# Synthesis, Characterization and Applications of Shiff Bases: A Review

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## ABSTRACT

It has been found from the various studies that organic compounds play important role in ever branch of science including synthetic chemistry, analytical chemistry, medicinal chemistry and coordination chemistry etc. Therefore, many organic compounds are being synthesized all over the world. One of the typical organic compounds are known as Schiff Bases, Imines and Anils. Schiff Bases are synthesized worldwide as these have a typical functional group. Therefore, many researchers synthesized number of Shiff Bases from different derivatives of amines and carbonyl compounds and prepared Shiff Bases have been evaluated for their applications in various fields as mentioned above. Some recent researches of last 15 years on Schiff Bases are mentioned and reviewed in this study. It is concluded that synthesis of new Schiff Bases have been prepared worldwide but studies on their applications in various fields. Although, many Schiff Bases have been prepared worldwide but studies on their application part have not attracted much attention. So, it is recommended to study the same.

Key Words: Schiff Base, Imines, Anils, Synthesis and Characterization.

### **General Introduction**

Schiff Bases are organic compounds contain >C=N<. group. Schiff Bases were first introduced by Hugo Schiff in 1864<sup>[..]</sup>. He condensed primary amine with carbonyl compound and found that a typical compound was obtained with general formula >C=N<. These compounds were found to have great application in various fields like synthetic chemistry, analytical chemistry, medicinal chemistry and coordination chemistry etc. Therefore, many researchers synthesized number of Shiff Bases from different derivatives of amines and carbonyl compounds and prepared Shiff Bases have been evaluated for their applications in various fields as mentioned above. Some recent researches (of last 15 years) on Schiff Bases are mentioned and reviewed here.

#### Literature Review

Afkhami et al.  $(2009)^1$  studied equilibria of a new Schiff base derived from 3,6-bis((aminoethyl)thio)pyridazine spectrophotometrically with the aid of factor-analytical methods. Hard modeling program was used for determination of the acidity constants of the Schiff base in dimethylformamide (DMF)/water mixture (30:70 v/v). In this method acidity constant equations act as hard models and the score vectors obtained by decomposing of absorbance data matrix will be linear combinations of equilibrium concentrations of species that exist in the absorption matrix. Two rank annihilation factor analysis (TRAFA) was used as a standard method to investigate the accuracy of the method. The tautomerization constant,  $K_t$ , of the Schiff base solution in various DMF/water mixtures has also been determined using spectral variations of the Schiff base solutions in various volume ratios of water with the aid of evolving factor analysis (EFA) and multivariate curve resolution alternative least squares (MCR-ALS) methods. In addition, the intramolecular hydrogen bonding strength and its related thermodynamic parameters have been determined using MCR-ALS and spectral variation of the Schiff base solutions in different temperatures.

**Bach** *et al.*  $(2009)^2$  investigated kinetics of Schiff base formation between the cholesterol ozonolysis product 3 $\beta$ -hydroxy-5-oxo-5,6-secocholestan-6-al and dimyristoyl phosphatidylethanolamine. The activation energy of Schiff base formation at temperatures above and below the phase transition of the phospholipid was calculated. Increase in the activation energy derived from perturbation of the surface structure by the process of Schiff base formation was demonstrated. The presence of the Schiff base with the aldolization product of the oxysterol was also observed and its significance is discussed.

**Cakir et al.** (2009)<sup>3</sup> prepared novel Schiff-base of cysteine and saccharin  $[(2R)-2-(1, 1-\text{diox}-1, 2-\text{dihydro}-1\lambda6-benzo[d]isothiazol-3-ylideneamino)-3-mercapto-propionic acid] and characterized by UV–Vis, FT-IR, <sup>1</sup>H NMR and elemental analysis. The voltammetric behaviour of Schiff-base was investigated on the static mercury drop electrode (SMDE) by using Square-Wave voltammetry (SWV) and Cyclic voltammetry (CV). The voltammograms of the Schiff-base gave three reduction waves in Britton–Robinson buffer (pH 5.0–9.0) for the potential range from 0.0 to <math>-1.4$  V. The first reversible cathodic peak is due to reduction of the mercury thiolate, produced by the thiol group of Schiff-base which adsorbs at Hg electrode surface, to metallic mercury and free thiol. The second reduction peak may be assigned to the reduction of azomethine center (> C=N-) in the Schiff base and the last peak may be related to the catalytic hydrogen reduction.

**Qiu et al. (2009)**<sup>4</sup> found out that, Methyltrioxorhenium (MTO) forms complexes with Schiff-bases derived from 2pyridinecarboxaldehyde and amines. These complexes were isolated and fully characterized by NMR, IR, UV–Vis, EA, MS. Two were analyzed by X-ray crystallography, which showed that the compounds display distorted octahedral geometry in the solid state with a *trans*-position of Schiff-base ligand. The characterized results indicated that the more Lewis basic the ligand is, the stronger the metal–ligand interaction between the rhenium atom and the ligand. The complexes displayed high catalytic activity and selectivity when applied to the epoxidation of cyclohexene with urea hydrogen peroxide adduct (UHP) as oxidant in methanol, but poor performances with hydrogen peroxide (30%) as oxidant due to their decomposition. Experimental results revealed that the MTO Schiffbase complexes are, in general, more sensitive to water than MTO itself. Moreover, large excess of ligand is detrimental to the catalytic performance as it leads to the decomposition of the complexes.

**Rathee**  $(2009)^5$  synthesised some novel Schiff's bases by the condensation of para dimethyl amino aniline derivatives and phenyl glyoxal derivatives. There complexes with different metal ions were prepared with suitable methods. Stability constant and free energy change have been evaluated from classical methods.

**Kianfar et al.** (2010)<sup>6</sup> synthesized new tetradentate unsymmetrical  $N_2O_2$  Schiff base ligands, Ni(II) and Cu(II) complexes and chracterized by IR, UV–vis, <sup>1</sup>H NMR and elemental analysis. The electrochemical properties of the Ni(II) complexes were investigated. The thermogravimetry of the Ni(II) and Cu(II) complexes were carried out in the range of 20–700 °C. Decomposition of synthesised complexes is related to the Schiff base characteristics.

Kocyigit et. al (2010)<sup>7</sup> synthesized a novel Schiff base and its complexation properties with some transition metal ions. For this, the 2,3,4,6,7,10,11 hexahydroxytriphenylene (HHTP) as starting material was synthesized according to known procedure. Moreover, the 2-((2-chloroethylimino)methyl) phenol material was prepared with reaction of salicylaldehyde 2-chloroethylamine hydrochloride. and To give the 2,3,4,6,7,10,11hexakis(salicyliminoethoxy)triphenylene (HSE-TP) as a novel Schiff base, the HHTP were treated with 2-((2chloroethylimino)methyl)phenol in acetone media. Complexation properties of this Schiff base were investigated towards Ni(II), Cu(II), Co(II), Zn(II), Pd(II) and Cd(II) as transition metals. The structures of these new compounds (ligand and complexes) were characterized with FT-IR, magnetic susceptibility measurement, thermal methods (TGA), <sup>1</sup>H NMR and elemental analyses.

**Naiya et al** (2010)<sup>8</sup> synthesized two Schiff bases, HL<sup>1</sup> and HL<sup>2</sup> by the condensation of *N*-methyl-1,3propanediamine (mpn) with salicylaldehyde and 1-benzoylacetone (Hbn) respectively. HL<sup>1</sup> on reaction with Cu(ClO<sub>4</sub>)<sub>2</sub>·6H<sub>2</sub>O in methanol produced a trinuclear Cu<sup>II</sup> complex, [(CuL<sup>1</sup>)<sub>3</sub>( $\mu_3$ -OH)](ClO<sub>4</sub>)<sub>2</sub>·H<sub>2</sub>O·0.5CH<sub>2</sub>Cl<sub>2</sub> (1) but HL<sup>2</sup> underwent hydrolysis under similar reaction conditions to result in a ternary Cu<sup>II</sup> complex, [Cu(bn)(mpn)ClO<sub>4</sub>]. Both complexes have been characterised by single-crystal X-ray analyses, IR and UV–Vis spectroscopy and electrochemical studies. The partial cubane core [Cu<sub>3</sub>O<sub>4</sub>] of **1** consists of a central  $\mu_3$ -OH and three peripheral phenoxo bridges from the Schiff base. All three copper atoms of the trinuclear unit are five-coordinate with a distorted square–pyramidal geometry. The ternary complex **2** is mononuclear with the square–pyramidal Cu<sup>II</sup> coordinated by a chelating bidentate diamine (mpn) and a benzoylacetonate (bn) moiety in the equatorial plane and one of the oxygen atoms of perchlorate in an axial position. The results show that the Schiff base (HL<sup>2</sup>) derived from 1-benzoylacetone is more prone to hydrolysis than that from salicylaldehyde (HL<sup>1</sup>). Magnetic measurements of **1** have been performed in the 1.8–300 K temperature range. The experimental data clearly indicate antiferromagnetism in the complex. The best-fit parameters for complex **1** are g = 2.18(1) and J = -15.4(2) cm<sup>-1</sup>.

**Parida et al (2010)**<sup>9</sup> reported the synthesis, characterization and catalytic evaluation of a Fe(III)-Schiff base complex intercalated Zn-Al layer double hydroxide (LDH). The immobilized complex was characterized by powder X-ray diffraction, FT-IR, UV–vis spectroscopy, N<sub>2</sub> adsorption desorption, scanning electron microscopy and TGA techniques. The immobilization complex was found to be an effective catalyst for oxidation of <u>cyclohexane</u> using H<sub>2</sub>O<sub>2</sub> as an oxidant under mild conditions. A conversion of 45.5% of cyclohexane was obtained with selectivity of 100% of the cyclohexanone/cyclohexanol at 70 °C in 8 h in acetonitrile solvent. Recycling test of the catalyst showed that it was recovered and reused up to 3 more cycles without loss of performance.

Sahin et.al.  $(2010)^{10}$  synthesized two-armed poly( $\varepsilon$ -caprolactone) (TAPCL) polymers via the ring opening polymerization (ROP) of  $\varepsilon$ -caprolactone ( $\varepsilon$ -CL) using the Schiff's base complexes [Cu(SAEE)<sub>2</sub>] (1) and [Ni(SAEE)<sub>2</sub>] (2), which have two hydroxyl functional groups, as the two-site initiators and tin(II) 2-ethylhexanoate (Sn(Oct)<sub>2</sub>) as the catalyst in bulk at 115 °C. The Schiff's base complexes (1 and 2) were synthesized by utilizing the concentrated template synthesis method starting from salicyl aldehyde, 2-(2-aminoethoxy) ethanol and related metal acetate salts. The synthesized TAPCL polymers were characterized by GPC, FTIR, UV–vis, and electron paramagnetic resonance (EPR). The molecular weights of TAPCL polymers linearly increased with increasing molar ratio of the monomer to the initiator. The results obtained from FTIR, UV–vis, and EPR studies indicated that TAPCL polymers had the Schiff's base complexes at the junction point of PCL arms. The crystallization behavior of

TAPCL was studied by using differential scanning calorimetry (DSC) and polarizing optical microscopy (POM). Thermal behavior of TAPCL was also investigated by thermogravimetrical analysis (TGA).

**Wang et.al**  $(2010)^{11}$  used two kinds of Schiff base, *m*-phenylenediamine-glyoxal (Schiff base A) and pphenylenediamine-glyoxal (Schiff base B), as 'seed' to induce the polymerization of aniline and hence prepare polyaniline (PANI) nanorods. The different preparation conditions including the Schiff base structure, dosage and acidity of the reaction medium, were investigated to discuss the influence of these conditions on the conductivity of the resulting samples through two-probe method at room temperature. The products were also characterized by Fourier transform infrared (FTIR), ultraviolet–visible (UV–vis), scanning electro microscope (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD) and thermogravimetric analysis (TGA) techniques. The results implied that these conditions play an important role in the formation of PANI nanorods. Moreover, the resulting PANI nanorods exhibited an unusual electromagnetic loss at the microwave frequency (f = 8.2-12.4 GHz) arose from order arrangement of polaron as charge carrier caused by a nanorods morphology and can be used for the potential application as microwave absorbing materials.

