

CH 3101 - 2025

July 2025						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

August 2025						
S	M	T	W	T	F	S
						2
3			6	7		9
10			13	14	15	16
17			20	21		23
24			27	28		30
31						

September 2025						
S	M	T	W	T	F	S
			3	4		6
7						8
14			17	18		20
21			24	25		27
28	29	30				

October 2025						
S	M	T	W	T	F	S
			1	2	3	4
5			8	9		11
12			15	16		18
19			22	23		25
26			29	30		

November 2025						
S	M	T	W	T	F	S
						1
2			5	6		8
9			12	13		15
16			19	20		22
23	24	25	26	27	28	29
30						

December 2025						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Syllabus

Nomenclature and isomerism: structures and isomers of coordination compounds

CFSE and Structural effects: Jahn-Teller Distortions,

Bonding in metal complexes: ML 4 and ML 6 MO types (sigma donor-pi donor, sigma donor, sigma donor-pi acceptor) Ligand Field Theory: Symmetry and Group Theoretical approach, spectrochemical series and its correlation to the MO diagram, metal carbonyl bonding, metal olefin bonding, MO diagram of Ferrocene, Metal-Metal Bond

Microstates, selection rule, Hund's rule, Orgel diagram, Tanabe-Sugano diagrams (1 L), Spin-states, Interpretation of Spectra d 1 -d 9 (Octahedral, Tetrahedral, high-spin, low spin, Charge-transfer Spectra,

Orbital and spin magnetic moments, spin only moments of d n ions and their correlation with effective magnetic moments, Curie law, para-ferro, anti-ferro and ferri-magnetic systems, Oxidation States and Structural trends, Representative compounds, Lanthanides and Actinides

Reaction mechanism of complexes: Inorganic Reaction Mechanisms, Ligand Substitution Reaction, Kinetics, Stereochemical aspects of Octahedral, Square-Planar complexes, Trans effect, Isomerization reactions, Inner-sphere reaction, Outer-sphere reaction, Marcus Equation, Robin-Day Classification, Electrophilic Substitutions, Photochemical reactions, Photochemistry of [Ru(bpy)₃]²⁺ and related complexes.

Transition metals

	1																	18
1	<div>1 H</div>	2											13	14	15	16	17	<div>2 He</div>
2	<div>3 Li</div>	<div>4 Be</div>											<div>5 B</div>	<div>6 C</div>	<div>7 N</div>	<div>8 O</div>	<div>9 F</div>	<div>10 Ne</div>
3	<div>11 Na</div>	<div>12 Mg</div>	3	4	5	6	7	8	9	10	11	12	<div>13 Al</div>	<div>14 Si</div>	<div>15 P</div>	<div>16 S</div>	<div>17 Cl</div>	<div>18 Ar</div>
4	<div>19 K</div>	<div>20 Ca</div>	<div>21 Sc</div>	<div>22 Ti</div>	<div>23 V</div>	<div>24 Cr</div>	<div>25 Mn</div>	<div>26 Fe</div>	<div>27 Co</div>	<div>28 Ni</div>	<div>29 Cu</div>	<div>30 Zn</div>	<div>31 Ga</div>	<div>32 Ge</div>	<div>33 As</div>	<div>34 Se</div>	<div>35 Br</div>	<div>36 Kr</div>
5	<div>37 Rb</div>	<div>38 Sr</div>	<div>39 Y</div>	<div>40 Zr</div>	<div>41 Nb</div>	<div>42 Mo</div>	<div>43 Tc</div>	<div>44 Ru</div>	<div>45 Rh</div>	<div>46 Pd</div>	<div>47 Ag</div>	<div>48 Cd</div>	<div>49 In</div>	<div>50 Sn</div>	<div>51 Sb</div>	<div>52 Te</div>	<div>53 I</div>	<div>54 Xe</div>
6	<div>55 Cs</div>	<div>56 Ba</div>	<div>*</div>	<div>72 Hf</div>	<div>73 Ta</div>	<div>74 W</div>	<div>75 Re</div>	<div>76 Os</div>	<div>77 Ir</div>	<div>78 Pt</div>	<div>79 Au</div>	<div>80 Hg</div>	<div>81 Tl</div>	<div>82 Pb</div>	<div>83 Bi</div>	<div>84 Po</div>	<div>85 At</div>	<div>86 Rn</div>
7	<div>87 Fr</div>	<div>88 Ra</div>	<div>**</div>	<div>104 Rf</div>	<div>105 Db</div>	<div>106 Sg</div>	<div>107 Bh</div>	<div>108 Hs</div>	<div>109 Mt</div>	<div>110 Ds</div>	<div>111 Rg</div>	<div>112 Cn</div>	<div>113 Nh</div>	<div>114 Fl</div>	<div>115 Mc</div>	<div>116 Lv</div>	<div>117 Ts</div>	<div>118 Og</div>
Lanthanides*			<div>57 La</div>	<div>58 Ce</div>	<div>59 Pr</div>	<div>60 Nd</div>	<div>61 Pm</div>	<div>62 Sm</div>	<div>63 Eu</div>	<div>64 Gd</div>	<div>65 Tb</div>	<div>66 Dy</div>	<div>67 Ho</div>	<div>68 Er</div>	<div>69 Tm</div>	<div>70 Yb</div>	<div>71 Lu</div>	
Actinides**			<div>89 Ac</div>	<div>90 Th</div>	<div>91 Pa</div>	<div>92 U</div>	<div>93 Np</div>	<div>94 Pu</div>	<div>95 Am</div>	<div>96 Cm</div>	<div>97 Bk</div>	<div>98 Cf</div>	<div>99 Es</div>	<div>100 Fm</div>	<div>101 Md</div>	<div>102 No</div>	<div>103 Lr</div>	

