Applications of Schiff Bases and Their Metal Complexes: - A Short Review

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Abstract

Schiff bases are most widely used versatile ligands which are prepared by the condensation of primary amines with carbonyl compounds. Transition metal complexes derived from Schiff bases are having various applications in the fields of catalysis, industrial, dyes, polymers, plant growth regulators and organic intermediate synthesis. Due to their broad spectrum of biological activities, Schiff base complexes are useful in pharmaceutical fields. Biological activities of Schiff base complexes including antifungal, antibacterial, anticancer, antimalarial, anti-inflammatory and antiviral. In this review, we present the uses of Schiff bases and their metal complexes in different areas.

Keywords: Schiff bases, metal complexes, catalysis, antimicrobial activity.

1.Introduction

Schiff bases and their metal complexes are flexible compounds which are prepared by condensation of primary amines with active carbonyl compounds under specific conditions and they were first synthesized by Hugo Schiff in 1864. Schiff bases are represented as $R - CH = N - R^1$ where R and R^1 may be alkyl, aryl or heterocyclic group. Due to effective conjugation, Schiff bases of aromatic aldehydes are more stable than aliphatic aldehydes[1]. Ketones react slower than aldehydes in condensation reaction due to steric hindrance. Schiff bases are generally bidentate, tridentate, tetradentate and polydentate ligands to form stable complexes with transition metals. Schiff bases are effective ligands due to the presence of the azomethine group. Schiff bases derived from aromatic carbonyl compounds and primary amines have more applications in the fields of biological, analytical, inorganic chemistry, catalysis and optical materials. Schiff base ligands have donor atoms that may be nitrogen, oxygen or Sulphur which provided binding sites through non- bonding electrons[2]. The presence of the ─ CH =N group in the transition metal complexes which contains donor nitrogen atom is responsible for the stability, reactivity and biological activity of complexes. Transition metal Schiff base complexes are wide applications in medicinal chemistry, catalysis, polymerization reactions, dyes, corrosion, plant growth regulators and analytical chemistry. Due to chelation transition metal Schiff base complexes are more stable and have wide applications in antibacterial, antifungal, antiviral, anticancer, and anti-inflammatory.

2. Applications of Schiff bases and their complexes

2.1. Antibacterial Activity

In 2011, Xueqiong et al. were synthesized seven Schiff bases from o- carboxymethyl chitosan and para-substituted benzaldehydes and reported antibacterial activities against E.coli and S. aureus[3]. 4-((2-hydroxyl-1-naphthyl) methylene amino)-1,5-dimethyl-2-phenyl-1H-pyrazole-3(2H)-one Schiff base and its metal (Pt, Ni, Re, Cu, VO) complexes were synthesized and reported antibacterial activity against Gram-positive bacteria B. Subtilis and S.aureus and Gram-negative bacteria E.coli and P.aeruginosa (Zoubi et al., 2017) [4]. Cu(II), Ni(II) and Co(II) complexes of Schiff base were synthesized from anthranilic acid and salicylaldehyde and reported a good antimicrobial activity against E. coli, B.subtilis, B.cereus and P. aeruginosa using ciprofloxacin as a standard (Prajapati et al., 2019). The activity order of metal chelates is as follows: Cu(II)> Ni(II) > Co(II)> Ligand [5]. In 2018, Alzahrani et al. were synthesized Cu(II), Ni(II) and Zn(II) complexes of Schiff base derived from 2-aminobenzoic acid and different substituted aldehydes and reported as antibacterial activity against S.aureus, S. pneumonia, E.coli and P. aeruginosa [6]. Transition metal complexes of Co(II), Hg(II),Cd(II), Cu(II), Ni(II) and Zn(II) were synthesized from Schiff base ligand derived from 4-aminoantipyrine and 3-hydroxy-4-nitrobenzaldehyde were screened antibacterial activity against S.aureus, B.subtilis, E.coli and S.Typhi. Based on chelation theory metal complexes have higher antibacterial activity than free ligand (Raman et al.,2007) [7]. Copper, Cobalt, Nickel and Chromium complexes derived from (Z)-4-fluoro-N-(2,7-dimethylhept-6-enylidene) benzenamine were antibacterial studied by agar diffusion method. Schiff base ligand and metal complexes were evaluated for antibacterial activity against E. coli, S. Typhi, P. aeruginosa and B. subtilis (G Sridhar et al., 2017)[8]. A new series of metal complexes of Pd(II), Au(III) and Pt(IV) with Schiff base derived from condensation of 2-furaldehyde and 4-aminoantipyrine were screened against S. aureus, B. subtilis, P. aeruginosa and E. coli. The antibacterial data show that metal complexes are more potent antibacterial than the free Schiff baes ligand (Foziah A. Al-Saif,2013) [9].