Yang et.al. (2010)<sup>12</sup> synthesized two functionalized copper(II) and oxovanadium(IV) Schiff base complexes of type  $[M(N_2O_2), M = Cu, VO]$  bearing chloromethyl groups directly anchored onto amino-modified SBA-15 materials and examined as catalysts for styrene oxidation. The purity of each ligand was confirmed by <sup>1</sup>H NMR, FT-IR and elemental analysis, XRD, N<sub>2</sub> adsorption/desorption and TEM results indicated that the mesoporous structure of SBA-15 remained intact throughout the grafting procedure. FT-IR, UV-vis spectroscopy plus TG-DTA data demonstrated the incorporation of copper(II) and oxovanadium(IV) complexes on amino-modified SBA-15. ICP-AES, SEM-EDX combined with XPS data further showed the different anchorage status of copper(II) and oxovanadium(IV) species on amino-modified SBA-15. The copper(II) Schiff base complex was anchored through the coordination of copper atom with the nitrogen atom of the amino group modified on the SBA-15 external surface. The oxovanadium(IV) Schiff base complex, however, was covalently anchored on SBA-15 via the condensation reaction of the chloromethyl group of the Schiff base with the amino group from the modified SBA-15 matrix. The catalytic properties of supported copper(II) and oxyanadium(IV) complexes in the oxidation of styrene with air or  $H_2O_2$  as oxidant were investigated and compared with the properties of their homogeneous analogues. It was found that both heterogeneous copper(II) and oxovanadium(IV) catalysts were more active than their homogeneous analogues and that the product selectivity varied in cases of different oxidants. The supported oxovanadium(IV) complex showed high yield of styrene oxide (56.0%) and good recoverability when using air as oxidant.

Afkhami & Khajavi (2011)<sup>13</sup> synthesized Schiff base (PABST) and its complex with Cu(II) (Cu-PABST) with CN<sup>-</sup> in a 30:70 (v/v) mixture of DMF: water was investigated at pH 6.0 and 10.0, respectively, using multivariate curve resolution alternative least squares (MCR-ALS) method. The effects of different parameters such as volume percent of DMF, pH and surfactants and β-cyclodextrin (β-CD), on observed rate constant of the reactions were investigated. Cetyltrimethylammonium bromide (CTAB) decreased the rate constant of PABST reaction and increased the rate constant of Cu-PABST reaction with CN<sup>-</sup>. Sodium dodecyl sulfate (SDS) and Triton X-100 decreased the rate constant of both reactions. Also, the stability constant for the inclusion complexes of PABST and Cu-PABST, and observed rate constants for the reactions of β-CD-PABST and β-CD-Cu-PABST) with CN<sup>-</sup> were determined. β-CD decreased the rate constant of PABST reaction with CN<sup>-</sup> by protecting iminium groups of the Schiff base, while β-CD increased the rate constant of the reaction of Cu-PABST with CN<sup>-</sup>.

Afkhami et.al  $(2011)^{14}$  worked on ground and excited states acidic dissociation constants of a recently synthesized Schiff base was obtained in a DMF:water mixture of 30:70 ( $\nu/\nu$ ) using absorption and fluorescent spectra of the Schiff base in different pH values with the aid of chemometric methods. In addition, the fluorescent of the two kinds of tautomers of this Schiff base was investigated and the rate of tautomerization was obtained using rank annihilation factor analysis (RAFA). The effect of different kinds of surfactants such as sodium dodecyl sulfate (SDS), cetyltrimethylammonium bromide (CTAB) and Triton X-100 on fluorescence spectrum of the Schiff base while SDS and Triton X-100 had no significant effect on it.  $\beta$ -Cyclodextrin increased the fluorescence intensity of the Schiff base while SDS and Triton X-100 had no significant effect on it.  $\beta$ -Cyclodextrin increased the fluorescence intensity of the Schiff base showed prominent fluorescent signal in the presence of Zn<sup>2+</sup>, whereas other metal ions failed to induce response and ground-state dissociation constant of the complex was determined by direct fluorimetric titration as a function of Zn<sup>2+</sup> concentration.

**Durmus et al.**  $(2011)^{15}$  synthesized tridentate Schiff base (H<sub>2</sub>L) ligand via condensation of o- hydroxybenzaldehyde and 2-aminothiophenol. The metal complexes were prepared from reaction of the ligand with corresponding metal salts presence of substituted pyridine in two different solvents (MeOH or MeCN). The ligand and metal complexes were then characterized by using FTIR, TGA, <sup>1</sup>H NMR and <sup>13</sup>C NMR spectroscopies. The FTIR spectra showed that

H<sub>2</sub>L was coordinated to the metal ions in tridentate manner with ONS donor sites of the azomethine N, deprotonated phenolic-OH and phenolic-SH. Furthermore, substituted pyridine was coordinated to the central metal atoms. The thermal behavior of the complexes was investigated by using TGA method and dissociations indicated that substituted pyridine and ligand were leaved from coordination. This coordination of the metal complexes was correlated by <sup>1</sup>H NMR and <sup>13</sup>C NMR. Finally, electrochemical behavior of the ligand and a Ni(II) complex were investigated.

**Erdtman et al.** (2011)<sup>16</sup> explained that Schiff bases are common and important intermediates in many bioenzymatic systems. The mechanism by which they are formed, however, is dependent on the solvent, pH and other factors. In the present study, researchers have used density functional theory methods in combination with appropriate chemical models to get a better understanding of the inherent chemistry of the formation of two Schiff bases that have been proposed to be involved in the catalytic mechanism of porphobilinogen synthase (PBGS), a key enzyme in the biosynthesis of porphyrins. More specifically, we have investigated the uncatalysed reaction of its substrate 5-aminolevulinic acid (5-ALA) with a lysine residue for the formation of the P-site Schiff base, and as possibly catalysed by the second active site lysine, water or the 5-ALA itself. It is found that cooperatively both the second lysine and the amino group of the initial 5-ALA itself are capable of reducing the rate-limiting energy barrier to 14.0 kcal mol<sup>-1</sup>. We therefore propose these to be likely routes involved in the P-site Schiff-base formation in PBGS.

**Gupta & Rathee** (2011)<sup>17</sup> performed a study on separation and identification of metal complexe of novel Schiff Base with Cd(II), Fe(III), Mn(II), Cu(II) and Co(II) has been carried out. For this, Silica Gel is used as adsorbent and the mixture of complexes was run on thin layer of Silica Gel; the Rf values of the complexes were determined in Methanol, Benzene-Acetone, Nitrobenzene-Methanol and Dioxane. The complexes were separated and were identified by comparing their Rf values and developing time. It was found that the extent of separation of complexes varied considerably with the nature of solvent systems employed and comes in Methanol > Benzene-Acetone > Nitrobenzene-Methanol > Dioxane order.

Ali et al.  $(2012)^{18}$  prepared Copper(II) complexes of general empirical formula, Cu(apsme)X (apsme = monodeprotonated form of the 2-aminoacetophenone Schiff base of S-methyldithiocarbazate (Hapsme);  $X = CI^-$ ,  $Br^-$ ,  $NCS^-$ ) and characterised by a variety of physico-chemical techniques. The crystal and molecular structures of the Schiff base, Hapsme (1), [Cu(apsme)Br] (2), [Cu(apsme)(NCS)] (3) and [Cu(apsme)CI] (4) have been determined by X-ray diffraction. In the solid state the copper(II) complexes 2, 3 and 4 are dimers in which the anionic Schiff base, (apsme<sup>-</sup>) coordinates with a copper(II) ion as a tridentate NNS chelating agent *via* the amino nitrogen atom, the azomethine nitrogen atom and the thiolate sulfur atom. The fourth and fifth coordination positions of a copper atom are occupied by a co-ligand and bridging thiolate sulfur atoms, respectively.

**Ceyhan et al.** (2012)<sup>19</sup> prepared two Schiff base ligands N-(4-hydroxy phenyl)-2,4-di-methoxy benzaldimine (TS<sup>1</sup>) and N-(4-hydroxy phenyl)-2,5-di-methoxybenzaldimine (TS<sup>2</sup>) and characterized by structural, spectroscopic and analytical methods. The ligands TS<sup>1</sup> and TS<sup>2</sup> were obtained as single crystals from ethanol solution. X-ray diffraction data for two compounds showed that the bond lengths are within the normal ranges. The electrochemical properties of the Schiff base ligands were studied in different solvents and at various scan rates. The luminescence properties of the ligands TS<sup>1</sup> and TS<sup>2</sup> in different solvents and at different pH values have been investigated. The results show that the ligands exhibit more efficient luminescence properties in CH<sub>3</sub>CN and n-butanol.

**Kumari et al.**  $(2012)^{20}$  prepared a mesogenic Schiff-base, *N*,*N*'-di-(4'-octyloxybenzoatesalicylidene)-1",8"-diamino-3",6"-dioxaoctane; H<sub>2</sub>dobsdd (H<sub>2</sub>L<sup>3</sup>), that nematogenic mesophase and its structure studied by elemental analysis and FAB mass, NMR and IR spectra. The Schiff-base, H<sub>2</sub>L<sup>3</sup>, upon condensation with hydrated lanthanide(III) nitrates, yields Ln<sup>III</sup> complexes of the general composition [Ln<sub>2</sub>(L<sup>3</sup>H<sub>2</sub>)<sub>3</sub>(NO<sub>3</sub>)<sub>4</sub>](NO<sub>3</sub>)<sub>2</sub>, where Ln = La, Pr, Nd, Sm, Eu, Gd, Tb, Dy and Ho. The IR and NMR spectral data imply a bi-dentate of the Schiff-base through two phenolate oxygens in its zwitterionic form (as L<sup>3</sup>H<sub>2</sub>) to the Ln<sup>III</sup> ions, rendering the overall geometry of the complexes to seven-coordinated polyhedron — possibly distorted mono-capped octahedron. Among the metal complexes, only that of La<sup>III</sup> and Gd<sup>III</sup> are found to be mesogenic.

Liu et al. (2012)<sup>21</sup> prepared a novel Schiff-base liquid crystal diepoxide polymer via a thermal copolymerization of a Schiff-base epoxy monomer (**PBMBA**) with a diamine co-monomer (MDA). They first proposed that specific effects of highly conjugated Schiff-base moiety on thermal properties of the Schiff-base epoxy polymer (**PBMBA**/MDA). Thermal degradation behavior of the polymer was characterized using thermogravimetric analysis (TGA) under nitrogen and under air, respectively. Thermogravimetric data obtained from TGA under nitrogen and under air reveal that **PBMBA**/MDA exhibits higher thermal stability compared with bisphenol-A type epoxy polymer (DGEBA/MDA) and other mesogene-containing epoxy polymer. It is worth pointing out that the outstanding residual char value for the Schiff-base epoxy polymers had been rarely reported. For thermal degradation mechanism of **PBMBA**/MDA under nitrogen, thermogravimetric analysis/infrared spectrometry (TG-

IR) were used to investigate volatile components, and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) was used to explore morphologies and chemical components of the residual char. The effects of calcination temperature and calcination time on evolution of morphologies and chemical components of the residual char have been studied. It is proposed that the highly  $\pi$ -conjugated Schiff-base moiety is not only involved in a formation of intramolecular hydrogen bonding increasing the onset thermal degradation temperature ( $T_d$ ), but also possesses an effective charring ability retarding a further degradation of polymers. Due to the presence of the specific effects, the thermal stability of the Schiff-base epoxy is improved.

Shakya et al.  $(2012)^{22}$  synthesized a mesogenic Schiff-base, N,N'-di-(4-decyloxysalicylidene)-2',6'diaminopyridine, H<sub>2</sub>ddsdp (abbreviated as H<sub>2</sub>L<sup>3</sup>) that exhibits nematic mesophase and its structure studied by elemental analysis, mass spectrometry, NMR & IR spectral techniques. The Schiff-base, H<sub>2</sub>L<sup>3</sup>, upon condensation with hydrated lanthanide(III) nitrates, yields Ln<sup>III</sup> complexes of the general composition [Ln<sub>2</sub>(L<sup>3</sup>H<sub>2</sub>)<sub>3</sub>(NO<sub>3</sub>)<sub>4</sub>](NO<sub>3</sub>)<sub>2</sub>, where Ln = La, Pr, Nd, Sm, Eu, Gd, Tb, Dy and Ho. Among the metal complexes, only that of Ho<sup>III</sup> is found to be mesogenic with smectic-X and nematic phases. The IR and NMR spectral data imply a bi-dentate bonding of the Schiff-base in its zwitterionic form (as L<sup>3</sup>H<sub>2</sub>) to the Ln<sup>III</sup> ions through two phenolate oxygens, rendering the overall geometry of the complexes to seven-coordinated polyhedron, possibly distorted mono-capped octahedron.