MARKS DISTRIBUTUION

$$\mathbf{70} + 30$$

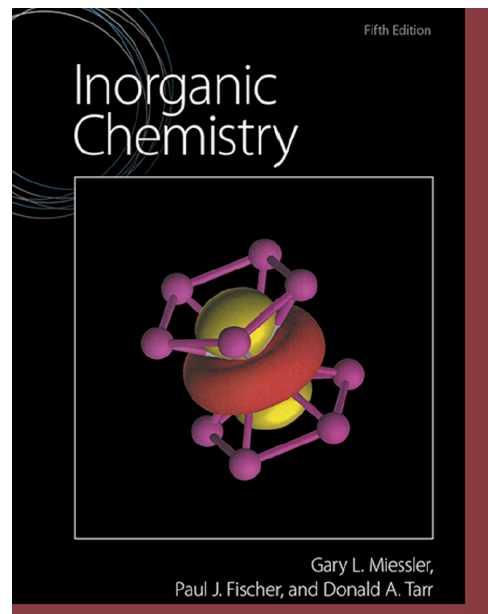
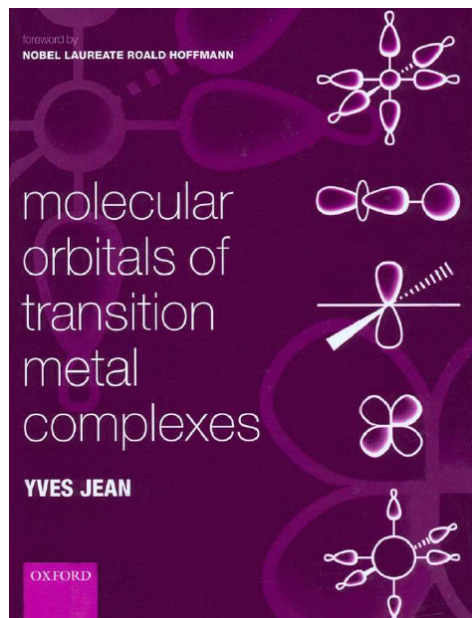
MID SEM(20) + END SEM (25)

+

3 Class Tests (each 20 Marks)

(Best two: 40 scaled down to (25))

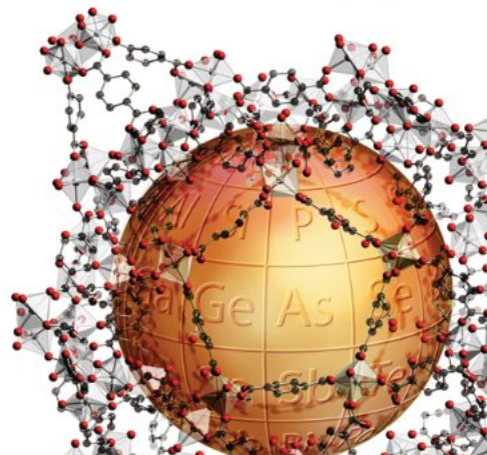
BOOKS



Shriver & Atkins'

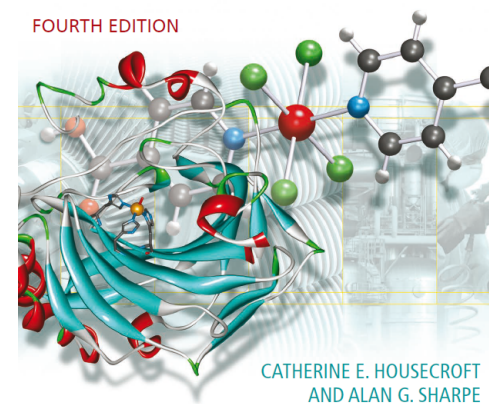
Inorganic Chemistry

Atkins • Overton • Rourke • Weller • Armstrong • Hagerman



INORGANIC CHEMISTRY

FOURTH EDITION



ALWAYS LEARNING

PEARSON

NOMENCLATURE

Metal

Ligand

Denticity

Bridging

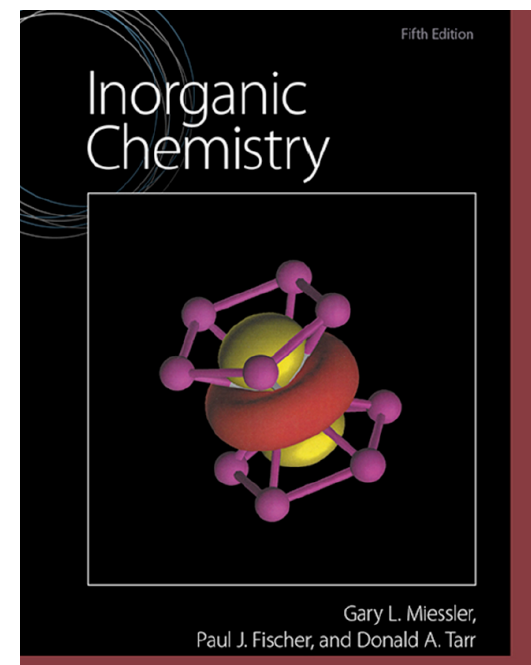


Table 7.7 Names and structures of selected ligands.

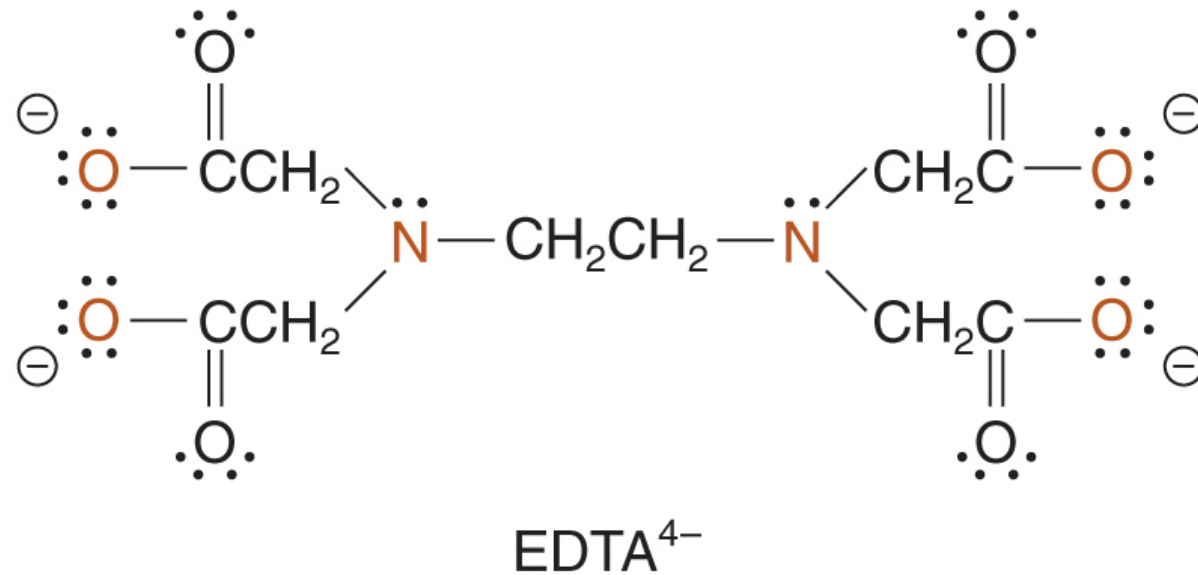
Name of ligand	Abbreviation (if any)	Denticity	Structure with donor atoms marked in red
Water		Monodentate	
Ammonia		Monodentate	
Tetrahydrofuran	THF	Monodentate	
Pyridine	py	Monodentate	
1,2-Ethanediamine [†]	en	Bidentate	
Dimethylsulfoxide	DMSO	Monodentate	

Acetylacetonate ion	[acac] [−]	Bidentate	
Oxalate or ethanedioate ion	[ox] ^{2−}	Bidentate	
2,2'-Bipyridine	bpy or bipy	Bidentate	
1,10-Phenanthroline	phen	Bidentate	
1,4,7-Triazaheptane [†]	dien	Tridentate	
1,4,7,10-Tetraazadecane [†]	trien	Tetradentate	
<i>N,N,N',N'</i> -Ethylenediaminetetraacetate ion [‡]	[EDTA] ^{4−}	Hexadentate	See eq. 7.75

Table 2.1 Naming of different numbers of donor groups bound to a single metal ion, with examples of typical simple linear ligands of each class.

