Research Article

A Sustainable Alternative to Conventional Strategy for the Synthesis of Schiff Base and their Transitional Metal Complexes: A Greener Approach

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Abstract

Schiff bases and their transitional metal complexes play an important role in the field of coordination chemistry compounds research since their discovery. Schiff bases and their metal complexes exhibit various pharmacological applications being antibacterial, antimicrobial, anticancer, antiviral, and anti-inflammatory. Nowadays, the field green chemistry is becoming highly demanding research topic. Green chemistry focuses on the reduction or elimination of harmful byproducts, and enhancing the yield of reaction. In this review a comparative study on the synthetic methods of Schiff bases and their metal complexes has been made. The synthesis of Schiff bases and their metal complexes are carried out by conventional methods and green methods. In conventional methods, Schiff bases are synthesized by refluxing an ethanolic solution of carbonyl compounds such as aldehydes and ketones with primary amine under constant stirring for about five to eight hours. While green method does not require any solvent for carrying out the reaction. Green methods require a less amount of time for the synthesis of Schiff bases and their complexes, also produces high percentage yield as compared to the conventional methods. Green methods are better than the conventional methods.

Keywords: Schiff bases, Green chemistry, Conventional methods, and Microwave irradiation

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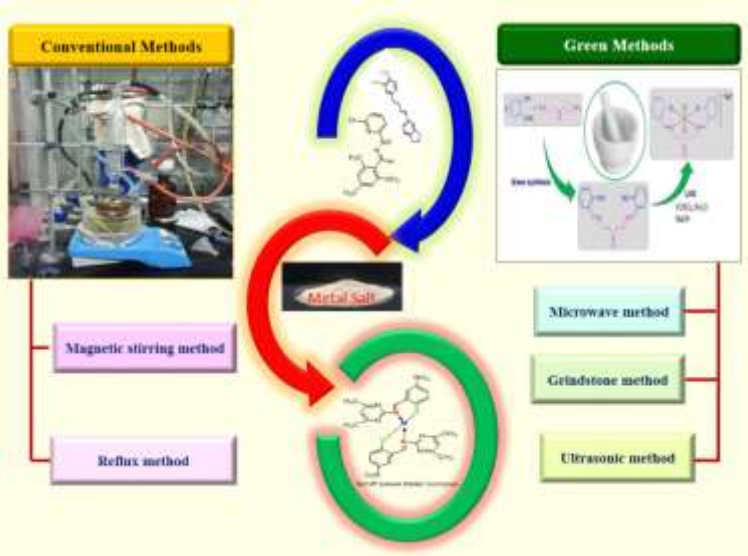


Introduction

The study of Schiff base ligands and their corresponding metal complexes is an active research area in current time owing to their enormous biological and catalytic applications [1-3]. The term Schiff base was introduced by Hugo Schiff, an Italian chemist in 1834 and the first Schiff base was also synthesized by him in 1864 [4]. Usually Schiff bases are synthesized by the condensation reactions of aldehydes and ketones with primary amine and the synthesized compound was characterized as Schiff base by the presence of imine or azomethine group. Since the discovery of Schiff bases, these ligands are considered as one of the most broadly used ligands due to their considerable versatility. Schiff bases are a class of interesting ligands because of their easy synthesis and ability to form stable complexes with most of the transition metals [5, 6]. In recent years Schiff bases and their coordination compounds have gained extensive attention owing to their significant biological activities being antifungal, antibacterial, anti-inflammatory,

and antiviral activities [7-9], catalytic activities [10-15], electroluminescent properties [16, 17], fluorescence properties [18-20], nonlinear optical (NLO) properties [21], and enormous applications in the field of sensors [22]and organic photovoltaic materials [23]. As a result, during the last decades the symmetrically-substituted Schiff base metal complexes have been intensively considered as they posse's specific eminent catalytic activities and this field has been the subject of frequent reviews. Schiff base ligands played an important role in the development of coordination chemistry of main group elements, transition metals and lanthanides [24]. The present review is divided in three main parts; we will focus on the synthesis, functions, and properties of multidentate Schiff bases and their metal complexes, based on selected recent works. Nowadays, coordination chemistry encloses a wide region of inorganic chemistry research, primarily concerned with the study of metal complexes. The design of Schiff base ligands and their corresponding complexes constitutes a significant and competent goal in the improvement of coordination chemistry [25, 26]. In the field of Inorganic chemistry, these Schiff base ligands play a principal role owed to synthetic flexibility, varied denticities and very good binding ability of azomethine group in chelation process[27, 28]. A number of researchers from their researches have evaluated that on chelation of Schiff base ligand with transition metal atom, the chelation increases their biological activities and thus the transition metal complexes that are obtained from the reaction of Schiff base ligands and metal salt posses promising biological activity and are considered as the focus of widespread investigations in coordination chemistry [29]. Due to their numerous structural modifications, extensive biological applications, photochromic effects, enzyme inhibitory properties, crucial role in homogenous and heterogenous catalysis, and use as agrochemicals, transition metal complexes with Schiff bases are exclusively synthesized and studied [30]. The result is that transition metal complexes containing Schiff base ligands have a variety of biological applications, including antibacterial [31], antifungal [32], anticancer [33], antitumor, antimalarial [34], antiviral [35], antiradical [36], antitubercular [37], ROS scavengers [38], anti-inflammatory [39], and antioxidant activities [40]. The Schiff base ligands can coordinate with the central metal atom in bidentate, tridentate, tetradentate, pentadentate, and hexadentate manner as shown in **Figure 1**.

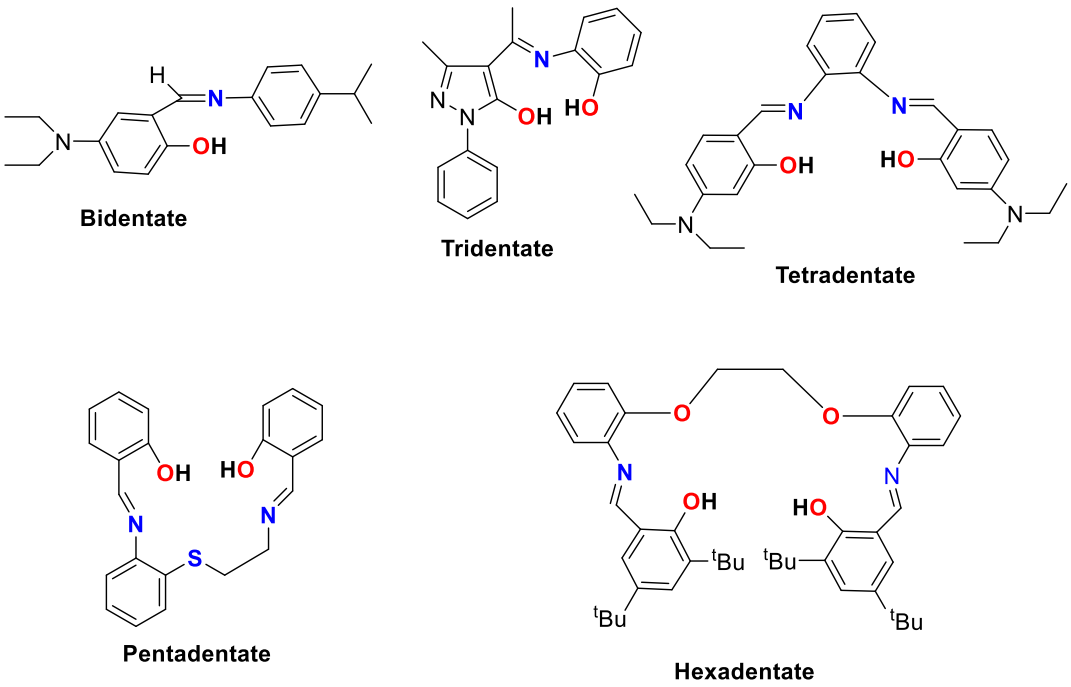
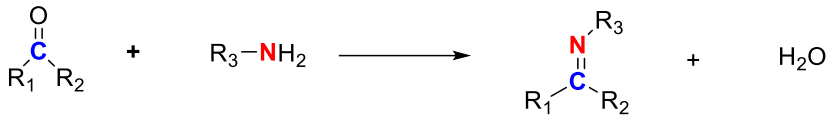


