarium iodide mediated reactions and their regiochemical and stereochemical outcome. So that means there is more effect of this proton source, sometimes they are actually increases the reactivity of samarium. Inorganic additives, inorganic salts are another important additive used to enhance the rate and selectivity of samarium iodide mediated reactions.

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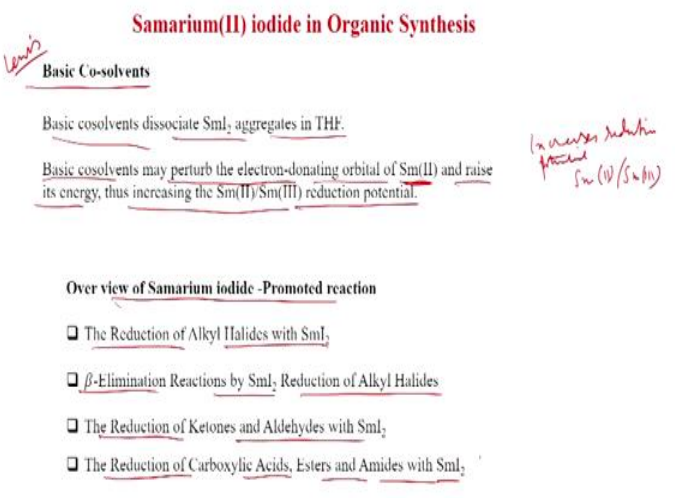

Samarium(II) iodide in Organic Synthesis

Lewis

Basic Co-solvents

Basic cosolvents dissociate SmI_2 aggregates in THF.

Basic cosolvents may perturb the electron-donating orbital of Sm(II) and raise its energy, thus increasing the Sm(II)/Sm(III) reduction potential.

Increases reduction potential Sm(II)/Sm(III)

Over view of Samarium iodide -Promoted reaction

☐ The Reduction of Alkyl Halides with SmI_2

☐ β-Elimination Reactions by SmI_2 Reduction of Alkyl Halides

☐ The Reduction of Ketones and Aldehydes with SmI_2

☐ The Reduction of Carboxylic Acids, Esters and Amides with SmI_2

And this is basic co-solvents, so Lewis basic co-solvents. Basic co-solvent dissociates samarium iodide aggregates in THF. This is very important the aggregates has been dissociated but basic co-solvents also basic co-solvents may perturb the electron donating orbitals of samarium II and raise its energy, thus increasing the samarium II, samarium III reduction potential. So this is very important increases reduction potential. So that means the reaction will be much faster, Reduction potential samarium II, samarium III. Overview of samarium iodide promoted reaction so today we will discuss the reduction of alkyl halides with samarium iodide. Beta elimination reactions with samarium iodide, reduction of alkyl halides, the reduction of ketones and aldehydes with samarium iodide, the reduction of carboxylic acid, esters and amides with samarium iodide.

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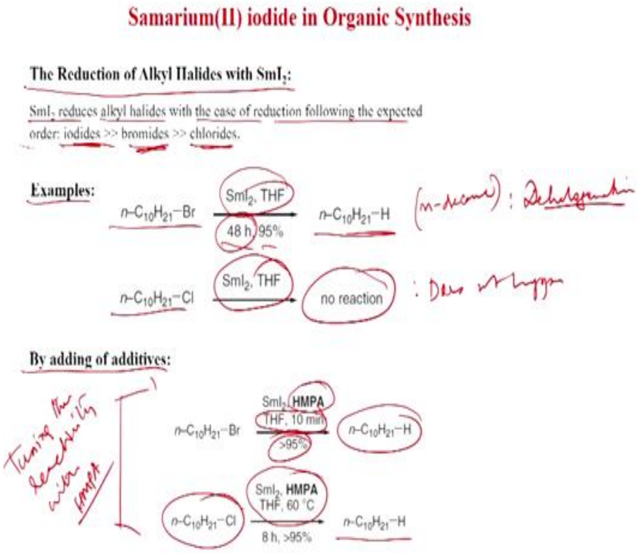

Samarium(II) iodide in Organic Synthesis

The Reduction of Alkyl Halides with SmI_2:

SmI_2 reduces alkyl halides with the ease of reduction following the expected order: iodides >> bromides >> chlorides.

