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SCHIFF BASE METAL COMPLEXES OF BIOINORGANIC AND MEDICINAL RELEVANCE: A REVIEW

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ABSTRACT

Schiff bases are versatile ligands and play important role in medicinal and bioinorganic fields because of their wide spectrum of biological activities. Schiff bases are multipurpose ligands which are amalgamated from the condensation of carbonyl compounds with an amino compound. Schiff bases and their metal complexes are also used for industrial purposes and their metal complexes have been screened for their in vitro biological activities against bacteria, fungi and yeast. These complexes also show significant growth inhibitory activity against the bacteria like Staphylococcus aureus, Escherichia coli, Bacillus subtilis, Klebsilla Pneumonia, etc. than the free ligands. Most of them show biological activities such as antibacterial, antifungal antioxidant, biocidal, antiviral as well as antitumor activity. It has been observed that the antimicrobial activities of these metal complexes are higher than that of the free ligand.

Keywords: *Metal complexes, Biological activities, Schiff base, Biocidal, antiviral, Antitumor activity.*

1. INTRODUCTION

The chemistry of the carbon-nitrogen double bond plays a vital role in the progress of chemical science [1]. Schiff bases are studied widely due to their synthetic flexibility, selectivity and sensitivity towards the central metal atom [2,3]. Schiff-bases have been widely used as ligands because of high stability of the coordination compounds, of them and their good solubility in common solvents such as ethanol, methanol, chloroform, dimethyl formamide[4]. A large number of Schiff base complexes are characterized by an excellent catalytic activity in a variety of reactions at high temperature (>100°C) and in the presence of moisture. In recent years, there have been numerous reports of their use in homogeneous and heterogeneous catalysis[5]. Schiff bases and their metal complexes are increasingly being used as catalysts in various biological systems, polymers and dyes. Moreover, it is confirmed that these compounds can act as enzyme preparations [6]. Inorganic elements play crucial role in biological processes, and it is evident that many organic compounds used in medicine do not have a purely organic mode of action some are activated or bio-transformed by metal ion metabolism [7]. Metal complexes make the compounds effective as stereospecific catalysts towards oxidation, reduction, hydrolysis, biological activity and other transformations of organic and inorganic chemistry. Schiff base complexes play a vital role in designing metal complexes related to synthetic and natural oxygen carriers [8-11]. Presently, there is a growing interest in the design and synthesis of coordination compounds of Schiff base ligands with tetradentate substituents due to their potential applications in the areas such as

MRI, imaging with isotopes and radiotherapy, luminescent probes and DNA cleavage [12]. Tetradentate Schiff base complexes are well known to form stable complexes, where the coordination takes place through the N_2O_2 type donor set [13]. Discoveries of binuclear cores at the active sites of some metalloproteins have aroused interest in the investigation of multimetallic systems [14]. The potential of these metal complexes to act as therapeutic agents is already well established and notable are copper, nickel and oxovanadium metal ions. These enormous biological applications have prompted to synthesize tetradentate Schiff base metal complexes with metal ions.

2. BIOINORGANIC AND MEDICINAL RELEVANCE

2.1 Antibacterial activity

For the control of infectious diseases, the development and discovery of antibiotics are among the most powerful and successful achievements of modern science and technology. However, due to increasing microbial resistance to antibiotics nowadays require the search for new compounds with potential effects against pathogenic bacteria. In medicinal chemistry, the most spectacular advances have been made when heterocyclic compounds played an important role in regulating biological activities.