Anacona & Santaella  $(2013)^{23}$  synthesized M(II) coordination compounds of Mn, Fe, Co and Ni with a Schiff base (HL) derived from the condensation of cephalon antibiotic with 1,2-diaminobenzene and characterized by several techniques, including elemental and thermal analysis, molar conductance and magnetic susceptibility measurements, electronic, FT-IR, EPR and <sup>1</sup>H NMR spectral studies. The analytical and molar conductance values indicated that the chloride ions coordinate to the metal ions. Based on these studies, the general formulae [M(L)Cl(H<sub>2</sub>O)] (M(II) = Mn, Fe, Co, Ni) are proposed for the complexes. The ligand HL behaves as a monoanionic tetradentate NNNO chelating agent.

**Ceyhan et al.** (2013)<sup>24</sup> synthesized three Schiff base compounds, N,N'-bis(2,4-dimethoxy benzaldiimine)-1,4diamino cyclohexane (IGA<sup>1</sup>), N,N'-bis(2,3,4-trimethoxybenzaldiimine)-1,4 diamino cyclohexane (IGA<sup>2</sup>) and N,N'bis(3,4,5-trimethoxy benzaldiimine)-1,4-diamino cyclohexane (IGA<sup>3</sup>) and characterized by the spectroscopic and analytical methods. The electrochemical and photoluminescence properties of the compounds IGA<sup>1</sup>–IGA<sup>3</sup> have been investigated in the different conditions. All the synthesized Schiff base compounds IGA<sup>1</sup>, IGA<sup>2</sup> and IGA<sup>3</sup> were screened for their cytotoxicity (HeLa and Vera cells). The structural characterization of the Schiff base compounds was determined by single crystal X-ray diffraction studies. The molecules IGA<sup>1</sup> and IGA<sup>3</sup> both lie on centers of symmetry but in IGA<sup>2</sup> the molecule has no crystallographically imposed symmetry. In the compound IGA<sup>1</sup>, Schiff base molecules are linked by  $\pi$  stacking interactions. There is no evidence of  $\pi$  stacking in both IGA<sup>2</sup> and IGA<sup>3</sup>, however there are some C–H… $\pi$  and C–H…O interactions in these compounds. The thermal stabilities of the compounds were investigated in the nitrogen atmosphere.

**Fani et al.**  $(2013)^{25}$  investigated the molecular mechanism of a Schiff base complex ((E)-((E)-2-(3-((E)-((E)-3(mercapto (methylthio) methylene)cyclopentylidene) amino) propylimino) cyclopentylidene) (methylthio) methanethiol) binding to Human Serum Albumin (HSA) by fluorescence quenching, absorption spectroscopy, molecular docking and molecular dynamics (MD) simulation procedures. The fluorescence emission of HSA was quenched by this Schiff base complex that has been analyzed for estimation of binding parameters. The titration of Schiff base solution by various amount of HSA was also followed by UV–Vis absorption spectroscopy and the corresponding data were analyzed by suitable models. The results revealed that this Schiff base has an ability to bind strongly to HSA and formed 1:1 complex. Energy transfer mechanism of quenching was discussed and the value of  $5.45 \pm 0.06$  nm was calculated as the mean distance between the bound complex and the Trp residue. This is implying the high possibility of energy transfer from HSA to this Schiff base complex. Molecular docking results indicated that the main active binding site for this Schiff base complex is site III in subdomain IB. Moreover, MD simulation results suggested that this Schiff base complex can interact with HSA, without affecting the secondary structure of HSA but probably with a slight modification of its tertiary structure. MD simulations, molecular docking and experimental data reciprocally supported each other.

**Fani et al.** (2013)<sup>26</sup> examined the interaction of two Schiff base complexes with human serum albumin (HSA), by different kinds of spectroscopic and molecular modeling techniques. Fluorescence quenching and absorption spectra were investigated in order to estimate the binding parameters. The analysis of absorption data at different temperatures were done in order to estimate the thermodynamics parameters of interactions between Schiff base complexes and HSA. The experimental data suggested that both complexes demonstrated a significant binding affinity to HSA and the process is enthalpy driven. Molecular docking study indicated that both Schiff base complexes bind to polar and apolar residues located in the subdomain IB of HSA. Molecular dynamics (MD) simulations were also performed with the GROMACS program package to study the characters of HSA in binding states. Molecular dynamics results suggested that both Schiff base complexes can interact with HSA, without

affecting the secondary structure of HSA but probably with a slight modification of its tertiary structure. All the molecular docking and molecular dynamics results kept in good consistence with experimental data.

**Kocyigit** (2013)<sup>27</sup> synthesized novel Schiff base and its complexation properties with Fe(III) and Cr(III). A Schiff base bearing dopamine (TRDPA) was synthesized using dopamine hydrochloride and 1,3,5-tris (formylphenoxymethyl)benzene in methanol media. The prepared TRDPA was then reacted with four new trinuclear Fe(III) and Cr(III) complexes involving tetradenta Schiff bases N,N-bis(salicylidene)ethylenediamine-(salenH<sub>2</sub>) or bis(salicylidene)-o-phenylenediamine-(salophenH<sub>2</sub>). The structures of these compounds were characterized through <sup>1</sup>H NMR, <sup>13</sup>C NMR, FT-IR, thermal analysis (TG), elemental analysis, and magnetic susceptibility measurements. The complexes were also characterized as low-spin distorted octahedral Fe(III) and Cr(III) bridged by a catechol group.

Anacona et al.  $(2014)^{28}$  synthesized a metal(II) coordination compounds of a cephalexin Schiff base (HL) derived from the condensation of cephalexin antibiotic with sulphathiazole. The Schiff base ligand, mononuclear  $[ML(OAc)(H_2O)_2]$  (M(II) = Mn, Co, Ni, Zn) complexes and magnetically diluted trinuclear copper(II) complex  $[Cu_3L(OH)_5]$  were characterized by several techniques, including elemental and thermal analysis, molar conductance and magnetic susceptibility measurements, electronic, FT-IR, EPR and <sup>1</sup>H NMR spectral studies. The analytical and molar conductance values indicated that the acetate ions coordinate to the metal ions. The Schiff base ligand HL behaves as a monoanionic tridentate NNO and tetradentate NNOO chelating agent in the mono and trinuclear complexes respectively.

Asadi et al.  $(2014)^{29}$  studied a new method in synthesis of nano uranyl Schiff base complexes. In this method slow addition of dilute uranyl(VI) acetate solution to dilute Schiff base solution following the reflux for about 24 h, yields nano uranyl(VI) Schiff base complexes. Characterization of Schiff base ligands and nano uranyl complexes has been done using <sup>1</sup>H NMR, IR, UV–vis spectroscopy, elemental analysis. Schiff base ligands were synthesized by the condensation of one mole 3,4-diaminobenzophenone and two moles salicylaldehyde or substituted salicylaldehyde (3-OMe, 4-OMe, 5-OMe, 5-Br, 5-Cl). The electrochemical properties of the uranyl(IV) complexes were investigated by cyclic voltammetry. A good correlation was observed between the oxidation potentials and the electron withdrawing character of the substituents on the Schiff base ligands, according to the following trend: 5-MeO < H < 5-Br  $\approx$  5-Cl. Also, the effect of the position of the substituted groups of Schiff base on the anodic potentials is as follows: 5-OMe < 3-OMe < 4-OMe.

**Hosny et al.** (2014)<sup>30</sup> synthesized four new metal complexes derived from the reaction of Cu(II), Co(II), Ni(II) and Zn(II) acetates with the Schiff-base ligand (H<sub>3</sub>L) resulted from the condensation of the amino acid 2-amino-3-hydroxyprobanoic acid (serine) and acetylacetone and characterized by, elemental analyses, ES–MS, IR, UV–Vis., <sup>1</sup>H NMR, <sup>13</sup>C NMR, ESR, thermal analyses (TGA and DTG) and magnetic measurements. The results showed that the Schiff-base ligand acts as bi-negative tridentate through the azomethine nitrogen, the deprotonated carboxylate oxygen and the enolic carbonyl oxygen. The optical band gaps measurements indicated the semiconducting nature of these complexes. Molecular docking was used to predict the binding between the Schiff base ligand with the receptor of prostate cancer mutant H874Y. The interactions between the Cu(II) complex and calf thymus DNA (CT-DNA) have been studied by UV spectra. The results confirm that the Cu(II) complex binds to CT-DNA in an intercalative mode.

**Lekha et al.** (2014)<sup>31</sup> synthesized several new lanthanide complexes of Pr(III), Sm(III), Gd(III), Tb(III), Er(III) and Yb(III) with the sodium salt of the Schiff base, 2-[(5-bromo-2-hydroxy-benzylidene)-amino]-5-methyl-pentanoic acid, derived from leucine and 5-bromosalicylaldehyde. These complexes having general formula  $[Ln(HL)(NO_3)_2(H_2O)]$ ·NO<sub>3</sub> were characterized by elemental analysis, UV–vis., FT-IR, EPR, Mass spectrometry and Thermal analysis. The FT-IR spectral data suggested that the ligand behaves as a tridentate ligand with one nitrogen and two oxygen donor atoms, sequence towards central metal ion. From the analytical data, the stoichiometry of the complexes was found to be 1:1 (metal:ligand). The physico-chemical data suggested eight coordination number for Ln(III) Schiff base complexes. Thermal behaviour (TGA/DTA) and fluorescence nature of the complexes were also studied. The Gd(III) Schiff base complex was found to be an efficient catalyst for the oxidation of aniline and substituted anilines under mild conditions.

**Marwani et al.** (2014)<sup>32</sup> synthesized novel heterocyclic Schiff base dyes were prepared by the reaction of salicylaldehyde/2-Hydroxy-1-naphthaldehyde with different heterocyclic amines. Results of the newly synthesized compounds established by FT-IR, <sup>1</sup>H-NMR, <sup>13</sup>C-NMR and GC–MS spectroscopic experiments were consistent with their chemical structures. Resulted heterocyclic Schiff base dyes were found to be pure from data obtained by the elemental analysis. In addition, spectrophotometric and spectrofluorimetric studies showed that these dyes were good absorbent and fluorescent. Fluorescence polarity study data revealed that some of these compounds were sensitive to the polarity of the microenvironment provided by different solvents. Time-based fluorescence steady-

state measurements also showed that these heterocyclic Schiff base dyes have high photostability against photobleaching.

Anacona et al.  $(2015)^{33}$  synthesized metal(II) coordination compounds of a cephalothin Schiff base (H<sub>2</sub>L) derived from the condensation of cephalothin antibiotic with sulfadiazine. The Schiff base ligand, mononuclear [ML(H<sub>2</sub>O)<sub>3</sub>] (M(II) = Mn, Co, Ni, Zn) complexes and magnetically diluted dinuclear copper(II) complex [CuL(H<sub>2</sub>O)<sub>3</sub>]<sub>2</sub> were characterized by several techniques, including elemental and thermal analysis, molar conductance and magnetic susceptibility measurements, electronic, FT-IR, EPR and <sup>1</sup>H NMR spectral studies. The cephalothin Schiff base ligand H<sub>2</sub>L behaves as a dianionic tridentate NOO chelating agent. The biological applications of complexes have been studied on two bacteria strains (*Escherichia coli* and *Staphylococcus aureus*) by agar diffusion disc method.

**Devi & Batra** (2015)<sup>34</sup> synthesized a series of transition metal complexes of Co(II), Cu(II), Ni(II) and Zn(II) metal ions using different uninegative bidentate Schiff base ligands which was derived by condensing piperonylamine and 2-hydroxy-1napthaldehyde/substituted salicylaldehyde derivatives and characterized by various spectroscopic techniques (<sup>13</sup>C NMR, <sup>1</sup>H NMR,FT-IR, UV–Vis, fluorescence, ESR), mass spectrometry, conductometric studies, magnetic susceptibility measurements and different physical studies likeDTA, DTG, and TGA. The studies suggested that Schiff bases coordinates via nitrogen of azomethine and phenolic oxygen that is deprotonated (NO) with metal centres in 2:1 molar ratio having octahedral geometry for Co(II), Ni(II), Zn(II) complexes and square planar for Cu(II) complexes. The formed compounds were analysed for their antimicrobial activities against two fungal strains (*C. albicans and A.niger*). The study suggested thatZn(II)metal complex(MIC value 0.0016– 0.0021  $\mu$ M/mL) were found more active against antimicrobial activity than their Schiff base and other synthesized metal complexes. QSAR study proposed that transition metal complexes have more antimicrobial activity against *E. coli* than free ligands.