Examples:

$$n\text{-}C_{10}H_{21}\text{–}Br \xrightarrow[\text{48 h, 95\%}]{SmI_2,\ THF} n\text{-}C_{10}H_{21}\text{–}H$$

(n-decane) : Dehalogenation

$$n\text{-}C_{10}H_{21}\text{–}Cl \xrightarrow{SmI_2,\ THF} \text{no reaction}$$

: Does not happen

By adding of additives:

$$n\text{-}C_{10}H_{21}\text{–}Br \xrightarrow[\text{>95\%}]{SmI_2,\ \mathbf{HMPA},\ THF,\ 10\ min} n\text{-}C_{10}H_{21}\text{–}H$$

$$n\text{-}C_{10}H_{21}\text{–}Cl \xrightarrow[\text{8 h, >95\%}]{SmI_2,\ \mathbf{HMPA},\ THF,\ 60\ °C} n\text{-}C_{10}H_{21}\text{–}H$$

Tuning the reactivity with HMPA

So the reduction of alkyl halides with samarium iodide is a popular reaction that is called the dehalogenation reaction like tributyl tin halides and AIBN does. So here samarium iodide reduces alkyl halides with the ease of reduction following the expected order. Iodides more than bromides that is more than chlorides. Examples we will see like here, N decyl bromide with samarium iodide in only THF 48 hours 95 percent yield of this product. N- decane you get on this bromide. So this is actually dehalogenation. Also with chloride the reaction does not occur with samarium iodide THF under same condition the reaction does not happen.

That means the carbon shell bond is strong, by adding of additives you can also put additive like HMPA, hexamethyl phosphoryl amide and with this one the reactivity is increased and only 10 minutes earlier it need to 48 hours, now only 10 minutes you get this product n-decane in greater than 95 percent. And now chloride can also be used with samarium iodide HMPA THF 60 degree centigrade, 95 percent yield of the n-decane, so that means tuning the reactivity, actually it is increasing the reactivity, tuning the reactivity with HMPA. So this is very important with HMPA, samarium iodide become more stronger reducing agent.

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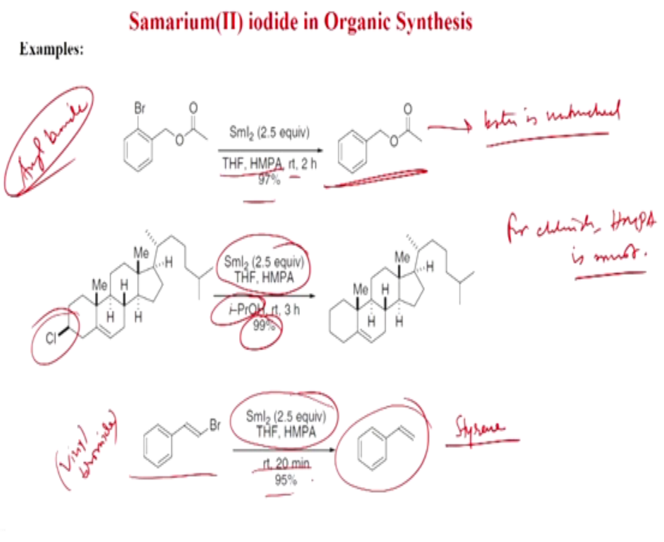

Samarium(II) iodide in Organic Synthesis

Examples:

Aryl bromide

→ ester is untouched

for chlorides, HMPA is must.

