

Review Article

Synthesis, Characterization and Biological Activities of Schiff Bases and Their Transition Metal Complexes

Desalegn Tesfa Tefera

Department of Applied Chemistry, School of Natural and Applied Science, Adama Science and Technology University, Adama, Ethiopia

Email address:

dtesfa30@gmail.com

To cite this article:Desalegn Tesfa Tefera. Synthesis, Characterization and Biological Activities of Schiff Bases and Their Transition Metal Complexes. *World Journal of Applied Chemistry*. Vol. 8, No. 2, 2023, pp. 22-33. doi: 10.11648/j.wjac.20230802.11**Received:** March 22, 2023; **Accepted:** May 17, 2023; **Published:** May 29, 2023

Abstract: Schiff bases are aldehyde or ketone derivatives that are made by condensation of primary amines and carbonyl compounds and have their carbonyl organization ($C=O$) replaced by an imine or azomethine organization ($>C=N-$). Schiff bases are a key ligand elegance in coordination chemistry and are widely used in a variety of fields. Metallic buildings have extra organic action than the relating ligands. Schiff base complexes in particular are particularly intriguing due to their stability, electron-donating potential, photochromic, optical nonlinearity properties, and biological interest. The coordination of Schiff bases with steel ions serves as the foundation for each one. With $-NH_2$ and $-COOH$ coordination sites, amino acids are functionally important in many biological processes and form Schiff bases that easily coordinate with metallic ions when combined with aldehydes or ketones. The majority of Schiff bases derived from amino acids and their metallic complexes exhibit specific pharmacological properties. This assess centers around research related with Schiff base buildings of amino corrosive subordinates throughout the course of recent years. We spotlight the antimicrobial, anticancer and cell reinforcement amino acids of a couple of Schiff base mixtures with nitrogen, oxygen and sulfur contributors and different metallic particles.

Keywords: Schiff Base Complexes, Synthesis, Characterization, Biological Activity

1. Introduction

Background of the Review

Researchers are currently paying attention to coaching and studying inorganic compounds that contain ligands that are essential to biological processes. That is a direct result of the way that, positive steel particles are energetic in numerous natural methodologies; this is because there are numerous biological applications for positive steel ions; Low-molecular-weight species, their fascinating structural homes, and the reactivity of these ion complexes make them important compounds. Metals like copper, magnesium, calcium, iron, zinc, chromium, vanadium, and manganese cations are important metals that are determined to exhibit first-rate organic activity when they are related to specific protein ligands, allowing complexes to discover significant capabilities; collaborations in oxygen transportation, digital switch reactions, or ion storage have piqued a lot of interest in the study of structures. Containing these metals. (Shoaib et al., 2013).

Hugo Schiff, one of the founders of current chemistry, is credited for discovery of sophistication of ligands called the Schiff base. The Schiff base is called after Hugo Schiff and is a compound with a functional institution that carries a $C=N$ double bond with the nitrogen connected to an aryl or alkyl institution. Schiff bases in a vast feel have the general formula $R_1R_2C=NR_3$, in which R is an organic side chain. Schiff base is synonymous with azomethine and may also be referred to as imines (Sakhare, 2020).

Due to their extensive coordination chemistry and ease of synthesis, Schiff bases have attracted a lot of interest. [3] Schiff bases are a spinoff of aldehyde or ketone which have carbonyl group ($C=O$) has replaced by way of an imine or azomethine institution ($>C=N-$), and are made by using condensing number one amines and carbonyl compounds. Schiff bases are one of the most normally used organic chemical compounds, with a spread of packages which includes organic synthesis intermediates, chemosensors and polymer stabilisers [4], in meals enterprise [5], as dye and

pigments, catalysis [6] and others. Schiff base also shape ligands have been extensively employed in recent years to synthesize metalloprotein substitutions inclusive of galactose oxidase, catechol oxidase, superoxide dismutase [7], cytochrome, phosphatase, phenoxazinone synthase [8], urease and lots of others. Most Schiff bases have the interesting potential to coordinate to metallic ions to produce their respective complexes of essential institution, transition metal, lanthanide, and actinide factors, with their characteristics greatly stepped forward by means of doing so. Additionally, they were played a key position within the development of stable complexes with steel ions is due to the azomethine (N = CH) lone pair of electrons bonding of their shape [9]. Schiff bases are usually used as powerful and stereospecific catalysts in natural and inorganic chemistry for oxidation, discount, hydrolysis, and other differences. [10]

It need to be referred to that hydrazones are a captivating sequence of ligands with the formulation $R_1R_2C = NNH_2$, which are generated by using changing the oxygen in ketones or aldehydes with the NNH_2 practical group of the perfect hydrazone. These compounds are powerful ligands that, depending at the substituents in the fragrant ring connected to the hydrazone unit, may be coordinated to the metal middle in a tridentate, bidentate, or tetradentate way, based on the benzene earrings substituents connected in a tridentate, bidentate association. The hydrazido-hydrazones, which could come across keto-enol tautomerization, are a captivating kind of hydrazones. Hydrazone compounds and their metallic complexes play a critical function in the development of new therapeutics. they have a various set of organic functions, consisting of anticoagulant, antimicrobial, antitubercular, antimalarial, anticancer, powerful DNA binding, and antioxidative. [11]

those complexes have observed capability packages in a diffusion of fields, inclusive of oxidation catalysis, electrochemistry, analytical chemistry, food, dye enterprise, agrochemical, pharmaceutical, and biological fields, because of their artificial flexibility, selectivity, and sensitivity in the direction of a spread of organisms. [11]

