Coordination Chemistry of Networking Materials

Ataf Ali Altaf, Sumbal Naz and Amin Badshah

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Abstract

The coordination chemistry explains the chemistry, physical properties, structure, bonding, and other properties of the compounds of d-block elements. In the current chapter, we have discussed the coordination chemistry of networking complexes of d-block elements. The networking complexes of d-block elements comprise of metal organic frameworks (MOF) also known as coordination polymers. In this context, the geometry around central metal atom of MOFs has been discussed to explain their different properties. Different theoretical approaches (like hybridization, valence bond theory, molecular orbital theory, and crystal field theory) have been utilized to explain the properties of some selected exemplary compounds, e.g., [Ag(1,4-pyrazine)_{1.5}CF_3SO_3], [Cu(3,4-Hpdc)_{2}(H_2O)_{2}]·2dmso]_n, and [Zn(II)(SEPCPU)]_n.

Keywords: coordination chemistry, networking materials, metal organic frameworks, geometries, properties of MOF

1. Introduction

The coordination chemistry mention to a versatile branch of which flourishes depends upon inorganic chemistry. The foundation of coordination chemistry breaks down the boundaries of physical, organic, and inorganic chemistry and it alters to joint part of various chemical fields. Coordination chemistry forms an assured achievement in research and practical applications due to its different properties. Theories that explain bonds in coordination compounds are valence bond theory (VBT), crystal field theory (CFT), and ligand field theory (LFT). Properties of coordination chemistry enter into microscale from macrolevel. It accentuates the study on microlevel such as study of the internal structure of molecule. Latest coordination chemistry follows different mathematical models to turn the qualitative description of compounds into quantitative way [1].
Due to higher valency of transition metals, the solution of bonding was expected by Alfred Werner. Werner’s analysis provided the basis for field of transition metal complexes in coordination chemistry [2]. Werner, the beginner of coordination chemistry, granted his concepts of metal ligand complexes in his book in 1905 and his book was translated into another language like English in 1911 [3]. According to Webster, coordinate means to convey into proper order of molecules. Coordination chemistry provides important conceptual basics and chemical content of chemistry. In this chemical branch, some important concepts of chemistry were developed like stereochemistry of compounds of higher coordination numbers, bonding in d orbital systems, and mechanism of reactions [4]. The control of molecular conformation in solid materials is the significant motif of modern chemistry. For proper molecular organization, there is preference to use directional bonds (coordinate covalent bond and hydrogen bond) [5]. Coordination compounds are formed by dual aggregation of metal and multidentate ligands. In these coordination compounds, molecules and atoms may be considered as specific points. In these, network is connected, and metal and ligand are connected with each other to form a coordination compound. If inferred impulsions are applied to coordination number of metal through beating its coordination sphere by its counterions, then prediction of formation of final network should increase. The chorography of coordination network is expected to follow from geometry of its constituent parts [6]. The connection of ligand toward metal atom is controlled by covalent synthesis. The prophecy of network structure depends upon coordination properties of metal atom. The coordination of metal is effected by counter ion, duplicity of ligand, and solvent [7].

2. Coordination polymers

Polymers can be described as molecules of high molecular weight which are formed by repetition of their monomeric subunits connected by covalent bonds [8]. However, coordination polymers are formed by central metal atom connected with organic ligands via coordination bonds and weak chemical bonds. These compounds are also named as metal organic frameworks [9]. The organization of different factors in coordination polymers exists in solid form most of the time [10]. Coordination polymers are completely regular in shape, having high porosity and designable frameworks. Synthesis of these networks is done under mild conditions by using discrete subunits and this method is commonly known as bottom-up method. Components of these polymers are blocking ligands, counteranions, and template molecules. Transition metal ions are often used as functional connectors in the formation of coordination polymers. Variable geometries of a polymer can be formed by varying reaction conditions like solvents, ligands, and counteranions, etc. [11].

3. Examples of coordination polymers

3.1. [Ag(1,4-pyrazine)\textsubscript{1.5}CF\textsubscript{3}SO\textsubscript{3}] complex

In a clean glass vial, a solution of silver triflate in acetone was added to a solution of 1,4-pyrazine in acetone covered by Teflon cap. Precipitates of white color are formed. For production of clear solution, heat this vial on hot water bath at 85°C. The resultant mixture was filtered at the same time to remove water by using Whatman No. 50 filter paper. On cooling, the clear solution becomes
turbid. The resulting mixture was heated in oven at 70°C and homogeneous mixture was cooled at room temperature; colorless long needle-like structures were formed for XRD analysis.