(vinyl) bromide

Styrene

Some more example here aryl bromide is there and samarium iodide THF HMPA room temperature you get this, so this is very important. In samarium iodide mediated reaction if there are different groups. So the highly reactive bond will first react. So here ester is untouched. But we will see later that ester can be also reduced with samarium iodide and here the double bond is present and this is many chiral centers are present, only selectively with samarium iodide THF HMPA, isopropanol 99 percent yield. So when chloride is there for chlorides HMPA is must, otherwise no reaction and isopropanol is the proton source. Then you get 99 percent of this product. And this is vinyl bromide. With vinyl bromide also you can get the reaction. Here also you need the HMPA, samarium iodide 2.5 equivalent THF, HMPA room temperature 20 minutes you get this styrene in 95 percent yield.

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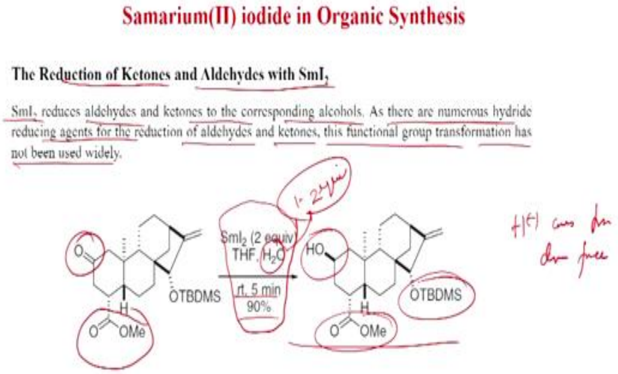

Samarium(II) iodide in Organic Synthesis

The Reduction of Ketones and Aldehydes with SmI_2

SmI_2 reduces aldehydes and ketones to the corresponding alcohols. As there are numerous hydride reducing agents for the reduction of aldehydes and ketones, this functional group transformation has not been used widely.

Now we will see the reduction of ketones and aldehydes with samarium iodide. So if you do not put LDA then they will be reduced actually. So samarium iodide reduces aldehydes and ketones to the corresponding alcohols. As there are numerous hydride-reducing agents for the reduction of aldehydes and ketones, this functional group transformation has not been used widely. However, in certain cases it has been used to get the diastereoselective product like here a ketone is present and ester is present.

So selectively the ketone has to be reduced also if you need the one stereoisomer, then this condition samarium iodide THF water. So in this case water may be less equivalent, may be 1, 2 equivalent because if you give more then, the this ester will reduce. Water also is important for the reduction of esters. And room temperature 5 minutes 90 percent yield you get this one. So here this OTBDMS group is untouched. This ester is untouched. And selectively the hydride come from the down face. So that you get the beta alcohol.

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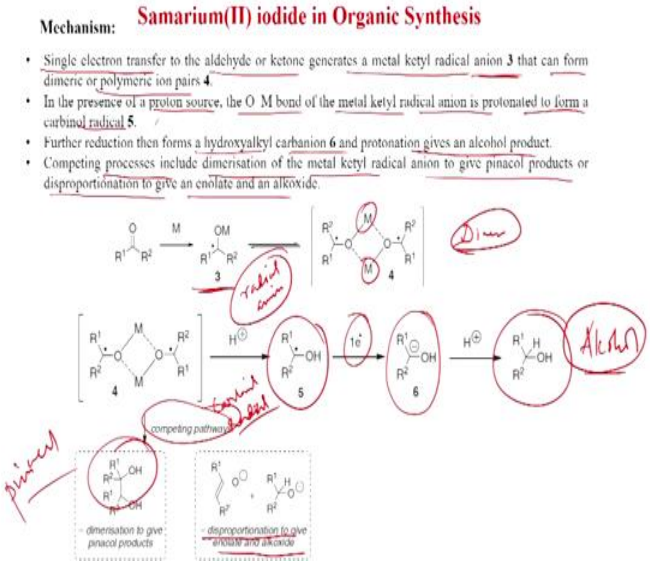

Mechanism: Samarium(II) iodide in Organic Synthesis

- Single electron transfer to the aldehyde or ketone generates a metal ketyl radical anion **3** that can form dimeric or polymeric ion pairs **4**.
- In the presence of a proton source, the O M bond of the metal ketyl radical anion is protonated to form a carbinol radical **5**.
- Further reduction then forms a hydroxyalkyl carbanion **6** and protonation gives an alcohol product.
- Competing processes include dimerisation of the metal ketyl radical anion to give pinacol products or disproportionation to give an enolate and an alkoxide.

