Advanced Transition Metal Chemistry – Periodic Table
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Lecture – 9
Werner's Coordination Theory

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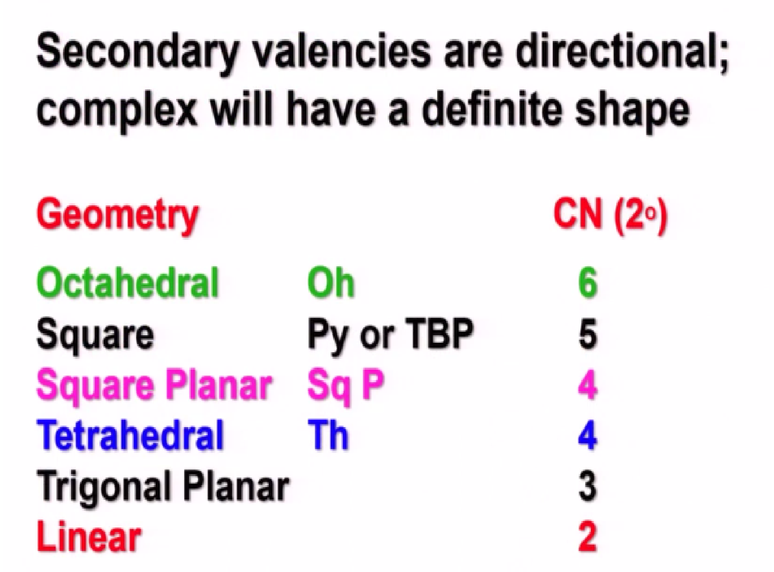

Secondary valencies are directional; complex will have a definite shape

Geometry		CN (2°)
Octahedral	Oh	6
Square	Py or TBP	5
Square Planar	Sq P	4
Tetrahedral	Th	4
Trigonal Planar		3
Linear		2

Welcome you all to MSB lecture series on advanced transition metal chemistry. In my previous lecture, I started discussion on coordination theory with a little bit of historical background and initiated discussion on Werner's coordination theory, so let me continue from where I had stopped. With his systematic experimental work and conductivity measurement, he established geometries for different coordination number, I would say secondary valency.

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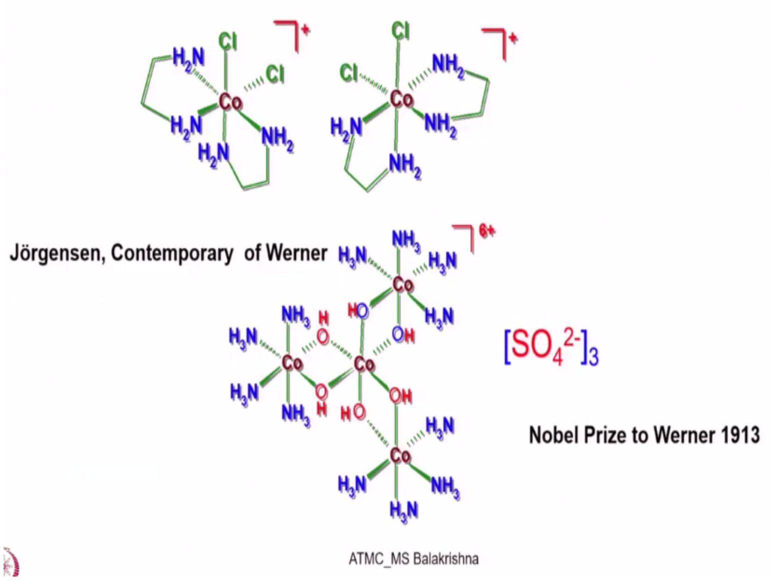

Jörgensen, Contemporary of Werner

$[SO_4^{2-}]_3$

Nobel Prize to Werner 1913

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And then he did not stop at this stage, he went on further to isolate these compounds and in fact he isolated these compounds where you can see two ethylenediamine bidentate ligands are there, and then these compounds showed optical properties. And when again, he presented his work, Jorgensen argued with him and he ridiculed making any optically active compound without having a chiral carbon.

So, he firmly believed that in order to have an optically active compound there must be a chiral carbon. So, he was more inclined towards organic chemistry understanding, although he was an excellent experimental inorganic chemist of that time. However, when he heard this kind of criticism, Werner, he took this as a challenge and he made this compound, here, you can see, here. He made this octahedral compound.

In this one, there is no carbon ligand at all. So, you have only OH and ammonia is there. He made this compound and he separated both the optical isomers D and L. And then when it was shown eventually people started respecting Werner's coordination theory, and after establishment of optical activity of this compound without having a carbon and they started appreciating his theory, and now people thought that coordination theory is complete.

And eventually he was given Nobel Prize in 1913. It is a very interesting molecule, first of its kind, you can see this is optically active compound. Of course, later optically active compounds were made with trisethylenediamine complexes, and all those things, but this one without having a carbon atom.

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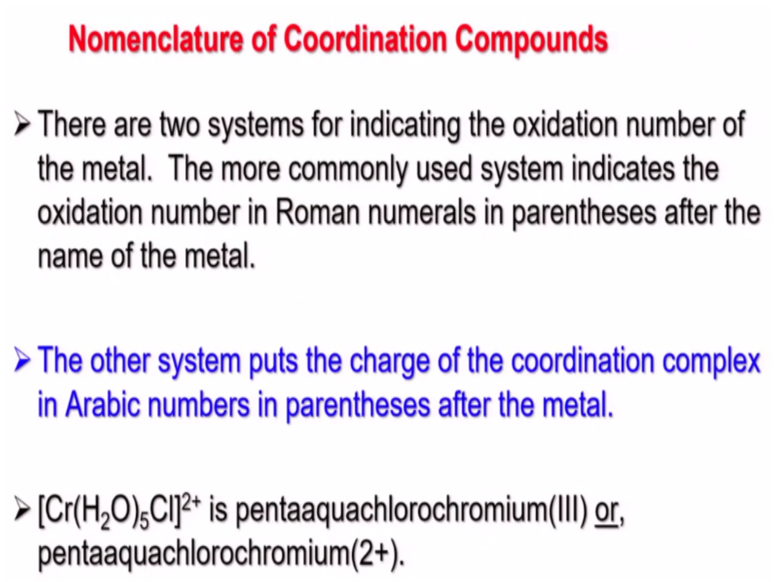

Nomenclature of Coordination Compounds

- There are two systems for indicating the oxidation number of the metal. The more commonly used system indicates the oxidation number in Roman numerals in parentheses after the name of the metal.
- The other system puts the charge of the coordination complex in Arabic numbers in parentheses after the metal.
- $[Cr(H_2O)_5Cl]^{2+}$ is pentaaquachlorochromium(III) <u>or</u>, pentaaquachlorochromium(2+).

Now, let us come to the nomenclature of coordination compounds. There are two systems for indicating the oxidation number of the metal. The more commonly user system indicates the oxidation number in Roman numerals in parentheses after the name of the metal or you can take the symbol and put superscript in the form of Arabic number with plus or minus denoting whether it is cation or anion.

For example, chromium 2+, cobalt 3+ or something. Also, one can use cobalt in the bracket Roman numerals indicating its oxidation state, both are in the practice. The other system puts the charge of the coordination complex in Arabic numbers in parenthesis after the metal, something like this. Something like this, one can use or something like this, one can use. It appears to me, this is more appropriate rather than writing like this, and this should be used only when we are using a symbol.

And even when you are expanding any element like chromium, then it should again come in Roman numerals in the bracket. And here writing full name of an element and putting 2+ as a superscript also does not look good, this is the correct practice.