No. bound donors	Ligand denticity	Examples of ligands (donor atoms highlighted in bold)
One	Monodentate	NH_3 OH_2 F^-
Two	Didentate	$\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ $\text{H}_2\text{N}-\text{CH}_2-\text{CO}-\text{O}^-$
Three	Tridentate	$\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ $^-\text{O}-\text{CO}-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CO}-\text{O}^-$ $\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{S}-\text{CO}-\text{CH}_2-\text{P}(\text{CH}_3)_2$
Four	Tetradentate	$\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ $^-\text{O}-\text{CO}-\text{CH}_2-\text{N}^--\text{CO}-\text{CH}_2-\text{N}^--\text{CO}-\text{CH}_2-\text{NH}_2$
Five	Pentadentate	$\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ $^-\text{O}-\text{CO}-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{S}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{O}^-$
Six	Hexadentate	$^-\text{O}-\text{CO}-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CH}_2-\text{CO}-\text{O}^-$

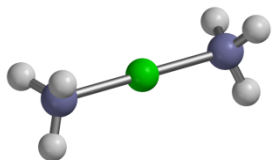
A **polydentate ligand** is a *chelating agent*,
complexes containing polydentate ligands:



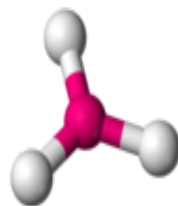
Ethylenediaminetetraacetate ion:
hexadentate ligand

Basic Structure of Metal – Ligand Complex

Monodentate Ligand



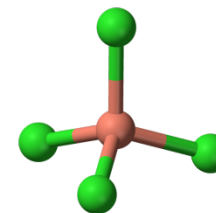
Coordination # 2 = linear
Rare for most metals;
common for d^{10} metal ions,
especially: Cu^+ , Ag^+ , Au^+ ,
and Hg^{2+}



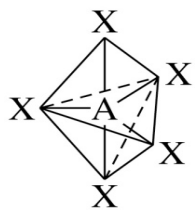
Coordination # 3
Encountered with d^{10} metal
ions e.g. Cu^+ & Hg^{2+}

Coordination # 4
Two common structures:
tetrahedral & **square planar**

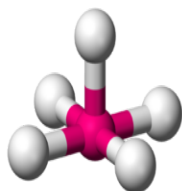
Tetrahedral: all 4-coordinate
complexes of
non-transition metals and d^{10} ions
and **first-row** transition metals,



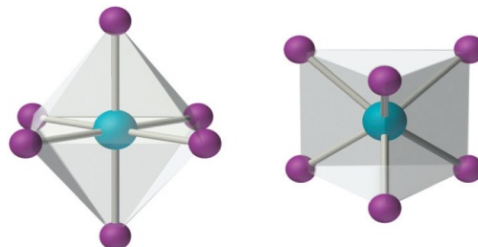
Coordination # 5
trigonal planar structure



Trigonal
bipyramidal

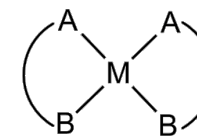
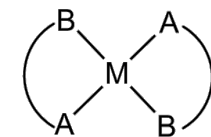


Coordination # 6
Most common: six ligands at
vertices of an **octahedron** or a
distorted octahedron.



Octahedral and trigonal prismatic ML_6

Square planar: 4-coordinate
complexes of
2nd & 3rd row **transition metals**
with d^8 e^- configurations,
e.g. Rh^+ , Pt^{2+} and Pd^{2+} ,
also encountered in some Ni^{2+}
& Cu^{2+} complexes