Kumar et al. (2015)<sup>35</sup> synthesized a series of acyclic Schiff base chromium(III) complexes with the aid of microwave irradiation method. The complexes were characterized on the basis of elemental analysis, spectral analysis such as UV–Visible, Fourier transform infrared (FT-IR), nuclear magnetic resonance (NMR), electron paramagnetic resonance (EPR) spectroscopies and electrospray ionization (ESI) mass spectrometry. Electrochemical analysis of the complexes indicates the presence of chromium ion in +3 oxidation state. Cr (III) ion is stabilized by the tetradentate Schiff base ligand through its nitrogen and phenolic oxygen. From the spectral studies it is understood that the synthesized chromium(III) complexes exhibits octahedral geometry. Antimicrobial activity of chromium complexes was investigated towards the Gram positive and Gram negative bacteria. In the present work, an attempt was made to fabricate a new kind of modified electrode based on chromium Schiff base complexes for the detection of catechol at nanomolar level

**Rudbari et al.** (2015)<sup>36</sup> derived a new unsymmetrical Schiff base ligand (H<sub>2</sub>L) from the 1:1 M condensation of 2,3dihydroxybenzaldehyde with allylamine. Molybdenum(VI) complex, MoO<sub>2</sub>L<sub>2</sub>, was synthesized from the reaction of  $MoO_2(acac)_2$  with the Schiff base ligand in a 1:2 ratio in methanol at ambient temperature. The Schiff base ligand and its Mo(VI) complex were characterized by elemental analyses, FT-IR, <sup>1</sup>H NMR, <sup>13</sup>C NMR and UV–Vis spectroscopies and single crystal X-ray analysis. The molecular structure of schiff base ligand and Mo(VI) complex showed pseudo-scorpionate structure in solid state. The  $MoO_2L_2$  complex adopts an octahedral environment around the Mo center with a *cis*-oxo configuration. The other coordination sites are occupied by the hydroxyl oxygen atoms of the two Schiff base ligand and its Mo(VI) complex were also tested for their in vitro antimicrobial activity against *Staphylococcus aureus* (ATCC 29737) and *Pseudomonas aeroginosa* (PTTC 1570) as examples of Gram-positive and Gram-negative bacterial strains, respectively, by disc diffusion method. The results indicated that the Schiff base ligand had a better antibacterial activity than its Mo(VI) complex and surprisingly, they were synergistic when used against *P. aeroginosa* PTTC 1570.

**Rudbari et al.** (2015)<sup>37</sup> provided a Schiff base reaction by 1,2-bis(2'-aminophenoxy)-4-methylbenzene with 2pyridinecarboxaldehyde. The stereochemical rigidity of *ortho*-aminophenyl diamines causes this latter, as well as the corresponding nitro precursors, be chiral. The chiral conformation of the diamine precursor is maintained in the octahedral zinc(II) and cobalt(II) complexes prepared from the Schiff base. The crystal structures of [ZnL(NO<sub>3</sub>)(H<sub>2</sub>O)]NO<sub>3</sub> and CoLCl<sub>2</sub> complexes exhibit non-planar *cis*- $\alpha$  configurations with both enantiomers ( $\Delta$  and  $\Lambda$ ). This implies that in the Schiff base ligand the two  $\alpha$ -diimine systems shape an octahedral cavity having the same chirality of the precursory diamine.

**Mahlooji et al.**  $(2016)^{38}$  synthesized two unique heteronuclear Schiff base complexes of Cu(II), [{Cu(L)Na(ClO<sub>4</sub>)}<sub>2</sub>( $\mu$ -H<sub>2</sub>L)] (1) and Ni(II), [{Ni(L)Na(BF<sub>4</sub>)}<sub>2</sub>( $\mu$ -H<sub>2</sub>L)] (2) and characterized by different spectroscopic methods as well as X-ray crystallography. The Schiff base ligand (H<sub>2</sub>L) was synthesized from the condensation meso-1,2-diphenyl-1,2-ethylenediamine with 3-methoxysalicylaldehyde. The 3d metal ions in these

complexes have been accommodated by the inner  $N_2O_2$  compartment of the Schiff base ligand, while the  $O_2O'_2$  outer compartment has accommodated the Na(I) ion (O and O' denote the phenolic and methoxy oxygen atoms, respectively). Besides, a Schiff base ligand has doubly bridged the M(II)/Na(I) moieties via the (OO')<sub>2</sub> coordination mode. This mode of bidentate action of a potentially tetradentate Schiff base ligand is very rare and has been observed for the first time in such 3d-ns complexes. The in vitro antibacterial activity of the Schiff base ligand and the complexes (1) and (2) were tested against human pathogenic bacteria such as *Bacillus subtilis* (Gram positive); *Staphylococcus aureus* (Gram positive); *Salmonella typhi* (Gram negative); and *Escherichia coli* (Gram negative). The results showed that these new hetero-polynuclear complexes had moderate antibacterial activity against both Gram type bacteria.

Menati et al. (2016)<sup>39</sup> prepared a schiff base by the condensation reaction of 1,2-bis(2'-aminophenoxy)benzene with 2-pyridinecarbaldehyde mole ratio of 1:2 Four Schiff in a base complexes, CoL(NO<sub>3</sub>)<sub>2</sub> (1), NiLCl<sub>2</sub> (2), ZnL(NO<sub>3</sub>)<sub>2</sub> (3) and Pd<sub>2</sub>LCl<sub>4</sub> (4) have been prepared by direct reaction of the ligand (L) and appropriate metal salts. The Schiff base ligand (L) has been characterized by IR, <sup>1</sup>H NMR and <sup>13</sup>C NMR spectroscopy and elemental analysis. Also, all complexes have been characterized by IR and XRD spectroscopy techniques and elemental analysis. The synthesized complexes have very poor solubility in all polar and non-polar solvents such as: H<sub>2</sub>O, MeOH, EtOH, CH<sub>3</sub>CN, DMSO, DMF, CHCl<sub>3</sub>, CH<sub>2</sub>Cl<sub>2</sub>, THF, etc; therefore, they have been used as heterogeneous catalysts. Catalytic performance of the complexes was studied in oxidation of thioanisole using hydrogen peroxide  $(H_2O_2)$  as the oxidant. Various factors including the reaction temperature, amount of oxidant and catalyst amount were optimized. The palladium Schiff base complex, Pd2LCl4 (4), shows better catalytic activity than other complexes. Therefore, the Pd(II) Schiff base has been used as a catalyst for oxidation of different sulfides to complex their corresponding sulfones in acetonitrile with hydrogen peroxide as the oxidant. The palladium Schiff base complex, Pd<sub>2</sub>LCl<sub>4</sub> (4), has shown a very good recyclability, up to five times, without any appreciable decreases in catalytic activity and selectivity.

**Mumtaz** et al. (2016)<sup>40</sup> prepared a series of transition metal(II) complexes of new Schiff base by the condensation of sulphadizine and 2-carboxybenzaldehyde in ethanol. The Schiff base and transition metal complexes were characterized by using different instrumental techniques like microanalysis, thermogravimetric analysis and spectroscopy. The synthesized ligand and metal complexes were subjected to antibacterial studies. The studies show the enhance activity of metal complexes against one or more species as compared to the un-complexed ligand. The data showed that the transition metal complexes have significant improved antibacterial activity than parent drug.

**Rathee** (2016)<sup>41</sup> evaluated Stability Constant and Free energy change during the chelation between azomethine derivative (Schiff Base) and Cd (II) & Mn(II) have been evaluated using absorbance measurement employing mole ratio method. It has been concluded from the study that one mole of azomethine derivative reacts with one mole of each Cd(II) and Mn(II) to form stable chelates. The stability constant of the chelate in was found to be 0.3457 x 106 and the free energy change at 300C was 6. 293 K cal / mole in Cd(II) chelate while 0.1860 x 105 and 5.916 K cal / mole respectively in Mn chelate.

Su et al.  $(2016)^{42}$  studied the polysaccharide-based microgels with high water content, excellent biocompatibility and controllable particle size as ideal candidates for drug release and delivery. In this study, microgels based on dextran were developed *via* the Schiff base formation between aldehyde dextran and ethylenediamine in a water-inoil (W/O) microemulsion. Particle size of the resulted microgel was controllable between 800 and 1100 nm by modulating the amount of the employed co-surfactants (Span 80/Tween 80). Furthermore, fluoresceins (*e.g.*, aminofluorescein) and drugs (*e.g.*, doxorubicin) with free amino groups can be conjugated onto the network of the dextran-based microgel *via* Schiff base linkages. Since the Schiff base linkages are degradable *via* hydrolysis and their stability decreases with the environmental pH decreases, the resulted Schiff bases contained microgel showed a pH dependent degradation profile. These results indicated that the pH-sensitive microgel based on dextran could be used as promising drug delivery systems for biomedical applications.

**Hossain** *et al.* (2017)<sup>43</sup> synthesized metal complexes of Mn(II), Fe(II), Co(II) and Cd(II) ions with Schiff base ligand 4- {(pyridin-2-ylimino)methyl}phenol which obtained from condensation of 2-amino pyridine and 4-hydroxybenzaldehyde. Characterization of ligands and their metal complexes were done by thermogravimetric analysis, elemental analysis, magnetic susceptibility, conductometric studies and spectroscopic techniques (IR, UV-Vis, <sup>13</sup>C NMR, <sup>1</sup>H NMR, ESR, mass). During complex formation, Schiff base act as a deprotonated tridentate ligand and IR spectra revealed that N and O atoms are coordinated to the central metal atom. The data also suggested that the complexes have octahedral geometry. The Schiff base and its metal complexes have been found to be moderate to strong antibacterial active. TGA analysis displayed that Fe(II) complex are more stable than that of Cd(II) complex. Biological activity was tested for free ligands and its metal complexes and it was shown that complexes have better antibacterial activity as compared to the antibiotic (*Ampicillin*).

Morgan et al. (2017)<sup>44</sup> prepared a novel series of transition metal complexes of Cu(II), Co(II), Ni(II), Mn(II) and Cd(II) from Schiff base derived from 4-aminoantipyrine and guinoline-2-carbaldehyde to give 4-((quinolin-2yl)methyleneamino)-1,2-dihydro-2,3-dimethyl-1-phenylpyrazol-5-one (QMP). The structural features were derived from elemental analysis, mass spectroscopy, X-ray, IR, <sup>1</sup>H NMR, electronic spectra, molar conductance magnetic susceptibility and thermogravimetric studies. On the basis of the studies the coordination sites were proven to be through oxygen of the ring C=O and nitrogen of the azomethine (HC=N) group. The thermodynamic parameters were calculated using Coats-Redfern and Horowitz-Metzger methods. From the values of the thermal activation energy of decomposition ( $E_a$ ) of Schiff base (OMP) and its metal complexes (1–5), it was found that the  $E_a$  value for the complex (3) is higher compared to the other complexes. The Gibbs free energy of decomposition ( $\Delta G^*$ ) for Schiff base (QMP) and its metal complexes is positive value which indicates that the processes are nonspontaneous. The interaction between Schiff base (QMP) and its metal complexes and calf thymus DNA shows hypochromism effect coupled with obvious bathochromic shift. From the values of binding constant ( $K_b$ ) we noted that the highest value of  $K_b$  is belong complex (3) and these indicated that the Ni(II) is highly binding with CT-DNA and these due to the lower ionic radius. Furthermore, quantum chemical parameters of Schiff base and its complexes were calculated and discussed. The antimicrobial activity of Schiff base (QMP) and its M(II) complexes were studied and compared with the standard antibacterial and antifungal drugs.