Stoichiometry of complex of silver as a central metal atom and 1,4-pyrazine as a ligand is ML$_{1.5}$. The structure of complex contains endless chains of cyclical 1,4-pyrazine molecules and metal ions to form ladder-like structure. This ladder-like structure was formed by alternation of 1,4-pyrazine and metal ions. The pyrazine subunits on chain are at a distance of about 3.55. The plane of pyrazine units is 77.8° toward plane of poles of ladder structure. The crystallization solvent of this complex is acetone. Silver is four-coordinated metal bonding to one oxygen atom of triflate and three nitrogen atoms of 1,4-pyrazine. Silver adopts sawhorse geometry. The N-Ag(I) bond distances are 2.246 (N1), 2.312 (N2), and 2.460 Å (N3) and the N-Ag(I)-N bond angles are 173.2 and 87.3°. The Ag(I)-O bond distance is 2.590 Å [7] (Figure 1).

Hybridization of given complex can be explained on the basis of VBT. In this complex, charge on Ag is +1, its magnetic moment indicates that paired electrons are present per atom and one electron is lost from 5s orbital, no electron loss from d orbital, one of d orbital electrons may participate in bonding by acting as lone pair to cause lone pair-bond pair repulsion.

Figure 1. In the [Ag(1,4-pyrazine)$_{1.5}$CF$_3$SO$_3$] complex, chains that run along an axis (at top of figure). This figure indicating the coordination sphere of silver(I) in the [Ag(1,4-pyrazine)$_{1.5}$CF$_3$SO$_3$] complex in which geometry of silver(I) is sawhorse geometry with specified bond lengths and bond angles (at the bottom of figure).
Due to presence of repulsion, this complex showed sawhorse geometry instead of tetrahedral geometry having $\text{dsp}^3$ hybridization in which one d orbital, one s orbital, and three p orbitals of almost same energy of same shell are involved, such type of complexes are known as spin paired complexes. Magnetic moment indicates that this complex is diamagnetic in nature because all electrons present in d orbital are paired. After intermixing of these orbitals, this complex gives five $\text{dsp}^3$ hybrid orbitals.

3.2. $\left[\text{Cu}(3,4\text{-Hpdc})_2(\text{H}_2\text{O})_2\right]\cdot2\text{dmso}]_n$

Formula weight of this compound is 588.05 g M$^{-1}$ and density is 1.607 g cm$^{-3}$. Its crystal system is monoclinic. To synthesize this complex, 3,4-pyridinedicorboxlic acid was dissolved in DMSO, and this mixture was added in ethanol solution of CuCl$_2$$\cdot$6H$_2$O by diffusion method. Elemental analysis shows that ratio of metal and ligand is 1:2 in this complex [12]. The resultant mixture becomes green; after 3 weeks, the color of the solution has changed to blue. Blue crystals were suitable for XRD analysis; these crystals were collected by filtration and washed by using DMSO.

XRD analysis indicates that crystals which are formed are monoclinic in nature with space group $P_{21}/n$. In given complex, central metal atom is coordinated to two nitrogen and two oxygen atoms of 3,4-Hpd$^-$ ligands and two molecules of water leads to six coordination with octahedral geometry. Each 3,4-Hpd$^-$ molecule is deprotonated partially, with only one carboxylate ion involving in coordination toward metal center due to the presence of vibrational frequency of CO and (COO$^-$). No any basic material was added into reaction mixture and the reaction was carried out under optimum conditions to obtain partially protonated material. The bond distance of Cu-O$_5$ (2.467(3) Å) is much larger than that of Cu-O$_4$ and Cu-N$_{1ii}$ are (1.977(2) Å) and (2.006(2) Å) [13, 14]. In two-dimensional sheet of polymer, Cu$^+$.Cu distance is about 8.781 Å [15].

Thermal analysis indicates that this complex polymer molecule has coordinated molecules of water and DMSO molecule in the resulting network. Two hydrogen bonds involved in
coordinated water molecules—one with DMSO molecule and another with carboxylate ion—are observed [16] (Figure 2).

Hybridization of this complex polymer molecule can be explained on the basis of VBT. The charge on central metal atom is Cu$^{2+}$. Its magnetic moment indicates that complex is paramagnetic because one unpaired electron was left in one of 3d orbitals. The vacant 4dx$^2$-y$^2$ and 4dz$^2$ orbitals are hybridized with vacant 4s and 4p orbitals to give six sp$^3$d$^2$ hybrid orbitals. All water and 3,4-Hpdc$^-$ can donate two electrons to one of sp$^3$d$^2$ hybrids [17].