A remarkable deal of facts concerning the houses of synthetic Schiff bases of capacity biological hobby has arisen at some point of the last few years, distinct lessons of organic compounds containing wealthy conjugated system may be observed while these compounds incorporate hydroxyl corporations attached to aromatic jewelry. As an example,

compounds containing an azomethine organization ($-CH=N-$) called Schiff bases are formed through the condensation of a number one amine with carbonyl compounds. Schiff bases received from fragrant aldehydes and fragrant amines have an powerful conjugation device and pretty stable. Schiff bases are vital compounds as a result of their wide range of biological sports and commercial utility. They were found to own the pharmacological sports which includes anticancer, antimicrobial, and antioxidants. Such sports can be related to the structural preparations of the ligands and to the character of the substituent corporations. [9]

Aside from biological activities, Schiff bases are also used as catalysts, intermediates in organic synthesis, dyes, pigments, polymer stabilizers, and corrosion inhibitors. Studies enlightened that metal complexes display greater organic hobby than loose organic compounds. Augmentation of organic hobby became suggested via implementation of transition metals into Schiff bases. Schiff bases performed an influencing position in improvement of coordination chemistry and had been concerned as key point in the development of inorganic biochemistry and optical materials.

In coordination chemistry, Schiff's bases are an essential elegance of ligands and locate sizeable applications in special fields. The interaction of those ligands and metallic ions offers complexes of special geometries which are probably biologically energetic. The π -system in a Schiff's base frequently imposes a geometrical constriction and impacts the electronic structure as properly. Thermo chemical properties of Schiff's bases have attracted the interest of many researchers, in view of their potential to bind through NO or N_2O_2 donor atom sets [12].

This seminar paintings affords evaluation of the synthesis and organic activity of Schiff bases and their steel complexes.

2. Literature Review

Schiff bases are of huge interest as chelating retailers for various steel ions because of the presence of nitrogen, oxygen, and sulfur donor atoms [13]. Lots of researchers had studied the metal complexes of Schiff base ligands which includes one aromatic ring. Furthermore, the metal complexes of Schiff base ligands with two aromatic jewelry have been studied. In truth, many metal complexes of sulfur-nitrogen chelating sellers were revealed to display authorised cytotoxic (anticancer) sports.

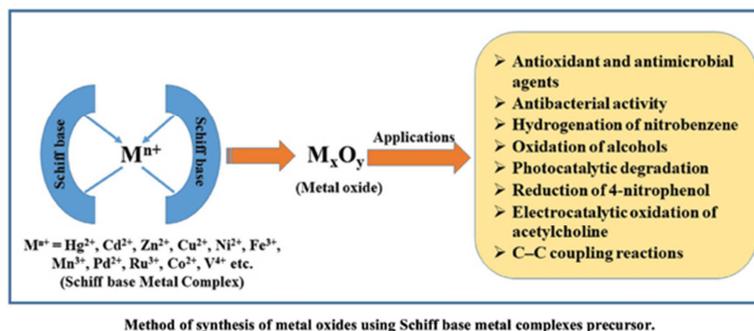


Figure 1. Method of synthesis of metal oxides using Schiff base metal complexes precursor.

Within the closing twenty five years, a excellent deal of subject has been given to the take a look at of metal complexes of sulfur ligands. Structural characterization and synthesis of this kind of ligands are vital to ligands containing both hard and gentle donor atoms may also yield steel complexes with unusual magnetic homes and exciting stereochemistry and a number of the ligands and their steel complexes are envisioned to reveal organic pastime. This work centered to synthesis new Schiff base and its metallic complex. Special characterization gear had been used for identification of the systems of the prepared compounds. The in vitro antibacterial and anti-breast cancer activities had additionally been screened [13, 14] on this evaluate to the instruction of a brand new thermally strong Schiff base (E)-2-(((three-aminophenyl)imino)methyl) phenol ligand from the condensation reactions of m-phenylenediamine and 2-hydroxybenzaldehyde and its metal complexes has been taken into consideration. The interplay of the ligand with metal ions turned into investigated by way of using diverse spectroscopic techniques as elemental evaluation, XRD, SEM, TEM, TGA, FT-IR, UV-Vis, ¹H-NMR, mass spectroscopic research and molecular docking techniques. Schiff base ligand and its metal complexes have been optimized theoretically and the quantum chemical parameters had been calculated and mentioned. The synthesized ligand and its complexes have been screened for antimicrobial activities against bacterial species [15].

2.1. Transition Metal Complexes

Transition metals have various utility and thrilling chemistry. Coordination compounds are crucial due to their role in biological and chemical structures in various methods. It's been observed that metal complexes with appropriate ligands are chemically greater large and particular than the metal ions and authentic [16]. Presently the importance of steel ions in diverse organic systems has emerge as critical, as they are extra powerful inhibitor of an enzyme in comparison to uncomplexed organic lively compounds. Furthermore, the evidences assisting the usage of steel complexes within the combat towards most cancers, tumor, viruses and micro organism have in addition made this subject a count number of amazing research interest. There are a huge number of steel complexes which can be anticancer, antitumor and antibacterial. The complexation of metallic factors with biologically inactive compounds renders them lively; and in case the compounds are already active, it makes them extra active. The mechanism concerned in improving this biological activity upon complexation continues to be needed to be similarly investigated a good deal extra interest has been committed by means of bioinorganic in addition to via medicinal chemists to develop the relationship between the metal ions and their complexes to use as antitumor and antibacterial agents. In vitro research have indicated that some biologically lively compounds may grow to be extra carcinostatic and bacteriostatic upon chelation. Such interaction of transition metallic ions with amino acids,

peptides and pyrroles, are of great organic significance. Numerous evaluations indicates that the metallo-natural chemistry of such compounds substantially have an impact on their organic action highlighting the catalytic characteristic or metals in many biological techniques [17].