Sedighipoor *et al.* (2017)<sup>45</sup> synthesized a new asymmetrical tetradentate N<sub>2</sub>O<sub>2</sub> Schiff base ligand from 2hydroxyacetophenon, 2-hydroxynaphthaldehyde and 1,2 phenylenediimine. The new oxidovanadium(IV) Schiff base complex, V<sup>IV</sup>OL (L = N-2-hydroxyacetophenon-N'-2-hydroxynaphthaldehyde-1,2 phenylenediimine), was prepared by reaction of Schiff base ligand with vanadyl acetylacetonate. The Schiff base ligand (L) and the oxidovanadium(IV) complex were characterized by spectroscopic methods. The crystal structure of the complex was determined by the single crystal X-ray analysis. The complex crystallized in the orthorhombic system, having one  $V^{4+}$  ion coordinating in an approximately square pyramidal N<sub>2</sub>O<sub>3</sub> geometry by two azomethine N atoms and phenolic oxygens from Schiff base ligand in a square plane and one oxygen atom in an apical position. Electrochemical properties of the complex were examined by means of cyclic voltammetry. The catalytic activity of the oxidovanadium(IV) Schiff base complex was tested in the <u>epoxidation</u> of cyclooctene.

**Tyagi** *et al.* (2017)<sup>46</sup> synthesized metal complexes with Schiff base ligand which was prepared by condensation reaction of amine derivative of 1,2,4-triazole moiety with 2-hydroxy-4- methoxybenzaldehyde. The structure of the Schiff bases and metal complexes were characterized by spectroscopic techniques(<sup>1</sup>H NMR, UV–Vis, mass), TGA and molar conductivity. The spectral data shows that the ligands behave as binegative tridentate. On the basis of data an octahedral geometry has been assigned for Co(II), Ni(II); and tetrahedral for Cu(II) and Zn(II) complexes. The anticancer activity was screened against MCF-7 (human breast cancer) andHep-G2 (human hepatocellular liver carcinoma) cell lines. Result indicates that metal complexes have good cytotoxicity to cell lines as compared to free ligand. Cu(II) complexes show highest cytotoxicity to cancerous cells among metal complexes.

**Yuan et al.** (2017)<sup>47</sup> synthesized a novel metal-organic frameworks (MOFs) UiO-66-Schiff base successfully by post-synthetic modification to investigate the cobalt sorption behaviour in simulated wastewater. The thermodynamic and kinetic parameters demonstrated the sorption process to be spontaneous, endothermic and pseudo-second-order chemisorption. The maximum cobalt sorption capacity of the synthetic MOFs was approximately 256 mg g<sup>-1</sup>, and the stable and porous Schiff base-derived material displayed excellent regenerated availability with at least five recycle applications. Moreover, density functional theory (DFT) calculations have been performed to explore the coordination modes between cobalt ions and ligands in UiO-66-Schiff base, which revealed that the Schiff base group could take cobalt (II) from cobalt ions hydrates  $[Co(H_2O)_6]^{2+}$  and Co-CHES (Co-2-(cyclohexylamino)-ethane sulfonic acid) complex  $[Co(CHES)(H_2O)_5]^+$  to form  $[CoL_N(H_2O)_5]^{2+}$  or  $[CoL_0(H_2O)_4]^+$ . This study offers a facile approach for developing Schiff base modification MOF sorption of cobalt (II) ions from aqueous solutions and provides theoretical and practical guidance on new MOF designs for selective removal of radionuclides.

**Anush et al.** (2018)<sup>48</sup> reported a novel series of Schiff base by the reaction of Chitosan with different substituted pyrazole-4-carbaldehydes in acidic media. The synthesized compounds were characterized by Fourier-transform infrared spectroscopy (FTIR), thermo gravimetric analysis (TGA), X-ray diffraction (XRD) and <sup>13</sup>C NMR techniques. Chitosan and the Schiff bases were compared for their antimicrobial activity against the bacteria; Staphylococcus aureus, Bacillus subtilis, Klebsiella pneumonia, *Escherichia coli* and a fungi, Candida albicans. The results indicated stronger inhibitory effect of the Schiff bases on these microorganisms compared to Chitosan and the extent of inhibition varied with the nature of substitution.

**Egekenze et al.** (2018)<sup>49</sup> synthesized a mono and disubstituted tridentate Schiff base ligands from the reaction of 2(2-aminoethyl)pyridine with 5-bromosalicylaldehyde (H-L<sup>1</sup>) and 3,5-dibromosalicylaldehyde (H-L<sup>2</sup>) respectively, which were subsequently reacted with NaBH<sub>4</sub> to yield the corresponding reduced Schiff base ligands H-rL<sup>1</sup> and H-

rL<sup>2</sup>. The complexes;  $Mn^{II}$ -(L<sup>1</sup>)<sub>2</sub> (1),  $Mn^{II}$ -(rL<sup>1</sup>)<sub>2</sub> (3), and  $Mn^{II}$ -(L<sup>2</sup>)<sub>2</sub> (2),  $Mn^{II}$ -(rL<sup>2</sup>)<sub>2</sub> (4) were obtained by the reaction of the ligands with  $\{Mn(ClO_4), 6H_2O\}$ . The ligands and complexes were characterized by UV–Vis, ESI-MS and FT-IR spectroscopy. The <sup>1</sup>H NMR spectra of the ligands as well as the crystal structures, and electrochemical properties of the complexes were obtained. The crystal structures of  $Mn^{III}-(L^1)_2$  and  $Mn^{II}-(L^2)_2$  show coordination of the ligands in tridentate mode in octahedral geometry. Cyclic voltammetric studies of  $Mn-(L^{2})_{2}$  and  $Mn-(L^{2})_{2}$  in acetonitrile solution show two prominent reversible peaks attributed to the redox processes: Mn(II)/Mn(III),  $(E_{1/2} = 0.203 - (-0.204 \text{ V}) \text{ and } \text{Mn(III)/Mn(IV)}, (E_{1/2} = 1.103 - 0.195 \text{ V}) \text{ versus } \text{Ag/AgCl} \text{ while that of } \text{Mn-}$  $(rL^4)_2$  showed three quasi reversible peaks suggesting three redox couples: Mn(II)/Mn(III) ( $E_{1/2} = -0.109$ ); Mn(III)/Mn(IV),  $(E_{1/2} = 0.125 \text{ and } (Mn(IV)/Mn(V), (E_{1/2} = 0.649) \text{ vs Ag/AgCl. Epoxidation of cyclohexene and 1$ hexene by hydrogen peroxide catalyzed by the manganese complexes gave epoxide yield of 42-53% with a turnover of 10.50–13.25 after 20 h of reaction for the reduced Schiff base complexes { $Mn^{III}$ -(rL<sup>1</sup>)<sub>2</sub> and  $Mn^{II}$ -(rL<sup>2</sup>)<sub>2</sub>} at 0 °C. El-Halim et al. (2018)<sup>50</sup> prepared a new Schiff base ligand via a condensation reaction of quinoline- 2carboxaldehyde and 2- aminophenol in a molar ratio of 1:1. Its transition metal mixed ligand complexes with 1,10phenanthroline (1,10- phen) as co-ligand were also synthesized in a 1:1:1 molar ratio. Metal complexes were characterized using elemental analysis, infrared, <sup>1</sup>H NMR, mass and UV-Vis, molar conductance, magnetic measurements, thermal analysis, ESR and X-ray diffraction. Molar conductance measurements showed that all complexes have an electrolytic nature, except Cd(II) complex. The geometric structures of complexes were found to be octahedral. The anticancer activity of ligands and its metal complexes were also studied againstMCF-7 (breast)andHCT-116(colon) cell lines. The metal complexes showed  $IC_{50}$  higher than that of ligand, especially the Cu(II) complex shows the highest IC<sub>50</sub>value 3 pneumoniae showed that the activity of all metal complexes was less than that of ligand. However, screening against Gram negative bacteria P. aeruginosa showed that the activities of Cr(III) and Fe(III) complexes were less than that of ligand79µg against breast cell line. The results against colon cancer cell line show that Zn(II) complex have highest IC<sub>50</sub> value10.8 µg. Screening against Gram-positive bacteria. Jawoor et al. (2018)<sup>51</sup> synthesized a Novel transition metal complexes from refluxing method using Schiff base prepared via condensation of ethyl 2- amino-4, 5, 6, 7- tetrahydrobenzo-thiophene-3-carboxylate with 8carbaldehyde-7-hydroxy-4- methylcoumarin. All the synthesized compounds were characterize using different analytical, physicochemical and spectral methods such as magnetic moment measurement, FTIR, <sup>1</sup>H NMR, <sup>13</sup>C NMR and UV-Vis. The size and morphology of the nano metal complexes were determined using atomic force microscope (AFM) and X-ray powder diffraction (PXRD). All the tested compounds show good DNA cleavage and in vitro anticancer activity against PA-I (human ovarian) cell line because of their increase in surface area to volume ratio. Copper complex showed the highest cytotoxic effect with  $IC_{50}$  value 9.25 $\mu$ M.

Tadavi et al. (2018)<sup>52</sup> synthesized mononuclear metal complexes of Mn(III), Co(II), Ni(II) and Cu(II) by using tetradentate NO donor symmetric Schiff base 6,6'-((1E,1'E)-(1,2phenylenebis(azanylylidene))bis(methanylylidene)) bis(5-isopropyl-2-methylphenol) HL with the appropriate metal chloride or acetate salts. The prepared metal complexes were characterized by various spectroscopic techniques (<sup>13</sup>C NMR. <sup>1</sup>H NMR, FT-IR, UV-Vis, fluorescence, ESR, and mass), conductometric studies, magnetic susceptibility measurements and different physical studies like Derivative thermogravimetry, Differential thermal analysis, and Thermal gravimetric analysis. The synthesized complex were tested for their antimicrobial and antioxidant activities and it shows that Ni(II) and Cu(II) complexes showed better antibacterial activity against E. coli, P. aeruginosa, B. subtilis and S. aureus as compared to standard drug ciprofloxacin. The Co(II) complex show enhanced antifungal property against C. albicans, A. flavus, C. neoformans as compared to free ligand. The Mn(III) and Cu(II) complexes with  $EC_{50}$  value= 0.1157µMshows the better antioxidant activity as compared to ascorbic acid.

Ali *et al.* (2019)<sup>53</sup> synthesized complexes of Co(II), Ni(II), Cu(II) and Zn(II) metal ions by from the condensation of succinic acid dihydrazide with 5-chloroisatin in alcoholic medium. Complexes were characterized by elemental analysis, molar conductance, thermal analysis, magnetic susceptibility, mass spectrometry, FTIR, EPR, <sup>1</sup>H NMR, UV-Vis spectroscopy. These studies suggest an octahedral geometry for all the complexes. The compounds show antibacterial properties and found to be active against *B. subtilis*, *S. aureus*, *P. aeruginosa* and *E. coli* bacteria. The Zn(II) complex showed significant anticancer activity with IC<sub>50</sub> value 46.9-41.4µMagainstSCC4 (Squamous Carcinoma cells) which tested by the MTT assay and highest antibacterial property with MIC value 8-64µg/mL among all the complexes.

**Amali** *et al.* (2019)<sup>54</sup> synthesized the new Schiff base ligand (6,6'- ((1E,11E)-5,8-dioxa-2,11-diazadodeca-1,11-diene-1,12diyl)bis(2,4-dichlorophenol)), and its derived metal(II) complexes .The synthesized materials were characterized by using various analytical and spectroscopic techniques like<sup>1</sup>H NMR and FTIR. MTT assay has been chosen for the evaluation of *in vitro* cytotoxic activity with the MCF-7 cancer cells. The antimicrobial and anticancer activity against all the microbes was maximum for Cu(II) complex with IC<sub>50</sub> value19  $\pm$  1.1µg/mL.

Al-Azawi et al. (2019)<sup>55</sup> synthesized a series of Schiff base metal complexes by the condensation of MCl<sub>2</sub>.nH<sub>2</sub>O (M

= Co, Ni, Cu) with 1-(2hydroxybenzylideneamino) quinolin-2(1H)-one. The Schiff base and it metal complexes have been characterized by various instrumental techniques like element chemical analysis, molar conductance, magnetic susceptibility measurements and spectral studies. The investigated complexes were subjected to antioxidant studies using H<sub>2</sub>O<sub>2</sub> scavenging activity assay. The investigated complexesNi(44.38  $\pm$  1.00%), Co( 42.11  $\pm$  1.50%) and Cu(76.93  $\pm$  1.50%) showed an excellent activity as antioxidant as compared to the parent Schiff base and standard compound (H<sub>2</sub>O<sub>2</sub>).