So what is the mechanism for this ketone reduction, so of course the single electron transfer will happen to the aldehyde or ketone generates a metal ketyl radical anion 3 that can form dimeric or polymeric ion pairs 4. So like this the radical anion, this is actually radical anion. And this radical anion will stay at the dimer to atom a metal is present here and in the presence of proton source the OM bond of the metal ketyl radical anion is protonated to form a carbinol radical 5. So after protonation you get this because your OM is replaced by OH now carbinol radical. And further reduction then forms a hydroxy alkyl carbanion 6 again another electron comes then like Birch reduction we have seen hydroxy alkyl carbanion 6 and protonation gives an alcohol product, so this is alcohol.

So like Birch reduction, we have seen that there the benzene system reduce, here the ketone is reducing and in the similar mechanism that is the radical, then the proton and then radical, and then again the anion is forming. Competing processes including dimerization of the metal ketyl radical anion to give pinacol products or disproportionation to give an enolate and an alkoxide. So that is also possible we will see later a competing pathway that is the pinacol formation, so this is pinacol because this is radical it can dimerize easily, also it can generate enolates and alkoxides by disproportionation. So that is also possible from this dimer that one goes to the enolate and another does to the alkoxide.

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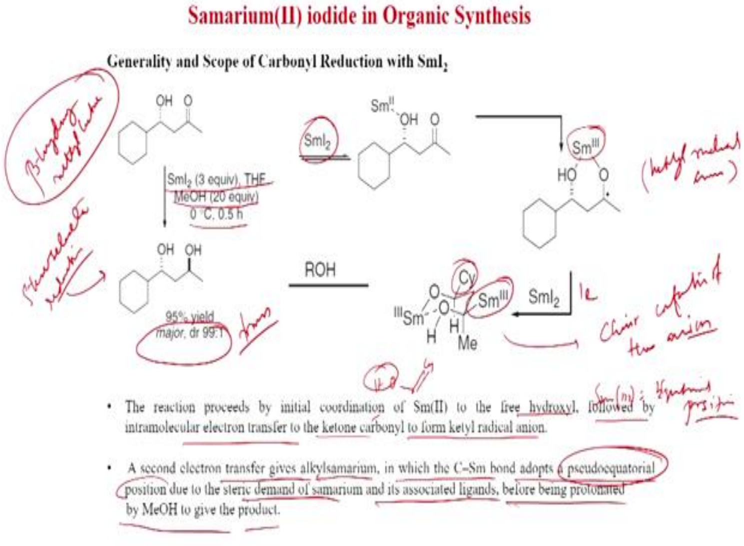

Samarium(II) iodide in Organic Synthesis

Generality and Scope of Carbonyl Reduction with SmI_2

- The reaction proceeds by initial coordination of Sm(II) to the free hydroxyl, followed by intramolecular electron transfer to the ketone carbonyl to form ketyl radical anion.
- A second electron transfer gives alkylsamarium, in which the C–Sm bond adopts a pseudoequatorial position due to the steric demand of samarium and its associated ligands, before being protonated by MeOH to give the product.

Now we will see the generality and the scope of carbonyl reduction with samarium iodide. This is beta hydroxy ketone. Now whether we know that the hydroxy group is important. Hydroxy group binds a samarium that we have seen in the cyclopropanation reaction samarium CH2I2. Here we will see the samarium iodide mediate a reduction 0 degree centigrade. Here also this hydroxy group binding because you get a diastereomeric product greater than 99 is to 1 that means the hydroxy group is binding and then the stereoselective so this means the stereoselective reduction is happening here.