2.2. Properties of the Schiff Bases Ligands

They're relevant in extensive unfold of complicated formation reactions due to their ease of synthesis, excessive affinity to form complexes with metallic ions (metal atom), high stability, their pharmacological activity, and marked anticancer properties.

2.3. Methods of Synthesis of Schiff Bases and Their Transition Metal Complexes

There are a way of synthesis for schiff bases ligands and also for transition metal complexes, there a stepwise manner that to follow to be able to get the product.

2.3.1. Synthesis of Schiff Bases

A not unusual technique of synthesis of Schiff base is the nucleophilic attack of amines on electrophilic carbon of aldehydes or ketones. The cease end result of this reaction is a compound wherein C=O double bond is changed via a C=N double bond (Scheme 1). This form of compound is referred to as an imine or a Schiff base [18].

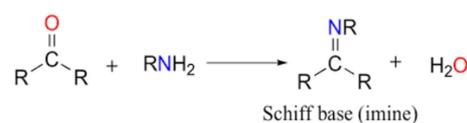


Figure 2. Synthesis of Schiff base.

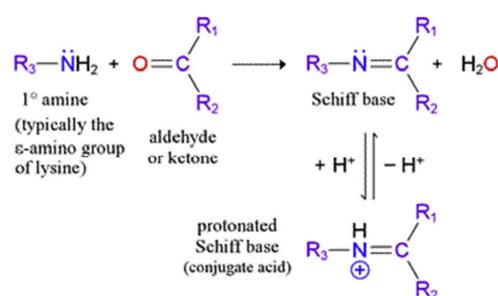


Figure 3. General scheme for formation of Schiff bases.

The Schiff base became synthesised by using the condensation of benzil-2, 4-dinitrophenylhydrazone and aniline (1:1 molar ratio), dissolved in ethanol. The resulting reaction mixture became refluxed for» 1 hr and the yellow strong precipitate of Schiff base acquired become filtered, washed with distilled water dried, recrystallised from ethanol and finally preserved in a desiccator. Yield: 58% (m.p.: 138°C) [19].

Synthesis of Schiff base (ETSAN), in step with okay. Mounika, et al, The Schiff base turned into prepared by way of condensation of three-ethoxy salicylaldehyde (1. sixty six g; zero.01 mol) with 2-amino benzoic acid (1.37 g; 0.01 mol) in ethanol (25 mL) and the combination was refluxed for 2 hrs.

The ensuing solution became evaporated under vacuum to put off the solvent. The product become collected by way of filtration, washed several instances with ethanol and recrystallized from hot ethanol and dried in a vacuum desiccator. The melting factor of the ensuing Schiff base was found to be 148°C. The color of the product is purple with 95% yields [1].

2.3.2. Synthesis of Complexes

In line with the preceding literature ([19]), the Copper(II), cobalt(II), nickel(II) and zinc(II) complexes of Schiff base derived from benzil-2, four-dinitrophenylhydrazone with aniline, were prepared by using undergoing those reactions An ethanolic (10 ml) solution of Schiff base (10 mM) changed into combined with metallic (II) chloride (five mM) in ethanol (10 ml) answer maintaining ligand-metallic ratio 2:1 accompanied by way of few drops of acetic acid (pH = 6). The aggregate was then refluxed for » 1 h on a water tub until the complicated induced out. Precipitate obtained changed into dried over KOH pellets. The strong product obtained became filtered, washed with distilled water and dried in vacuo.

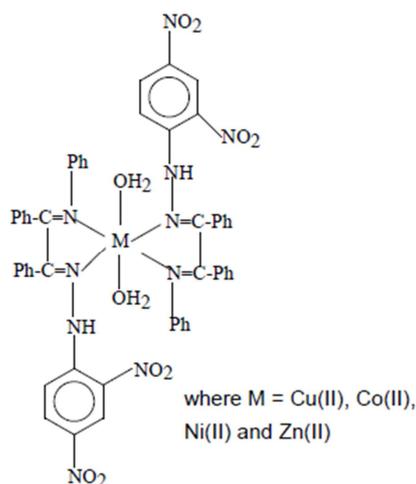


Figure 4. Structures of the complexes.

2.3.3. Synthesis of Imine Derivative of 2-amino-2-ethyl-1,3-propanediol (VAEPD)

To the solution of two-Amino-2-ethyl 1-1, three-propanediol (5ml; zero.05moles) prepared via the use of 50ml of water and the 4-Hydroxy-three-methoxybenzaldehyde(zero.05moles) answer (Made by means of the usage of 50ml of methanol) became jumbled together a clean 250ml spherical bottom flask and stirred with a magnetic stirrer and then it turned into refluxed for one hour on a water tub. On cooling yellow needles were separated out. It turned into separated via filtration and washed numerous instances with hot water after which dried. The compound became recrystallized from methanol. Yield seventy two%, Melting factor 171-174°C [21].