A.M. Hamil *et al.* have reported the synthesis of 2-(2-1-(hydroxyphenyl)ethylaminophenyl) ethanimidoyl-phenol by mixing of an ethanolic solution of o-phenylenediamine with same solvent of 2-hydcoxyacetophonone.They studied that 2-(2-1-(hydroxyphenyl)ethyl-aminophenyl)ethan- imidoylphenol show significant activity against *B. cereus, S. aureus* and *E. Coli*[15]. Cheng *et al.* have reported the synthesis of a series of peptide and Schiff bases(PSB). The inhibitory activities and molecular docking simulation were carried out against *E. coli.* These *β*-ketoacyl-acyl carrier protein synthase were investigated *in vitro* and these ten PSB compounds possess both good inhibitory activities along with well binding affinities. The results demonstrate compound *N*-(3-(5-bromo 2hydroxybenzylidene- amino) propyl)-2-hydroxybenzamide as a potential antibiotic [16]. S.Pattanaik *et al.* have synthesized Schiff base ligand by using p-chlorobenzaldehyde with p-chloroaniline followed by reduction. These Schiff base ligands and their metal chelates were screened for their antibacterial in vitro against *S. aureus*, *Enterococcus faecalis*, *P. aeruginosa*, *K. Pneumoniae.* The result shows Ni(II), Zn(II), and Cu(II) complexes showed moderate antimicrobial activity [17]. Ronad *et al.* have prepared a series of 7-(2-substituted phenylthiazolidinyl)-benzopyran-2-one derivatives of Schiff bases and evaluated for anti-bacterial activities against various bacterial strains. The result showed that above compound exhibited good anti-bacterial as that of standard antibiotics Griseofulvin and ciprofloxacin [18].

2.2 Antioxidant activity

Aging is an evident phenomenon that has to face a human. Production of reactive oxygen species (ROS) increases with time, in the human body and leads to many physiological disorders including cardiovascular diseases. Schiff bases and their metal complexes plays vital role in the production of ROS (42) and therefore, can show antioxidant properties.

Shih *et al.* have synthesized a series of substituted thiazolidinone and thiazoline derivatives and evaluated them for antioxidant activity. DPPH (1, 1-diphenyl-2-picrylhydrazyl) exhibited antioxidant activity and also show radical scavenging activity, comparable to that of vitamin E [19]. Li *et al.* have reported antioxidant capacities of ferrocenyl Schiff bases including *o*-(1 ferrocenylethylidene amino) phenol (OFP), *m*-(1-ferrocenyl ethylidene amino) phenol (MFP), and *p*-(1-ferrocenylethylideneamino) phenol (PFP) were evaluated OFP, MFP and PFP possessed similar activities to trap DPPH and ABTS+. Schiff bases contaning ferrocenyl employed here behaved as pro-oxidants in Cu2+/GSH- and -OH-induced oxidation of DNA except that OFP exhibited weak antioxidant activity in -OH-induced oxidation of DNA. The introduction of ferrocenyl group to Schiff base increased the antioxidant effectiveness more remarkably than benzene-related Schiff bases [20]. K.J. Prathap *et al.* have reported the synthesis of a new series of ketone 1-(5- (pyridin-3-yl)-1,3,4-thiadiazol-2-yl)-hydrazone derivatives by the condensation of 1-(5-(pyridin-3-yl)-1,3,4-thiadiazol-2-yl) hydrazine with substituted and unsubstituted

ketones. They evaluated their antioxidant property by using 1, 1-diphenyl-2-picrylhydrazil (DPPH) method. All the compounds demonstrated good antioxidant activity due to the presence of (–NH–N=) moiety attached to aryl and heteroaryl nuclei thereby, stabilizing the free radical [21]. Tzanova *et al.* have described an efficient synthesis of three novel benzophenones containing 1,3-thiazol moiety. Their antioxidant power was evaluated *in vitro* and in three cell lines (the cancerous MCF7, noncancerous hTERT-HME1 mammary cells, and the H9c2 cardiomyoblastic cells). One analogue 5-(2,5-dihydroxybenzoyl)-2(3*H*)-benzothiazolone displayed an important antioxidant activity and low cytotoxicity and could decrease reactive oxygen species production generated by tert-butyl hydroperoxide (*t*BHP) in all three cell lines[22].