So what could be the mechanism of this, so samarium I2 first reacts with OH and then it is making reduction, then the ketyl radical is forming and now the samarium III will coordinate with OH as well as the, this oxygen. And now it will take chair confirmation of the anion. So after one electron reduction you get the anion and then this anion means there samarium will come. Then cyclohexyl will be like this and samarium III will take an equatorial position, samarium III equatorial position. And methyl is here, and this oxygen and the OH is coordinating with another molecule of samarium. And here you can see this cyclohexyl and methyl are in the opposite side and here it will give first this alcohol of course, this OH here.

And then if you draw a zigzag because and then here this OH are in the same side but after you make this methyl here then they will be trans, so this is trans. The reaction proceeds by initial coordination of samarium II to the free hydroxyl, followed by intramolecular electron transfer to the ketone carbonyl to form ketyl radical anion, so this is the ketyl radical anion. A second electron transfer gives alkyl samarium, in which C-samarium bond adopts a pseudo equatorial position due to the steric demand of samarium and its associated ligands, before being protonated by methanol to give the product. So this is very important the chair confirmation.

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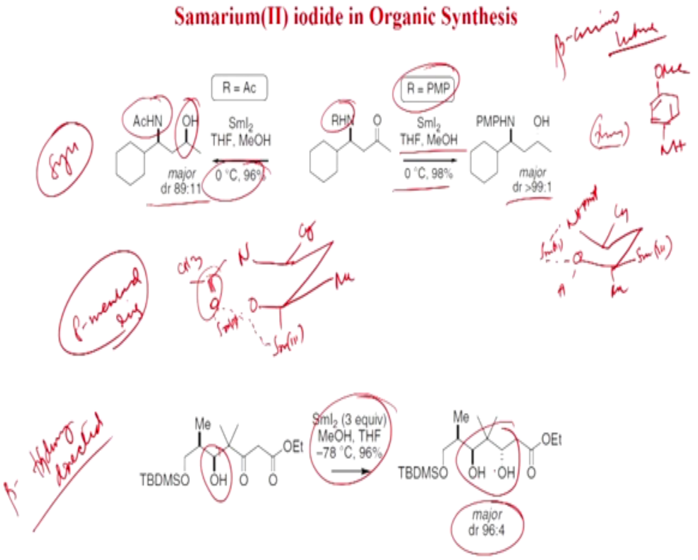

Samarium(II) iodide in Organic Synthesis

Now if you have a amine, so this is beta amino ketone, then if it is a PMP group. So PMP is here paramethoxy phenyl. So this is the PMP. So NHPMP that means here NH is there, then you get the similar like hydroxy ketone you get the trans and major diastereomer is had the 99 is to 1. So under the similar conditions, samarium iodide THF methanol 0 degree centigrade you get 98 percent yield of this product. So here also we can think that similar like earlier we have seen that for the hydroxy ketone here also this NHPMP that will coordinate with the samarium. Here methyl, this coordination will happen with NHPMP that is why you get this similar selectivity greater than 99 is to 1.

On the other hand if R is equal to acetyl and interestingly they are now syn, so syn is major here. And you get 96 percent yield under same condition then the diastereomeric ratio is almost 9 is to 1. So what is happening here, so this is cyclohexyl and what happens here 8 member ring is form because this N shows this amide carbonyl bond that is coordinated with samarium III and also this somehow this samarium takes an pseudo axial position because of this coordination and methyl stays here.

So that is why you get a different geometry here. So this is an 8 member ring. So it is quiet flexible because of this coordination may be this also coordination is samarium III because this is very much nucleophilic this wants to coordinate samarium and then this to samarium wants to stay close by or close to the amide carbonyl and that is why you get this geometry. Also hydroxy directed so this is hydroxy directed, we have already seen one. Beta hydroxy ketone, so here you can see this is the trans is forming here that is obtain also 96 is to 4 on the samarium iodide III equivalent methanol THF minus 78 degree centigrade, 96 percent yield.