2.2. Antifungal Activity

Metal complexes of Cu(II), Ni(II) and Zn(II) are synthesized with Schiff bases derived from 2-aminobenzoic acid and substituted aldehydes viz, o-vanillin, 2-carboxybenzaldehyde, salicylic acid, 1-(3-formyl-4-hydroxyphenylazo)-4-methylbenzene, then tested against fungi candida albicans. Zn(II) complexes exhibit more inhibition than Cu(II), and Ni(II) complexes (Alzahrani et al., 2018). The metal complexes of Ni(II), Co(II), Cu(II) and Zn(II) are synthesized with Schiff base derived from anthranilic acid and 3-ethoxysalicyaldehyde, then tested against two fungi A. niger and F. oxysporum. Cu(II) complex shows more fungal activity than the other complexes. The complexes of Cu(II), Ni(II) and Co(II) are synthesized from Schiff bases 3,4-dichloroaniline, 3,4-dimethylaniline and 5-bromosalicyaldehyde, then tested against A. niger and C. albicans by using miconazole as control. Antifungal activity of metal complexes are more than their ligands and activity increase upon coordination(Jain and Mishra, 2012) [10]. A Schiff base ligand derived from salicylaldehyde and 4-methyl-o-phenylenediamine formed complexes with Co(II), Ni(II), Cu(II) and Mn(II) and then tested for antifungal activity against A. niger and T. viride. The order of antifungal activities of the synthesized complexes is as follows Cu(II) >Ni(II) >Co(II) > Mn(II) >Ligand(Munde et al.,2010) [11]. The Cu(II), Co(II), Ni(II) and Cr(III) complexes of Schiff base derived from 4-chloroaniline and 2-hydroxy-3-methoxybenzaldehyde have been synthesized in an alcoholic medium(K Rathore et al.,2010). The antifungal activity of the ligand and its metal complexes were evaluated by agar diffusion method against two fungi F. oxysporum and A. niger using fluconazole as standard [12]. The Co(II), Mn(II) and Fe(II) complexes with Schiff base derived from anthranilic acid and o- vanillin showed antifungal activity against A. flavu and Fusariumoxy.The metal complexes show more antifungal activity than free ligand (Pradhan et al.,2018) [13]. The metal complexes of Co(II), Ni(II), Cu(II) and VO(II) with Schiff base 2-chlorobenzylidene-2-amino-4-chlotophenol showed antifungal activity against C. albicans and T. polysporum using nystatin as control (Mishra et al.,2009) [14]. Transition metal complexes of Co(II), Ni(II) and Mn(II) with Schiff base derived from salicylaldehyde and p- chloroaniline showed antifungal activity against A. flavus and mucor using ketoconazole as control (Ibrahim et al.,2018) [15].

2.3. Antiviral Activity

Schiff base derived from 3-amino-2-phenyl quinazoline-4(3) H-one with various substituted carbonyl compounds showed antiviral activities against Vaccinia virus, Influenza (A and B) virus, Reovirus, Sindbis virus (Kumar et al.,2010)[16]. Schiff bases derived from 1-amino-3-hydroxyguanidine tosylate showed good antiviral activity against mouse hepatitis virus (Sriram et al.,2006)[17]. Schiff bases derived from amino phenoxy ethane and substituted salicylaldehyde are effective against the Bovine herpes virus and influenza 3-virus(Haken et al.,2005) [18]. Schiff bases derived from 5-fluoroistatin, benzyl statin, istatin with 1^0 aromatic amines are effective against the Vaccinia virus, Herpes virus(1and 2) and Vesicular stomatitis virus(Aliasghar et al.,20007)[19].

2.4. Anticancer Activity

Binuclear metal complexes of Cu and Ni with Schiff base derived from 3,5-dichloro-2-hydroxyacetophenone and 4-chloro-o-phenylenediamine were screened for their anticancer activity against human breast cancer (MCF-7) cell (Bhoopathy et al.,2017) [20]. Transition metal complexes of zinc, copper, nickel and cobalt with Schiff base derived from 2-amino-4-phenyl-5-methylthiazole and salicylaldehyde were screened for their anticancer activities against liver cancer cell ($HepG_2$), colorectal cancer (HCT116), breast cancer cell(MCF-7) and lung cancer(A549) cell(Mokhles et al.,2016)[21]. Cadmium complex with Schiff base derived from tryptophan and 2-acetylpyridine showed anticancer activity against breast cancer(MDA-231) cell (Zhang et al.,2012)[22].