3.3. [PVA-Ni(II)]$_n$ complex

These polymer metal complexes were prepared by using template method. A solution of polyvinyl alcohol is dissolved in water and the given solution was stirred magnetically and was heated at specific temperature on hot plate. One mole of metal chloride was diffused in water; this mixture was added dropwise into solution of polymer, again stirred and heated on hot plate approximately for 1 h. Complexes were precipitated by using acetone and filtered, then washed with acetone and then dried in oven. Complexes of polyvinyl alcohol are not soluble in water. Elemental analysis showed polymer and metal ratio of about 126:1. These complexes are not prepared in the form of tablets and pellets due to its springy nature [18, 19]. These complex polymers are diamagnetic and show square planar geometry [20]. No electronic bands were formed due to insolubility of these polymers in water; these metal complex polymers show rubber-like structure. This polymer exhibited about 17% of rubber naturally. Due to its rubber-like structure, stress-strain experiments of these complex materials were performed. This complex polymer molecule has breaking strain value of about 83%. These stress-strain values are due to hydroxyl group (Figure 3).
This complex polymer is square planar polymer resulting from dsp² hybridization; in this, one d, one s, and two p orbitals of same energy of same shell are involved; charge on central metal atom is Ni²⁺. Magnetic moment of this polymer complex indicated that this complex polymer is diamagnetic because all electrons are paired in 3d orbitals of central metal atom. Color of this complex is green. Polyvinyl alcohol donates two electrons to one of dsp² hybrid orbitals [20].

3.4. [Zn(II)(SEPCPU)]n

The name of ligand in this complex polymer is sebacoylbis-p-chlorophenyl urea. This ligand was prepared by condensation of 0.1 mmol of sebacoyl dichloride (prepared by sebacic acid and double-distilled thionyl chloride) and 0.2 mmol of p-chlorophenyl urea (prepared by p-chloroaniline and glacial acetic acid and sodium cyanate solution) in sodium-dried benzene for almost 5 h. Coordination polymer by using this ligand was formed by mixing ligand and metal acetate in minimum amount of hot dimethylformamide separately. Both solutions of ligand and metal acetate were filtered and then mixed under hot conditions. Reaction mixture was refluxed on oil bath for 5–6 h at 135–145°C. The colored products obtained were filtered and washed first with hot DMF and then with ethanol and acetone for elimination of unreacted reactants if present and finally dried in oven. This complex polymer is insoluble in water completely. Normal method of characterization is proton NMR and electronic spectra cannot be attained in solution.

IR sharp band appears at 1656 cm⁻¹ due to C〓O stretching vibrations; this band disappears in coordination polymers due to enolization and coordination of metal atom. This coordination polymer is diamagnetic in nature and shows tetrahedral geometry. This complex polymer is white in color. All coordination polymers are thermally stable and show insolubility in all organic solvents and due to their thermal stability, they can be used as powder coating materials (Figure 4).

This complex is tetrahedral resulted from sp³ hybridization. In this type of hybridization, one s and three p orbitals of same shell having same energy are involved; charge on central metal atom is Zn²⁺. Magnetic moment of this complex polymer indicates that this complex is diamagnetic because all electrons are paired in 3d orbitals of central metal atom. Color of this complex is green. Polyvinyl alcohol donates two electrons to one of dsp² hybrid orbitals [20].
is diamagnetic due to the presence of paired electrons in 3d orbitals. Color of this complex polymer is white. O and N atoms of ligand can donate two electrons to one of four sp³ hybrid orbitals [21].

3.5. ([Cu(L)(CF₃COO)]₂)ₙ

In this polymer complex, ligand is Schiff base ((E)-2-((pyridin-2-yl)methyleneamino)-5-chlorobenzoic acid) which was prepared by reflux condensation of 0.536 g, 5 mmol of 2-pyridinecarboxaldehyde, and 0.858 g, 5 mmol of 2-amino-5-chlorobenzoic acid in 50 ml solution of methanol for 1 h approximately. The resulting solution is orange red in color. Performed TLC of this solution indicates the presence of Schiff base ligand. This product was separated by performing column chromatography by using mixture of ethyl acetate and light petroleum in a ratio of 1:1. Then, evaporation of this content yields pure ligand [22].