Figure 1 Various coordinating sites of Schiff base ligands

Synthetic routes of Schiff base ligands and their metal complexes

There are different methods for the synthesis of Schiff base ligands and their metal complexes. Generally the two methods for their synthesis are conventional methods and green methods. The conventional methods are Magnetic stirring method and the Reflux method. The green methods for the synthesis of Schiff bases are Microwave method, Grindstone method and Ultrasonic method. In conventional methods, the Schiff base ligands are generally synthesized by refluxing an ethanolic solution of carbonyl compounds such as aldehydes and ketones with primary amine for about 5 to 8 hours with the elimination of water molecule. The standard chemical formula of Schiff bases is $RCH=NR_1$ where R and R_1 are alkyl or aryl substituent [41, 42].According to the following **scheme 1**, the Schiff bases are typically synthesized by the nucleophilic addition of the NH_2 group to the C=O of the aldehyde, forming a

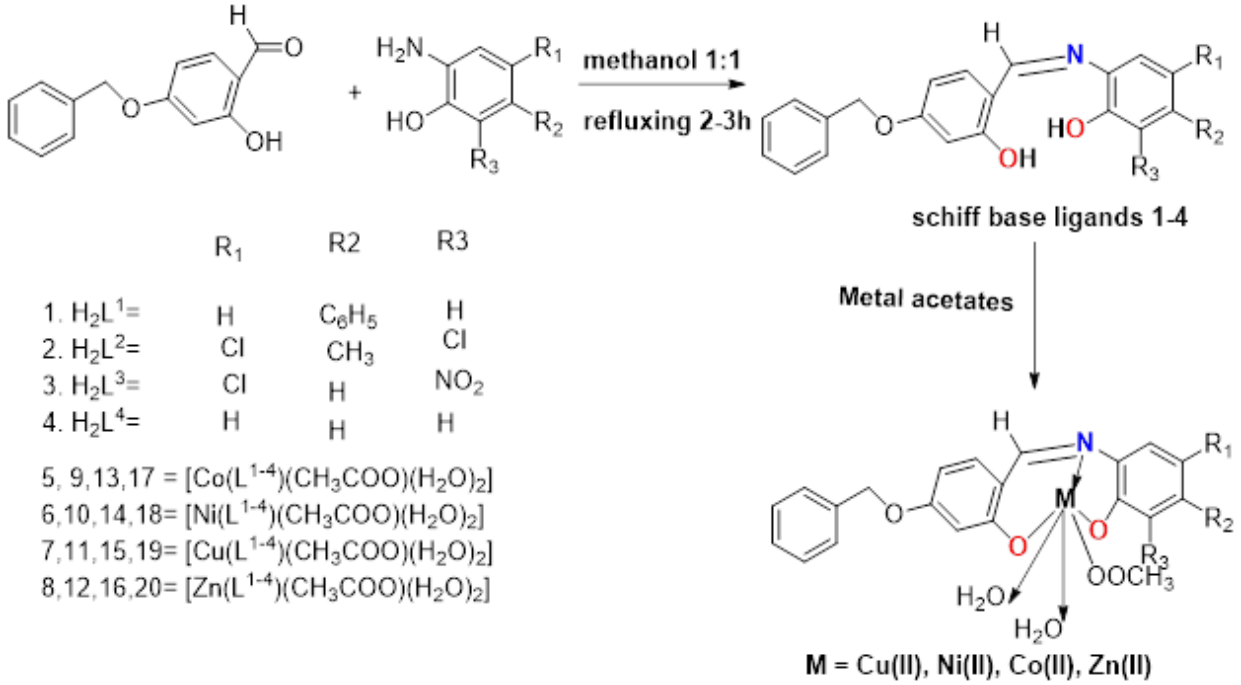
hemiaminal compound in an azeotropic refluxing condition while simultaneously removing water to produce an imine [43].



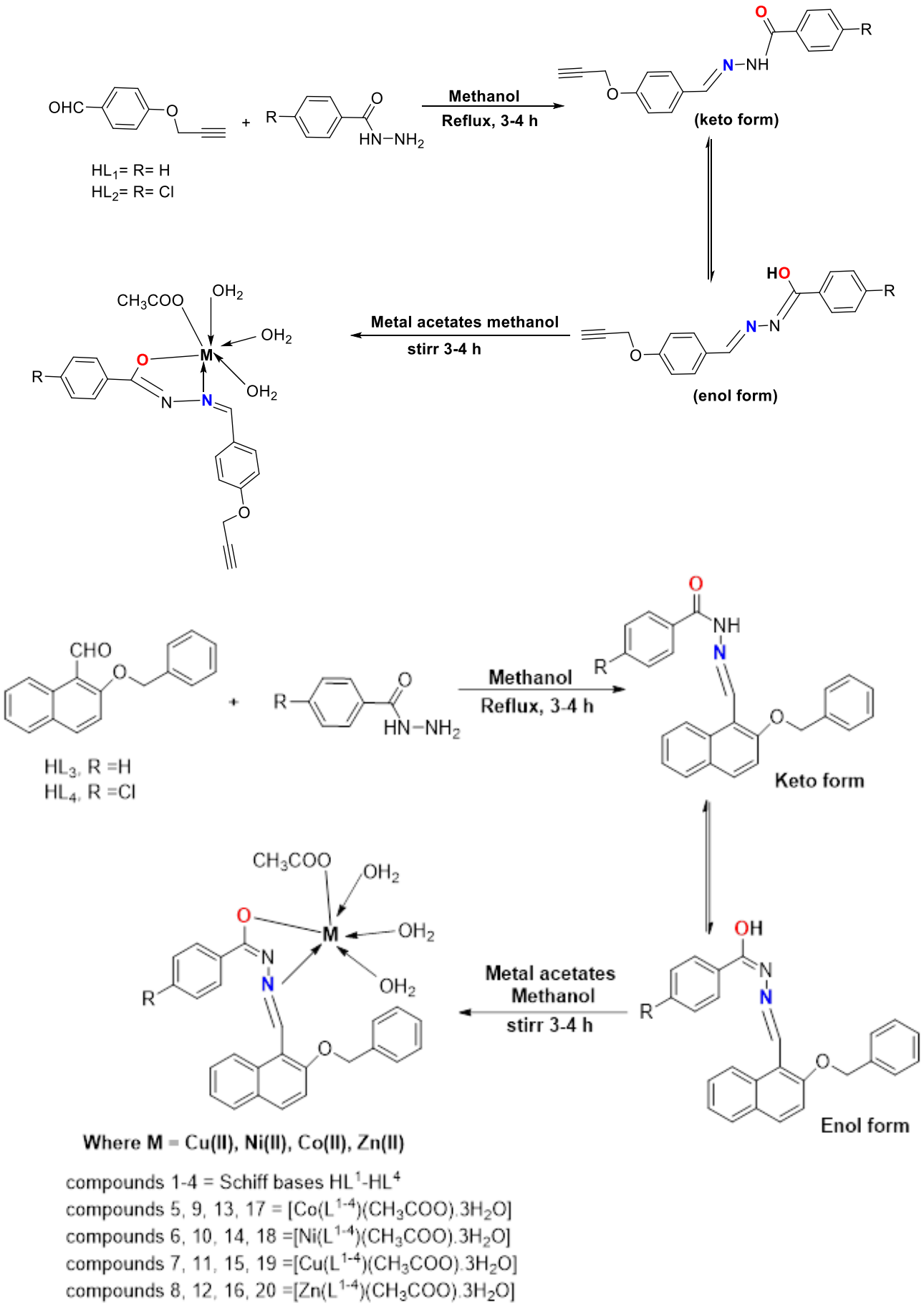
Scheme 1 Synthesis of Schiff base ligands