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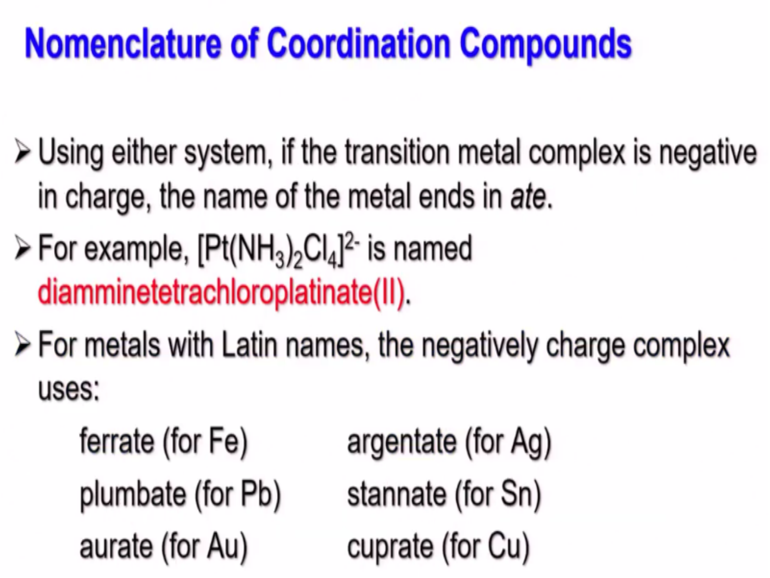

Nomenclature of Coordination Compounds

- Using either system, if the transition metal complex is negative in charge, the name of the metal ends in *ate*.
- For example, $[Pt(NH_3)_2Cl_4]^{2-}$ is named diamminetetrachloroplatinate(II).
- For metals with Latin names, the negatively charge complex uses:

ferrate (for Fe)
plumbate (for Pb)
aurate (for Au)
argentate (for Ag)
stannate (for Sn)
cuprate (for Cu)

So, using either system, if the transition meal or complex is negative in charge, the name of the metal ends in ate. So that means, if we have an anionic complex, the name of the metal is pronounced at the end, ending with the term "ate". For example, if you take this one, this is an anionic compound because platinum is in +2 state and diamine-tetrachloroplatinate. So, in this one this is named as diamine tetrachloroplatinate, because it is anion.

If it is neutral or cationic compound, then simply we should use that term the way it is. For metals with Latin names, the negative charge complex uses ferrate, for example, when it is an anionic complex, for the following, the name we should use is given here. For iron we should use ferrate, for lead we should use plumbate, for gold we should use aurate, for silver we should argentate, for tin stannate and copper cuprate. And of course, palladium palladate, platinum platinate we use, cobalt cobaltate, iridium iridate; so it continues like that.

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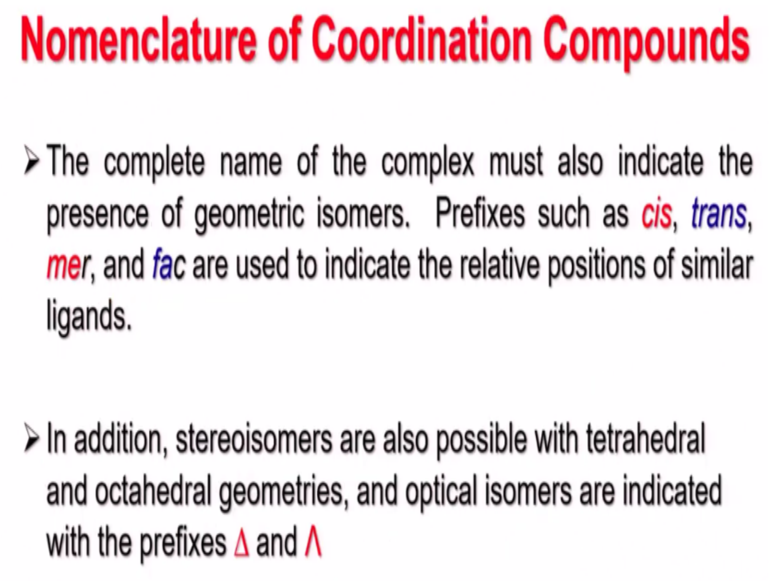

Nomenclature of Coordination Compounds

- The complete name of the complex must also indicate the presence of geometric isomers. Prefixes such as *cis*, *trans*, *mer*, and *fac* are used to indicate the relative positions of similar ligands.
- In addition, stereoisomers are also possible with tetrahedral and octahedral geometries, and optical isomers are indicated with the prefixes Δ and Λ

The complete name of the complex must also indicate the presence of geometric isomers. Let us have different ligands present on a metal and if that is the case and if there is a possibility of seeing more than one isomer then the name given should also indicate the type of isomer we are talking about. Then the prefixes such as cis, trans, meridional or facial should be included in the front of the complex, when we write it.

In addition, stereoisomer is also possible with the tetrahedral and octahedral geometries. In that case, there is a possibility of optical isomerism. Then optical isomers also should be represented in the name by using prefixes something like this. So, one should use these symbols in front of optical isomers to denote the nature of the isomer.

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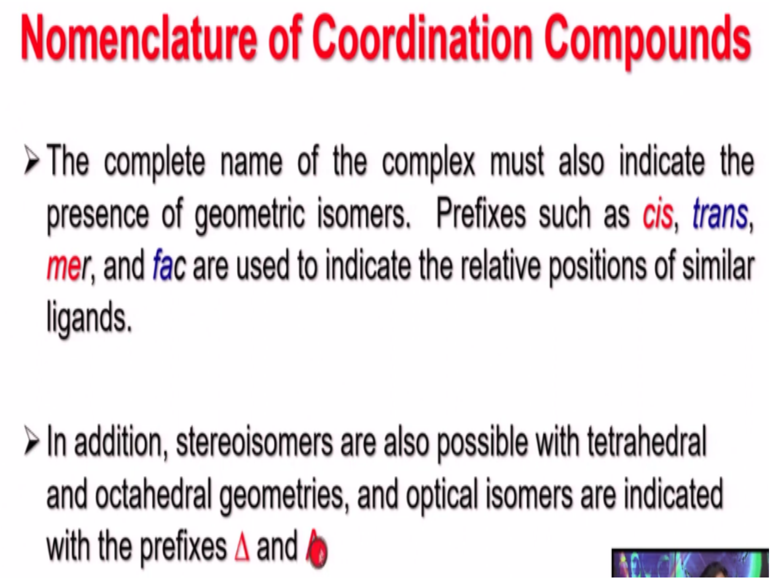

Nomenclature of Coordination Compounds

- The complete name of the complex must also indicate the presence of geometric isomers. Prefixes such as *cis*, *trans*, *mer*, and *fac* are used to indicate the relative positions of similar ligands.
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And if you have bridging ligands that bridges two metal centres, one should use that “mu” (μ) here and of course when a ligand is bridging two metal centres it is obvious that minimum two are needed when the ligand acts as a bridging ligand, in that one, there is no need to put any subscript 2 here, although if you put subscript 2 nothing wrong with it (μ_2), but without subscript also one can write, that indicates this ligand is bridging two metal centres.

In case, if the ligand is bridging three metal centres, then mu3 (μ_3) should be there where 3 is the subscript. So, mu3 (μ_3-) hyphen we should write in the complex formula. And if chelating bidentate ligands are there in a complex, then they have to be denoted using your prefix eta2 (η^2) and of course eta 2 is not used now, kappa 2 (κ^2) is used, eta 2 was earlier used for bidentate ligand making connection to the same metal and for a tridentate ligand making connection to the same metal is eta 3 (η^3) or tetradentate ligand all, 4 donor atoms are binding to the same metal is called eta 4 (η^4).

And if 5 donor atoms are emerging from a ligand and going to the metal then eta 5 (η^5), etc., for example cyclopentadienyl. So, when we have olefinic ligands eta (η) symbol makes sense because it mentions hapticity, whereas in other conventional ligands, if they are bridging non-olefinic ligands it is better to use kappa (κ) rather than eta.