2.3 Antifungal activity

Fungal infections may be life threatening and are not limited to tropical areas but can also lead to increased risk of systemic infections. Factors for an increase in systemic fungal infections are surgeries, geriatric patients, AIDS, treatment of various tumors, hematopoietic stem cells, transplantation of hard organs, and immunosuppressive treatment. Therefore, it is important to develop and formulate more effective and safe antifungal drugs.

Chimenti *et al.* have reported the synthesis of a novel series of 2-thiazolylhy -drazone derivatives and the influence of the substituents on the thiazole ring on antifungal activity. All synthesized compounds were screened for their *in vitro* activities against [22] clinical isolates of *Candida* sp., representing six different species, compared to clotrimazole as a reference compound. Some of the tested compounds were found to possess significant antifungal activity when compared to clotrimazole[23]**.** Suman Malik *et al.* have synthesized complexes of 2-aminobenzimidazole-5-bromosalicylald- ehyde (HL) with chlorides of Ni(II) and Mg(II). They reported that the synthesized complexes have been screened for their antifungal activity against *C. Albicans* and *A. Niger.* The synthesized Schiff base shows Elemental analysis indicated 2:1 (L:M) ratio in the metal complexes [24]. Narayana *et al.* have prepared a series of 5-{2-(*N*-substituted aryl) amino-1, 3-thiazol-5-yl} 2-hydroxy benzamides by reacting 5-(bromoacetyl) salicylamide with thiourea, thioformamide, thioalkylamide and substituted thioureas in absolute ethanol. These compounds were converted to 5-(2-substituted–1, 3-thiazol-5-yl)-2-alkoxybenz -amides and 5-(2-*N*-(substituted aryl)-1, 3-thiazol-5-yl)-2-alkoxy benzamides by reacting with *n*-alkylbromides in presence of a base. The synthesized compounds were screened for their anti -fungal activity. These derivatives of compound exhibited significant activity [25]. Suman Malik *et al.* have reported the synthesis of vanadium and copper complexes of tridentate Schiff base derived from the condensation of 1H-Benzimidazol-2-amine with 2-hydroxybenzaldehyde. They studied that the pure compound, its Schiff base and the metal complexes have been screened *in vitro* for their antifungal activity against *C. albicans* and *A. niger* fungal strains. These metal complexes are moderately more active than the ligands because metal complexes may serve as a vehicle for activation of ligands as the principle cytotoxic species [26].

2.4 Antitumor activity

Cancer is a disease which leads to death and more than 200 cancer types have been reported in the human body. Schiff bases have been tested against cancerous cell which are obtained from cumarin and pyrazole aldehyde and showed mild anti-cancerous activities. Moreover, in another study, mono and bis-Schiff bases have been reported effective against cancer cell.

Popsavin *et al.* have reported a set of 2-(2, 3-anhydrofuranosyl) thiazole-4-carboxamide (2', 3'-anhydro tiazofurin) derivatives and screened them for their anti-tumor activity. This most active compound was found to be active against K_{562} malignant cells, with IC_{50} values ranging from 0.09-0.49 µM [27]. Chetan *et al.* have synthesized six compounds with hydroxamate in linker region with piperazine as Zinc Binding Group (ZBG). They were screened against three cancer cell-lines (NClH460, HCT116 and U251) [28]. A hybrid pharmacophore approach was used to design and synthesize isatin–benzothiazole analogs by Solomon *et al*. *In vitro* anticancer activity

of the synthesized compounds was tested by the National Cancer Institute, and two of them have revealed the anticancer activity on leukemia, melanoma, lung, colon, CNS, ovarian, renal, prostate, and breast cancers cell lines [29]. Prabhu *et al.* have synthesized novel series of 2-(3-(4-oxo-2-substituted phenylthiazolidin- 3-yl) phenyl) benzodthiazole-6-carboxylic acid derivatives PP1–PP8 by various benzothiazole Schiff 's bases by reaction with thioglycolic acid and evaluated their *in vitro* anticancer activity by 3-(4,5-dimethylthiazole-2-yl)-2,5- diphenyltetra zolium bromide (MTT) assay on human cervical cancer cell line (HeLa) [30].