Conventional methods for the synthesis of Schiff base

Schiff base ligands are synthesized by refluxing an ethanolic solution containing equimolar amount of primary amines and aldehydes for 8-12 hours. The reaction is acid catalyzed and usually proceeded with an azeotroping agent (if necessary), or by separating the formed water [44, 45]. This reaction is significantly reversible and it is helpful to eliminate the formed water away from the reaction mixture in order to obtain a highest yield of the Schiff bases [46, 47].Devi *et al.* [48] have reported the synthesis of Schiff base ligands synthesized from the condensation reaction of 4-(benzyloxy)-2-hydroxybenzaldehyde with aminophenol derrivatives. They have also reported the synthesis of a series of sixteen complexes of Co(II), Ni(II), Cu(II) and Zn(II) derived from the synthesized Schiff base ligands that are 4-((4-(benzyloxy)-2-hydroxybenzylidene)amino)-[1,1'-biphenyl]-3-ol(H_2L^1),6-((4-(benzyloxy)-2 hydroxybenzylidene)amino)-4,6-dichloro-3-methylphenol(H_2L^2),2-((4-(benzyloxy)-2-hydroxybenzylidene)amino)-6-chloro-4-nitrophenol(H_2L^3),5-(benzyloxy)-2-(((2-hydroxyphenyl)imino)methyl)phenol (H_2L^4).All the synthesized ligands and metal complexes were characterized by using various spectroscopic techniques like FT-IR, UV–Vis, NMR, ESR, SEM, fluorescence, mass spectrometry, elemental analysis and physical studies (TGA, XRD, molar conductance, melting point).The compounds (1–20) were tested for their in vitro antioxidant activity, and it was discovered that the synthesized metal(II) complexes are highly potent and also demonstrate good efficiency for decolorizing the purple-colored solution of DPPH compared to free Schiff base ligands. Cu(II) complexes were the most potent, having IC_{50} values in the 2.98–3.89 M range. By using the serial dilution method, the compounds (1–20) were tested for their *in vitro* antimicrobial activities against four bacterial strains (*S. aureus, B. subtilis, P. aeruginosa, and E. coli*), two fungal strains (*A. niger*, *C. albicans*), and it was discovered that the metal(II) complexes are more toxic than free Schiff base ligands. The most effective compounds, according to the antibacterial activity results, were the complexes 10, 11, 14, and 15. Complex 11 ($Cu(L^2)(CH_3COO)(H_2O)$ was shown to have antifungal activity against *C. albicans* that was comparable to that of a typical medication. The scheme for synthesis of Schiff base ligands (1-4) and their Co(II), Ni(II), Cu(II), and Zn(II) complexes (5-20) in **Scheme 2** was proposed by the molecular docking of ligand H_2L^1 and its Cu(II) complex (11) with enzyme *C. albicans* sterol 14-alpha demethylase.



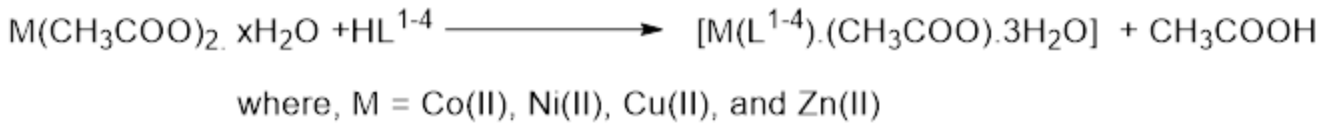
Scheme 2 Scheme for synthesis of Schiff base ligands (1–4) and their Co(II), Ni(II), Cu(II) and Zn(II) complexes (5–20)



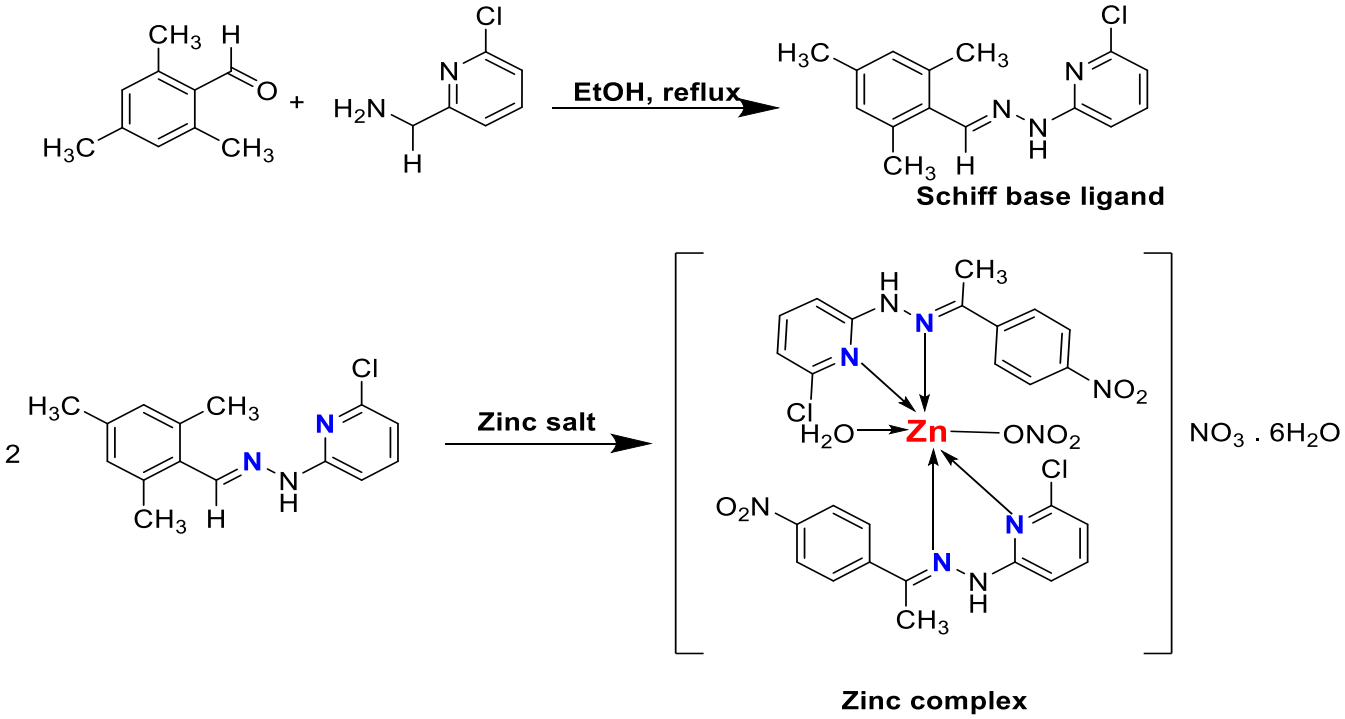
Scheme 3 Synthetic reaction scheme for the synthesis of Schiff bases (HL^1–HL^4) and their transition metal(II) complexes