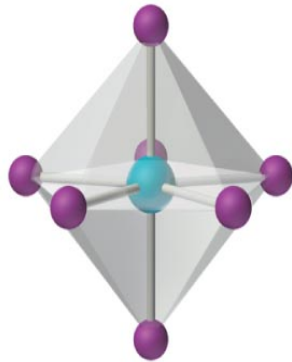


... and 2nd & 3rd row transition

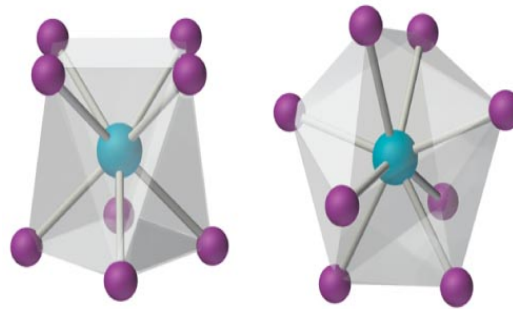
metals

7, 8 & 9

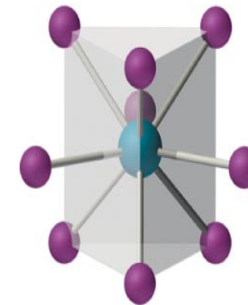
coordination #'s,
give other geometries



Pentagonal bipyramidal ML_7



Square antiprismatic and
trigonal dodecahedral ML_8

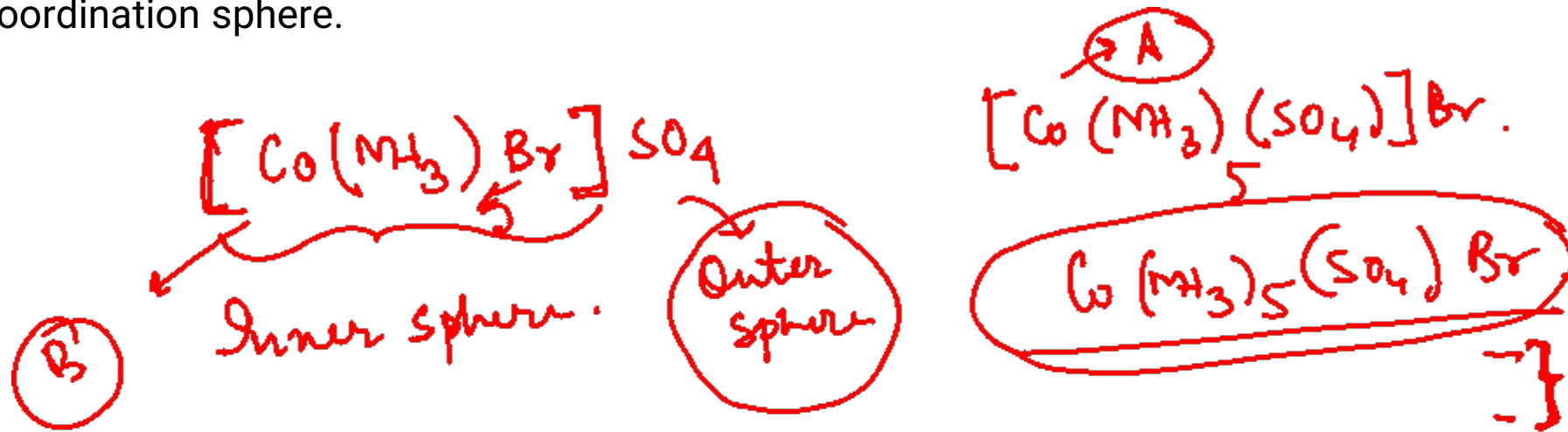


Tricapped trigonal prismatic ML_9

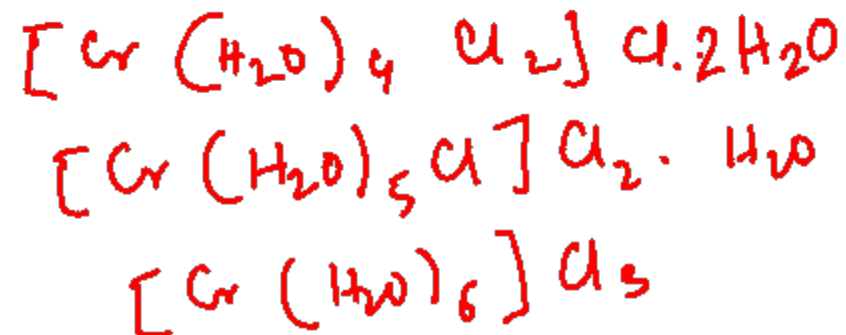
ISOMERISM

Structural isomerism

1. Ionization isomers : Interchange of an anionic ligand within the first coordination sphere with an anion outside the coordination sphere.



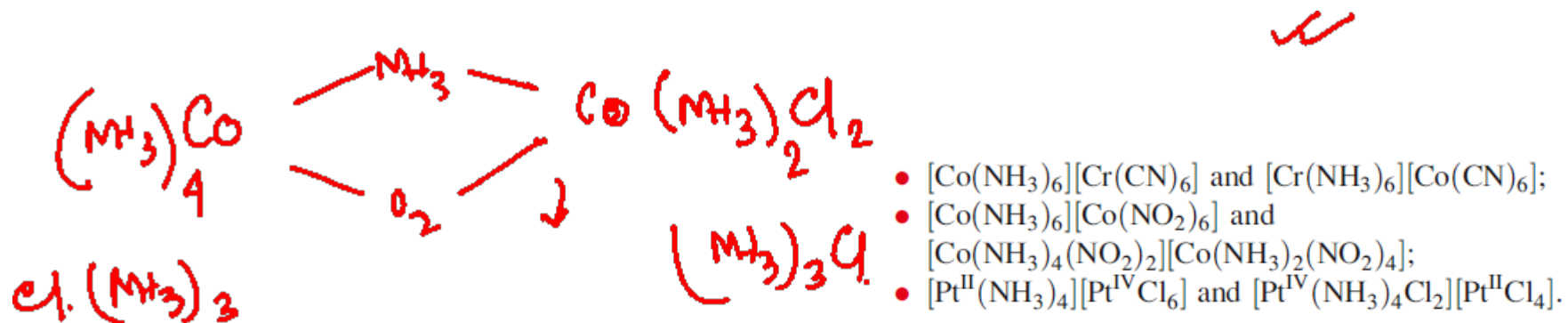
2. Hydration isomers : Hydration isomers result from the interchange of H_2O and another ligand between the first coordination sphere and the ligands outside it.



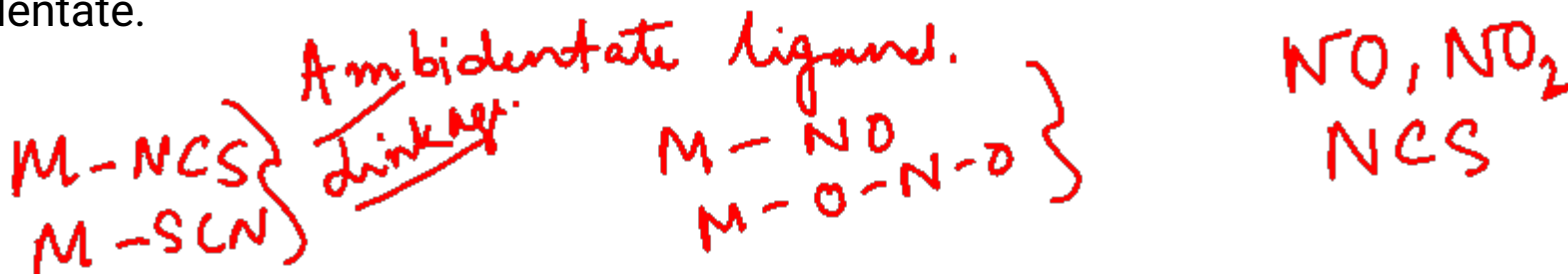
Structural isomerism continues....

3. Coordination isomerism: Coordination isomers are possible only for salts in which both cation and anion are complex ions

(Coordination position isomerism: In some of the polynuclear complexes, interchange of the ligands between the two metal nuclei takes place, which is give to rise to coordination position isomerism



4. Linkage isomers Linkage isomers may arise when one or more of the ligands can coordinate to the metal ion in more than one way, e.g. in $[\text{SCN}]$ both the N and S atoms are potential donor sites. Such a ligand is ambidentate.