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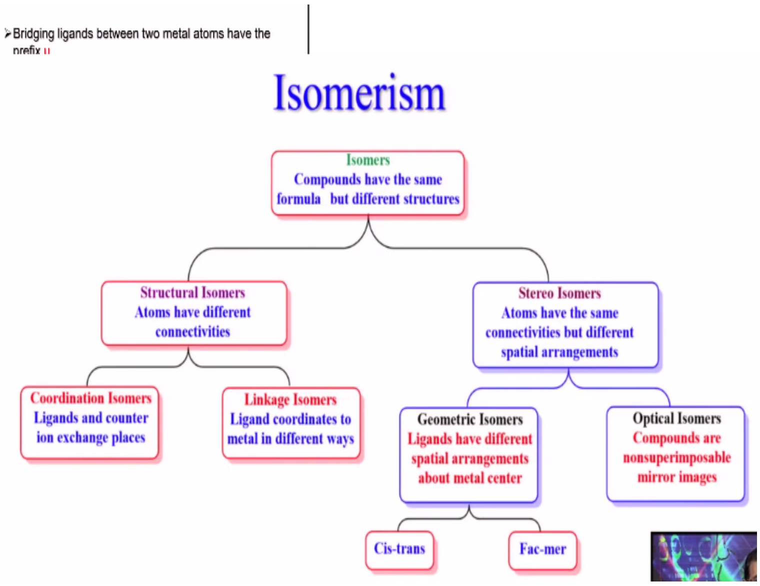

➢Bridging ligands between two metal atoms have the prefix μ

Isomerism

Isomers
Compounds have the same formula but different structures

Structural Isomers
Atoms have different connectivities

Stereo Isomers
Atoms have the same connectivities but different spatial arrangements

Coordination Isomers
Ligands and counter ion exchange places

Linkage Isomers
Ligand coordinates to metal in different ways

Geometric Isomers
Ligands have different spatial arrangements about metal center

Optical Isomers
Compounds are nonsuperimposable mirror images

Cis-trans

Fac-mer

Now, let us look into isomerism. And you know that isomers are nothing but compounds have the same formula, but different structures. So, again these isomers can be classified into two types of compounds, one is structural isomers, another one is stereo isomers. In the structural isomers we end up with lots of isomers, here atoms have different connectivities. That means, you can also have coordination isomers and linkage isomers.

And in the coordination isomers, ligands and counterions exchange places, whereas in linkage isomers, ligand coordinates to metal in different ways. That means you have a ligand having more than one type of donor atom in it, in that case what happens, either of the donor atoms can bind resulting in linkage isomerism. For example, if you take NO_2 group either N can coordinate to the metal centre or O can establish a link to the metal, so nitrito or nitro we call them.

Similarly, we come across the stereo isomers, here atoms have the same connectivity but different spatial arrangement. Stereo isomers, atoms have the same connectivities but different spatial arrangements are there. For example, MA_2B_2 is there. In that case, what happens, two As can be opposite to each other or of the same side, so, that results in geometric isomers. That means ligands have different spatial arrangements about metal centre.

In that case, we can have cis and trans geometries, especially in case of square planar complexes and also in case of octahedral complexes. Then we have MA_2B_2 in case of square planar complexes, and MA_4B_2 or MA_2B_4 in case of octahedral complexes, we come across the central isomers, whereas in case of octahedral compounds when we have MA_4B_2 or MA_2B_4, we have cis and trans isomers.

Similarly, when we have MA_3B_3, we end up with having two isomers which are called facial and meridional. In facial all the three ligands are in the same face, whereas in meridional all are in different face. Then, if the compounds are nonsuperimposable mirror images, then we call them as optical isomers.

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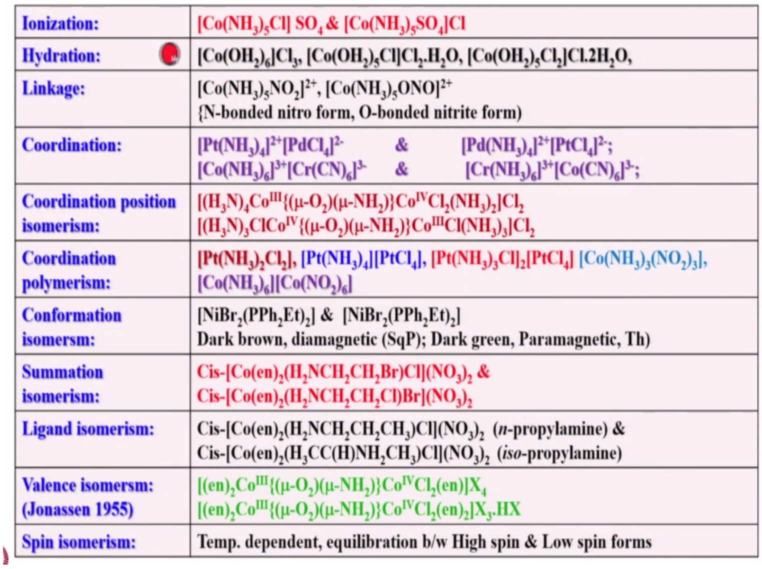

Ionization:	$[Co(NH_3)_5Cl]\ SO_4$ & $[Co(NH_3)_5SO_4]Cl$
Hydration:	$[Co(OH_2)_6]Cl_3$, $[Co(OH_2)_5Cl]Cl_2.H_2O$, $[Co(OH_2)_5Cl_2]Cl.2H_2O$,
Linkage:	$[Co(NH_3)_5NO_2]^{2+}$, $[Co(NH_3)_5ONO]^{2+}$ {N-bonded nitro form, O-bonded nitrite form)
Coordination:	$[Pt(NH_3)_4]^{2+}[PdCl_4]^{2-}$ & $[Pd(NH_3)_4]^{2+}[PtCl_4]^{2-}$; $[Co(NH_3)_6]^{3+}[Cr(CN)_6]^{3-}$ & $[Cr(NH_3)_6]^{3+}[Co(CN)_6]^{3-}$;
Coordination position isomerism:	$[(H_3N)_4Co^{III}\{(\mu\text{-}O_2)(\mu\text{-}NH_2)\}Co^{IV}Cl_2(NH_3)_2]Cl_2$ $[(H_3N)_3ClCo^{IV}\{(\mu\text{-}O_2)(\mu\text{-}NH_2)\}Co^{III}Cl(NH_3)_3]Cl_2$
Coordination polymerism:	$[Pt(NH_3)_2Cl_2]$, $[Pt(NH_3)_4][PtCl_4]$, $[Pt(NH_3)_3Cl]_2[PtCl_4]$ $[Co(NH_3)_3(NO_2)_3]$, $[Co(NH_3)_6][Co(NO_2)_6]$
Conformation isomersm:	$[NiBr_2(PPh_2Et)_2]$ & $[NiBr_2(PPh_2Et)_2]$ Dark brown, diamagnetic (SqP); Dark green, Paramagnetic, Th)
Summation isomerism:	Cis-$[Co(en)_2(H_2NCH_2CH_2Br)Cl](NO_3)_2$ & Cis-$[Co(en)_2(H_2NCH_2CH_2Cl)Br](NO_3)_2$
Ligand isomerism:	Cis-$[Co(en)_2(H_2NCH_2CH_2CH_3)Cl](NO_3)_2$ (*n*-propylamine) & Cis-$[Co(en)_2(H_3CC(H)NH_2CH_3)Cl](NO_3)_2$ (*iso*-propylamine)
Valence isomersm: (Jonassen 1955)	$[(en)_2Co^{III}\{(\mu\text{-}O_2)(\mu\text{-}NH_2)\}Co^{IV}Cl_2(en)]X_4$ $[(en)_2Co^{III}\{(\mu\text{-}O_2)(\mu\text{-}NH_2)\}Co^{IV}Cl_2(en)_2]X_3.HX$
Spin isomerism:	Temp. dependent, equilibration b/w High spin & Low spin forms

I have given some examples for various isomerism. The first one is ionization isomerism. You can see here in case of ionization isomerism, what we have is: chloride, is secondary valency and sulfate is primary valency, whereas in this one, other isomer, sulfate is secondary valency, whereas chloride is primary valency. In hydration, we can have several isomers. For example, you take first one hexaaqua cobalt 3 chloride and in this one, 6 water molecules are secondary valency.

Whereas in this one, the second one, the composition is same, we have 6 water molecules and 3 chlorides, but they change their positions. In this one, 5 water molecules are inside of the secondary valency, and one chloride is there, whereas here we have 2 chlorides outside and water of hydration is there. And in this case, we have 4 water molecules are there inside, and 2 chlorides are there, one chloride is primary valency and 2 water molecules are hydrated.

So, that means here it should be 4, read it as 4. Linkage isomerism as I mentioned when we have two donor atoms in a ligand either of them can bind at a time. So, here in this one if the nitrogen is bonded, you can call nitro form, and if the oxygen is bonded O we can call O-nitrate, nitrito or N-nitro, one can mention like this, so you have linkage isomerism. We also come across linkage isomerism in case of NCS where either N can coordinate to the metal or S can coordinate to the metal.