2.4. Synthesis of Copper (II)-VAEPD Complex Metal Complex

Because it has been worked within the referred to article

([21]), This complex was prepared by including requisite (2.2g, zero.009moles) quantity of Schiff base in 50ml of fifty% methanol to the copper metallic ion (0.009moles) in water in presence of sodium acetate and refluxed aggregate for two hours on a water bath. The reaction mixture was poured in excess of cold water. coloured precipitate of metallic complex changed into received with right yield. This product become washed numerous instances with hot water and bloodless methanol to unfastened them from unreacted metal salt and ligand respectively and ultimately with ether and dried in a vacuum dessicator. 2.2. 4. Synthesis of cobalt (II)-VAEPD complicated The cobalt complex of Vanillin and 2-Amino-2-ethyl 1-1,3-propanediol Azomithine was organized by way of heating the response combination in a clean 250ml round bottom flask containing the ligand VAEPD (2g, zero.008moles) dissolved in 50ml of fifty% methanol and hydrated cobalt sulphate (0.008moles) dissolved in minimum amount of 5ml of H₂O for two hours. On cooling and gradual evaporation, the solid metallic complicated turned into shaped. It turned into separated with the aid of filtration, and washed numerous instances with hot water and methanol. Then it changed into dried in vacuum dessicator.

2.4.1. Synthesis of Cobalt (II)-VAEPD Complex

The cobalt complicated of Vanillin and a couple of-Amino-2-ethyl 1- 1,3-propanediol Azomithine become organized by means of heating the reaction combination in a smooth 250ml round backside flask containing the ligand VAEPD (2g, zero.008moles) dissolved in 50ml of 50% methanol and hydrated cobalt sulphate (0.008moles) dissolved in minimal quantity of 5ml of H₂O for 2 hours. On cooling and gradual evaporation, the stable metal complex turned into shaped. It turned into separated through filtration, and washed several times with warm water and methanol. Then it was dried in vacuum dessicator [21].

2.4.2. General Experimental Procedure for the Preparation of the Metal Complexes

A aggregate of the Schiff base under investigation (0.01 mop) in 25 ml ethanol and the identical amount of the equal solvent of metallic salt (zero.01 mol) (MX₂, where M= Ni (II), Co (II), Cu(II) and Zn(II); X=Cl/NO₃/acetates) have been refluxed for 2 hours at 70-eighty°C on water bath. On cooling, colored stable product was collected with the aid of filtration after which washed numerous times with hot ethanol till the bathing becomes colourless. The product changed into dried in air and stored in a desiccator over anhydrous CaCl₂ beneath vacuum. All of the steel complexes are colored and stable to air and moisture, the technique has been investigated with the aid of [20].

3. Characterization Techniques

3.1. Elemental Analysis

Elemental analysis marks the foundation of chemical know-how. It has furnished crucial facts approximately

materials and their composition from the beginning of the development of chemical principles and technology in popular. Elemental analysis can be qualitative, determining which factors are gift or quantitative, determining the ranges of factors.

Novel Schiff's base ligands and their complexes are analyzed micro analytically for carbon (C), hydrogen (H), Sulfur(S) and nitrogen (N) contents to discover their empirical compositions. Which means Elemental evaluation of a compound permits one to determine the empirical system of the compound. The empirical system is the method for a compound that includes the smallest set of integer ratios for the elements in the compound that gives the right elemental composition through mass. So physical characteristics and elemental analysis of C, H and N of the compounds are considered to decide the composition of complexes and the unconventional ligand. The effects of C, H and N percentage are in accordance with the composition recommended for the most complexes [18].

3.2. NMR Spectra

Besides identity, NMR spectroscopy affords specific data approximately the structure, dynamics, reaction kingdom, and chemical surroundings of molecules. The most not unusual forms of NMR are proton and carbon-13 NMR spectroscopy, but it's miles relevant to any type of sample that includes nuclei possessing spin.

¹H-NMR and ¹³C-NMR spectra were had been taken in DMSO-d₆. The peaks of all of the proton and carbon atoms had been has constant of their predicted place. The NMR spectrum of Schiff base ligand confirmed the absence of aldehyde top at δ 9-10 ppm and presence of azomethine at δ 8. seventy five ppm. Phenyl protons appeared at δ eight.11-7.22 ppm at the same time as the methyl protons showed values at δ 2.14-2.04 ppm. ¹³C-NMR spectra also verify azomethine height at δ 163.1 ppm. The peaks of different groups in ligand showed values δ 121.1-135.6 ppm (thiophene carbon), δ 122.1-149.2 ppm (phenyl) and δ 22.4-22. nine ppm (-CH₃) respectively. The diamagnetic Zn(II) complicated confirmed a moderate change in spectra due to multiplied conjugation and coordination to steel ion [22].

3.3. Magnetic Properties

Magnetic homes represent supplementary statistics to help other facts such as microanalyses. An example is the willpower of the nature of the energetic websites in metalloenzymes: almost half the essential enzymes incorporate one or greater transition metals on the active website.

The magnetic moments of one, 2 and three have been decided to determine unpaired single electron numbers and predict coordination geometries of the complexes. The magnetic second of one changed into 1.39 BM, similar to one unpaired electron of Cu²⁺. This cost turned into lower than predicted and refers to the presence of antiferromagnetic exchange [23]. The complex 2 changed into diamagnetic and a

low spin cobalt (III) complicated [24]. This result indicated that the cobalt (II) become oxidized to cobalt (III) because of publicity to air at some stage in the experiments. in this evaluation which aimed to provide an explanation for the shape, the NMR spectrum changed into no longer wished, because the distinctive structure of 2 turned into determined via X-ray analysis. The magnetic second of 3 become in agreement with the price of the octahedral geometry (three.10 BM) [25].