5. Polymerization Isomer: The empirical formula obtained from elemental analysis identifies the ratio of components, not their actual number. Thus an empirical formula MA_2B_2 could be considered as any of $[\text{MA}_2\text{B}_2]_n$ (for $n=1, 2, 3, \dots$), *a series of compounds with the same empirical formula, and* with the molecular formula of each some multiple of the simplest formula

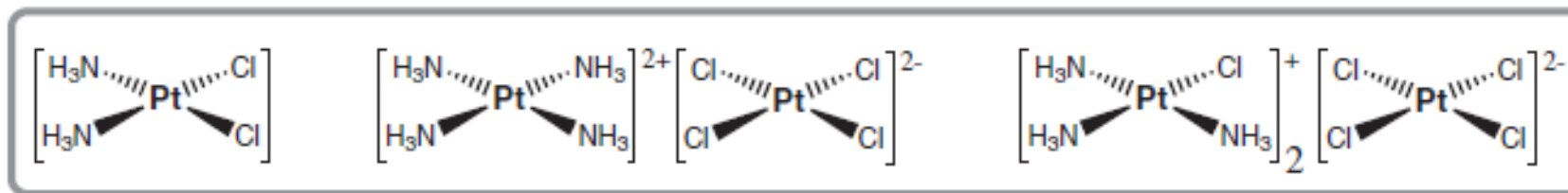
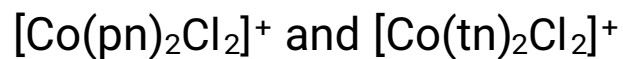
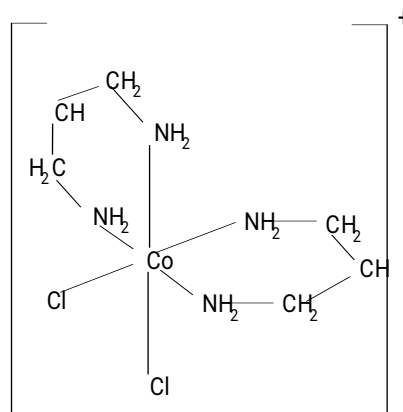
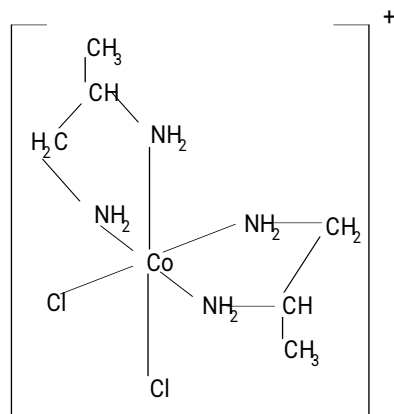
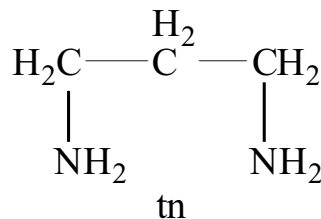
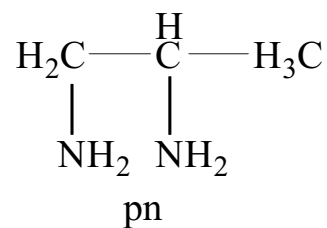


Figure 4.27

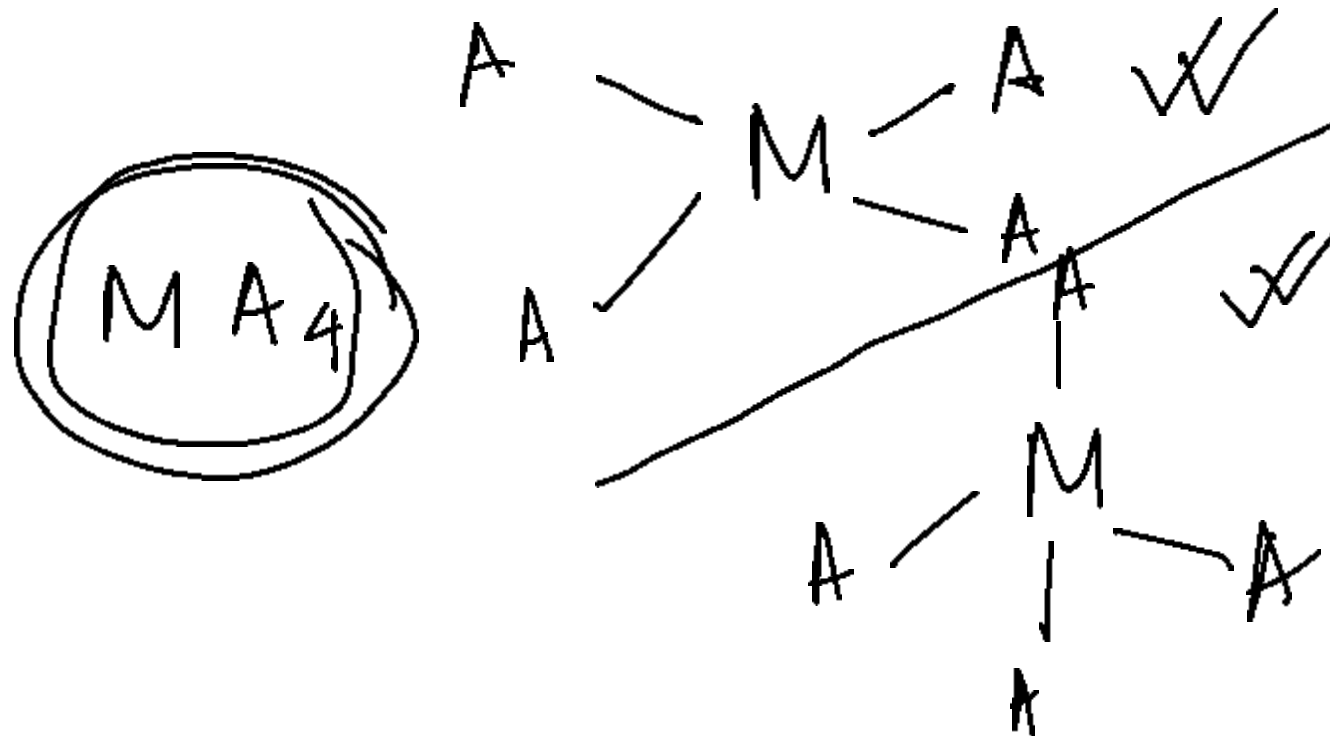
Polymerization isomers: the complexes exemplified have identical empirical formulae but differ in the number of replications of the empirical formula, $\{\text{Pt Cl}_2(\text{NH}_3)_2\}_n$.

6. Ligand isomerism: Some of the ligands themselves are capable of existing as isomers, e.g. diaminopropane can exist isomers as 1, 2-diaminopropane (pn) and 1, 3-diaminopropane (tn).



Stereoisomerism: diastereoisomers

Stereoisomers are molecules of the **same empirical formula** that have identical coordination number and basic shape, and display the same atom-to-atom bonding sequence throughout, but in which the **ligand atoms differ** in their locations in space.



Diastereomers are the general class of stereoisomers, and includes geometric isomers (such as *cis, trans isomeric forms*) as a ~~sub-class~~.

Any particular diastereomer may have an enantiomer, which is a stereoisomer that is a *non-superimposable mirror image of the original diastereomer*

Not all compounds will exist as two mirror image forms (the enantiomers), as it is a property related to the symmetry of the compound; consequently, diastereomers are not the same thing as enantiomers.