2.5 Anti-inflammatory activity

Non-steroidal anti-inflammatory drugs (NSAIDs) are being used for the treatment of pain and perform their function by inhibiting the production of prostaglandins (PG), which are involved in many physiological activities. Occasionally, these NSAIDs are not targeted for the particular enzyme involved in the biosynthesis of prostaglandins; therefore, for more targeted attack on the particular isozyme new effective molecules are required.

Holla *et al.* have reported different series of arylaminothiazoles, arylidene/5-aryl-2-furfurylidene hydrazinothiazoles and conceal them for their antibacterial and anti-inflammatory activities. Two of the above compounds showed anti-inflammatory activity comparable with that of ibuprofen [31]. Nehad *et al.* have reported anti-inflammatory evaluation of series of *N*-phenylformamidine derivatives with different substituted phenyl moieties revealed lower activity compared to diclofenac sodium. The structure-activity relationship studies concluded that the electronic nature of the substituent on the phenyl ring affects activity as found with the electron withdrawing nitro group giving highest activity and lowest when there was an electron donating methoxy group [32]. 2-mercaptobenzothiazole was synthesized by encompassing novel bis-heterocycles using click chemistry approach by Shafi *et al.* The synthesized compounds have been tested for their anti-inflammatory activity by using biochemical cyclooxygenase activity assays and carrageenan induced hind paw edema [33].

2.6 Antiviral Activity

A large number of viral diseases are treated either adopting vaccination or by using antiviral drugs. Drug resistance reported in viral diseases is a serious issue for humanity therefore new therapeutic molecules is constantly required. Some common viral diseases like, small pox, influenza, rubella, chicken pox and polio can be controlled by vaccines administration, while viral diseases like hepatitis is still under the process of vaccine discovery.

Nagarajan *et al.* have synthesized benzothiazole-6-sulfonic acid that shows the replacement of *t*-butylurea moiety by benzothiazole sulfonamide provided protease inhibitors with improved potency and antiviral activity since the inhibitors incorporated a variety of isosteres including the hydroxyethylurea at the protease cleavage site [34]. Galaĭko N V *et al.* have studied that the novel hydrazones of lupane and 19-β-28-epoxy-18-α-oleanane type were synthesized via interaction of 2, 3 - secotriterpenic aldehydonitriles with substituted hydrazines. Acetylhydra- zone of 1-cyano-2, 3-seco-19-β-28-epoxy-18-α-olean-3-al exhibited a high prophylactic activity 0.00016 μg/ml to vesicular stomatitis virus and inhibited a virus reproduction in primarily infected cells in 0.21 μg/mL concentrations [35].

2.7 Catalysis

Many Cu(II) Schiff base complexes are known to be useful reagents for oxidative and hydrolytic cleavage of DNA. In addition to the biological properties a large number of Cu(II) Schiff base complexes have been used as catalysts in the aziridination and cyclopropanation of olefins and in the per oxidative oxidation of phenol to dihydroxy benzenes, in which they act as models for catalase enzymes.

Vigato P A *et al.* have studied that Schiff bases derived from hydroxybenzaldehyde are used in oxidation of cyclohexane into cyclohexanol and cyclohexanone in presence of hydrogen peroxide. The most efficient catalysts are the Fe(III) complexes which is unusual because, in general, the Co(II) complexes have high activity for alkane oxidation reactions [36]. Sheldon *et al.* have reported that Schiff base transition metal complexes are a family of attractive oxidation catalysts for a variety of organic substrates because of their cheap and easy synthesis and their thermal stability and chemical all the complexes show good activity [37]. Important oxidation reactions include the transformation of alcohols to either the corresponding, the oxidation of sulfides to sulfoxides, carboxylic acids, alkenes to epoxides and diols, and the activation of hydrocarbons etc. The activities of these cobalt complexes are slightly lower than that of Cu(II), Fe(II) and Mg(II) analogues of the investigated Schiff bases [38,39]. Park *et al.* have studied that catalytic activities of the Mn(II), Fe(III), Co(II) and Cu(II) complexes are observed for their activity towards phenol hydroxylation reaction. The major product of the reaction was found to be catechol. The Co(II) complex is found to be inactive, which may be due to the dimer formation. The copper complex was found to be the most active catalyst. So that it is unable to bind with the oxygen to form the intermediate [40].