**Bahron** *et al.* (2019)<sup>56</sup> synthesized a Schiff base ligand, 6,6'-dimethoxy-2,2'[ophenylenebis (nitrilomethylidyne)] diphenolate and its mononuclear and binuclear Ni(II) and Co(II) complexes 'Structural elucidation was carried out via elemental analysis, XRD, molar conductivity, IR, <sup>1</sup>H NMR, UV-Vis spectroscopy, TGA and magnetic susceptibility data. Anticancer screening againstHCT-116 (human colorectal cancer) cell lines revealed that both binuclear complexes were more active than their mononuclear counterparts. Even without the presence of any metal, the ligand itself has the ability to interact and alter the DNA present in HCT-116, hence retarding its growth. Ni binuclear complex exhibited the most potent anticancer activity with IC<sub>50</sub> value of 0.8  $\mu$ M.

**Chand** *et al.*  $(2019)^{57}$  synthesized tetradentate Schiff base ligand Bis(furfural)-1,8-naphthalenediimine (L) and characterized them by physical, analytical and spectral data. Metal complexes of Co(II), Ni(II), Cu(II) and Zn(II) of general composition MLX<sub>2</sub> [L = C<sub>20</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub>and X = Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup> and OAc<sup>-</sup>] were synthesized in 1:1 molar ratio of metal to ligand. The elemental analysis, molar conductance measurements, magnetic susceptibility measurements, (mass, IR, UV-Vis, NMR, EPR), spectral studies of the compounds lead to the conclusion that the ligand acts in a tetradentate manner with Co(II), Ni(II) and Cu(II) complexes, while as bidentate fashion in Zn(II) complex. Co(II) and Ni(II) complexes possesed an octahedral geometry ,while Cu(II) posses tetragonal geometry. The thermal studies revealed that the complexes were more stable than ligands. The antibacterial studies of the compounds were examined against the human pathogenic, Gram negative bacteria i.e. *E. coli*, *Y. enterocolitica, K. pneumoniae* and *S. typhi* and Gram positive bacteria *i.e. L. monocytogenes* and *E. faecalis* and found that [NiLCl<sub>2</sub>] was highly active against *L. monocytogenes, E. coli* and *K. pneumonia* and [ZnLCl<sub>2</sub>] complex was found active against *E. coli* and *E. faecalis*.

**Chaurasia** *et al.* (2019)<sup>58</sup> synthesized a Schiff base ligand from the condensation of an equimolar amount of 2hydroxy-4-methoxybenzaldehyde and 3-amino-1,2,4-triazole and complexes of Co(II), Ni(II), Cu(II) and Zn(II) were further prepared from ligand . All synthesized compounds were characterized by elemental analysis, IR, <sup>1</sup>H NMR, <sup>13</sup>C NMR, electronic spectra, molar conductance and EPR. The DNA binding studies of metal complex has shown affinity to bind with DNA and revealed that electrostatic binding of DNA with metal complexes. The binding of a metal complex with DNA gives some light to design and improve the metal-based therapeutic drugs. DNA binding studies shows that Co(II), Ni(II) and Cu(II)complex (binding constant  $4.45 \times 10^6$ ,  $4.35 \times 10^6$  and  $4.20 \times 10^6$  M<sup>-1</sup> respectively)bind with DNA.

**Gaber** *et al.* (2019)<sup>59</sup> synthesized a new Schiff base, namely 3-{(5-mercapto-1,3,4-thiadiazol-2-ylimino) methyl}-4H-chromen-4-one, and its complexes of divalent Co, Ni, and Cu ions. Elemental analyses, molar conductance, TGA, magnetic moment measurements and spectral studies PXRD, IR, EI-mass spectrometer, <sup>1</sup>H NMR, <sup>13</sup>C NMR, UV–Vis, and ESR have been employed for structure elucidation of the target complexes. The spectral and analytical data revealed that the Schiff base acts as monobasic tetradentate ligand via deprotonated SH, oxygen atom of carbonyl group, and azomethine nitrogen atom for Ni(II) and Cu(II) complexes; bidentate via oxygen atom of carbonyl group and azomethine nitrogen atom for Co(II) complex. The anticancer activity of the target compounds is evaluated against HEPG-2 (human liver carcinoma) cells. The inhibition growth of the tested cells showed that Cu(II) complex is more potent anticancer agent. Ni(II) shows maximum activity against Grampositive bacteria (*S. aureus*).

**Palanimurugan & Kulandaisamy (2019)**<sup>60</sup> synthesized new mono cationic Cu(II), Co(II), Ni(II), VO(II) and Zn(II) Schiff base complexes from salicylalidene-4-imino-2,3-dimethyl-1-phenyl-3-pyrazolin-5-one and 2-aminothiazole. The prominent structural features of synthesized compounds were studied by elemental analysis, UV–Vis, FTIR, <sup>1</sup>H-NMR, <sup>13</sup>C-NMR, EPR, Fluorescence emission and Powder XRD. The Schiff base and its complex have been tested for their anticancer effect towards theMCF-7(human breast cancer) cell line by MTT assay method with different concentrations. A comparative study of the Schiff base and its complexes exhibit higher antimicrobial activity than the Schiff base. Copper complexwith IC<sub>50</sub> value 47.87 $\mu$ M have higher sensitivity towards the breast cancer lines than the free ligand.

**Bocian et al.**  $(2020)^{61}$  searched the environmental and economic aspects render for new nonprecious metal hydrosilylation catalysts an up-to-date challenge. Cobalt stands as an interesting alternative to the benchmark platinum-based species, nonetheless its relative infancy necessitates further studies, particularly regarding the structure of organic ligands that decorate the catalytically active metallic centre. As a continuation of our previous communication, we synthesized and characterized a series of new cobalt(II) chloride bench-stable precatalysts

coordinated to a small library of structurally similar Schiff base ligands. Thus, the synthesized species were evaluated for their ability to act as olefin hydrosilylation catalysts in the presence of alkali metal triethylborohydrides. From the crystal engineering point of view, it was observed that the number and arrangement of the Schiff base non-coordinating hydrogen bond donors affects the composition of formed complexes, resulting in predominant formation of either  $[CoLCl_2]$  'open' or  $[CoL_2]^{2+}$  'closed' species or a mixture of these. This affects their catalytic properties, with the benzimidazole/2H-imidazole 'open' system being the most efficient in terms of hydrosilylation selectivity and lowest catalyst loading. All in all, our work shows that seemingly similar coordination motifs do not necessarily lead to the isostructural group of catalytically open cobalt(II) coordination compounds, which is an important factor to consider in the design of new catalysts in general.

**Hamil** *et al.*  $(2020)^{62}$  synthesized the transition metal chelates of Mn(II), Ni(II) and Cu(II) from Schiff base of 1-((2E,3E)-3- (hydroxyimino)butan-2-ylidene)thiourea. The results of magnetic moment measurements demonstrated that the chelates of Mn(II) and Cu(II) have unpaired electrons and chelates of Ni(II) is diamagnetic. The results of the Schiff base ligand and its chelates suggest that the Mn(II) and Cu(II) chelates have octahedral structure and Ni(II) chelate is square planar. The synthesized complexes were screened for antibacterial activity against *S. typhi.*, *E. coli and S. aureus* showing moderate to good activities against all bacteria.

Li. *et al.* (2020)<sup>63</sup> obtained the schiff base which is urgent and important to detect heavy metals in environments. In this work, novel reaction-based fluorescent probes by Schiff base reaction. The probes with Schiff base moiety (-C=N-) undergo irreversible hydrolysis in the presence of Hg<sup>2+</sup> and Fe<sup>3+</sup>. They exhibit perfect high selectivity and sensitivity to Hg<sup>2+</sup> and Fe<sup>3+</sup> ions. Upon the addition of Hg<sup>2+</sup> and Fe<sup>3+</sup>, fluorescence intensity of the probes increased notably. And the color of the probe changes from brown to bright green under UV light, which can realize "naked eye" detection. In addition, Schiff base group was introduced into polyurethane chain through condensation polymerization reaction. As expected, the fluorescent polyurethane probe (P2) maintained the detection performance of its original small molecules (BSD). Even more P2 showed a more sensitive detection effect than BSD, and the detection limits of P2 for Hg<sup>2+</sup> and Fe<sup>3+</sup> reach 0.19 µM and 0.21 µM, respectively. It indicates that Reaction-based probes could be a useful tool for the detection of Hg<sup>2+</sup> and Fe<sup>3+</sup>.

**Rao** *et al.* (2020)<sup>64</sup> synthesized benzothiazole based Schiff base ligand 2-((E)- (6-ethoxybenzo[d]thiazol-2-ylimino) methyl)-4-nitrophenol and their Co(II), Ni(II),Cu(II), Zn(II) and Cd(II) complexes which characterized by various spectroscopic techniques (<sup>13</sup>C NMR,<sup>1</sup>H NMR,FT-IR, UV-Vis, fluorescence, ESR, mass), conductometric studies, magnetic susceptibility measurements and different physical studies like DTA, DTG, and TGA. Spectro-analytical data suggested square planar geometry of metal complexes. The synthesized Schiff base acts as monobasic bidentate ligand which coordinates through imine nitrogen and phenolic oxygen atom to the metal. The metal complexes also interact with DNA binding which was shown by CT (Calf thymus) DNA assay. The study of DNA binding properties of metal complexes has been investigated by using UV-Vis electron absorption spectroscopy, fluorescence emission spectra and viscosity measurement techniques. DNA photo cleavage ability of the same were analysed by agarose gel electrophoresis. The antibacterial activity was evaluated against various gram positive and gram-negative bacteria. Cytotoxicity studies of Schiff base ligand and their metal complexes were investigated against different cells. Cu complex showed potent activity as compared to other complexes and the free ligands.

**Çakır et al.** (2021)<sup>65</sup> investigated the present work in the hydroxyl and Schiff base functionalization, characterization, and H<sub>2</sub> storage of multi walled carbon nanotubes (MWCNTs) have been. The samples were analyzed using Brunauer–Emmett–Teller, scanning electron microscopy, Fourier transform infrared spectroscopy, and thermogravimetric analysis. The adsorption of H<sub>2</sub> gas was performed by volumetric method in different pressures at 77 K using the Hiden IMI PSI instrument. The surface area of MWCNT decreased with functionalization, but the surface areas of MWCNT-O-Schiff base-Me complexes generally increased. Scanning electron images showed that due to the increase in hydrophilic properties of modified samples, MWCNTs were separated from each other and morphology changed. According to the Fourier transform infrared analysis, functional groups were formed on the structures. While MWCNT was thermally stable, the functionalized samples degraded in three steps. Functionalized MWCNT, MWCNT-OH and MWCNT-O-Schiff base were 0.281, 0.321 and 0.37 wt% at 10 bar, respectively at cryogenic temperature. The hydrogen storage capacities of MWCNT-O-Schiff base-Me complexes varied in the range of 0.101–0.396 wt%. MWCNT-O-Schiff base-Cu had the highest hydrogen storage capacity.

**Cao et al.** (2021)<sup>66</sup> prepared a new chitosan Schiff base (CS-NB) and its CS-NB-NiFe nanocomposite and characterized by FTIR spectroscopy, XRD, SEM and DSC. FT-IR spectra and XRD patterns revealed the preparation of chitosan Schiff base CS-NB and its CS-NB-NiFe nanocomposite. DSC demonstrated the endo and exothermic correspondence the evaporation of solvent and decomposition of pyranose ring, respectively. Antibacterial activities were evaluated for the as-prepared compounds against two Gram-positive

(Staphylococcus aureus and Bacillus cereus) and two Gram-negative (*Escherichia coli* and Pseudomonas aeruginosa) bacteria and the results shows that the antibacterial activities of the compounds are found to be stronger than that of chitosan. The order of antibacterial effect according to inhibitory zone around is as follows: *S. aureus* > *E. coli* > *B. cereus* > *P. aeruginosa*. In addition, the removal of methyl green (MG) dye using CS-NB and its CS-NB-NiFe nanocomposite were analyzed and results showed that the compounds can be effectively used to remove of MG from aqueous solution. Results show that the percentage removal of MG by nanocomposite is higher than Schiff base.

**Miao et al.** (2021)<sup>67</sup> synthesized two kinds of chitosan-Schiff base derivatives (BCSB and PCSB) by the different average degrees of deacetylation (DD) of chitosan with benzaldehyde or propanal, respectively. Tremendous awareness of determination of chitosan content accurately is increasing, due to it has great significance to the quality control of chitosan The total mass of Schiff base derivative product was dried and obtained without washing and certain amount of the prepared Schiff base compound loss. Then. а was taken to hydrolyze into glucosamine hydrochloride (GAH) in strong hydrochloric acidic environment, whose concentration was quantified by HPLC, and the mass of GAH contained in hydrolysis solution could be calculated. Subsequently, the total quality of GAH obtained by hydrolysis of all of the Schiff base product was calculated and obtained, and then the theoretical mass of chitosan could be deduced and calculated by further converse calculation. Finally, the chitosan content was obtained by combining the sample mass used in Schiff base reaction and the theoretical mass of chitosan. This method was accurate and convenient, providing a preeminent idea and method for the determination of chitosan content.