Yadav *et al.* [49] have reported the synthesis of a series of coordination complexes of Co(II), Ni(II), Cu(II) and Zn(II) metals. They have also reported the synthesis of four novel Schiff base ligands (E)-N'-(4-(prop-2-yn-1-yloxy)benzylidene)benzohydrazide (HL^1),(E)-4-chloro-N'-(4-(prop-2-yn-1-yloxy)benzylidene)benzohydrazide (HL^2), (E)-N'-((2-(benzyloxy)naphthalen-1-yl)methylene)benzohydrazide (HL^3), (E)-N'-((2-(benzyloxy)naphthalen-1-yl)methylene)-4-chlorobenzohydrazide(HL^4) obtained by the condensation reaction of benzoic acid hydrazide/4-chloro benzoic acid hydrazide with oxy derivatives of 2-hydroxy-1-napthaldehyde/4-hydroxy benzaldehyde. These synthesized Schiff base ligands were further used for the synthesis of metal complexes by refluxing a methanolic solution of Schiff base ligands and metal acetates under constant stirring for about 3-4 hours. The synthesized ligands and their corresponding metal complexes were characterized by using various spectroscopic techniques being FT-IR, NMR, UV-Visible, and XRD etc. The fully characterized ligands and metal complexes were further evaluated for their biological activities such as antioxidant and antimicrobial. Copper(II) complexes were found to be the most potent among all the synthesized compounds and copper(II) complex 19 was found to be the highest toxic against all tested strains. The order found for antioxidant activity was: Ascorbic acid > Cu(II) > Ni(II) > Co(II) > Zn(II) > Schiff bases. The copper(II) complex (11) exhibits the uppermost antioxidant activity among the experienced compounds (IC_{50} = 2.04 M). The scheme for the synthesis of Schiff base ligands and their metal complexes is given in **Scheme 3, 4** respectively.

Topal [50] has reported the synthesis of pyridine-based Zinc (II) complexes and the characterization of the synthesized ligands and corresponding complexes were done using various spectroscopic techniques like IR, NMR, Mass spectrometry, and XRD etc. The pyridine-based ligands offer nitrogen atoms as donor to the zinc center. The synthesized zinc complexes were also evaluated for molecular docking studies for lung cancer cell. The method for synthesis of ligands and their complexes is given in **Scheme 5**.



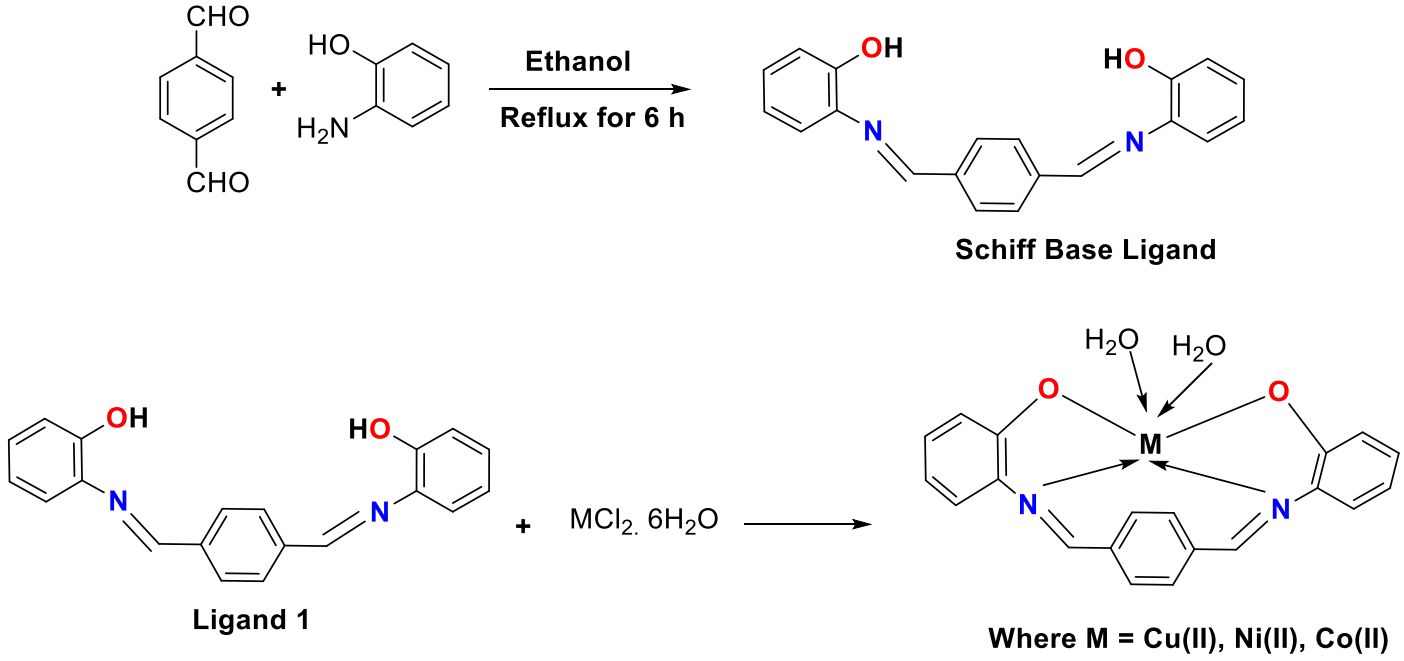
Scheme 4 $M(CH_3COO)_2.xH_2O$, $HL^{1-4} \rightarrow [M(L^{1-4})\cdot(CH_3COO)\cdot 3H_2O].CH_3COOH$ where, M = Co(II), Ni(II), Cu(II)and Zn(II)