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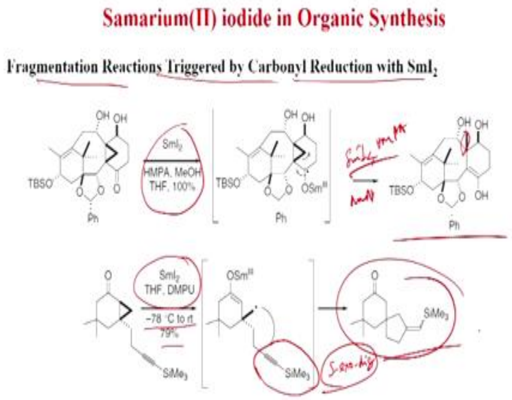

Samarium(II) iodide in Organic Synthesis

Fragmentation Reactions Triggered by Carbonyl Reduction with SmI_2

Now we will see fragmentation reactions triggered by carbonyl reduction with samarium iodide like here if you have a ketone with cyclopropyl group alpha beta position then this cyclopropyl group can be clipped because we know this is the radical chemistry here happening like samarium iodide HMPA methanol it will give this radical anion, this radical then will clip this cyclopropyl group and you get this.

So enol will form you can see here this radical going here and after quenching again of course samarium will come, samarium iodide and the methanol then you get this enol. So this methyl is coming from the cyclopropyl group, so this is very important if your ketone has a cyclopropyl group then there is a chance to break the cyclopropyl group. Also here this samarium iodide THF DMPU minus 78 degree centigrade to room temperature you get 79 percent yield of this product. So similarly here this radical anion will make the enolate and here this radical will form and then radical will react again with this triple bond because nicely it is fitted because 5 exo-dig will happen and you get exo cyclic olefin here.

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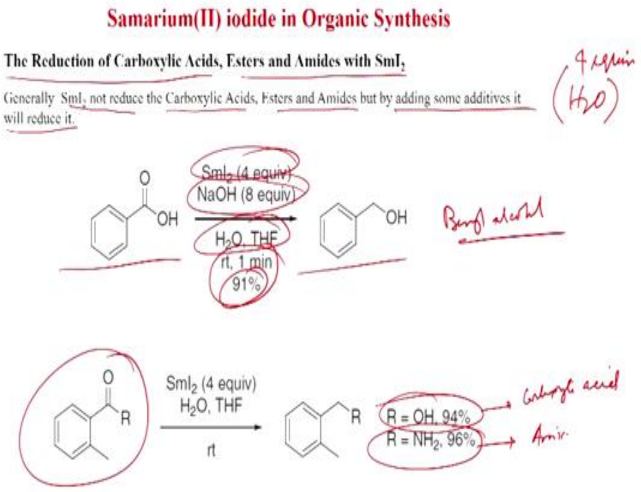

Samarium(II) iodide in Organic Synthesis

The Reduction of Carboxylic Acids, Esters and Amides with SmI_2

Generally SmI_2 not reduce the Carboxylic Acids, Esters and Amides but by adding some additives it will reduce it.

Now we will see, so far we have seen that carbonyl group like ketone can be reduced in presence of ester. Now we will see that under which condition the reduction of carboxylic acids, esters and amides with samarium iodide is possible. So generally samarium iodide not reduce the carboxylic acids, esters and amides but by adding some additives it will reduce it. Add generally water you have to add every 4 equivalent of water that we will see. Like here benzoic acid also base is added here, samarium iodide 4 equivalent sodium hydroxide 8 equivalent H2O THF solvent mixed at room temperature 1 minute so this is very fast reaction you get 91 percent yield of this benzyl alcohol. Here base is not added, so if you have a R is equal to OH that is the carboxylic acid only methyl will be present. And R is equal to NH2 so this is carboxylic acid and this is amide.