Shang et al.  $(2021)^{68}$  synthesized a new Schiff base monocrystal and used to sensitize TiO<sub>2</sub> NSs. And then we constructed photoelectrochemical (PEC) sensors based on Schiff base sensitized TiO<sub>2</sub> NSs for dopamine (DA) detection. The sensitized TiO<sub>2</sub> NSs can extend the absorption spectrum range to the visible light region, and the photocurrent of the PEC sensors was increased by one order of magnitude. Chitosan further decorated the sensors to enhance the selectivity. DA was oxidized by hole and covalently linked with chitosan. Subsequently, the DA oxide acted as electron acceptor to cause photocurrent quenching, enabling quantitative and selective detection of DA. The PEC sensors have wide detection range from 0.0005 to 5.0 mM with the detection limit (LOD) of 0.206  $\mu$ M (S/N = 3). The non-enzymatic PEC sensors have a good selectivity which can distinguish DA from ascorbic acid (AA) and uric acid (UA), and also have reliable stability and recovery, thus, it has a good application prospect in biomedicine.

**Tamer et al.** (2021)<sup>69</sup> developed a novel Chitosan-*g*-Octanal Schiff base amphiphilic polymer by click grafting technique and evaluated successfully in removing different types of oils spills. The chemical structure and the morphological changes of the developed Chitosan-*g*-Octanal Schiff base amphiphilic polymer have been followed using FT-IR spectroscopy and SEM. The amphiphilic character of the developed Chitosan-*g*-Octanal Schiff base polymer has been controlled through variations of the Octanal grafting percentages from 38% to 82%. Dramatic changes of the Chitosan-*g*-Octanal Schiff base polymer solubility have been founded. The ion exchange capacity and water uptake have been affected in the same manner. The oils adsorption capacity was founded in direct relation to the Octanal grafting percentages and followed the order: mineral <kerosene < diesel < light crude oil (LCO) < heavy crude oil (HCO). Operational conditions such as oil amount, adsorption time, adsorbent dose, and agitation speed have been studied. The oil adsorption capacity of the Chitosan-*g*-Octanal Schiff base polymer for light and heavy crude oil has been increased by 167% and 110% over Chitosan ones. Finally, the removal process is optimized using response surface methodology (RSM).

**Devi** *et al.* (2022)<sup>70</sup> synthesized complexes of Co(II), Ni(II), Cu(II) and Zn(II) from hydrazone by condensation reaction of 6-chlorothiochroman4-one with benzhydrazide/nicotinic hydrazide/isonicotinic hydrazide/p-toluic hydrazide. The synthesized complexes were characterized by spectroscopic techniques (FTIR, <sup>1</sup>H NMR, <sup>13</sup>C NMR, ESR, UV–Vis, mass), powder XRD,TGA/ DTA, elemental analysis (CHN), magnetic susceptibility and molar conductance measurements. Antimicrobial activity *in vitro* of synthesized metal complexes were evaluated against two gram positive bacteria (*B. subtilis* and *S. aureus*); two gram negative bacteria (*P. aeruginosa* and *E. coli*); and two fungal strains (*C. albicans* and *A.niger*). The anticancer activity of complexes were performed on human cancer cell lines A549 (lung), DU145 (prostate) and SW620 (colorectal) by MTT assay. It was found that complex 11  $[Cu(L^2)_2(H_2O)_2]$  was the most potent against A549, DU145 and SW620 cancer cell lines with IC<sub>50</sub> values of 3.46, 18.21 and 7.61 µM respectively. Complexes 11, 13, 14, 19 show good antimicrobial activity with MIC value ranges from 0.0178-0.0356µmol/mL).

**Karaoğlan, G.K.** (2022)<sup>71</sup> obtained new Schiff base ligand, from the condensation reaction of 1,10-phenanthrolin-5amine with 4-fluorobenzaldehyde, and its novel stable series of Schiff base metal complexes (M = Ni(II), Cu(II), Zn(II), Co(II)) were synthesized in suitable conditions to contribute to increase anticancer drug activity in drug transport systems. The new compounds have been characterized using FT-IR, UV-Vis, <sup>1</sup>H NMR, LC-MS and

elemental analysis. The thermal stabilities of these complexes were studied by applying thermogravimetric (TGA/DTA) and the related decomposition steps were investigated. The TGA measurements were carried out to determine the effect of metals on the thermal strength of the newly synthesized complexes. The Cu(II) complex exhibited higher thermal strength. The photophysical properties of the Schiff base ligand and its metal complexes were studied in different solvents such as DMF, DMSO, methanol and ethanol. Dynamic quenching constant ( $K_{SV}$ ) values of the compounds as important parameters for biological systems in fluorescence quenching studies were calculated and the highest  $K_{SV}$  value (17.42) was obtained for compound **6** in DMSO, however, the highest  $K_{SV}$  value (7.80) was determined for compound **3** in DMF. The  $K_{SV}$  values of the Schiff base ligand and its zinc complex were higher than those that have been reported in the literature. Due to the high  $K_{SV}$  values of these compounds (**3** and **6**), they can be listed as anticancer drug active ingredients in drug transport systems.

**Keshtkar et al.** (2022)<sup>72</sup> synthesized some novel Ni(II), Cu(II) and Zn (II) metal complexes with new triazo Schiff base ligand (N-(2quinolylmethylidene)-4X-2-aminobenzene)imine (where X = Me, Cl, NO<sub>2</sub>)). Various spectral techniques such as elemental analysis, magnetic susceptibility, conductivity, <sup>1</sup>HNMR, IR, UV–Vis spectra, Mass spectrometry, powder XRD and EDX were used to confirm the structures. It has been found that the Schiff base behaves as a tridentate ligand forming chelates with 1:1 metal:ligand stoichiometry. The prepared Schiff base compounds were screened in vitro for their antibacterial activity against a number of pathogenic Gram positive and Gram negative bacteria, namely S.aureas and E.coli. The complexes show more potent activities than their free ligands. Spectrophotometric method and SQUAD program were applied to extract thermodynamic parameters to explain the complex formation behavior in solution at 25 °C in constant ionic strength (I = 0.1 M NaClO<sub>4</sub>). Also, density functional theory calculations at different level of DFT and basis set were employed to investigate optimized geometry, vibrational frequency analysis, electronic structure (energy of the HOMO and LUMO, Mulliken atomic charge, dipole moment, hardness and softness, electrophilicity and spectral properties) of the prepared Schiff base compounds. The DFT results showed that proposed structure and stability in ligands and their complexes are in accord with the experimental outcomes.

Long et al.  $(2022)^{73}$  demonstrated a novel Carbon Dots (CDs), green and effective corrosion inhibitor. Nevertheless, it still remains an enormous challenge to obtain CDs corrosion inhibitors by an energy-efficient and time-saving way. Meanwhile, there is no investigation to evaluate the inhibition effect of CDs with Schiff base structures. To surmount the barrier, a facile and scalable approach is elaborately designed to prepare CDs with Schiff base structures (Sc-CDs) by Schiff base reaction using *o*-phenylenediamine (*o*-PD) and *p*-benzoquinone (*p*-BQ) as precursors at 50 °C for 2 h, and their corrosion inhibiting properties for Q235 carbon steel in 1 M HCl solution are systematically investigated by weight loss test, electrochemical impedance spectra (EIS) and potentiodynamic polarization (PDP) measurement for the first time. Significantly, Sc-CDs with a long-term dispersion stability in HCl solution reveal a prominent inhibition efficiency of >96 % only at 200 mg/L incorporation. And according to the analyses of electrochemistry, adsorption isotherm and corrosion morphology, the inhibition mechanism of Sc-CDs is rationally attributed to the protective film established by Sc-CDs chemical and physical adsorptions. This work not only provides a facile, scalable, energy-efficient and time-saving approach to synthesize CDs, but also firstly evidences significant inhibition capacities of CDs with Schiff base structures. These findings would dramatically stimulate the development of truly low-cost and high-efficiency CDs corrosion inhibitors.

**Solanki et al.**  $(2022)^{74}$  synthesized metal Schiff-base complexes, Inspired by the blue fluorescent feature of the blue fluorescent Zn(II) complexes (**Zn-1** and **Zn-2**) bearing pyrazolone based azomethine ligands. The photophysical and electrochemical properties of these complexes have been investigated by several techniques in detail. Both complexes showed the emission in blue region and exhibited a good thermal stability. The single crystal X-ray structure analysis were performed to explicate their coordination adjustment around the Zn(II) metal ion. DFT and TDDFT methods performed to understand the involvement of metal ions and Schiff base ligand in the formation of frontier orbitals. For application in organic light emitting diodes, electroluminescent devices were fabricated by using simple solution-processed fabrication method. The best performance was observed at a low turn-on voltage of 3.5 V with a maximum external quantum efficacy of 3.2% for a deep-blue emission at a CIE<sub>v</sub> of 0.09.

**Tuna, M., & Ugur, T.** (2022)<sup>75</sup> used the oxidation catalysts in a wide range of industrial processes. For instance, stain bleaching in detergents, bleaching of raw cotton and wood pulp, and drying of alkyd-based paint can be given as examples of oxidation catalysts. In this study, methyl 2-(((3-hydroxynaphthalene -2-yl) methylene) amino) benzoate synthesized as the structure of a new Schiff base ligand by carrying out over 2-hydroxy-1-naphthaldehyde and methyl 2-aminobenzoate. By the reactions of the synthesized Schiff base ligand and Cu(II), Mn(II), and Co(II) acetate salts, their ML<sub>2</sub> type complexes were obtained. The structural characterizations of obtained metal ion-Schiff base complexes were performed using FT-IR, <sup>1</sup>H-NMR, <sup>13</sup>C-NMR, UV-*Vis*, MALDI-TOF, elemental analysis and melting point methods. The bleaching performances of the prepared Schiff base complexes were examined by the degradation of morin as a hydrophilic dye that characterizes the wine stains. The bleaching processes of Schiff base

complexes in the presence of catalyst and  $H_2O_2$  in an aqueous solution buffered with  $Na_2CO_3/NaHCO_3$  at pH: 10.5 were investigated using the online spectrophotometric method. It was found that the prepared catalysts exhibited better bleaching performance at 25 °C than that of tetraacetylethylenediamine (TAED) as a bleach activator commercially used in powder detergent formulations.

Anandan et al. (2023)<sup>76</sup> studied that hydroxyapatite (HAp) exists as an inorganic and crystalline composition present in bones and dental enamel, and hence can be utilized as a direct element or as part of the composition of biomaterials and implants for dental and orthopaedic applications. Listed below are a few synthesis techniques for HAp that are listed in the literature: solid-state and mechano-chemical methods (dry methods), wet chemical precipitation and sol-gel methods (wet methods), and combustion and pyrolysis methods (high-temperature processes). Nevertheless, there are new and more productive techniques that result in HAp with a regulated morphology, such as the Schiff base method, which, on reaction with calcium and phosphate precursors, forms chelating complexes to produce HAp nuclei. This research paper presents the comparison in characteristics between HAp synthesized using Schiff base (HAp-SB), wet chemical precipitation (HAp-WC) methods, and commercial HAp (HAp-CM) in their powdered and pelleted form. The average size of HAp-WC particles in the spherical form was found to be  $603 \text{ nm} \pm 176$ , HAp-SB were found to have rod-like morphology, which is very similar to human bone-like HAp, with an average length and width of 1522 nm  $\pm$  759 and 400 nm  $\pm$  112, respectively, and HAp-CM were found to have spherical morphology with dimensions of 52 nm  $\pm$  25. Biological studies show that cell viability of HAp-SB pellet (202.01%  $\pm$  8.16) seemed to have higher cell proliferation properties than HAp-WC pellet  $(145.7\% \pm 5.11)$  and HAp-CM pellet  $(71.53\% \pm 3.61)$  due to its higher aspect ratio, and hence higher surface area for the cells to adhere. In a detailed study, it is observed that both techniques had their advantages, and there were no significant disadvantages observed.