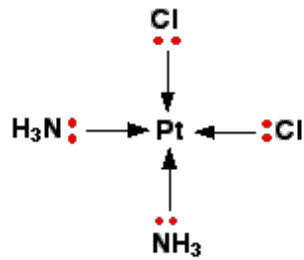
For complexes to have enantiomers, they must be either *asymmetric* (that is be a molecule totally lacking in symmetry apart from the identity operation) or *dissymmetric (that is lacking an S_n axis, which is a rotation-reflection axis – without an S_n axis, it can have neither a plane of symmetry nor a centre of symmetry; however, a dissymmetric molecule can have a proper axis of rotation, C_n ($n \geq 1$))*.

A molecule that is asymmetric or dissymmetric (and therefore not superimposable on its mirror image) is called a *chiral compound*; *this means that all enantiomers are chiral.*

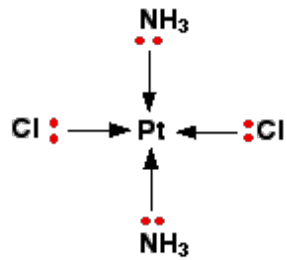
Such a compound will display *optical activity as an individual enantiomer, which is the* ability to rotate the plane of plane-polarized light (measured using a polarimeter), which is one way that we can detect the presence of an enantiomer and define its optical purity.

Whereas *diastereomers usually differ appreciably in their chemical and physical properties, enantiomers differ only in their ability to rotate polarized light and related optical properties*

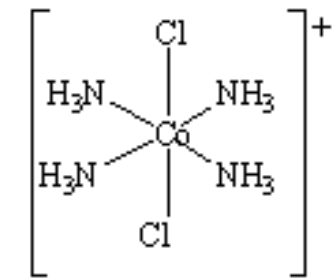
Metal complexes that differ only in which ligands are
 adjacent to one another (**cis**)
 or
 directly across from one another (**trans**).



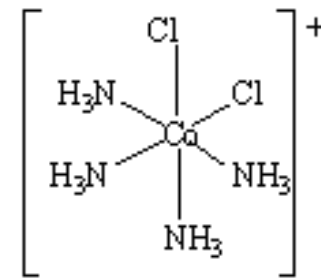
the "cis" form



the "trans" form



Trans - $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$



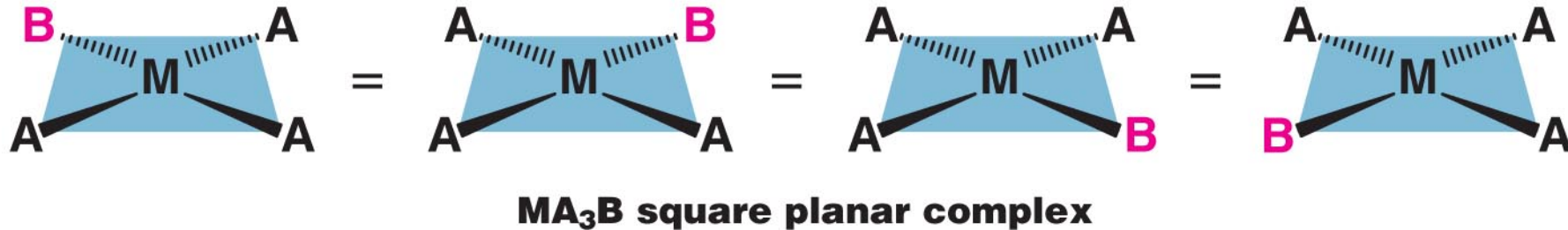
Cis - $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$

Geometrical isomers

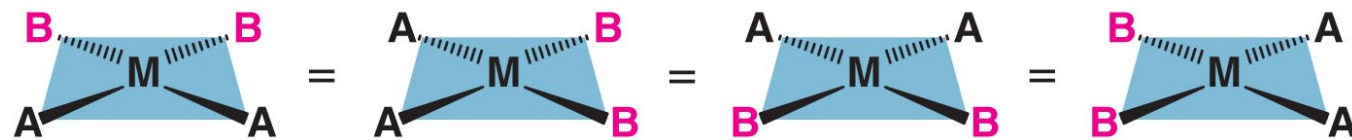
Square planar complexes:

all vertices of a square are **equivalent**,
it does not matter which vertex is occupied by ligand B

in a square planar MA_3B complex.
Only one geometrical isomer is possible



With **two**, there are other possible arrangements

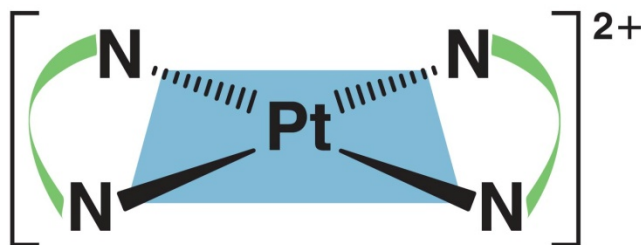


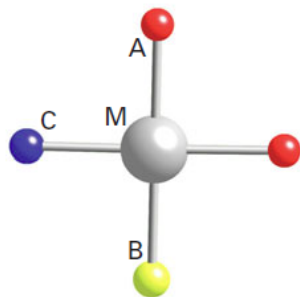
MA₂B₂ square planar complex, *cis* isomer



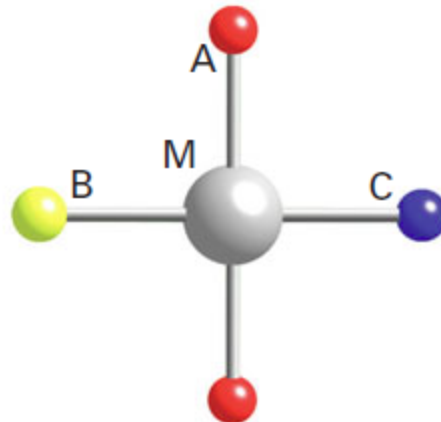
MA₂B₂ square planar complex, *trans* isomer

Symmetrical bidentate ligands also only have one structure

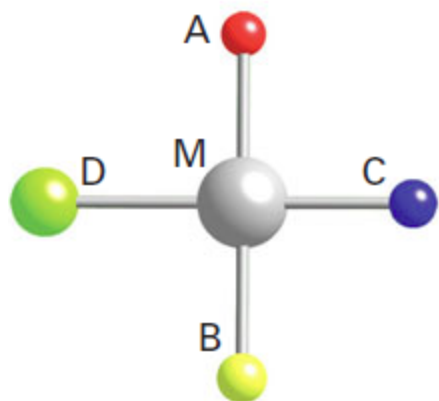




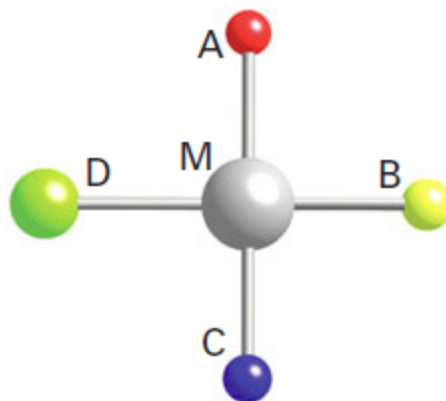
cis-[MA₂BC]