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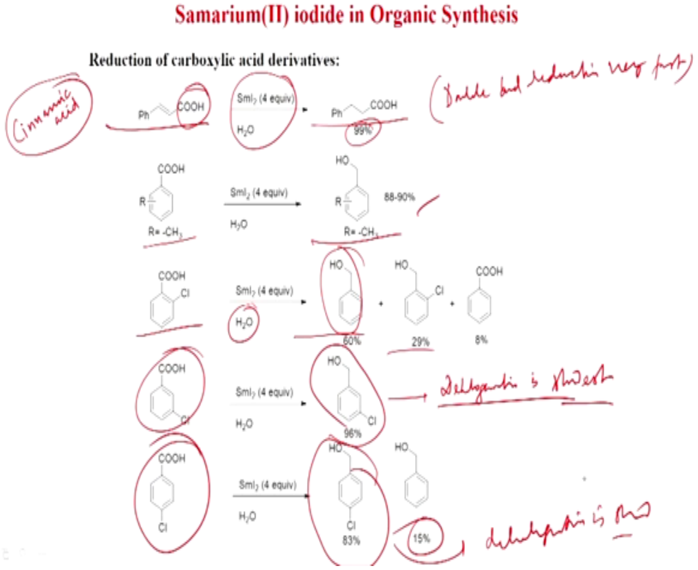

Samarium(II) iodide in Organic Synthesis

Reduction of carboxylic acid derivatives:

We will see some more example so with cinnamic acid, this is very important if you have a alpha beta unsaturated acid like cinnamic acid with samarium iodide 4 equivalent water also if you add a double bond only is reduced. So double bond reduction is very fast, very fast, because double bond is conjugated with this electron withdrawing group and you get this hydrocinnamic acid in 99 percent yield. Also benzoic acid derivative we have already seen in the benzyl alcohol will form like here orthochloro also.

Sometimes chlorine group can be eliminated like here you get this is the major chlorine because we know that samarium iodide can also reacts the aryl chloride under strong condition because water is added reactivity increased so you can get the dechlorination also. Here meta case also you do not get this. So here dehalogenation is slow. Ortho case because ortho is close to the electron withdrawing group but meta case it is quite fast. So it does not happen. Also para cases also you can see this slow, the dehalogenation is slow but you get some product, 15 percent you get. So meta case is best. Dehalogenation is slowest here actually.

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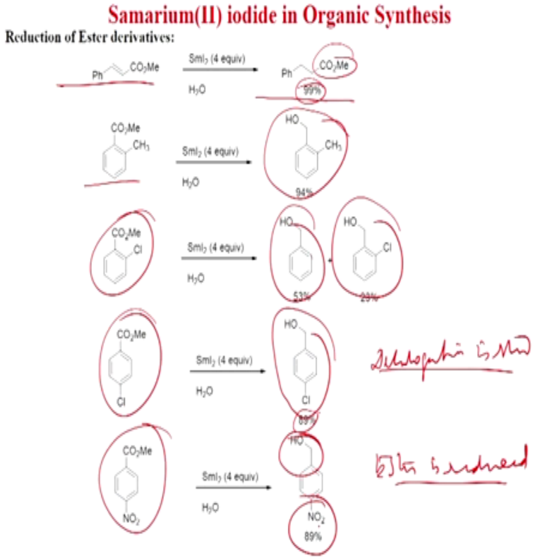

Samarium(II) iodide in Organic Synthesis

Reduction of Ester derivatives:

Now we will see the esters here also like acid the double bond reduction is fast. So here this methyl hydrocinnamate is formed in 99 percent yield and the ester group did not reduce here. Here this methyl, ester goes to alcohol with ortho-chloro similarly here 53 percent is dehalogenation, 23 percent is with para chloro, this is major 89 percent you get this with para-chloro, so dehalogenation is slow, dehalogenation is slow and this is very important; a nitro and CO2ME group is there. So with samarium iodide selectively the ester is reduced. So ester is reduced compared to nitro. So nitro is untouched here you get 89 percent yield of this product.