3.4. UV-Visible Spectroscopy

Ultraviolet-seen (UV-Vis) spectroscopy is a widely used approach in many regions of technology starting from bacterial culturing, drug identification and nucleic acid purity assessments and quantitation, to first-rate manage in the beverage enterprise and chemical studies.

UV-visible research was been made in DMSO. From the values of λ_{max} acquired it become determined that $n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$ transitions are observed that are due to chromophoric organizations (imine and fragrant ring) inside the ligands. The spectra of the complexes showed purple shift. All solutions have been of 10-four molar concentration; because of this dilute concentration no $d \rightarrow d$ transitions were located [26]. The acquired values were in comparison to literature values and it turned into discovered that values for copper, nickel and cobalt had been near the values for four coordinated systems and for manganese the values had been in the range of six coordinated machine (desk three) [1].

Table 1. UV spectral data of ligands and its Synthesized Transition Metal Complexes.

Compound	Wavelength	Absorption	Type of transition
1,	354, 230	1.50, 0.50	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
2,	440, 234	1.67, 0.55	$n \rightarrow \pi^*$ and $-\pi^*$
3,	447, 236	1.75, 0.751	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
4,	412, 265	1.65, 0.67	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
5,	383, 245	1.57, 0.852	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
6,	404, 247	1.64, 0.573	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
7,	365, 276	1.571, 0.541	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
8,	450, 260	1.75, 0.511	$n \rightarrow \pi^*$, and $\pi \rightarrow \pi^*$
9,	414, 287	1.62, 0.43	$n \rightarrow \pi^*$ and $-\pi^*$
10,	386, 290	1.58, 0.47	$n \rightarrow \pi^*$ and $-\pi^*$
11,	411, 276	1.60, 0.852	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$
12,	432, 268	1.73, 0.573	$n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$

3.5. Infrared Spectroscopy

Infrared spectroscopy (IR) is work inside the areas of willpower of molecular structure, identity of chemical species, quantitative/qualitative dedication of chemical species, and in a number of different applications. This method is relevant inside the investigation of matter in the solid, liquid, and gaseous states.

The steel-ligand bond changed into been established with the aid of evaluating the IR spectrum of the Schiff base ligand with metal (II) complexes. The ft-IR spectra predicted all the absorption bands of the Schiff base ligand and some new bands at precise frequency confirmed the modes of absorption and the coordination of the ligand with the steel ions thru

nitrogen and sulfur. The azomethine group of ligand 1611 cm^{-1} was shifted to 1613-1620 cm^{-1} in all of the complexes consequently suggested the coordination of steel to ligand bond via azomethine ($\text{HC}=\text{N}$). Absorption bands of the sulfonamides moiety within the synthesized ligand and in metal complexes have identical frequency. Further definitive evidence of the coordination of the Schiff base with the metallic ions changed into showed by using the arrival new bands at 417- 470 cm^{-1} and 340-353 cm^{-1} designate to the metallic-nitrogen $\nu(\text{M-N})$ and metallic-sulfur $\nu(\text{M-S})$ extending vibrations, personally. These bands were no longer gift within the spectrum of the unfastened ligand, therefore affirming the presence of S and N within the coordination. Furthermore, the $\text{C}=\text{N}$ stretching vibrations of pyrimidine ring have been found in ligand at 1590 cm^{-1} shifted barely in all the metallic complexes, indicating that those corporations aren't worried in coordination. The water-containing complexes present a huge diffuse band of medium intensity within the 3263-3440 cm^{-1} location which may be assigned to the OH stretching vibration for the coordinated water, according of the preceding literature [22].

The commonplace region for infrared evaluation in organo transition chemistry is 4000-two hundred cm^{-1} . IR spectra of

all the compounds were recorded the use of Kerb pellets within the variety 4000-four hundred cm^{-1} . The feature absorption bands have listed in table 2. The essential absorption frequencies are $\nu(\text{OH})$, $\nu(\text{M-O})$, $\nu(\text{M-N})$ and $\nu(\text{-C}=\text{N})$. Assignment of different vibration bands have made through the comparison of ligand spectra with that of transition metal complexes. Inside the spectra of the ligands a sturdy band at 3300 and 3450 cm^{-1} became assigned to -OH stretching vibration. After complex formation, that band become still observing in case of Mn complexes handiest, supporting the reality that water molecule is gift as water of coordination.

A robust band seemed in the range of 1600-1625 cm^{-1} in the loose ligand, became attributed to the $\text{-C}=\text{N}$ stretching vibration. In complexes the $\text{-C}=\text{N}$ stretching vibration shifted to decrease frequencies compared to the unfastened ligand. This shift indicated donation of the nitrogen lone pair of electron of the azomethine organization to the metallic atom [27]. Within the low frequency area, the band observed inside the complexes within the location of 500-550 cm^{-1} and 400-470 cm^{-1} is attributed to $\nu(\text{M-N})$ and $\nu(\text{M-O})$ respectively. The IR facts suggested that the metallic turned into been bonded to the Schiff base (Table 2).

Table 2. Infrared spectra of the ligands and metal complexes (Shoab et al., 2013).

Codes	$\nu \text{ O-H}$	$\nu \text{ C}=\text{N}$	$\nu \text{ M-O}$	$\nu \text{ M-N}$
1,	3316	1619	-	-
2,	3404	1604	430	539
3,	3430	1591	415	518
4,	3455	1596	434	535
5,	3435	1601	413	536
6,	3440	1589	469	531
7,	3439	1621	-	-
8,	3433	1602	417	544
9,	3440	1601	414	528
10,	3415	1596	418	528
11,	3428	1584	416	534
12,	3413	1585	416	533

3.6. XRD Data

XRD pattern may be very beneficial in numerous ways; identifying compounds evaluation of the lattice stress in case cloth is deformed, size lattice parameter from the peak, identify crystal structure, density of compounds.