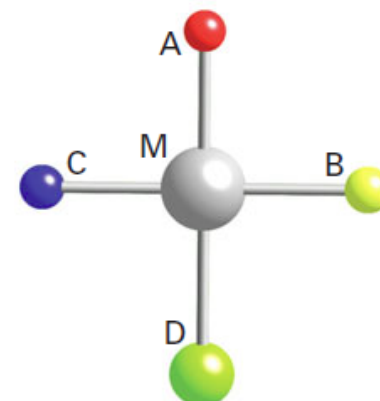
trans-[MA₂BC]



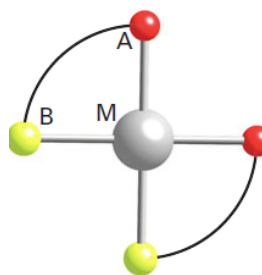
43 [MABCD], A *trans* to B



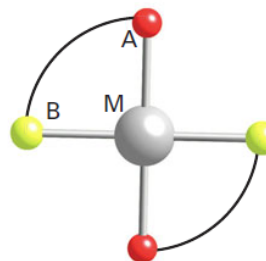
44 [MABCD] A *trans* to C



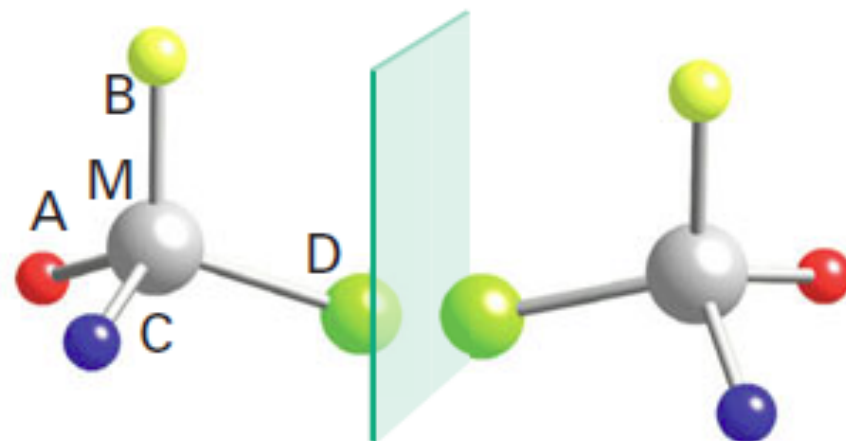
45 [MABCD] A *trans* to D



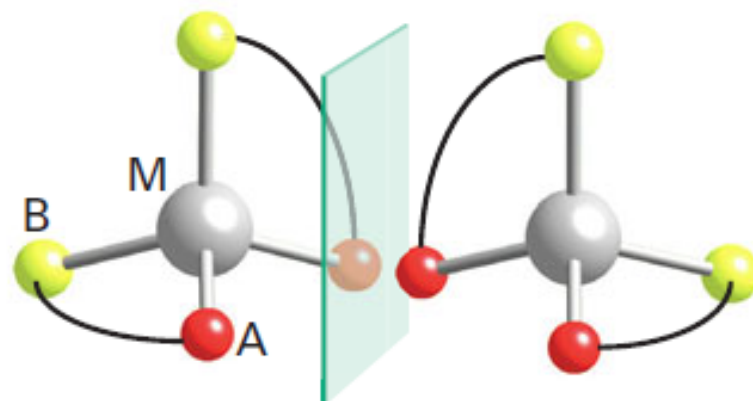
46 *cis*-[M(AB)₂]



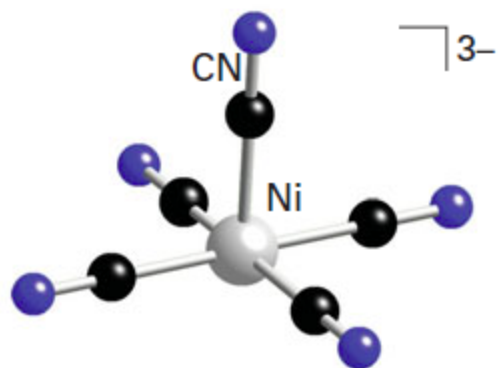
47 *trans*-[M(AB)₂]