Scheme 5 Synthesis of Schiff base ligands and their zinc complexes

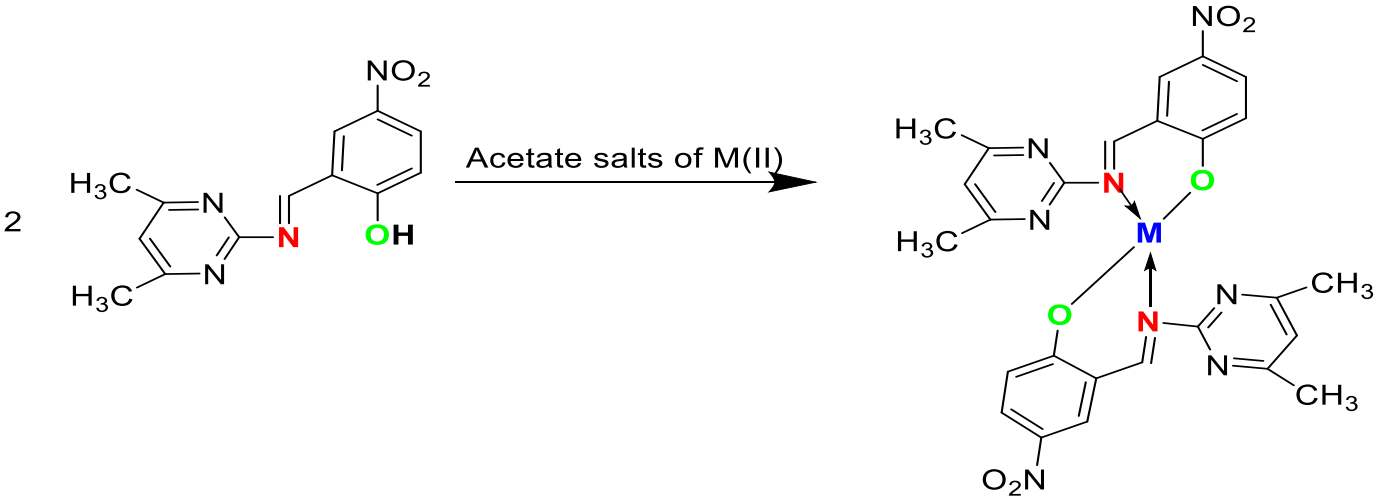
Saranya *et al.* [51] have also reported the synthesis of biologically active tetradentate Schiff base complexes of Cu(II), Ni(II), and Co(II). The ligands and their complexes were characterized using various spectroscopic techniques such as IR, UV, and X ray crystallography and an octahedral geometry is assigned to all the complexes. The

synthesized ligands and their complexes were further examined for their biological activity. The antibacterial activity was examined for the Schiff base ligands and their complexes in opposition to *Bacillus subtilis*, *Proteus vulgaris*, *Klebsiella sp.*, *S. aureus*, and *Escherichia coli*. Their antifungal activities were calculated against *Aspergillus flavus*, *Aspergillus niger*, *Cryptococcus neoformans*, and *Penicillium chrysogenum*. The results showed that the transition metal complex exhibits superior antibacterial and antifungal activities. The method for synthesis of the ligand and their metal complexes is given in **Scheme 6**.



Scheme 6 Synthesis of Bimetallic Zinc complexes

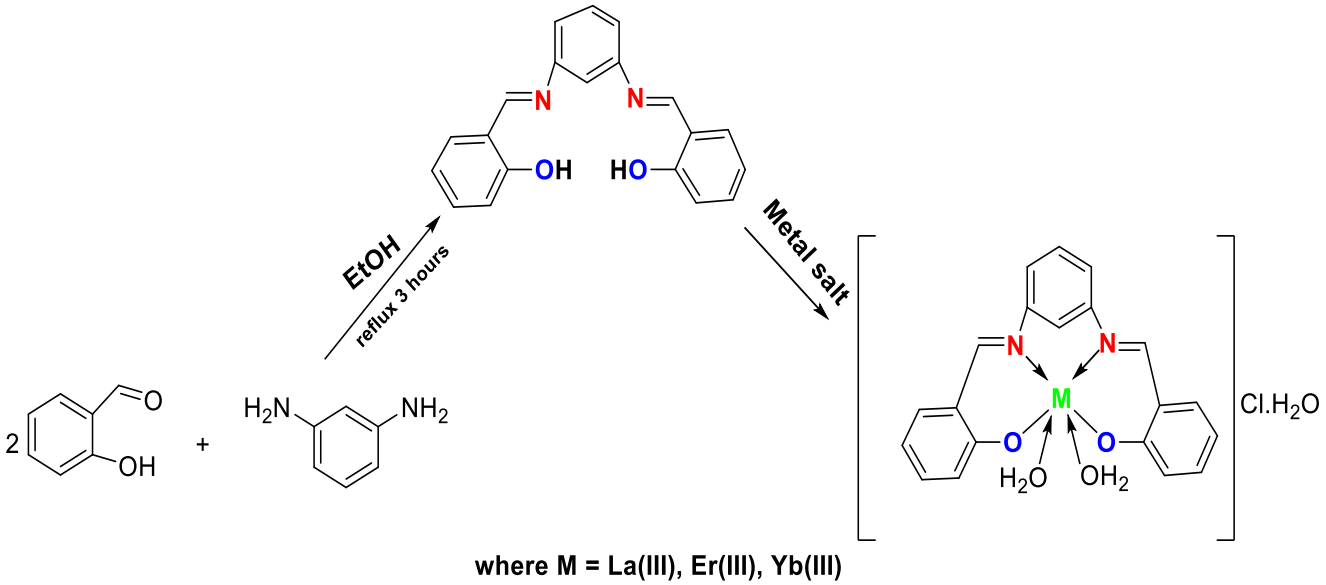
Revathi *et al.* [52] has also reported the synthesis of biologically active Cu(II), Co(II), Ni(II) and Zn(II) complexes of pyrimidine derivative Schiff base. The synthesized ligand and their corresponding metal complexes were characterized using several spectroscopic techniques like UV-Vis, IR, NMR, and XRD etc. The characterized ligands and corresponding metal complexes were also evaluated for their biological activities like DNA Binding, Antioxidant, Antibacterial and *In Vitro* anticancer activity. Antioxidant activity for the complexes was analyzed using DPPH and SOD assay. Antibacterial activity of the complexes was determined against different *Gram negative* and *Gram-positive* strains. In case of antibacterial studies, it was observed that the complexes are potent active against *Gram negative* and *Gram-positive* strains (**Scheme 7**).



M= Cu(II), Co(II), Ni(II), Zn(II)

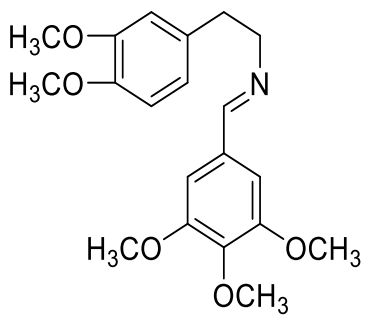
Scheme 7 Synthesis of metal complexes with Schiff base ligand

Diab *et al.* [53] has reported the synthesis of inner metal complexes of tetradentate Schiff base ligands (**Scheme 8**). The ligands and their complexes were characterized using elemental analysis FT-IR, NMR, UV-Visible spectra, molar conductance measurement, and TGA. All the complexes were found to have water of crystallization. Based on the results of all the characterization techniques an octahedral geometry is assigned to all the complexes. The synthesized Schiff base metal complexes were evaluated for their biological studies. The antifungal activity was studied against *C. albicans* and *A. fumigates*. The experimental results showed that the metal complexes exhibit good antimicrobial activities as compared to free ligands.