And coordination isomerism, so here if you see, we have one cation and one anion and if you just look into the ratio: one platinum, one palladium is there, and 4 ammonia and 4 chlorides are there and the composition remains same in these complexes, but here cation is a platinum compound and anion is a palladium compound, whereas here palladium is a cationic component, and platinum is an anionic compound.

So, this is coordination isomerism. Similarly, we come across in case of octahedral compounds also, we have hexammine cobalt 3+, a cation and hexacyanochromate as a counter anion, whereas here hexammine chromium 3+ is a cation, whereas here hexacyanocobaltate is the anion. So, they are coordination isomers. And coordination position isomers will come into picture where we can see cobalt 3 here, and cobalt 4 is there, and cobalt 4 is here, and cobalt 3 is here.

Rest is more or less same or there may be some change depending upon the change of oxidation state, anionic ligands may take different positions. So, this is called coordination position isomerism. Then coordination polymerism, again here we consider this diamino-dichloroplatinum. So, if you just look into it 1 platinum, 2 amines, 2 chlorides; composition is 1 : 2 : 2.

And now we have a combination of cationic and anionic compounds here, and again if you see, two metals are there and 4 ammonias, 4 chlorides mean again the composition remains same, this is coordination polymorphism and same thing is observed in rest of these complexes as well. And then conformation isomerism. Conformation isomerism can be seen exclusively in case of nickel d^8 system.

Some compounds can exist in tetrahedral geometry and the same compound can exist in a square planar geometry. For example, if you take dibromobisdiphenylethanephosphine complex this can show both square planar and tetrahedral geometry. So, dark brown, diamagnetic square planar and dark green, paramagnetic, tetrahedral. So, this is called conformation isomerism.

And summation isomerism, here you can see the number of constituent ligands remains the same, the composition remains the same. And if you take here, we have taken is the bromoethylamine, we have taken chloroethylamine, but when bromo is there chloride is in secondary valency, when chlorine is there, bromide is secondary valency, that means this is called summation isomerism. And the ligand isomerism is also there.

In case of ligand isomerism, you can take, like normal propylamine is there, and here iso propylamine is there. So, in this case what happens? You see, ligand isomerism is there. And valence isomerism was proposed by Jonassen in 1955, he was one of the students of Jorgensen. And here you can see the valence isomerism, here valency varies in this one. And then spin isomerism is also shown in complexes wherever the magnetism is temperature dependent.

Sometime what happens, with temperature high spin complex become low spin complex, and low spin complex become high spin complex when it is cold, this is called spin isomerism. That means we have several isomerization processes, and some examples are there in each case.

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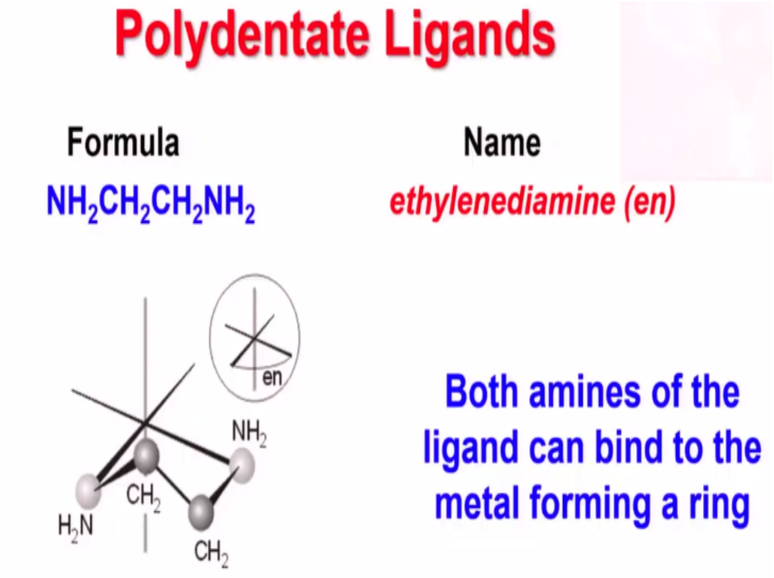

Polydentate Ligands

Formula	Name
$NH_2CH_2CH_2NH_2$	*ethylenediamine (en)*

Both amines of the ligand can bind to the metal forming a ring

When we go to polydentate ligands, a typical example is ethylenediamine. Both the amines of the ligand can bind to the same metal forming a ring. So, this is called chelate ring and then many polydentate ligands having longer chain capable of donating all the donor atoms binding or establishing bond with the donor atoms to the same metal, then they are called chelate ligands and such compounds are called chelate compounds or chelate complexes.

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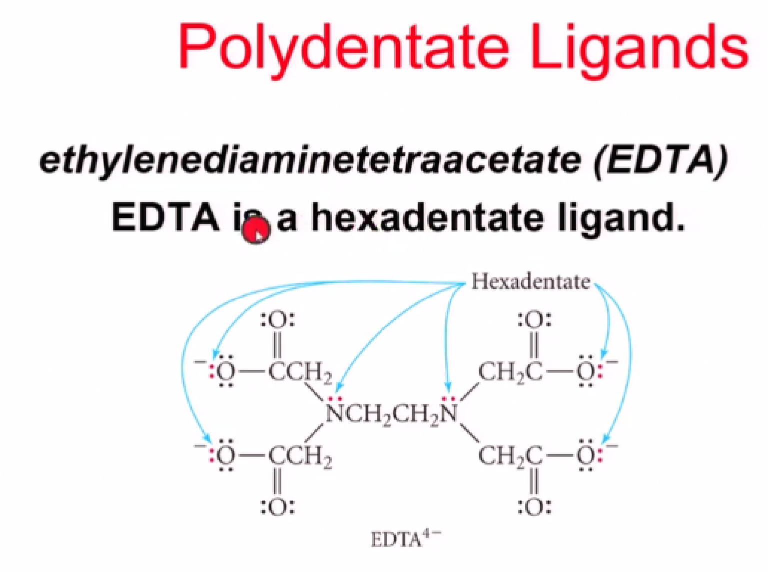

Polydentate Ligands

ethylenediaminetetraacetate (EDTA)

EDTA is a hexadentate ligand.

A typical example for polydentate ligand is hexadentate ligand EDTA. EDTA abbreviation expansion is ethylenediaminetetraacetic acid and then, if it is anionic then it is called tetraacetate. So, you can see EDTA^{4-} and here 2 nitrogen are there and 4 carboxylate ions will be establishing and it forms stable complexes with most of the transition elements and also some of the main group elements.

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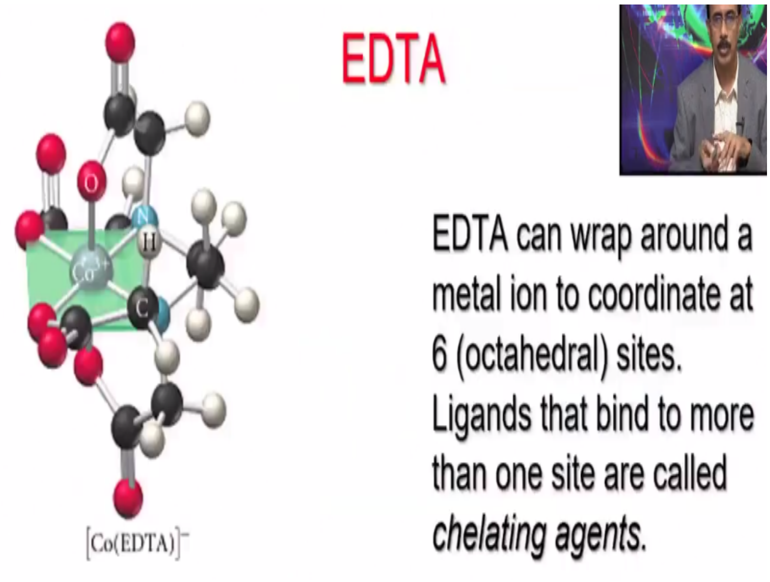

EDTA

EDTA can wrap around a metal ion to coordinate at 6 (octahedral) sites. Ligands that bind to more than one site are called *chelating agents.*

So, EDTA can wrap around the metal ion to coordinate at 6 coordination sites. Ligands that bind to more than one site are called chelating ligands.