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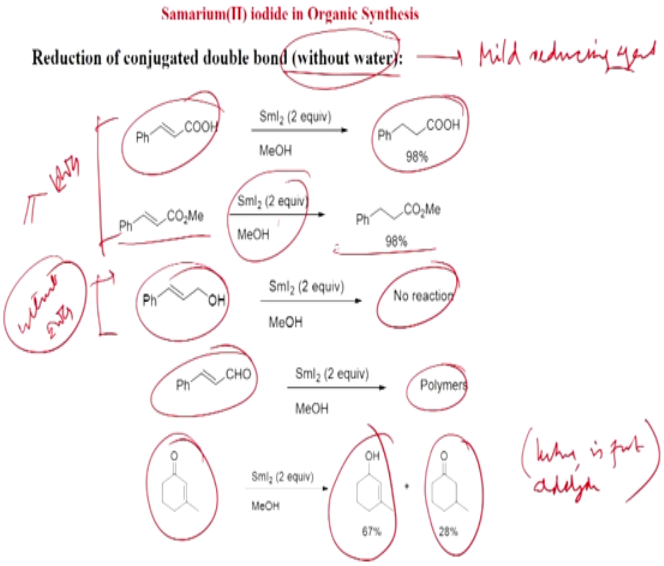

And without water this is mild reducing agent, so mild reducing agent. And Kagan already shown earlier also the cinnamic acid can be reduced the double bond so these are the EWG so olefin is connected with EWG then the double bond can be reduced like ester also just samarium iodide 2 equivalent methanol you can get this, so without EWG. Without EWG, that is the cinnamyl alcohol the no reaction of the double bond.

So double bond which is conjugated with the electron withdrawing group then only the reduction will happen like cinnamyl alcohol the reaction did not happen also with cinnamaldehyde you get polymers because here the both is competitive, the double bond as well as the aldehyde group that is why you get polymers. And with cyclohexanone you can get the ketone reduction with fast also here, 67 percent yield of this one and double bond reduction you get 28 percent yield. So ketone reduction, ketone is fast. Ketone, aldehyde is fast compared to double bonds.

So today in the reaction we have first discussed samarium mediated cyclopropanation reaction, we have seen samarium CH2I2 and we have seen different allylic alcohols can be done cyclopropanation in highly diastereoselective as well as regioselective manner. So if have other olefin then that olefin does not react only allylic olefin. Then we have seen this cyclopropanol chemistry first we have seen the alpha bromo ketone because it is going by the enolate, samarium enolate is forming and then the carbenoid is reacting with this double bond and you get the cyclopropanol.

Then we have seen that the enolate if we can form the enolate from the ketone then also this cyclopropanol formation is happening and we have seen that you can generate thermodynamic or kinetic enolate. The kinetic enolate at low temperature you have to generate and then you can get the kinetically stable cyclopropanol and on the other hand at high temperature like room temperature you can get the thermodynamic enolate and you can get the thermodynamically stable cyclopropanol. Then we have seen that the esters, tertiary amides and acid chloride when reacting with this samarium CH2I2 then also this cyclopropanol formation is happening.

So there also the alpha iodo ketone is forming and that is generating the enolate and reacting with extra samarium CH2I2 to generate the cyclopropanol. Also we have seen if you have a aromatic 1, 4 ketone then the cleavage happens the C-C bond and you generate the enolate again and you get the cyclopropanol. Then we have seen the samarium iodide chemistry as samarium iodide we have seen that this is very useful for dehalogenation reaction because it is one electron reduction. And different halides, aromatic halides also vinyl halides can be dehalogenated and you can get the corresponding alkene in high yield. Then we have seen the ketone reduction.

So ketone reduction is very important, here the ketyl radical is forming and then the ketyl anion and here we have seen the hydroxy directed that is very important, if you have a beta hydroxy ketone then we have seen the trans product is forming and also beta amino ketone with NHPMP that also gives trans on the other hand NHAc gives the syn product. Then we have seen the reductions of esters, amides and here we have seen that esters, amides can be reduced if you have water in the mixture and we have seen that these esters, different acids can be reduced to the alcohols.

Also we have seen if the cinnamic acid, cinnamic esters is there then the double bond reduction is much faster process than the reduction so only selectively the double bond is reduced. Also we have seen if you do not add the water then the reaction is very mild then in that case also the double bond can be reduced if it is connected with electron withdrawing group. Next cinnamyl alcohol the double bond is not reduced. Thank You.