The copper complex with this ligand was prepared by using 10 ml of methanolic solution; 0.261 g, 1 mmol of Schiff base was added to another methanolic solution of 0.290 g, 1 mmol of copper trifluoroacetate with slow stirring on hot plate for almost half an hour. The resulting mixture was blue in color and was filtered; the filtrate was kept undisturbed for 7 days. A plate-shaped blue-colored crystal of this complex was obtained.

In this complex, every cupric center is penta-coordinated in a distorted square planar geometry, where Schiff base ligands act as tridentate ligand toward one cupric center; in fact, they are tetradequate ligand. The basal plane of CuI is provided by nitrogen of pyridine and imine.

Figure 5. This figure showed the ORTEP view of asymmetric unit of complex polymer. Its bond lengths are described below.
and one carboxylate oxygen atom and one oxygen atom of monodentate trifluoroacetate group and apical position of the complex are occupied by symmetry-related ligand. In the same way, the basal plane of Cu2 is clocked up by N4, N3, O5, O7 and apical position is clocked up by O2 atom of Schiff base coordinated to Cu1 (Figure 5).

Bond lengths in this complex molecule are Cu1-O1, Cu2-O2, Cu1-O3, Cu2-O5, Cu1-N1, Cu2-O7, Cu1-N2, Cu2-N4, Cu1-O6, and Cu2-N4 1.904, 2.162, 1.941, 1.895, 2.011, 1.939, 2.006, 2.017, 2.178, 2.008 Å, respectively [23].

The geometry of this complex polymer is square pyramidal. Hybridization of this polymer is sp3d2 which involves one s and three p orbitals of same shell and outer two d orbitals of fourth shell. Charge on central metal atom is Cu2+; its magnetic moment indicates that this complex polymer is paramagnetic in behavior because one unpaired electron was left in one of 3d orbitals. And ligands show interactions toward metal center through sp3d2 orbitals by donation of two electrons.

4. Examples of transition metal compounds

4.1. [Ni(D)(G)]: D = dimethylglyoxime, G = N-acetylglycine

An ethanolic solution of potassium hydroxide of dimethylglyoxime and of N-acetylglycine was added to aqueous solution of metal salts after some stirring on water bath; precipitates of product are formed and immediately filtered and washed by mixture of ethanol and water in ratio of 1:3, and finally dried in oven at 60°C. The metal complexes which are formed are solids and completely insoluble in organic solvents showing complete solubility in DMF. IR spectra of DMG showed absorption bands at 3400, 2931, 1570, 1141, and 756 cm⁻¹ which are accounted for v(OH), v(C—H), v(C≡N), v(N—O), and v(C≡N—O), respectively. In metal ligand complexes, these bands shifted toward lower frequencies.

IR band of N-acetylglycine was appeared at 3380 cm⁻¹; on complexation, this band shifted toward lower value. Electronic spectra of Ni(II) complex show absorption bands at 445 nm.
IR study and electronic spectra indicated that dimethylglyoxime and N-acetylglucine were coordinated to metal by N and O atoms (Figure 6).

All metal complexes are insoluble in water as well as in most organic solvents but soluble in DMF and DMSO. They are nonelectrolytes. The electronic spectra of this complex indicate d^8 system showing absorption bands at 445 and 514 nm in visible region showing electronic transitions at A_g-A_2g, etc. Such type of transitions of these complexes indicates that structure of this complex is square planar.

This complex is resulted from dsp^2 hybridization. In this type of hybridization, one d, one s, and two p orbitals of same shell having same energy are involved. Charge on central metal atom is Ni^{2+}. Its magnetic moment indicates that two electrons of five 3d orbital are unpaired which become paired by using strong ligands such as dimethylglyoxime and N-acetylglucine; as a result, complex becomes diamagnetic in character and shows pink color. Due to dsp^2 hybridization, its geometry is square planar [24]

4.2. RuCl_2[P(C_6H_5)_3]_3

This complex is five-coordinated and d^6 system. This complex was prepared by Vaska by using (NH_4)_2RuBr_6 with triphenylphosphine in 2-methoxyethanol at 25°C. From magnetic moment, molecular weight of complex and its conductivity measurements show that such type of complexes is diamagnetic and monomeric. Compounds of Os and Ru are isomorphs of each other and their crystal structure is monoclinic. This complex can be distorted square pyramidal when Ru occupied the position of center of gravity.