For the duration of powder X-ray diffraction analyses, Co (II) and Cu (II) complexes of various Schiff's base metallic complexes exhibited sharp peaks at Co (II) are crystalline in nature. In Co (II) complexes, the road broadening of the crystalline diffraction top was exceedingly better. By means of comparing diffractograms of the ligand with complexes, the crystalline nature of the complexes were had been indicated. This could be because of the inclusion of water molecules in the coordination sphere based on literature. even though the maximum accurate source of records regarding the complex shape is unmarried-crystal X-ray crystallography, the problem of obtaining suitable symmetric shapes of crystals makes this technique undeserving for such have a look at [28].

3.7. Thermal Analysis

Thermal analysis detects the material residences as a function of temperature. A consultant thermogram of Ni-complicated has given in Figure 1. It changed into been found from the discern that the heating quotes had been suitably controlled at $10^\circ\text{C min}^{-1}$ under nitrogen ecosystem and the weight reduction changed into measured from the ambient temperature up to one thousand $^\circ\text{C}$. thermogram of Ni-complicated indicated, a complete weight loss of sixty seven% up to 1000°C , that is found in 3 steps, (i) a small weight loss within the variety of $40^\circ\text{C} - 80^\circ\text{C}$ which is assigned to loss of lattice water, (ii) most weight loss within the variety of $390- 450^\circ\text{C}$ is resulting from the loss of coordinated water (iii) and gradual weight reduction within the range of $540 - \text{one thousand } ^\circ\text{C}$ can be assigned to complete decomposition of ligand moiety across the steel ion respectively. Sooner or later the complicated is transformed into its metallic oxide [29]. The presence of water molecules is in addition confirmed by means of the endothermic bands

found in respective DTA curve within the temperature vicinity where TGA curves imply loss in weight.

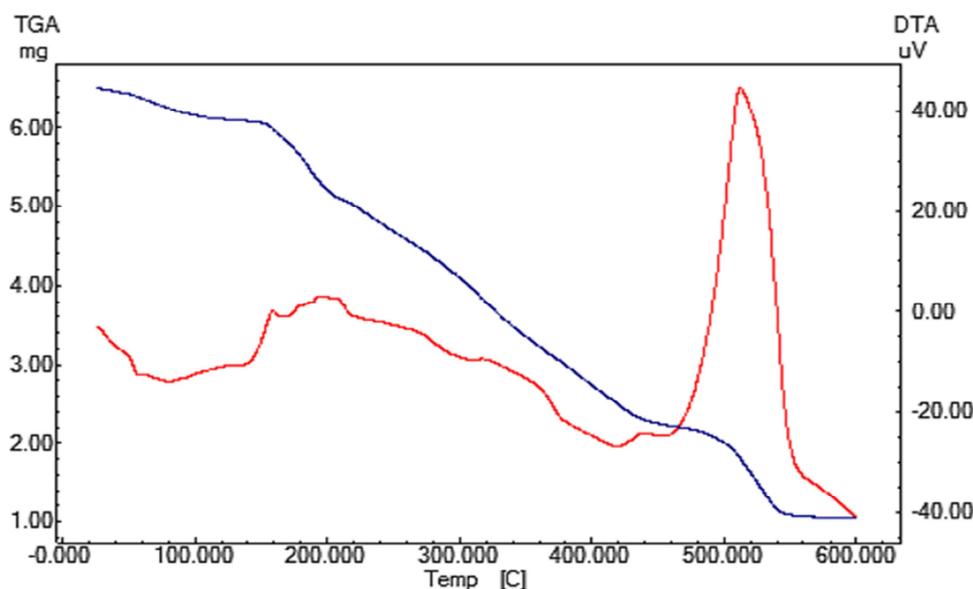


Figure 5. Thermogram of Ni (II) complexes.

4. Biological Activity

4.1. Antibacterial Activity

Extreme infections resulting from microorganisms are common among humans. They may be answerable for the full-size increase in morbidity and mortality, longer hospitalization and increased healthcare costs. For that reason, antimicrobials have a first-rate role in fixing this healthcare problem global. Researchers had been worried in wide variety investigations associated with coming across new antimicrobial agents (tablets) with better outcomes [2].

Antibacterial pastime of Schiff base ligand and its complexes have been tested in opposition to bacteria, along with *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella typhi*, which have been grown in a single day at 37°C temperature [30]. The usual traces were received from MTCC

Chandigarh. Dedication of minimum inhibitory concentrations (MIC) through Micro Broth Dilution technique changed into used to degree inhibition concentration wavelength at 475nm became evaluated in opposition to test bacteria for the awareness ranging between zero.4µg/ml to a hundredµg/ml [31]. DMSO and as compared with antibiotics viz. Streptomycin [32]. All the investigated compounds showed amazing organic hobby in opposition to micro organism in (desk.5). The acquired outcomes replicate that; (1) The Co(II) and Ni(II) complexes exhibited excellent antibacterial activity against *Escherichia coli*; (2) The Schiff base ligand, Ni(II), and Zn (II) complex showed desirable interest in opposition to *Staphylococcus aureus* micro organism; (3) The ligand and Co(II), Cu(II) complex exhibited notable antibacterial activity in opposition to *Salmonella typhi*. The figure ligand suggests terrific antibacterial pastime against *Salmonella typhi* [33].