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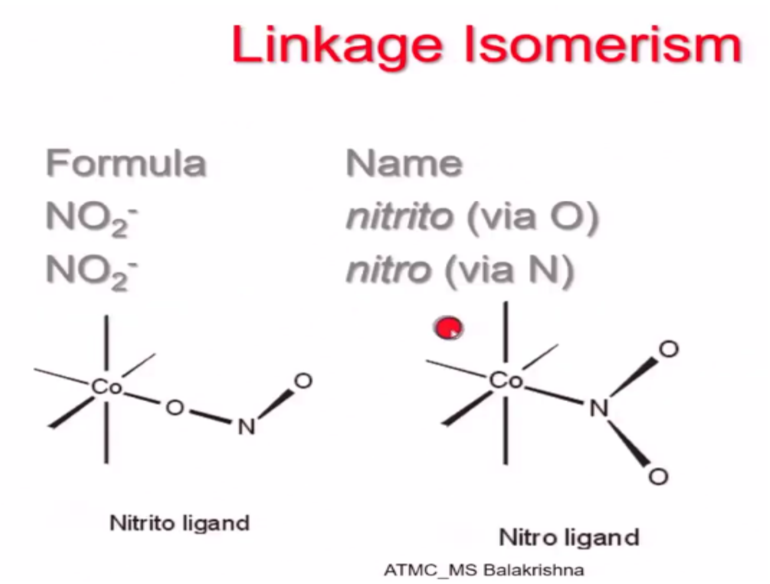

Linkage Isomerism

Formula	Name
NO_2^-	*nitrito* (via O)
NO_2^-	*nitro* (via N)

Nitrito ligand

Nitro ligand

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On linkage isomerism, I had mentioned, for example if you take this NO_2^-, when it is binding by oxygen we call nitrito. So, that means, the moment the ligand's name is pronounced as nitrito you should assume that, in this one, in NO_2^- oxygen is connected to the metal ion and not nitrogen. And when the nitrogen is coordinated, simply use the term nitro that indicates it is the N that is coordinating to metal, not the either oxygen atoms.

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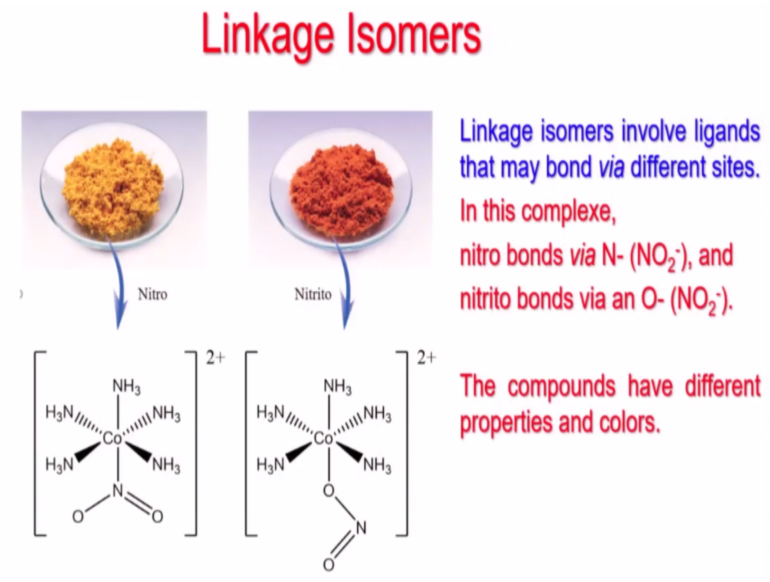

Linkage Isomers

Linkage isomers involve ligands that may bond *via* different sites.

In this complexe,

nitro bonds *via* N- (NO_2^-), and

nitrito bonds via an O- (NO_2^-).

The compounds have different properties and colors.

Linkage isomerism involves ligands that may bond via different sites. Again, I showed you in the previous slide, that I have written the structures here and one interesting thing is these compounds have different properties and also colours, you can see. When nitro is there, where nitrogen is coordinated, it is orange yellow in colour, and this one is orange red or something like that.

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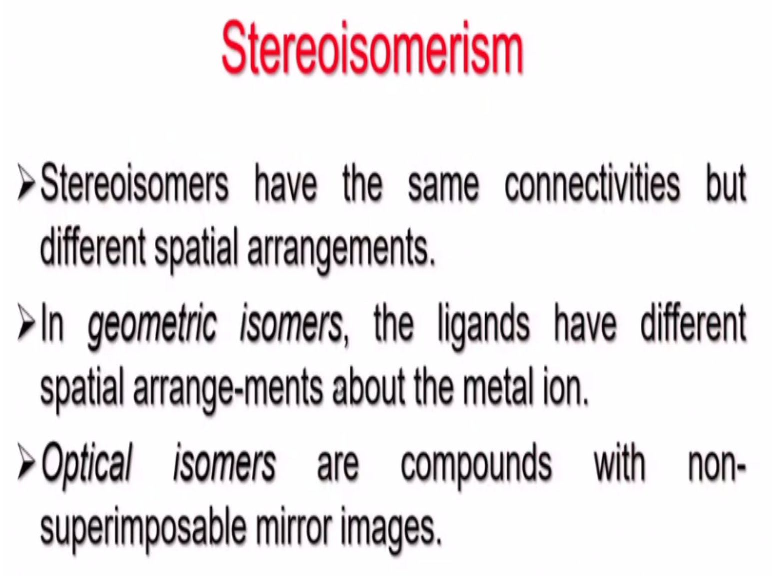

Stereoisomerism

- Stereoisomers have the same connectivities but different spatial arrangements.
- In *geometric isomers*, the ligands have different spatial arrange-ments about the metal ion.
- *Optical isomers* are compounds with non-superimposable mirror images.

And stereoisomerism, stereoisomers have the same connectivities but different spatial arrangements. In geometric isomers, the ligands have different spatial arrangements about the metal ion. Optical isomers are compounds with nonsuperimposable mirror images, they come under stereoisomerism.

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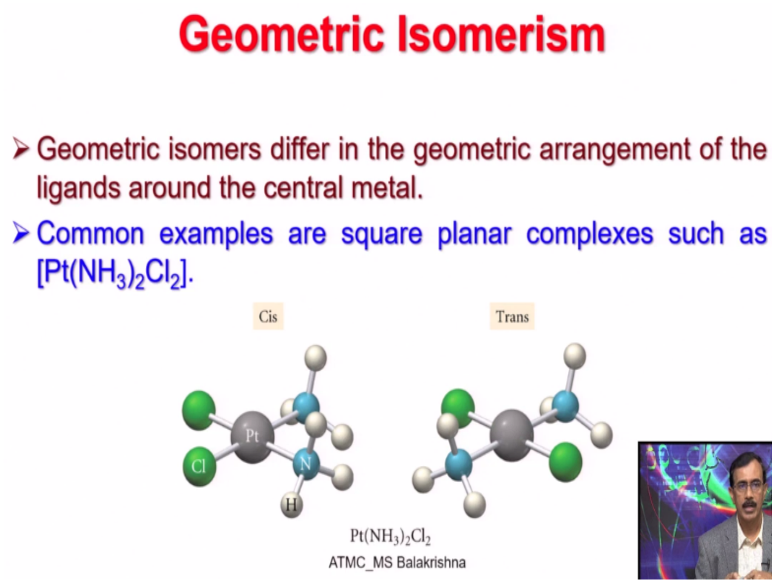

Geometric Isomerism

- Geometric isomers differ in the geometric arrangement of the ligands around the central metal.
- Common examples are square planar complexes such as $[Pt(NH_3)_2Cl_2]$.

$Pt(NH_3)_2Cl_2$

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And geometric isomerism; geometric isomers differ in the geometric arrangement of the ligands around the central metal as I already mentioned. For example, you consider this diaminedichloroplatinum, when two amines are cis to each other, we call it cisplatin and when they are trans to each other, we call that transplatin. So, that means this compound exhibits geometric isomerism, and cis and trans compounds can be separated or they can be prepared using different methods.