2.5. Antimalarial Activity

Schiff base derived from 4-pyridine carboxaldehyde and 3-aminoquinuclidine was effective against Plasmodium falciparum [23]. Schiff base N-(2-(2-hydroxyphenyl)methylamino ethyl)-7-chloroquinolin-4-amine with Ru and Os complexes are good antimalarial activity against Plasmodium falciparum (Erik Ekengard et al.,2015)[24]. Schiff bases derived from 2-hydroxy3-(morpholino methyl)benzaldehyde with mono and bis-aromatic amines in an ethanolic medium, and tested against Plasmodium falciparum (Jarrahpour et al.,2015)[25].

2.6. Plant Growth Regulator

Plant growth regulatory hormones are mainly 2,4-dichlorophenoxyacetic acid, naphthaleneacetic acid, indole-3-acetic acid and their derivatives are used in agriculture. Two novel Cu(II) complexes $Cu_2(C_{15}H_{31}COO)_4L_2$ and $Cu_2(C_{17}H_{35}COO)_4L_2$ derived from the same ligand 2-amino-6-bromobenzothiazole were synthesized and plant growth activity of metal complexes are tested on seeds of mung bean by standard Blotter method. Copper palmitate complex is a good root hair growth promoter while complex of copper caprylate is average growth promoter of root and shoot mass (Sonlata et al.,2016)[26]. The La(III), Nd(III), Pr(III), Sm(III), Gd(III), Eu(III), Dy(III) and Yb(III) complexes of Schiff base derived from 2,4-dichlorophenoxyacetic acid were synthesized and characterized by elemental analysis and spectroscopic techniques. In these complexes bidentate ligand coordinating through carboxylic acid after deportation. Auxin activity of Schiff base and its complexes was tested on seeds of wheat at different concentrations. The growth of root and shoot of wheat seeds was analyzed at different concentrations 0.00001M, 0.000001M and 0.0000001M. Schiff base and La(III) complexes have more plant growth regulatory activity at 0.000001M concentration than auxin(Naik et al.,2013) [27]. Salen and salophen type of ligands with Zn(II) complexes were synthesized and characterized by elemental analysis and spectral data. Plant growth regulatory activity of Schiff base ligands and their Zn(II) complexes were tested on seeds of papaya. N,N^1-bis(3-methoxy salicyalidinediamine)-o-phenylene monohydrate complex of zinc has the highest effect on germination and seeding growth of papaya(Acharjee et al.,2015)[28].

2.7. Catalysts

The catalytic activity of Schiff base transition metal complexes is high and depends upon coordination sites, metal ions and the nature of ligands. A series of new Co(II) complexes of Schiff bases bis-5-phenylazosalicyaldehyde-o-phenylenediimine and bis-5-phenylazosalicyaldehyde ethylenediamine were synthesized and characterized by elemental analysis and different spectral techniques. The catalytic properties of complexes of Co(II) were investigated for the oxidation of styrene into methyl phenyl ketone in the presence of oxygen and base pyridine. Bis -5-phenylazosalicyaldehyde-o-phenylenediimine Co(II) complex was more selective in propan-1-ol, on increasing the catalyst concentration in ethanol and propan-1-ol the reaction becomes more selective and bis-5-phenylazosalicyaldehyde ethylenediamine Co(II) complex, selectivity in propan-2-ol decreases when concentration of catalyst increases(Khandar et al.,2015) [29]. The catalytic performance of the Co(salen) for oxidation of the monomeric lignin (syringyl, 4-hydroxyl benzyl alcohol and vanillyl) was evaluated. On the basis of experimental observations, syringyl is easily oxidized into dimethoxy benzoquinone and pyridine ligand is coordinated with cobalt-salen catalyst. Vanillyl and 4-hydroxybenzyl alcohol did not undergo oxidation due to the lack of regeneration of the catalyst. By adding non coordinating bulky bases, vanillyl is converted into methoxy benzoquinone, which enhances the catalyst activity of Co complex(Cooper et al.,2020) [30]. The catalytic effects of some Fe(III), Cu(II) and Zn(II) Schiff base complexes derived from N,N^1-bis(o-hydroxy acetophenone) ethylenediamine were synthesized and the catalytic activity of complexes was investigated for the oxidation of phenol in presence of hydrogen peroxide under different conditions. The polymer anchored complexes of Fe(III) were more catalytic and high selectivity for catechol compare with Zn(II) and Cu(II) ions(Gupta and Sutar,2007) [31]. A monodentate Schiff base ligand N-benzylidene aniline was prepared by condensation of benzaldehyde and aniline. A series of transition metal Co(II) and Ni(II) complexes with this ligand have been characterized by IR and elemental analysis. These metal complexes were found to be moderate catalyst for benzoylation of phenol into phenyl benzoate(Talu and Yimer,2018) [32].

3 References

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