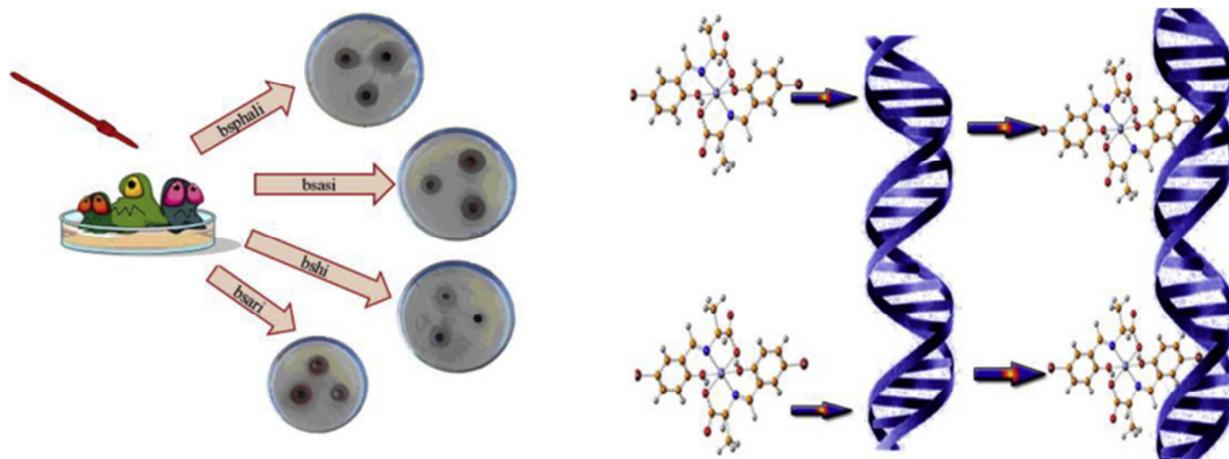


Figure 6. Schematic diagram for antibacterial activity and DNA interaction of the investigated complexes (Abu-Dief & Mohamed, 2015).

Table 3. Antibacterial activity of the ligands and their metal complexes.

Sr. No	Compounds	Minimal Inhibition Concentration ($\mu\text{g/ml}$)		
		E. coli	S. aureus	S. typhi
1	Ligand	250	100	50
2	Fe(III)	250	125	500
3	Mn(II)	250	125	250
4	Co(II)	100	125	100
5	Ni(II)	100	100	250
6	Cu(II)	250	125	125
7	Zn(II)	500	100	500
8	Cd(II)	500	500	250
9	Ag(I)	500	125	500

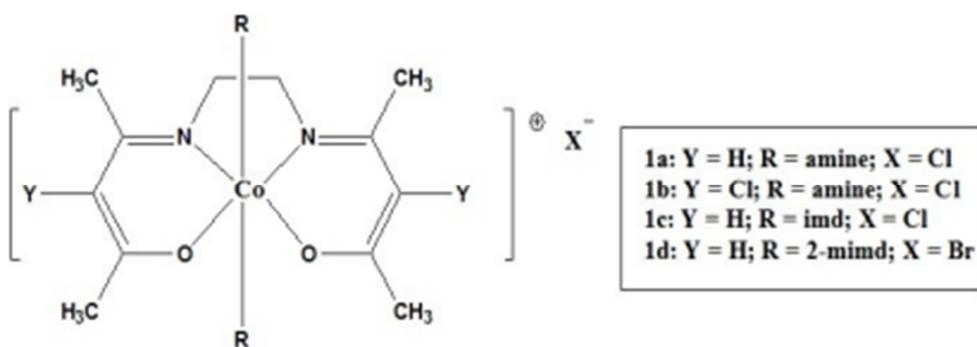
4.2. Antiviral Activities

Isatin has been recognized seeing that long for its organic hobby in mammals. Schiff bases and Mannich bases of isatin show a huge range of pharmacological homes together with antibacterial, anticonvulsant, anti-HIV, antifungal and antiviral hobby.

The simple Co^{3+} ion is unstable in water, but it may be stabilized towards reduction to Co^{2+} with the aid of coordination to ligands or chelators. By way of far the maximum common ligand type used to stabilize the cobalt (III) ion in aqueous solution is the chelating N, O donor ligand. pretty, cobalt (III) complexes derived from this ligand donor set have observed utility as antibacterial or antiviral sellers. one of the most promising instructions of Co(III) complexes containing N, O donor ligands is the CTC collection of complexes 1 based totally on a chelating Schiff base (imd = imidazole; 2-mimd = 2- methylimidazole). In 1998, Epstein and coworkers reported that the cobalt complicated CTC-96 (1d) turned into effective inside the treatment of epithelial herpetic keratitis, one of the essential reasons of blindness in commercial countries. research the usage of the CTC elegance of medicine have been done the use of a rabbit eye model infected with Herpes Simplex Virus kind 1 (HSV-1) and all

complexes inhibited HSV-1 replication in vitro with as little as 5 $\mu\text{g/mL}$ required for robust antiviral pastime [35]. Normally, cobalt (III) ion is not strong in aqueous answer. It is able to be stabilized in aqueous answer in presence of chelating N, O donor ligand ecosystem. This Cobalt(III) complexes of such ligands discovered to be vital because of their antibacterial or antiviral activities. In 1998, Epstein and co-people stated a chain of Co(III) complexes (1d) containing N, O donor ligands of the subsequent kind for their use inside the remedy of blindness in industrial international locations, known as epithelial herpetic keratitis [36]. first of all, the drug changed into carried out upon a rabbit eye model infected with Herpes Simplex Virus type 1 (HSV-1) and discovered to be lively inhibitor of HSV-1 replication in vitro. There are a few evidences that those series of complexes prevent virus access by inhibiting membrane fusion. The complex 1d inhibited plaque formation through vesicular stomatitis virus VSV and VZV (varicella-zoster virus) [37].