And of course, very nicely, trans effect was used, again Werner used the trans effect to make these isomers in their pure form starting from appropriate metal complexes. In one case, he used a tetraammonium platinum compound, in another case tetrachloroplatinate he used. I shall tell you about trans effect and preparation of different isomers using trans effect at later stage.

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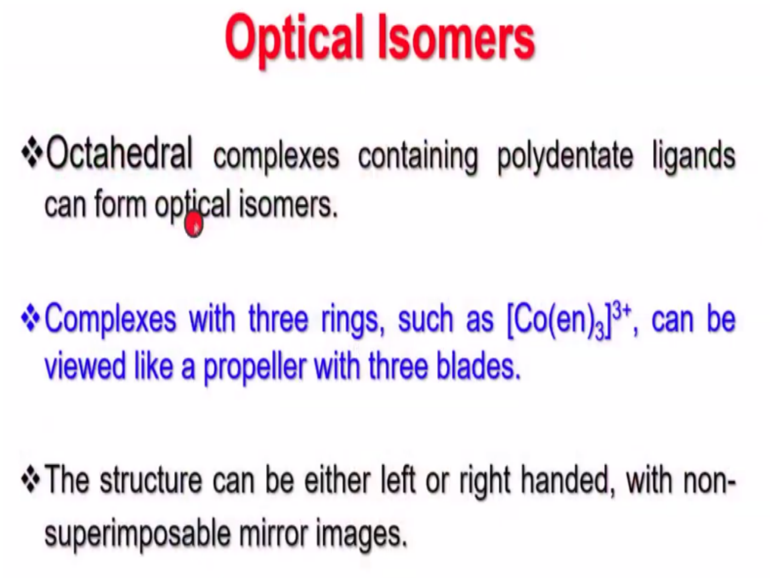

Optical Isomers

❖Octahedral complexes containing polydentate ligands can form optical isomers.

❖Complexes with three rings, such as $[Co(en)_3]^{3+}$, can be viewed like a propeller with three blades.

❖The structure can be either left or right handed, with non-superimposable mirror images.

Optical isomers; octahedral complexes containing polydentate ligands can also form optical isomers. Complexes with three rings, three bidentate ligands, for example ethylenediamine is there in this compound three ethylenediamines are having bond to cobalt in generating tris ethylenediamine cobalt 3+ compound. So, it can be viewed like a propeller with the three blades. The structure can be either left or right-handed with nonsuperimposable mirror images.

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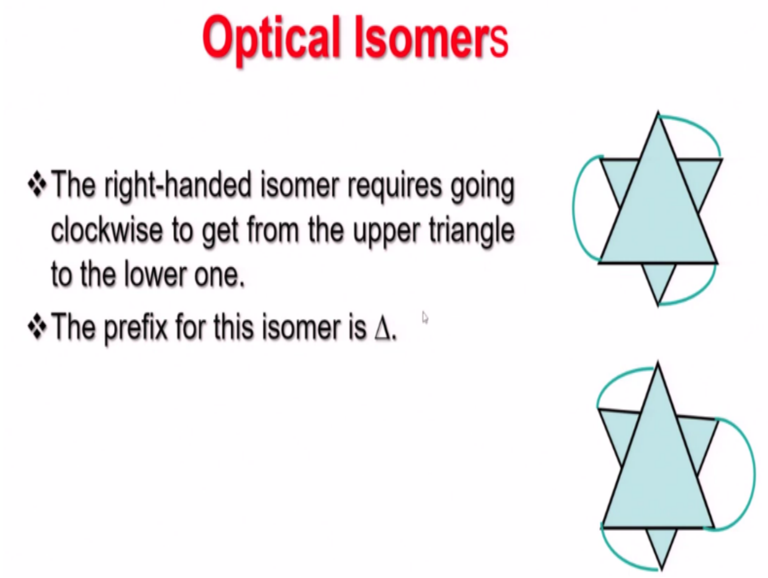

Optical Isomers

- ❖The right-handed isomer requires going clockwise to get from the upper triangle to the lower one.
- ❖The prefix for this isomer is Δ.

I have shown here, something like this. Then the right-handed isomer requires going clockwise to get from the upper triangle to the lower triangle. So, that means if you start tilting this one, basically what happens, it comes to this one. The prefix for this isomer is given as Δ, something like this. You should remember that right-handed isomer you just take this one and do clockwise rotation, one rotation and then you will end up with this one. So, in that case what happens, you should give a prefix del Δ.

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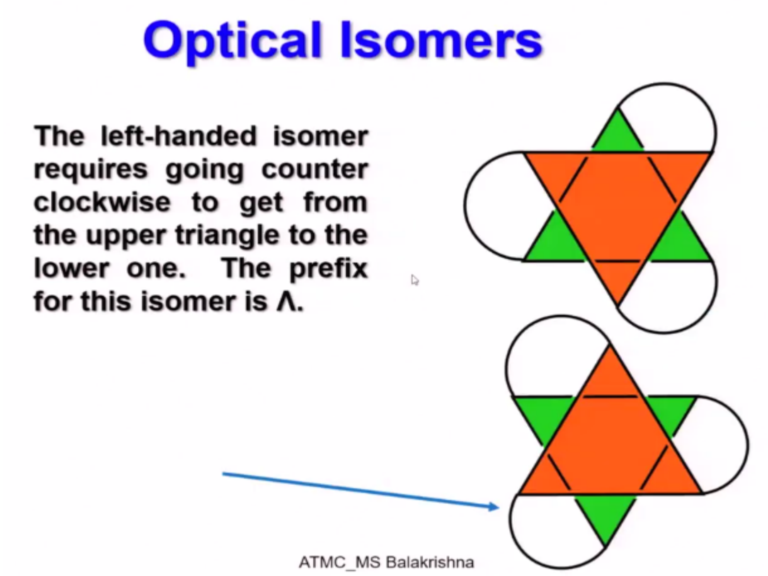

Optical Isomers

The left-handed isomer requires going counter clockwise to get from the upper triangle to the lower one. The prefix for this isomer is Λ.

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On the other hand, a left-handed isomer requires going counter clockwise to get from the upper triangle to the lower one. For example, instead of doing clockwise rotation, perform anticlockwise rotation and then for this one, the prefix for this isomer is “inverse Δ”. So, this is how you can distinguish between two optical isomers among coordination complex.

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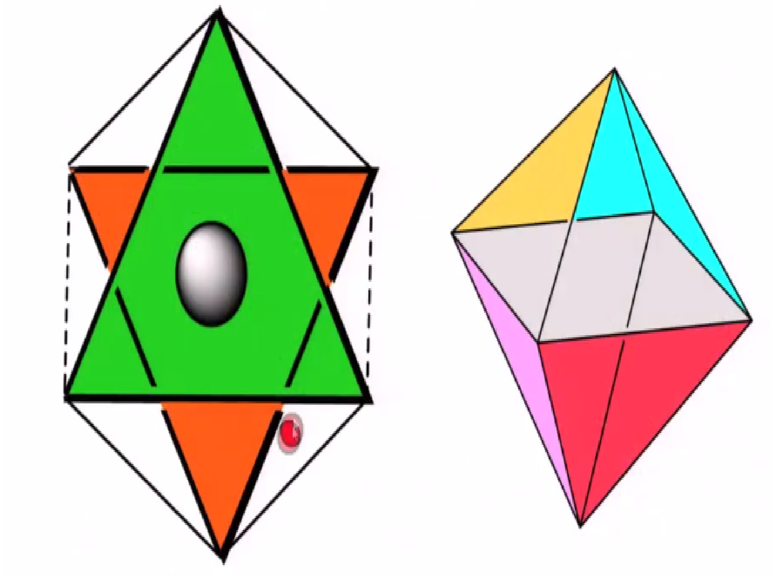

And this is a typical octahedral compound.