2.8 Biocidal properties

Biocidal activity of the synthesized Schiff base surfactants was measured at the fermentation biotechnology and applied microbiology center using inhibition zone technique in dimethyl formamide as a solvent. The studied microorganisms were identified for each strain as gram negative bacteria.

Kalaivani S *et al.* have reported that the Schiff bases obtained by the synthesis of b-keto esters and o-aminobenzoic acid have found biocidal use against*, E. coli, S. epidermidis, A. niger* and *B. cinerea* [41]. Upadhyay K. K *et al.* have studied that Schiff bases of isatin derivatives are used for the destruction of protozoa and parasites [42].

2.9 DNA Cleavage Activity

The cleavage efficiency of the complexes is due to their efficient DNA-binding ability. Metal complexes were able to convert super coiled DNA into open circular DNA. The oxidative mechanisms proposed account of DNA cleavage by hydroxyl radicals *via.* abstraction of a hydrogen atom from sugar units and predict the release of specific residues arising from transformed sugars, depending on the position where the hydrogen atom is removed. The cleavage is inhibited by the free radical scavengers implying that hydroxyl radical or peroxy derivatives mediate the cleavage reaction. Metallocomplexes modulated this reaction and bound hydroxyl radical or a peroxo species generated from the co-reactant H_20_2.

Abd El-Wahab *et al.* have studied the importance of certain compounds in medical diagnosis and genomic research is based on the ability of compounds to bind and cleave double stranded DNA under physiological conditions. The oxidative and hydrolytic cleavage pathways are involved in DNA cleavage reactions [43]. Prasad, R. N *et al.* have reported that the formation of fragments may be considered to take place through enzymatic processes which occurs due to hydrolysis of phosphodiester. The nucleobase degradation and oxidation of sugar by abstraction of sugar hydrogen atoms take place during oxidative process. The oxidative cleavage of DNA is brought about by various methodologies and which involves irradiation with visible light of long wavelength, has achieved significant importance for their major use in photodynamic therapy (PDT) of cancer [44-46].

2.10 Enzymatic Activities

Prostatic acid phosphatase (PAP) is enzymes that are produced by the prostate and it's evaluated in prostate cancer. Acid phosphatase are found in metastasized prostate cancer in highest levels while diseases of blood cells, such as sickle-cell disease or multiple myeloma

diseases of the bone, such as Paget's disease or hyperparathyroidism or lysosomal storage diseases, such as Gaucher's disease, will show moderately increased levels.

M. Sivasankaran Nair *et al.* have studied that Schiff base linkage with pyridoxal-5-phosphate (PLP) which abolished the enzyme activities of proteins a derivative of pyridoxine commonly known as vitamin B6. PLP play a critical role in helping these enzymes to catalyze their reaction. The metabolism of amino acids involved in catalyze reactions with PLP when interact with enzymes. PLP forms a Schiff base link with Lysine residue on the enzyme also PLP dependent enzymatic reactions. Another Schiff Base complex of 2-pyridine carboxyaldehyde and its derivative show high super oxide dismutase activities 45. Ternary complex of Cu (II) showed DNA Cleavage activities containing NSO donor Schiff base.

3. CONCLUSION

Schiff bases and their metal complexes have a variety of applications including clinical, analytical and industrial. It has been observed that the compounds showed very good antibacterial, antifungal and so many types of activities. Biological activity of this class of compounds still requires further investigation. Both Schiff bases and their metal complexes are interesting research subject that constantly provides us with new information about newly created compounds.