This complex molecule consists of only 68% by weight of carbon; so the structure of this complex is based on Ru, P, and Cl atoms. Bond distances of Ru-P'_1, Ru-P'_2, Ru-P'_3, Ru-Cl'_1, and Ru-Cl'_2 are 2.374, 2.412, 2.230, 2.387, and 2.388 Å, respectively. In present case, vacant octahedral site of complex is occupied by phenyl ring especially by phenyl hydrogen. Ru and Os complexes of Vaska are slightly soluble in most solvents. In this complex, color change occurs
due to rotation of phenyl ring. Preferable geometry for this complex is square pyramidal or octahedral. But stability of this complex may arise by blocking of unused octahedral site by rotation of phenyl ring [25] (Figure 7).

This complex resulted from d²sp³ hybridization. Charge on central metal atom is Ru (+2). Magnetic moment of this complex showed that electrons are paired per Ru²⁺ atom. The 3dx²-y² and 3dz² orbitals, one s, and three p orbitals of same energy of same shell are involved in d²sp³ hybridization. Triphenylphosphine is the strong ligand force pairing of all electrons of Ru. This complex is diamagnetic in behavior and may be known as spin paired complex and forms octahedral geometry.

4.3. Zinc(4-amino-5-pyridyl-4H-1,2,4-triazole-3-thiol)₂

In ethanol, a mixture of isonicotinic acid from potassium hydroxide was dissolved; when fluxing or dissipation was complete, carbon disulfide was added slowly to this mixture. And then, it was stirred on hot plate for almost 10 h; dried ether was added to this content resulting in precipitates of yellow color; the precipitates are filtered and washed by using ether and dried. Then, these yellow precipitates were added into excess amount of hydrazine hydride and were refluxed along with stirring until estimation of hydrogen sulfide was done. This process was stopped by using lead acetate paper; after cooling, this mixture was filtered and then acidified by using hydrochloric acid to yield product of white color. That is the ligand used in this complex formation.

Ethanolic solution of metal salt zinc acetate dihydrate was added into ethanolic solution of ligand in metal to ligand ratio of about 1:2 and refluxed for 2 h; crystalline colored precipitates were appeared at room temperature and washed by hot methanol and left for drying and recrystallized by using ethanol.

FTIR spectra showed some specific vibrations of ligand at 3250 and 3213, 2736, 1645, 673, 529, 432 cm⁻¹ due to NH₂, S▬H, C〓N, M▬N, and M▬S of triazole ring and metal ligand complex, and the last one is due to stretching of C▬S bond, respectively. Tautomeric form of triazole could be responsible for deprotonation of ligand before complexation; after complexation, ligand can attach to metal ion either through N atom or through S atom of thioamide group; bonding at S atom is more preferable because this gives more stable chelate. Electronic spectra of ligand exhibit three bands at 263, 302, 309 nm due to (π-π*), (π-π*), (n-π*) intraligand transitions. The given complex is diamagnetic in behavior due to completely filled d-orbitals, so no any d-d transitions can be possible in visible region [26] (Figure 8).
The hybridization of this complex is sp³, in which one s and three p orbitals are involved. Magnetic measurement of this complex indicates that this complex is diamagnetic because its all d orbital electrons are paired, electrons lose only from s orbital of Zn due to charge on Zn²⁺ and no magnetic moment was observed and ligand attaches to metal atom via s and p orbitals of metal atom and exhibited tetrahedral geometry.

4.4. [Cu(acac)(Me₂bipy)(NCS)]

Ligands have been prepared by dissolving 2 mmol Me₂bipy in 20 ml of ethanol and other ligand has been prepared by 2 mmol acetylacetone. Stoichiometric quantity of Hacac on LiOH was added over 25 ml of aqueous solution of 2 mmol Cu(ClO₄)₂ rapidly. The slow process of evaporation of this mixture gives brown-colored crystals of complex [Cu(acac)(Me₂bipy)](ClO₄) which is square planar in geometry having sp³ hybridization. Perchlorate ion is not involved in geometry.

The above complex has been prepared by reaction of ethanolic solution of 0.5 mmol [Cu(acac)(Me₂bipy)](ClO₄) and aqueous solution of 10 ml of 0.5 mmol KCNS. The slow process of evaporation of this mixture leads to green-colored crystals. These crystals are monoclinic form. The resultant complex has square pyramidal geometry. The bond distance of Cu─O is shorter than that of Cu─N such as [1.882(3); 1.896(3) Å] and s [1.981(3); 1.984(3) Å] and the bond angles of O-Cu-O and N-Cu-N are 94.74(11) and 81.44(11), respectively.