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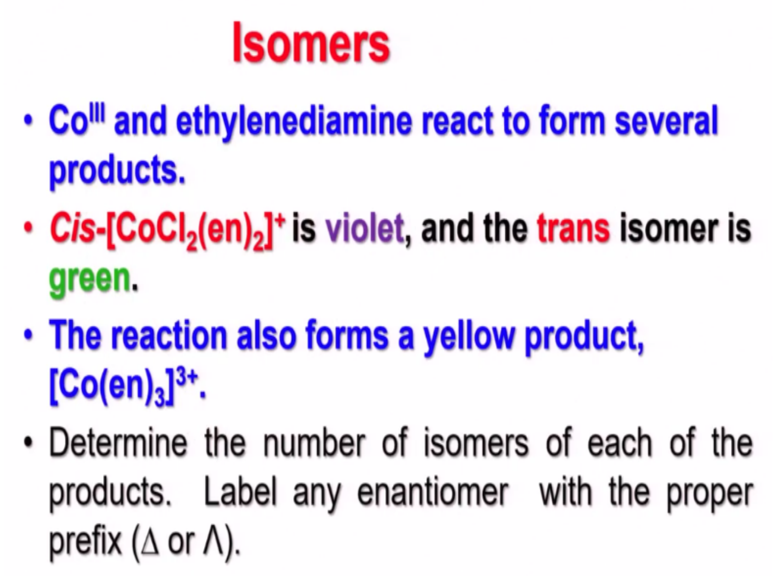

Isomers

- Co^{III} and ethylenediamine react to form several products.
- *Cis*-$[CoCl_2(en)_2]^+$ is violet, and the trans isomer is green.
- The reaction also forms a yellow product, $[Co(en)_3]^{3+}$.
- Determine the number of isomers of each of the products. Label any enantiomer with the proper prefix (Δ or Λ).

Let us look into some isomers. Cobalt 3 when it is treated with ethylenediamine it can react in different forms and several products can be formed. One such compound having 2 ethylenediamine 2 chloride in the secondary valency is violet and the trans isomer is green. So, that means when you are making this one, obviously, say, there is a possibility of formation of trans compound and the trans compound is green, whereas cis compound is violet.

When you are using excess ethylenediamine the reaction also results in the formation of a yellow product having this composition where we have trisethylenediamine cobalt 3+. So, if I ask you to write all possible isomers in this reaction, you should be able to write all possible

So, determine the number of isomers of each of the products, label any enantiomer with the proper prefix either this or that one, whether you make clockwise or anticlockwise rotation.

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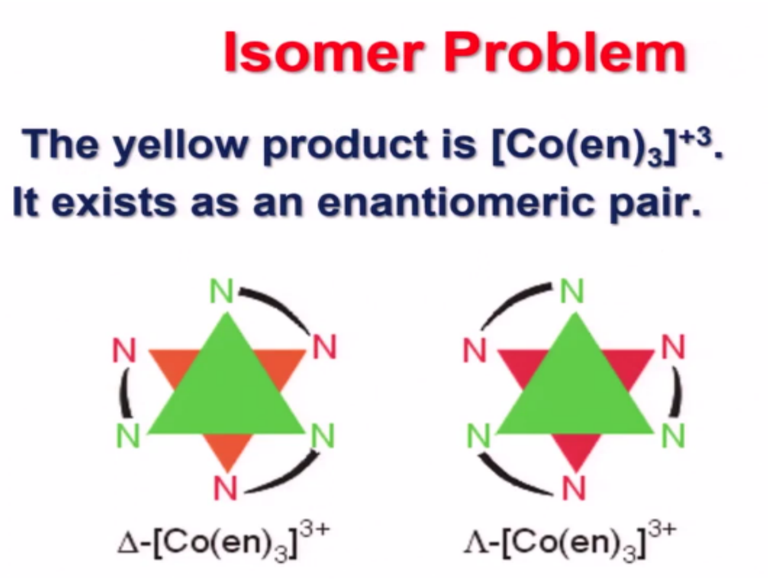

Isomer Problem

The yellow product is $[Co(en)_3]^{+3}$.
It exists as an enantiomeric pair.

Δ-$[Co(en)_3]^{3+}$ Λ-$[Co(en)_3]^{3+}$

The first one is the yellow product: this one tris ethylenediamine. So, of course once when you write this one, you will come to know that there is a possibility of writing another nonsuperimposable mirror image of this one, so we have this one. So, these two are; that means this one gives two isomers and besides giving one geometric isomer, one of them can be geometric isomer as well.

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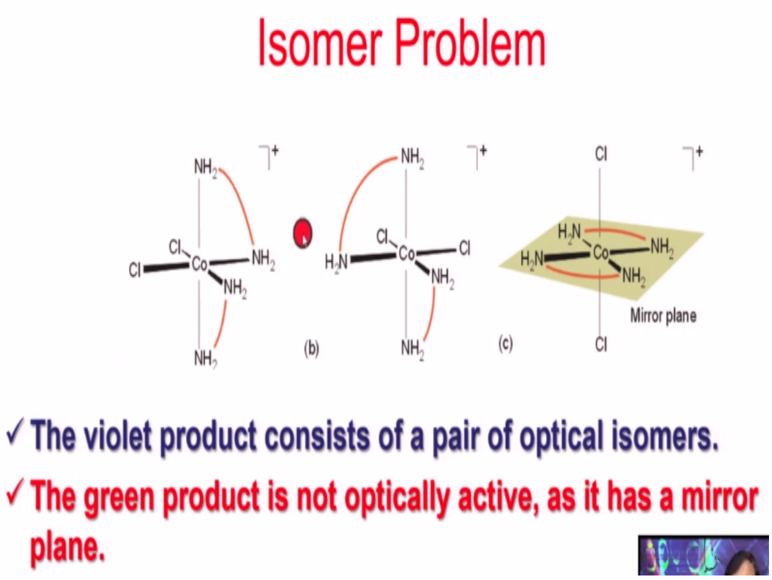

Isomer Problem

✓ The violet product consists of a pair of optical isomers.

✓ The green product is not optically active, as it has a mirror plane.

And then when you go for this one having 2 ethylenediamine 2 chlorides, there is a possibility of having two isomers here. So, one trans isomer, one cis isomer and the cis isomer can also exhibit optical isomerism having non-superimposed mirror images, something like this. So, that means, violet product consists of a pair of optical isomers and then the green product is not optically active because it has a mirror plane.

So, that means, we have 1, 2, 3 isomers are there, and with trisethylenediamine, we have two more isomers. So, totally when you interact cobalt 3 chloride with ethylenediamine there is a possibility of making 5 isomers.

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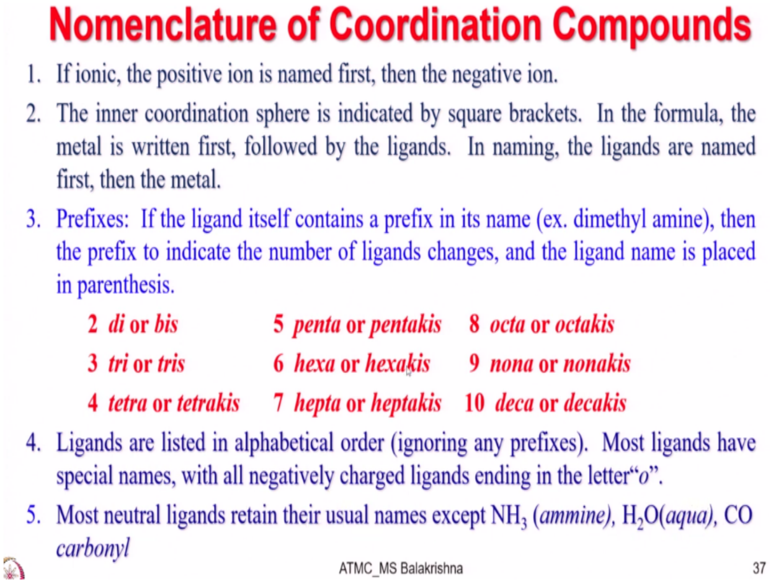

Nomenclature of Coordination Compounds

1. If ionic, the positive ion is named first, then the negative ion.
2. The inner coordination sphere is indicated by square brackets. In the formula, the metal is written first, followed by the ligands. In naming, the ligands are named first, then the metal.
3. Prefixes: If the ligand itself contains a prefix in its name (ex. dimethyl amine), then the prefix to indicate the number of ligands changes, and the ligand name is placed in parenthesis.