REFERENCES

1. S. Patai, The Chemistry of the Carbon-Nitrogen Double Bond, John Wiley & Sons Ltd., London, (1970).
2. Wail Al Zoubi, International Journal of Organic Chemistry, (2013), Vol. 3, pp 73-95.
3. Singh P., Chauhan K.B.S. and Singh Archana ; Oriental J. of Chemistry, (2000).vol. 16(I), 179-180,
4. Naeimi H., Safari J., Heidarnezhad A.: Dyes Pigments, (2007), Vol. 73, pp 251.
5. Lippard S. J., Berg J. M, Principles of Bioinorganic Chemistry. University Science Books, California, (1994).
6. Kumar S., Dhar D. N., Saxena P. N.: Applications of Metal Complexes of Schiff bases – A Review. J. Sci. Ind. Res., (2009), Vol. 68, pp 181–187.
7. Afanas'ev B, Dorozhko A I, Brodskii A V, Kostyuk V A, Potapovitch A I, Biochemical Pharmacology, (1989), Vol. 38, pp 1763-1739.
8. Prashanthi Y and Raj S, J. Sci. Res, (2010), Vol. 2, pp 114.
9. Dhar D N.and Taploo C L.J. Sci. Ind. Res., (1985), Vol. 41, pp 501.
10. Demir M A , Birol O K.and Mercimek B, Int. J. Durg Dev and Res., (2010), Vol. 2, pp 102.
11. Gudasi K B., Patil M S., Vadavi R S, Shenoy R.V, Patil S A. and Nethaji M, Trans. Met. Chemistry, (2006), Vol. 31, pp 580.
12. Sobha S, Mahalakshmi R, Raman N, Spectrochim. Acta. Part A (2012), Vol. 92, pp 175– 183.
13. Jian-ning Liu, Bo-wan Wu, Bing Zhang, Yongchun Liu, Turk J Chem (2006), Vol. 30: pp 41 -48.
14. Saleh O. Bahaffi, Ayman A. Abdel Aziz, Maher M. El-Naggar, J. Mol. Struct, (2012), Vol. 1020: pp 188–196.
    A. M. Hamil, K.M. Khalifa, A. AL-Houni and M.M. El-Ajaily, Rasayan J.Chem,(2009), Vol.2, No.2, pp 261-266.
15. Cheng, K, Zheng, Q.Z, Qian, Y, Shi, L, Zhao, J, Zhu,H.L. Bioorg. & Med. Chem. (2009), Vol. 17, pp 7861.
16. S.Pattanaik, S.S.Rout, J.Panda, P.K.Sahu and M Banerjee, Rasayan J.Chem, (2011), Vol. 4, No.1, pp 136-141.
17. Ronad, P.M, Noolvi, M.N, Sapkal, S, Dharbhamulla, S, Maddi, V.S. Eur. J. Med. Chem. (2010), Vol. 45, pp 85.
18. Shih MH, Ying KF. Bioorg Med Chem. (2004), Vol. 12, pp 4633-4643.
19. Li, Y.F, Zai-Qun. Liu. Eur. J. Pharm. Sci. (2011), Vol. 44, pp 158.
20. Jagadeesh PK, Himajaa M, Malib SV, Ranjithaa A, Karigarc A, Sikarward M. Journal of Pharmacy Research (2010), Vol. 3, pp 2460-2462.