The insertion of another ligand to complex of Cu which acts as bridging ligand leads to square pyramid. Reaction of [Cu(acac)(Me₂bipy)](ClO₄) and KCNS gives mononuclear complex with isothiocyanato ligand coordinated to copper in apical position. In this complex, two ligands overlap in face-to-face manner with interplanar distances of about 3.09–3.37 Å and 3.50–3.57 Å

Figure 9. Crystal structure of complex [Cu(acac)(Me₂bipy)(NCS)] (a) numbering scheme of atoms and its packing diagram, (b) stacking interaction among ligand molecules, and (c) stacking interaction among Me₂bipy ligand and acac ligands.
for acac and Me₂bipy ligands, respectively and give dimmers. Within dimer structures, distance between Cu(II) ions is 3.920 Å [27] (Figure 9).

The hybridization of this complex is sp³d² resulted by the involvement of one s, three p, and two d orbitals. Magnetic moment of this complex indicates that this complex is diamagnetic because all electrons are paired in 3d orbitals; electrons are lost from 3s orbital due to Cu²⁺ charge. The ligands are coordinated toward metal ion via one s, three p, and two 4d orbitals leading to square pyramidal geometry.

4.5. [Co(H₂O)(EDTAH)].2H₂O

A 0.291 g of Co(NO₃)₂.6H₂O was mixed with 0.416 g of sodium salt of EDTA in distilled deionized water at room temperature. On disintegration of these two reactants, 3% solution of hydrogen peroxide was added with constant stirring until changing in color was complete. The volume of water reduced slowly by evaporation over a period of several days. Crystals of compound were left. Purity of product and quality of crystals depend on the rate of reaction. The fast rate of reaction would lead to the impurity formation and mixture of products.

The structure of this complex is distorted pentagonal bipyramidal. Cobalt is attached to nitrogen atom and oxygen atoms of three acetate groups and one acetic acid group of EDTAH⁻³ and one oxygen atom of water molecule. Axial positions of the complex were being occupied by two oxygen atoms of different acetate groups, and pentagonal plane of this molecule was being occupied by two nitrogen donors, one oxygen of EDTAH⁻³, one oxygen atom of acetato group, and one oxygen atom of water molecule.

Bond distance of carbon and oxygen for protonated O(4) is 1.294 Å. The bond distance of coordinated O(3)-C(4) is 1.215 Å. Bond lengths of attached ligand molecule are longer than

Figure 10. Structure of Co(EDTAH)(H₂O) complex which indicates the distortion in pentagonal plane.
that of Co-EDTA complex. The bond lengths of Co(1)-O(1), Co(1)-O(5), Co(1)-O(3), Co(1)-
O(1W), Co(1)-O(7), Co(1)-N(2), Co(1)-N(1) are 2.124, 2.272, 2.465, 2.073, 2.078, 2.229, and
2.256 Å, respectively. Bond lengths and bond angles suggest that geometry of this complex is
pentagonal bipyramidal [28] (Figure 10).

The hybridization of this complex molecule is dsp³d² due to involvement of one s, three p,
and three d orbitals intermixed to give seven hybrid orbitals of dsp³d² which are arranged
in pentagonal bipyramidal symmetry. Charge on central metal atom is Co (+3); its magnetic
moment indicates that this complex is diamagnetic in behavior because all electrons present
in 3d orbitals become paired favored by EDTA ligand. Ligand showed interaction toward
central metal atom via one d, one s, and three p orbitals of third shell and two d(x²−y²) and d(z²)
resulting in seven dsp³d² hybrid orbitals.

5. Conclusion

This chapter is focused on coordination chemistry of metal organic frameworks and com-
ounds of transition metals. Bonding and hybridization in these compounds was explained
by valence bond theory and molecular orbital theory; specific distortions due to the presence
of lone pair of electrons were explained via crystal field theory. Magnetic behavior, color
of compounds described above, space groups, crystal shapes, and geometry of the complex
compounds were also explained.

Author details

Ataf Ali Altaf*; Sumbal Naz† and Amin Badshah‡

*Address all correspondence to: atafali.altaf@uog.edu.pk
†Department of Chemistry, University of Gujrat, Gujrat, Pakistan
‡Department of Chemistry, Quaid-i-Azam University, Islamabad, Pakistan

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