**Chen et al.** (2023)<sup>77</sup> discussed that the pure metal catalysts can cause environmental risks when they are released into lakes or rivers and difficulty in removing them from the catalyst system. Recently, several studies have focused on biopolymer-based catalysts owing to advantages such as biodegradability, high efficiency, and low cost. In this work, a novel lignin Schiff base-copper complex (L-SB-Cu) catalyst was synthesized and used for <u>methylene blue</u> (MB) and 4-nitrophenol (4-NP) reduction in aqueous solutions. The catalysts were characterized using elemental analysis (EA), Fourier-transform infrared spectroscopy (FT-IR), gel permeation chromatography (GPC), and proton <u>nuclear magnetic resonance spectroscopy</u> (<sup>1</sup>H NMR) proved that the lignin Schiff base (L-SB) was successfully synthesized. X-ray photoelectron spectroscopy (XPS) and energy dispersive spectrometry (EDS)-mapping proved that the copper ions were coordinated with L-SB, thus forming the L-SB-Cu catalyst. The catalyst exhibited a high catalytic reduction ability toward the organic pollutants MB and 4-NP with sodium borohydride (NaBH<sub>4</sub>) as the reducing agent. Even after three iterations of reusing the L-SB-Cu catalyst for MB and 4-NP reduction, the percentage reductions achieved were 87.3% and 75.65%, respectively. This work presents a new strategy for utilizing a bio-based material as a highly efficient catalyst for degrading organic pollutants.

**Darmawan** *et al.* (2023)<sup>78</sup> synthesized a new water-soluble Schiff base complexes with potential antimicrobial applications. A modification was made by adding a <u>sulfonate</u> group to the ligand to increase the ligand solubility in water. The Schiff base ligand was synthesized from a 4-aminoantipyrine compound with <u>salicylaldehyde</u> (L1) and salicylaldehyde-5-sodium <u>sulfonate</u> (L2), while the complex was synthesized using metal Co(II) with L1 (Co-L1) and L2 (Co-L2). Analysis and characterization were performed using a UV–Visible spectrophotometer, Fourier-transform infrared spectroscopy (FTIR), Nuclear magnetic resonance (NMR), Powder X-ray diffraction (XRD), magnetic susceptibility balance, and elemental analysis. All the ligands and complexes produced were crystalline, the geometry of the Co(II) complex is octahedral, and the ligand coordinates via the oxygen atom of the phenolic hydroxyl group and the nitrogen atom of the azomethine group. The sulfonate group causes the compounds L2 and Co-L2 to have greater solubility in water than L1 and Co-L2. The Density functional theory (DFT) results show that the presence of sulfonate groups causes the Co-L2 complex to have a larger dipole moment, is more reactive than Co-L1, and confirms its significant solubility in water. In addition, adding a sulfonate group also increases its antibacterial activity and is supported by molecular docking studies.

**Norouzi** *et al.* (2023)<sup>79</sup> produced a novel nanomagnetic tetra-azamacrocyclic Schiff base complex of copper(II) *via* a post-synthetic surface modification of an Fe<sub>3</sub>O<sub>4</sub> surface by a silane-coupling agent that contains acetylacetone functionalities at the end of its chain. Moreover, the target Cu complex that involves a tetradentate Schiff base ligand was obtained from a template reaction with *o*-phenylenediamine and Cu(NO<sub>3</sub>)<sub>2</sub>·3H<sub>2</sub>O. Furthermore, the prepared complex was nominated as [Fe<sub>3</sub>O<sub>4</sub>@TAM-Schiff-base-Cu<sup>(II)</sup>]. The Fourier-transform infrared (FT-IR) analysis indicates the presence of a Schiff-base-Cu complex in the catalyst. X-ray spectroscopy (EDS) and TGA analysis reveal that approximately 6–7% of the target catalyst comprises hydrocarbon moieties. The scanning electron microscope (SEM) and transmission electron microscopy (TEM) images demonstrate the presence of uniformly shaped particles, nearly spherical in nature, with sizes ranging from 9 to 18 nm. [Fe<sub>3</sub>O<sub>4</sub>@TAM-Schiff-

base-Cu<sup>(II)</sup>] was applied as a catalyst for the click synthesis of a diverse range of 5-substituted-1*H*-tetrazoles in PEG-400 as a green medium. Regarding the electrical properties of the Cu(II) complex, the presence of a tetra-aza (N<sub>4</sub> donor) macrocyclic Schiff base as an N-rich ligand was reasonable – leading to its excellent capacity to catalyze these organic transformations. Finally, the high magnetization value (44.92 emu g<sup>-1</sup>) of [Fe<sub>3</sub>O<sub>4</sub>@TAM-Schiff-base-Cu<sup>(II)</sup>] enables its recycling at least four times without compromising the catalytic efficiency. Ecofriendly synthesis of 5-substituted 1*H*-tetrazoles has been achieved *via* click reactions in the presence of a novel nanomagnetic tetra-azamacrocyclic Schiff base complex of copper(II) as the catalyst.

Alqasaimeh et al. (2024)<sup>80</sup> synthesized a receptor in the form of (E)-(4-(thiophen-2-yl)phenyl)-N-(4H-1,2,4-triazol-4-yl)methanimine Schiff base L through the reaction of 4-amino-4H-1,2,4-triazol with 4-(2-thiazol)benzaldehyde. The resulting Schiff base L was characterized by physicochemical techniques such as elemental analysis, UV-vis, Fourier transform infrared (FT-IR), mass spectrometry, and NMR. The Schiff base L receptor was exploited as an optical chemical sensor for nickel (II) metallic cationic concentration determination. The chemosensor demonstrated a consistent absorption intensity change at 385 nm related to the nickel (II) concentration in the range of 0–50  $\mu$ M with a calibration sensitivity of 0.0052 Abs/ $\mu$ M in addition to calibration linearity (R<sup>2</sup> = 0.9839) and possessing a response time of less than 5 mins. Other cations, Fe2 + Cu2+, Co2+, Zn2+, Cd2+, Mn2+, Mg2+, Cr2 + Ag+, Ca2+, Al3+, Li+, Na+, K+, Nd3+, Dy3+, Sm3 + and Tb3+, did not show any considerable change in absorbance intensity, except in the case of Pb2 + and Gd3+, where interference was observed. The mole-ratio method was used to determine the formula for the resulting Ni2 + -ligand complexation, and the Ni2+:ligand mole ratio was 1:1.

**Bariya el al.** (2024)<sup>81</sup> synthesized a novel aggregation-induced emission enhancement (AIEE) active Schiff-based fluorescent probe Cholyl Hydrazide Carbazole-Schiff base (ChHCz-SB) using cholyl hydrazide and carbaldehyde, and its properties were assessed using a range of spectroscopic methods. In a 70 % water-THF mixture, the ChHCz-SB showed the highest fluorescence intensity, which was 5.93 times greater than in pure THF. It was discovered that in the presence of different cations and anions. ChHCz-SB was a sensitive and selective "turn-off" fluorescence detector for Cu<sup>2+</sup> metal ions. The binding constant ( $K_a$ ) and limit of detection (LOD) were found to be  $5.3 \times 10^7 \text{ M}^{-1}$  and  $1.59 \times 10^{-7} \text{ M}$ , respectively. Job's plot was used to determine the 1:1 binding stoichiometry between copper (II) metal ion and ChHCz-SB. Moreover, Cu<sup>2+</sup> metal ion concentration in various water samples was successfully measured using the fluorescent probe ChHCz-SB. Furthermore, the distribution of electronic states in the Schiff base and the sensing mechanism were investigated through Density functional theory (DFT) calculations of ChHCz-SB.

 $(2024)^{82}$ et al. synthesized a Schiff base ligand termed (E)-4-methyl-N'-(2.4.5-Gosu trimethoxybenzylidene)benzohydrazide (HL) through a reversible condensation reaction, which engaged a carbonyl compound and a primary amine. This synthesized Schiff base ligand, HL, served as the foundation for the preparation of two metal complexes, namely,  $M_1L$  (Cu complex) and  $M_2L$  (La complex). To characterize these compounds, we employed various analytical techniques, including thermogravimetric studies, elemental analysis, powder X-ray diffraction, FT-IR spectroscopy and <sup>I</sup>H NMR. The examination of powder X-ray diffraction data provided valuable insights into the crystalline structures of the Cu and La complexes. These shifts are indicative of structural changes in the complexes. Our electronic spectrum analysis revealed the pivotal involvement of the ligand in promoting charge transfer processes, substantiated by an increased concentration of charge transfer transitions observed when the ligand was present. Additionally, we evaluated the antibacterial efficacy of the Schiff base ligand HL and its metal complexes (Cu, La) against a spectrum of bacteria, encompassing both gram-positive (Bacillus subtilis, Enterococcus faecalis) and gram-negative (Escherichia coli) strains. In the current investigation, we utilized molecular docking techniques to explore the interactions between the synthesized HL and its  $M_1L$  and  $M_2L$ complexes with protein receptor molecules. These results highlighted the favorable binding energies and stable interactions of these compounds with the protein receptor,  $M_1L$  displayed notably more stable interactions and lower binding energy compared to  $M_2L$ . This suggests that  $M_1L$  may have a stronger potential impact on the free binding energy and molecular interactions.

Kanagavalli et al. (2024)<sup>84</sup> synthesized a schiff base ligand (FHPB - 2-[N-(fluorophenyl)-4-hydroxy-4-phenyl] 3butene), and its copper complex Cu[FHPB]<sub>2</sub> were prepared and the structural framework of prepared compounds were characterized by analytical, spectroscopic and DFT calculation techniques. The result suggests that, prepared Cu[FPB]<sub>2</sub> complex possesses square planar geometry. Electrochemical studies reveal that Cu[FPB]<sub>2</sub> complex is quasi reversible in nature. Sensing ability of prepared ligand with various cations were analyzed by absorption and emission spectral techniques and infer that the ligand FHPB is highly sensitive and selective sensor for the Cu<sup>2+</sup> ion as compared to other selected metal ions. Antimicrobial activities of FHPB and Cu[FPB]2 against selected bacterial and fungal strains were checked by Disc Diffusion method. DNA interaction of prepared compounds were analyzed by spectrophotometric and spectrofluorometric techniques. The analysis illustrates that the synthesized compounds interact with calf thymus DNA by the way of an intercalation

mode. Moreover, the binding ability of **FHPB** and **Cu[FPB]**<sub>2</sub> were demonstrated by molecular docking and it evidences the strong binding with CT-DNA double helix.

Katariya et al. (2024) synthesized two series of coumarin Schiff base liquid crystals. These series involved molecules with variations in alkoxy chains at aldehyde ends: one being the Schiff base with 4'-hydroxy-[1,1']biphenyl-4-carbaldehyde (ASBP series) and the other being alkyl 4-formyl-[1,1']-biphenyl-4-carboxylate (AEBP series). The compounds were characterized using FTIR, NMR, and Mass spectral analyses. All the compounds were studied for their mesomorphic properties, differential scanning calorimetry (DSC) and polarized optical microscopy (POM). In both the homologous series, variation of alkyl chain length showed intriguing phase transitions. In the first homologous series ASBP, compound with phenyloxy chain displayed an enantiotropic nematic (N) phase, while those with chain lengths n = 8-16 exhibited enantiotropic smectic A (SmA) mesophase. Similarly, in the **AEBP** series, compounds with n = 6.8 chain length showed an enantiotropic nematic (N) phase, while those with higher chain lengths n = 10-16 exhibited enantiotropic smectic A (SmA) phases. SmA mesophase was further confirmed by powdered XRD analysis. The study included DFT theoretical calculations to comprehend the compounds' mesomorphic behaviour, comparing them with analogous reported compounds. Additionally, the investigation correlated experimental findings of individual compounds with calculated parameters like polarizability, dipole moment, and aspect ratio. Molecular electrostatic potential projections and analysis of frontier molecular orbitals were also employed to elucidate how polarity variations in terminal chains and mesogenic cores influenced the energy gap of FMOs and the distribution of electrostatic charges on these compounds. It has been found that the **ASBP** series has lower energy gap and higher dipole moment than the **AEBP** series.

#### Conclusion

Through the literature survey, it is concluded that synthesis of new Schiff Bases is a demand of current world as these have wide applications in various fields. Although, many Schiff Bases have been prepared worldwide but studies on their application part have not attracted much attention. So, it is recommended to synthesize, characterize and evaluate their various applications so that new organic compounds can be found which have applications in synthesis, analysis and biological activities.

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