21. T. Tzanova, M. Gerova, O. Petrov, M. Karaivanova, and D. Bagrel, European Journal ofMedicinal Chemistry, (2009), Vol. 44, No. 6, pp. 2724–2730
22. Chimenti F, Bizzarri B, Maccioni E, Secci D, Bolasco A, Fioravanti R, Chimenti P, Granese A, Carradori S, Rivanera D, Lilli D, Zicari A, Distinto S. Bioorg Med Chem Lett. (2007), Vol. 17, pp 4635–4640.
23. Suman Malik, Archana Singh and Nayaz Ahmed, Der Chemica Sinica, (2015), Vol. 6, pp 1-6.
24. Narayana B, Vijaya Raj KK, Ashalatha BV, Kumari NS, Sarojini BK. Eur J Med Chem. (2004), Vol. 39, pp 867–872.
25. Suman Malik, Archana Singh and Nayaz Ahmed, Journal of Applicable Chemistry, (2015), Vol. 4, pp 1486-1491.
26. Popsavin M, Spaic S, Svircev M, Kojic V, Bogdanovic G, Popsavin V. Bioorg Med Chem Lett. (2007), Vol.17, pp 4123-4127.
27. Chetan, B.; Bunha, M.; Jagrat, M.; Sinha, B.N.; Saiko, P.; Graser, G.; Szekeres, T.; Raman, G.; Rajendran, P.; Moorthy, D.; Basu, A.; Jayaprakash, V. Bioorg. & Med. Chem. Lett. (2010), Vol. 20, pp 3906.
28. V. R. Solomon, C. Hu, and H. Lee, Bioorganic and Medicinal Chemistry Letters, (2009), Vol. 17, no. 21, pp 7585–7592.
29. P. Prabhu, T. Panneerselvam, C. S. Shastry, A. Sivakumar, and S. Pande, Journal of Saudi Chemical Society, (2012).
30. Holla BS, Malini KV, Rao BS, Sarojini BK, Kumari NS. Eur J Med Chem. (2003), Vol. 38, pp 313-318.
31. Nehad, A.; El-Sayed.; Awadalla, F.M.; Ibrahim, N.A.; El- Saadi, M.T. Eur. J. Med. Chem. (2010), Vol. 45, pp 3147.
32. S. Shafi, M. M. Alam, N. Mulakayala, European Journal of Medicinal Chemistry, (2012), Vol. 49, pp 324–333.
33. S. R. Nagarajan, G. A. De Crescenzo, D. P. Getman, Bioorganic and Medicinal Chemistry, (2003), Vol. 11, No. 22, pp. 4769–4777.
34. Galaĭko NV, Tolmacheva IA, Grishko VV, Volkova LV, Prevozchikova EN, Pestereva SA.
35. Bioorg Khim, (2010), Vol. 36, pp 556-562.
36. Vigato P A, Tamburini S, Coordination Chemistry Reviews, (2004), Vol. 248, pp 1717-2128
37. Sheldon, R. A. Kochi, J. K., Metal-Catalyzed Oxidations of Organic Compounds, Academic Press, New York, (1981).
38. Van Wyka, J. L, Mapolie, S. F, Lennartson, A, Håkansson, M, Jagner,S. Inorg. Chim. Acta (2008), Vol. 361, pp 2094.
39. Van Wyk, J. J. L. Mapolie, S. F. Lennartson, A. Håkansson, M. Jagner, S. Z. Naturforch, (2007), Vol. 62, pp 331.
40. Park, J. N. Wang, J. K, Choi, Y, Dong, W. Y, Hong, S. J, Lee, C. W. J. Mol. Cat. A: Chem. (2006), Vol. 247, pp 73.
41. Kalaivani S., Priya N. P., Arunachalam S. IJABPT, (2012), Vol. 3, pp 219–223.
42. Upadhyay K. K., Kumar A., Upadhyay S., Mishra P. C. J. Mol. Struct, (2008), Vol. 873, pp 5–16.
43. Abd El-Wahab, Z H, Mashaly, M M, Salman A A, El-Shetary, B A, and Faheim, A, A,
44. Spectrochim. Acta, Part A, (2004), Vol. 60, pp 2861.
45. Prasad, R. N., Agrawal, M, Sharma, M., Jounal of Serbian Chemical Society, (2002), Vol. 67, pp 229.
46. M.Sivasankaran Nair, S.Theodore David. J. IndianChem.Soc. (2000), Vol.7, pp 7220.