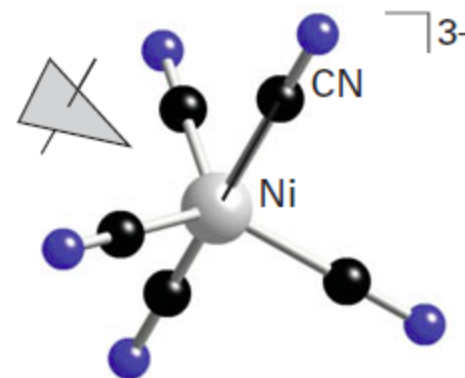
48 $[MABCD]$ enantiomers



49 $[M(AB)_2]$ enantiomers



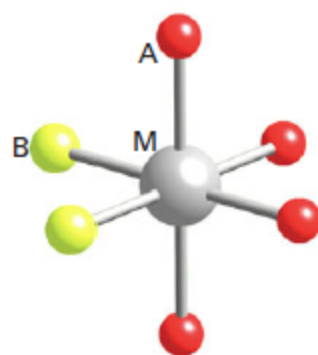
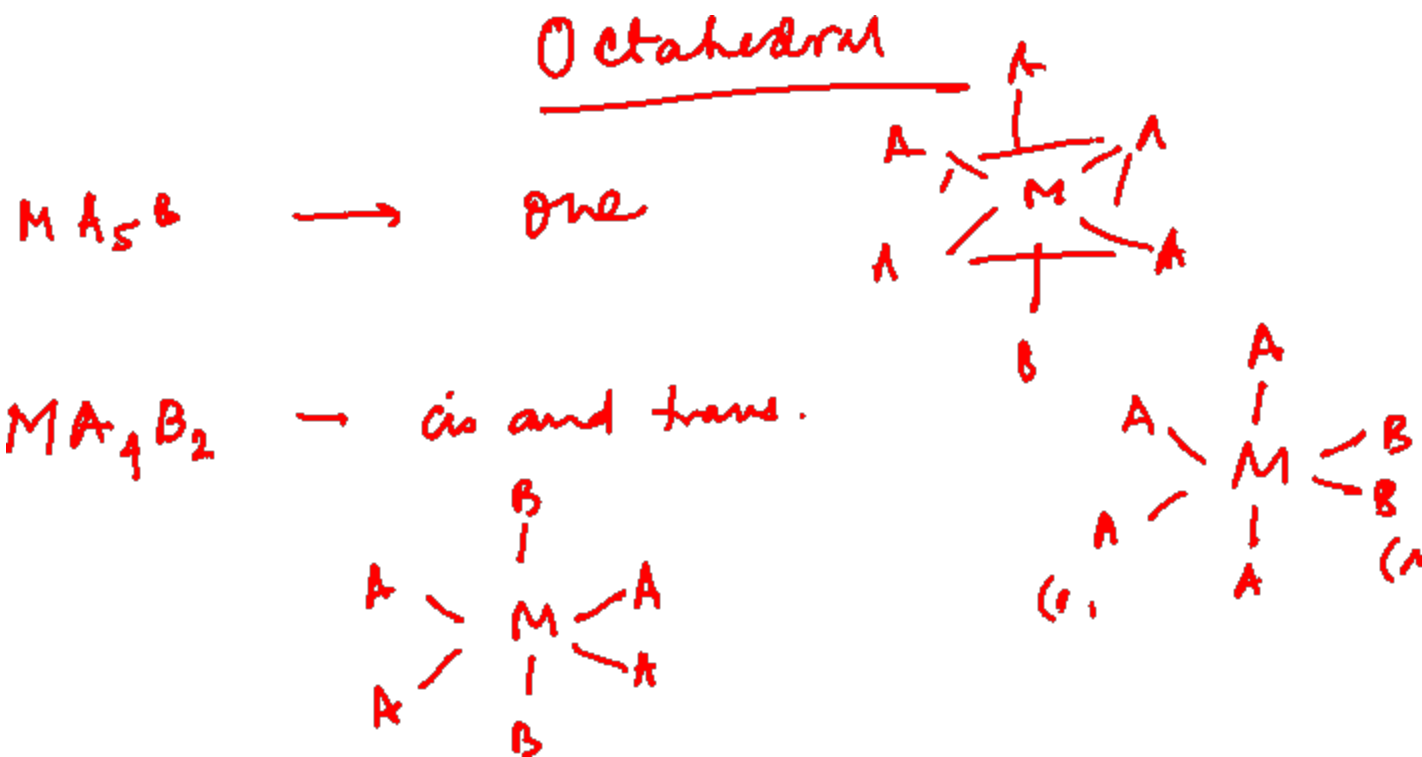
50 $[\text{Ni}(\text{CN})_5]^{3-}$, square pyramidal (C_{4v})



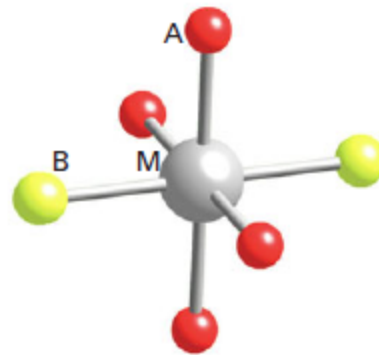
51 $[\text{Ni}(\text{CN})_5]^{3-}$, trigonal bipyramidal (D_{3h})

The energies of the various geometries of five-coordinate complexes often differ little from one another. The delicacy of this balance is underlined by the fact that $[\text{Ni}(\text{CN})_5]^{3-}$ can exist as both square-pyramidal and trigonal-bipyramidal conformations in the same crystal.

In solution, trigonal-bipyramidal complexes with monodentate ligands are often highly fluxional (that is, able to twist into different shapes), so a ligand that is axial at one moment becomes equatorial at the next moment: the conversion from one stereochemistry to another may occur by a Berry pseudorotation. Thus, although isomers of five-coordinate complexes do exist, they are commonly not separable.



54 *cis*-[MA_4B_2]



55 *trans*-[MA_4B_2]

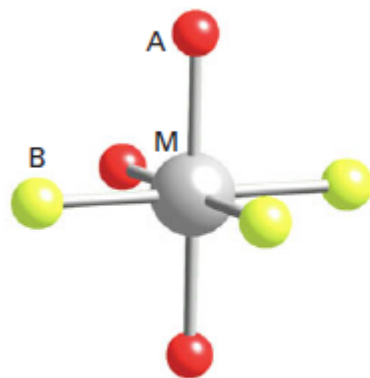
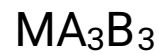


90°

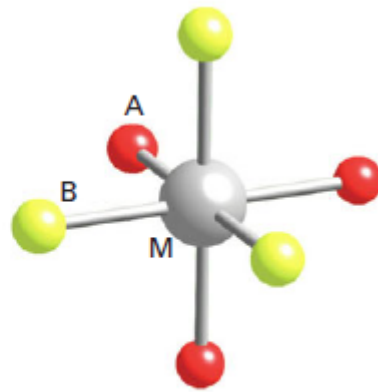
positions are similar.



cis/trans.



56 mer-[MA₃B₃]



57 fac-[MA₃B₃]

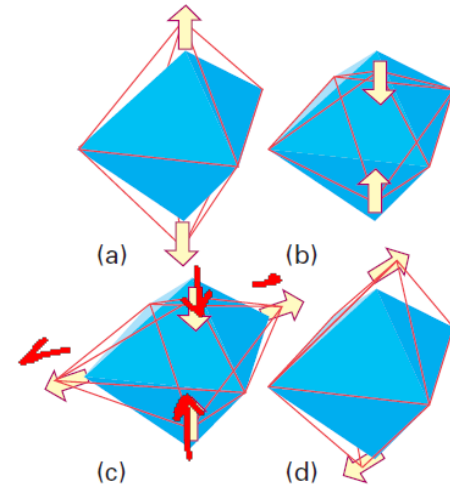
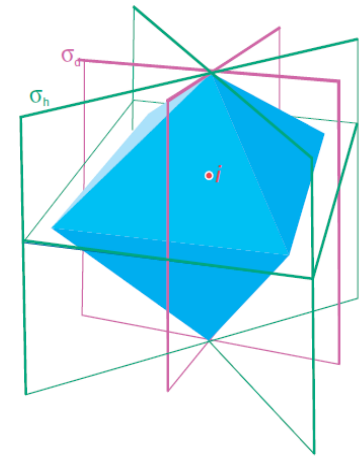
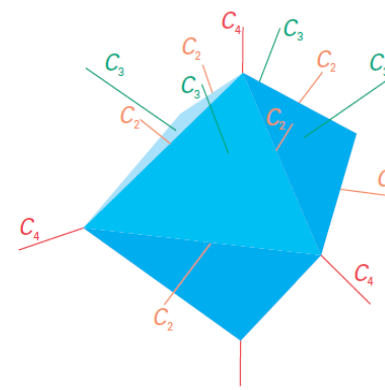


Figure 7.2 Distortions of a regular octahedron: (a) and (b) tetragonal distortions, (c) rhombic distortion, (d) trigonal distortion.