2 *di* or *bis*	5 *penta* or *pentakis*	8 *octa* or *octakis*
3 *tri* or *tris*	6 *hexa* or *hexakis*	9 *nona* or *nonakis*
4 *tetra* or *tetrakis*	7 *hepta* or *heptakis*	10 *deca* or *decakis*

4. Ligands are listed in alphabetical order (ignoring any prefixes). Most ligands have special names, with all negatively charged ligands ending in the letter"*o*".
5. Most neutral ligands retain their usual names except NH_3 (*ammine*), H_2O(*aqua*), CO *carbonyl*

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So, before I conclude this lecture, let me bring to your attention the nomenclature of coordination compounds once again. You should remember these things and one thing you should remember now. Earlier convention was irrespective of nature, anion ligand first, neutral come second and then cationic ligands at the end, and then we used to bring the name of the metal.

So, now the convention is irrespective of the nature of the ligands, we should use only alphabetical order. The alphabetical order should be used while pronouncing or naming your complex. If ionic, the positive ion is named first, then the negative ion. You should remember if complex is ionic and if it is cationic, the positive ion is named first and then the negative ion at the end. And then the inner coordination sphere is indicated by square brackets.

While writing, we should remember: in the formula the metal is written first followed by the ligands and here does not matter whether we write in alphabetical order or not, does not matter, but metal should be returned first in the square bracket followed by the ligands. In naming, the ligands are named first, then the metal. In naming, the ligands are named first in alphabetical order irrespective of the nature of the ligands and then the metal.

If the ligand itself contains a prefix in its name, say dimethyl amine or triphenyl phosphine, then again if more than one is there, so then to avoid confusion, we should use a different kind of prefix to indicate the number of ligands, and also number of such atoms present or group present in the ligand itself and the ligand name is placed in parentheses. For example, dimethyl amine is there; in that case, if two ligands are there in the coordination sphere, then rather look odd to say di dimethyl amine, instead of you should say bis(dimethylamine).

So, that means, appropriate prefix should be used for them. For example, for 2 instead of di use bis and for 3 instead of using tri use a tris and then for 4 instead of tetra use tetrakis. For 5 use pentakis, for 6 hexakis, 7 hepatakis, 8 octakis, and 10 decakis. So, ligands are listed in alphabetical order ignoring any prefix. You should remember irrespective of how many ligands are there, the first letter of the ligands should be considered while labelling them or naming them in alphabetical order.

If aqua and ammine ligands are there, no matter how many aqua ligands, water ligands are there and how many ammonia are there irrespective of that, the one that comes first ammonia should come and then aqua should come. So this is how it should be named. And while naming, while considering the alphabetical order, ignore any prefixes that indicates the number of ligands present.

Most ligands have special names with all negatively charged ligands ending in the letter o. For example, chloro, bromo, iodo, something like that. The most neutral ligands retain their usual names except ammonia, for example ammonia we call ammine and water we call aqua and CO we call carbonyl.

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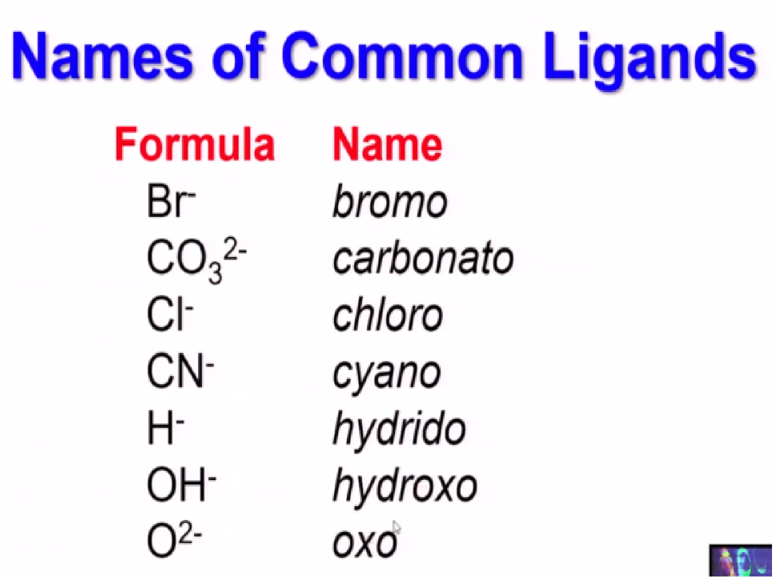

Names of Common Ligands

Formula	Name
Br^-	*bromo*
CO_3^{2-}	*carbonato*
Cl^-	*chloro*
CN^-	*cyano*
H^-	*hydrido*
OH^-	*hydroxo*
O^{2-}	*oxo*

So, the name of common ligands, I have listed here; bromo, carbonato, chloro, cyano, so H^- hydrido, OH^- hydroxo and O_2 oxo.

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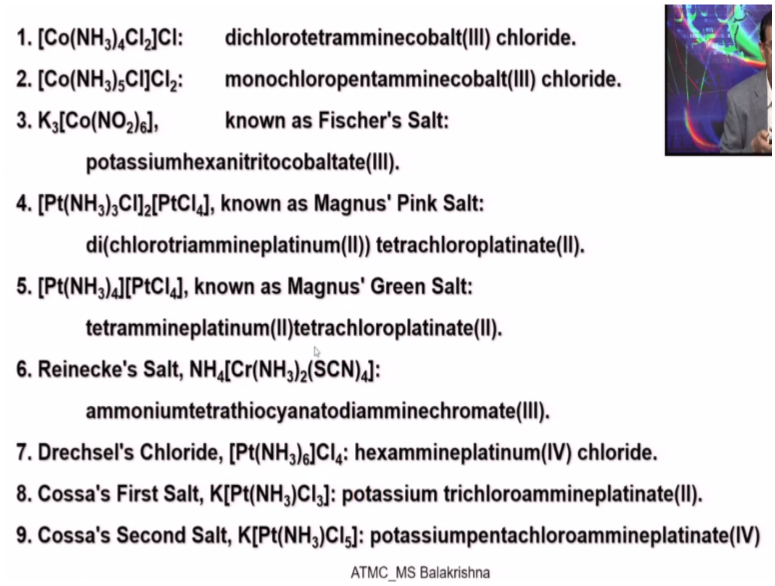

1. $[Co(NH_3)_4Cl_2]Cl$: dichlorotetramminecobalt(III) chloride.
2. $[Co(NH_3)_5Cl]Cl_2$: monochloropentamminecobalt(III) chloride.
3. $K_3[Co(NO_2)_6]$, known as Fischer's Salt: potassiumhexanitritocobaltate(III).
4. $[Pt(NH_3)_3Cl]_2[PtCl_4]$, known as Magnus' Pink Salt: di(chlorotriammineplatinum(II)) tetrachloroplatinate(II).
5. $[Pt(NH_3)_4][PtCl_4]$, known as Magnus' Green Salt: tetrammineplatinum(II)tetrachloroplatinate(II).
6. Reinecke's Salt, $NH_4[Cr(NH_3)_2(SCN)_4]$: ammoniumtetrathiocyanatodiamminechromate(III).
7. Drechsel's Chloride, $[Pt(NH_3)_6]Cl_4$: hexammineplatinum(IV) chloride.
8. Cossa's First Salt, $K[Pt(NH_3)Cl_3]$: potassium trichloroammineplatinate(II).
9. Cossa's Second Salt, $K[Pt(NH_3)Cl_5]$: potassiumpentachloroammineplatinate(IV)

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Some examples I have shown here to make you familiar with naming. Here you can see dichlorotetramminecobalt 3 chloride and here you should take monochloro or you can say monochloro or simply chloro, monochloro or chloro is fine, there is no need to indicate. When we write chloro, it obviously indicates that there only one chloride is there, so no need to put mono chloropentamminecobalt 3 chloride.

And here this is Fischer's salt, potassiumhexanitritocobaltate, nitrito means you should know that donor atom that is binding to the metal centre. And here in this one dichlorotriammineplatinum 2, tetrachloroplatinate 2. So, you have to say tetrachloroplatinate, anionic complex should come later. In this one Magnus' green salt tetrammineplatinum 2 and then tetrachloroplatinate minus.

So, similarly you can name these things and you can practice. Let me stop at this juncture. Continue talking about more interesting facts about coordination compounds in my next lecture. Until that have a wonderful time in reading and understanding chemistry.