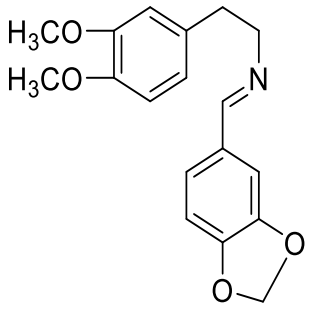


Scheme 8 Synthesis of Schiff base ligands

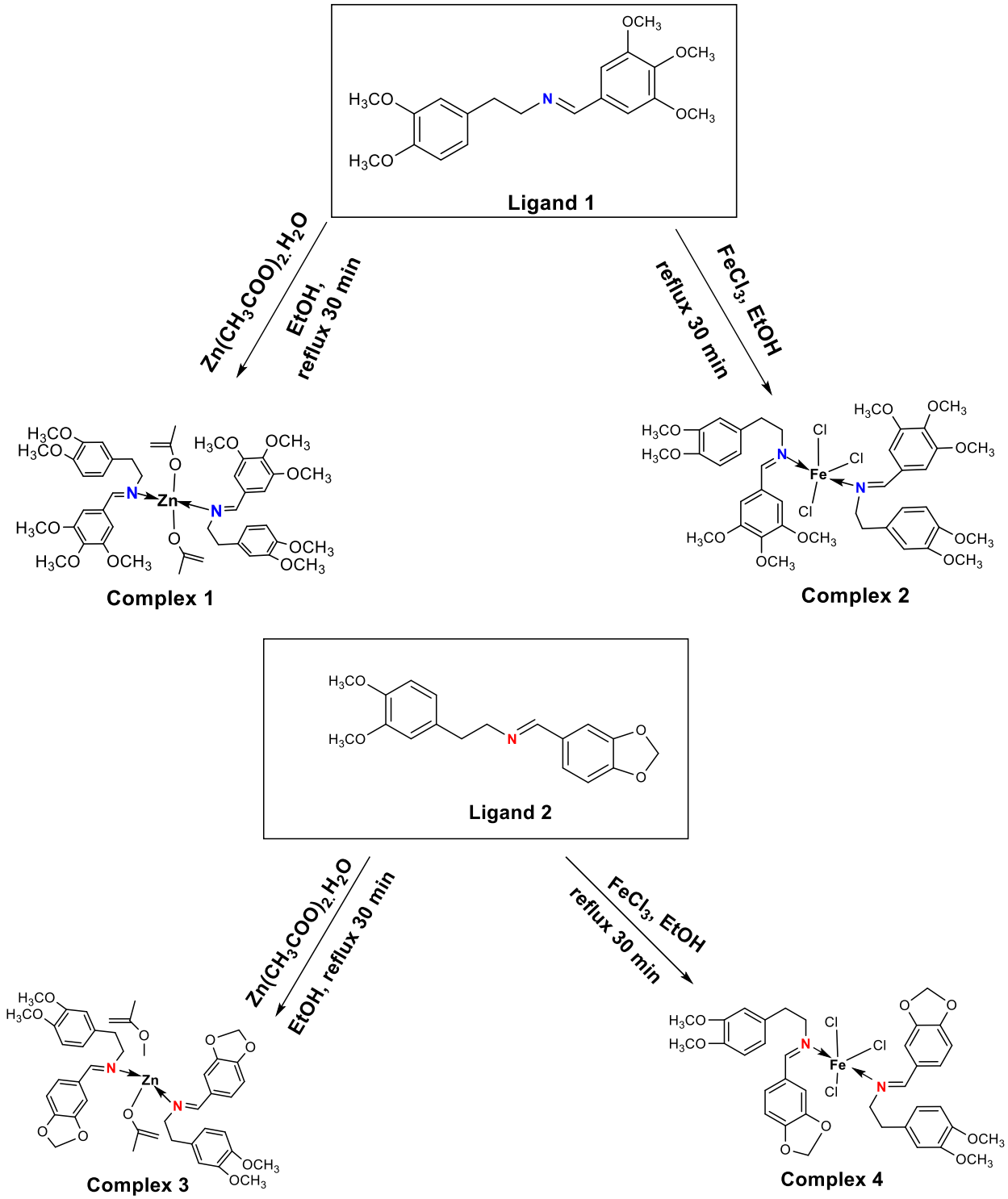
The production of Iron(III) and Zinc(II) monodentate Schiff base metal complexes has been described by Bushra et al. [54]. Various spectroscopic methods, including UV-Visible, IR, NMR, and mass spectrometry, were used to characterize the synthesized ligands and the metal complexes that corresponded to them. The biological uses of the synthesized ligands and their metal complexes, such as their antibacterial, antifungal, cytotoxicity, and antioxidant activities, were also assessed. The hypothesized structures of the ligands and their corresponding Iron(III) and Zinc(II) metal complexes were supported by the findings of all spectral characterization techniques. All ligands and their metal complexes were examined for their ability to inhibit the growth of gram-*positive (Pseudomonas aeruginosa)* and *gram-negative (Escherichia coli* and *Staphylococcus aureus*) bacteria. Tetracycline served as the reference medication. Every ligand was said to have some action against every type of bacterial species, however the metal complexes had stronger activities than the original ligands. All of the ligands and metal complexes underwent antifungal assessment using the well-in-agar method. *Candida glabrata* and *Candida albicans* was the test species employed. Nystatin was a widely used medication. When compared to *Candida glabrata*, all of the complexes were said to have more effectiveness against *Candida albicans*. Among all the ligands and complexes, zinc complexes were said to have the strongest antifungal effects. The DPPH test was used to check the antioxidant activity of the ligands and the corresponding metal complexes. Free ligands reportedly exhibited better antioxidant behavior. **Scheme 9** presents the structures of ligands and their metal complexes.



Ligand 1



Ligand 2

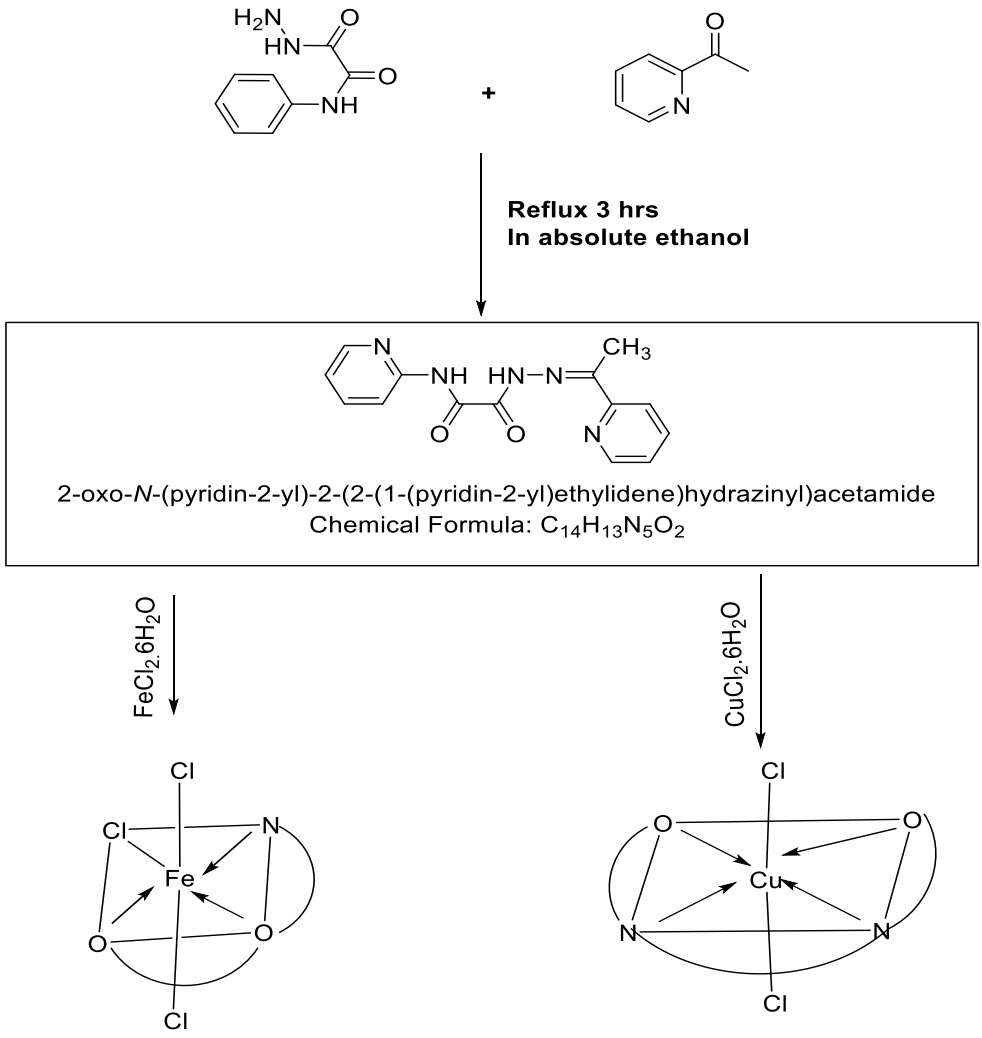


Scheme 9 Synthesis of Iron(III) and Zinc(II) complexes

Synthesis of Schiff base complexes via green methods

In the field of coordination chemistry, the creation of simple-stable complexes allowed for extensive study of Schiff base ligands. Ball milling chelation with diketone was used to create Ni (II), Co (II), and Cu (II) complexes with high yields. The VO (II) and Cu (II) complexes, which were synthesized in large quantities using Schiff base derivatives and examined for their biological properties as well as DNA-binding effectiveness, are examples of Schiff base complexes recognized for demonstrating broad biological properties. The area of chemistry that deals with tools, procedures, and technologies is known as "green chemistry." Chemists and chemical engineers can use it to create more environmentally friendly and productive goods, which may also have considerable financial advantages. It is now going to be a crucial instrument in synthetic chemistry. It is a new way of thinking about organic synthesis and the design of medicinal molecules, and it has significant advantages over conventional synthetic procedures in terms

of the environment and the economy. The growing interest in green chemistry has created a new challenge for organic synthesis since novel reaction conditions must be discovered that limit the use of dangerous toxic compounds and the emission of volatile organic solvents. They enhance selectivity, speed up response times, and simplify the separation and purification of production than the conventional methods. The traditional synthetic method for making Schiff bases was first described by Schiff, and it calls for the condensation of primary amines with carbonyl compounds during azeotropic distillation while simultaneously removing water. The interest in these compounds is largely a result of their structural resemblance to naturally occurring biological molecules, relatively easy synthetic processes, and synthetic flexibility that allows the design of functional structural features. They serve as a well-known intermediary in the production of several other derivatives, including azetidinone, thiazolidinone, formazone, arylacetamide, and metal complexes. One of the most potent classes of chemicals, Schiff bases have a wide range of biological applications, including antitubercular, anticancer, antibacterial, anti-inflammatory, antifungal, antitumor, diuretic, insecticidal, herbicidal, anthelmintic, anti-HIV, anti-proliferative, anticonvulsant, antihypertensive, and antiparasitic activities. For more than a century, the Schiff's base derivatives have been thoroughly studied and used in a variety of fields, such as magnetic chemistry, non-linear optics, photophysical research, catalysis, materials chemistry, chemical analysis, and oxygen absorption and transport. New environmentally friendly catalysts and techniques have been researched that are both economically and technologically possible because of their advantageous qualities, environmental demands, and strong interest in the development of green chemistry. For the synthesis of Schiff bases, the current researcher also uses certain natural, cheap, and eco-friendly catalysts, such as grape (*Vitis lanata*) juice, sweet lemon (*Citrus limetta*) juice, and mango (*Mangifera indica*) aqueous extract. Green techniques of synthesis have been used to create Schiff base ligands as well as Schiff base metal complexes, according to Hazmi and colleagues [55]. The usual method of synthesis was used to create the Schiff base ligand 2-oxo-N-(pyridine-2-yl)-2-(2-(1-(pyridin-2-yl)ethylidene) hydrazinyl)acetamide. Schema 10 outlines the green synthetic strategy and synthetic method for the Schiff base ligand used in the production of Schiff base metal complexes.



Scheme 10 Green synthesis of Schiff base metal complexes.

Shah *et al.* [56] have also reported the green synthesis of novel Schiff base complexes and also reported *in-vitro* screening further supported by *in-silico* study. The synthesized Schiff base complexes were further characterized by using various spectroscopic techniques like SEM, EDS, and XRD.

Conventional Methods *vs* Green Methods for Schiff base complex synthesis

By refluxing a combination of primary amine and aldehydes in non-aqueous solvents for around 5 to 6 hours while stirring continuously, conventional methods can produce Schiff base ligands and the accompanying transition metal complexes. Acid is used to trigger the reaction, which is often carried out with the help of an azeotroping agent (if necessary) or by separating the generated water. To obtain the highest possible yield of the Schiff bases, it is advantageous to remove the generated water from the reaction because it is very reversible. While grinding, natural acid-catalyzed procedures, microwave irradiation, and natural acid-catalyzed methods are all environmentally friendly ways to make Schiff base complexes. There are many researchers who compared conventional and green synthesis methods of Schiff base complexes.

In 2012, Sachdeva and his colleagues evaluated the efficacy of four alternative techniques for synthesizing Schiff bases. The grindstone friction-activated synthesis was evaluated in method I [57]. The same molar amounts of the aldehyde and dl-alanine amino acid were dissolved in the least amount of water. The mixture was then crushed in a mortar for five to ten minutes. The primary slurry mixture solidified for 20 to 25 minutes before being left overnight (8 hours). In technique II, the effectiveness of stirring was examined by combining an equimolar of the identical reactants with 5 ml of water, then swirling the mixture magnetically at (25°C) until the reaction had fully developed. Refluxing the same reactants with 10 ml of water for 1 hour was Method III. In contrast, method IV examined the effects of microwave irradiation by using an equimolar mixture of the same reactants with 5 ml of water and irradiating it at 250 W for 5–6 minutes. In this research, water is used as a green solvent to create Schiff bases. The outcomes show that procedures I and III are more difficult and time-consuming than stirring at 25°C and using a microwave. Since none of the aforementioned processes use organic solvents, they are all regarded as being environmentally friendly.

Chawla *et al*. [58] conducted yet another comparison study in which they synthesize a group of Schiff bases using various techniques. In the first method, they refluxed equimolar amounts of 4-amino benzene sulfonamides with various aromatic aldehydes at 50–60 °C, using ethanol as the solvent and glacial acetic acid as the catalyst. In the second technique, an open vessel was microwave-irradiated with or without organic solvents. Without a solvent, the condensation reaction was found to proceed quickly and effectively; however, if glacial acetic acid was introduced in a catalytic amount, the reaction only required 2-3 minutes. The third technique, the natural acid catalyst, produced the Schiff bases in outstanding yields (94%), mixing lemon juice (a natural acid) with the reactants for 30 minutes without the use of any solvents. This environmentally friendly reaction provides a number of advantages, including minimal reaction environments, simple work-up, and high yield. The fourth approach uses Lewis acids ($ZnCl_2$, $TiCl_4$, alumina, and P_2O_5) to get around problems with water removal. Lewis acid serves as a drying agent for effective water elimination in the second step in addition to accelerating the nucleophilic attack of amines on carbonyl carbon. The yield was 96.90% in the fifth procedure, which involved mixing an equimolar amount of p-toluidine and vanillin and preserving them in a UV chamber for 15 minutes. The catalyst acetic acid allowed the preceding experiment to be completed in 9–10 min with the same yield. The last procedure was mixing equal amounts of p-toluidine and vanillin in a pestle and pastel for 10–12 minutes. The product was then left to stand overnight in a dark environment, and the yield was 95.80%. In the end, they come to the conclusion that these approaches are more suited when compared to the traditional way because they provide a higher yield in less time and under simpler conditions, without generating any pollution. The microwave approach was the first priority.

In another study, Arafa and Shaker (2016) synthesized a group of new bis-Schiff bases under microwave irradiation, sonication and regular methods with no catalyst. They observed that, the ultrasound method enhanced the yield and minimized the reaction rate. Nevertheless, the microwave irradiation show no valued enhancement in the yield (70-88%) even when they increase the irradiation times. In a different study, Arafa and Shaker (2016) synthesized a collection of novel bis-Schiff bases using conventional techniques, sonication, and microwave irradiation without the use of a catalyst [59]. At the conclusion, they saw that the ultrasonic approach increased yield while reducing reaction pace. Hence it was concluded that the green methods are more beneficial as compared to conventional methods. Four synthetic methods of Schiff base were tested by Kapadnis and his team in 2016 [60]. The first time that 10% NaOH was given to reactants to change the pH was during the microwave irradiation. The reaction mixture was then microwave-irradiated for 8 minutes. The second approach involves 8 hours of refluxing the prior combination. The third procedure involved stirring the same preceding mixture for five hours at room temperature using a magnetic stirrer. The last procedure involved crushing the reactants with 10 ml of ethanol in a mortar and pestle. After about 20 minutes of grinding, the pH was adjusted with a few drops of citric acid. The outcomes showed

that the first approach had a significant benefit. It is ideal for industrial manufacturing, which has the best yield and uses the least amount of time. There are many ways for synthesising Schiff bases under microwave irradiation, according to a review study by Shntaif and Rashid (2016) [61]. The reactants were either mixed with or without alcohol, acetic acid was added with ethanol, glacial acetic acid was employed as a catalyst with DMSO, neutral alumina, silica gel, or concentrated sulfuric acid were all utilised as catalysts, as well as the combination of these. All of these procedures were carried out in a microwave environment. They come to the conclusion that these techniques were useful tools for reducing reaction times and improving yields.

A comparison research employing several Schiff base synthesis techniques was conducted by Dayma *et al*. [62]. In the traditional procedure, a mixture of salicylaldehyde and sulphanilic acid in ethanol was added, and the resulting liquid was agitated at room temperature for 4 hours. A solution of the same reactants in ethanol was agitated by a magnetic stirrer at (25^{o}C) for an hour while using the room temperature method (a few drops of acetic acid were added gradually). In contrast, the reactants in the grindstone procedure were combined with a few drops of acetic acid and pounded in a mortar and pestle to create a yellow solid in 20 to 40 minutes. One drop of glacial acetic acid was added to the reactants after they had been dissolved in ethanol for the microwave technique. The reactants are dissolved in ethanol for the microwave technique, a drop of glacial acetic acid is added, and the mixture is then microwaved at 140 W for two to three minutes and highest results were attained using the microwave technique. The outcome also shows how much better the grindstone process is than the conventional method. The reaction went quickly and produced good yields without the requirement for an organic solvent.

Sravanthi *et al.*have used green methodology to create a new series of Schiff bases as NO donors by condensation of 2-hydroxyacetophenone with furfuryl amine utilizing four different methods [63]. Utilizing a microwave-assisted reaction in a fruit juice medium, an effective, economical, and environmentally friendly technique has been created. This process was also contrasted with the traditional method, the way of grinding, and the typical microwave procedure. Compared to other synthesis techniques, the microwave method that uses fruit juice as a catalyst appears to be straightforward, efficient, and environmentally friendly.

Eftekhari *et al.* research on imidazole Schiff bases was novel [64]. Heating, microwave irradiation, and the use of ethanol are all used during the synthesis. According to the data, it only takes 2-4 minutes to produce Schiff bases using ethanol and a microwave, with maximum yields of 90–98%. The hour-long reaction time can be reduced to a minute, and the product yield can be increased thanks to microwave irradiation [65].The creation, synthesis, and chemo-photophysical evaluation of two Schiff bases generated from 4-aminobenzoic acid, 4-(4-(diethylamino)benzylidene)aminobenzoic acid, and 4-((4-methoxybenzylidene)aminobenzoic acid, were reported by Xochicale-Santana et al. in 2021. However, compared to conventional heating, the Schiff bases produced using green synthetic processes (ultrasound and microwave synthesis) use less time and energy [66].

Conclusion

Green chemistry outperforms conventional synthetic techniques in terms of both environmental and monetary benefits. In comparison to conventional procedures, the green synthetic techniques must improve selectivity, speed up reaction times, and simplify product purification. Primary amines and aldehydes condense to generate a Schiff base. In order to identify the best approach that provides higher yields in a shorter amount of time in an environmentally friendly setting, this study concentrated on the green synthetic methods utilized for Schiff bases synthesis. The evaluation took into account a variety of green synthetics approaches, with the microwave irradiation method coming out on top, followed by the ultrasonic, using natural acids, and grinding techniques. The green method that is the Microwave irradiation method has been proved here as a superior method for the synthesis of Schiff bases as it enhances the percentage (%) yield and this method is also an eco-friendly method. This field is now becoming an emerging research area owing to its wide range of applications in pharmaceutical industry, catalysis, dyes, and nanotechnology. So, it is required to switch to an eco-friendly method for the synthesis of these biologically active Schiff base ligands and their metal complexes for their future applications. The Schiff base metal complexes synthesized via green methods can be beneficial for the sustainable development of country.

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