The hobby of CTC-ninety six (1d) against adenovirus in cellular subculture version and adenovirus kerato conjunctivitis in a rabbit version changed into reported. these Co(III) Schiff base complexes have a potential to inhibit Sp1, a DNA binding zinc finger protein and used inside the treatment of human immunodeficiency virus kind 1 (HIV-1) [38].

**Figure 7.** Structure of CTC-type cobalt (III) complexes (imd = imidazole, 2-mimd = 2-methylimidazole).

K. S. Kumar et al. synthesized a set of Schiff Base compound based totally on 3-(benzylideneamino)-2-phenylquinazoline-four(3H)-one and presented a element report of anti-viral hobby of these compounds in opposition to herpes simplex virus-1 (KOS), herpes simplex virus-2 (G), vaccinia virus, vesicular stomatitis virus, herpes simplex virus-1 TK- KOS ACVr, para influenza-3 virus, reovirus-1,

Sindbis virus, Coxsackie virus B4, Punta Toro virus, pussycat corona virus, tom cat herpes virus, respiratory syncytial virus and influenza A H1N1 subtype, influenza A H3N2 subtype, influenza B [39].

4.3. Anti-Cancer Activities

Malignant growth is an assortment of illnesses that involves

particular cell development with the ability to assault or unfurl to different parts of the edge. It appears to be as a super open wellness bother for the span of the field in light of the fact that the most extreme dreaded visualization. Presently, Chemotherapy is the standard methodology for each restricted and metastasized most malignant growths. However, the current chemotherapeutic medications' curative effects have serious side effects. On this respect, many explores safeguard to foster all the more remarkable medications for treating patients with most tumors during the most recent fifty years. Inside the most recent couple of years, the regular builds containing Schiff bases as major piece of their designs have finished an incredible arrangement interest due to their anticancer properties. Chemists are particularly interested in steel complexes of Schiff base ligands due to their use as robust tablets or diagnostic agents. Due to their wide range of coordination numbers, geometries, and kinetic residences, metallic complexes can provide precise drug movement mechanisms that are impossible with pure organic molecules.. Rosenberg and co-employees [40] invented Cisplatin that is one of the nice-promoting anti-cancer pills all through the sector. After that many reviews had been published, till date, where the steel complexes of Schiff bases had been used as anti-cancer agents. a few metallic complexes of the Schiff base of salicylaldehyde with 2- amino-four- phenyl-5-methyl thiazole. The complexes have been studied against different human tumor cell strains: breast cancer MCF-7, liver most cancers HepG2, lung carcinoma A549 and colorectal cancer HCT116 in contrast with the activity of doxorubicin as a reference drug. The observe confirmed that ZnII complex showed amazing inhibition in opposition to human TRK in the four cell lines (HepG2, MCF7, A549, HCT116) via the ratio 80, 70, 61 and sixty four% respectively in comparison to the inhibition inside the untreated cells [39].

4.4. Antifungal Activity

Systematic fungal infection hazard is an issue of challenge for humans with suppressed immunity like the ones tormented by AIDS, or present process most cancers remedy and organ transplantation. N-(Salicylidene)- 2-hydroxyaniline has been proven to suppress *Alternaria brassicae* and *Alternaria brassicicola*, that are phytopathogenic fungi at 500 ppm attention. Chitosan derived Schiff bases have suppressed the increase of *Botrytis cinerea* and *Colletotrichum lagenarium* at one thousand ppm. 2, four-dichloro-five-fluorophenyl Schiff bases were found to inhibit the increase of *Aspergillus fumigates*, and *Aspergillus flavus* and so on. among 6.3-12.5 µg/mL dose range [41]. Schiff bases derived from piperonyl have inhibited the increase of *Trichophyton rubrum* and *E. floccosum* [42].

4.5. Anti-Inflammatory Activity

Schiff bases derived from dipropylenetriamine and a pair of-thiophene-carboxaldehyde were examined for his or her hobby [43]. Schiff bases derived from 3-(4-(benzylideneamino) phenylimino) four-fluoroindolin-2-one had been tested for his or her residences and determined to own good sized activity

corresponding to diclofenac 52. Four-aminoantipyrine (4-amino-1, five-dimethyl-2- phenylpyrazole-three-one) and benzaldehyde derivative has been examined as a brand new healing agent in opposition to oxidative pressure agent [44]. Schiff bases of four-aminophenazone had been screened for his or her sports the use of the Carrageen an-precipitated paw oedema (CIPO) and histamine prompted paw oedema (HIPO) methods with appreciable inhibition.

4.6. Antioxidant Activity of Schiff Bases

The look for metallic-derived antioxidants has received a good deal interest and effort for you to pick out the compounds having high capability in scavenging free radicals related to various disorders and illnesses related to oxidative harm, because of reactive oxygen species (ROS). Presently, artificial antioxidants are widely used due to the fact they're effective and less expensive than natural antioxidants. Currently some of Schiff-base steel complexes had been investigated as effective scavengers of ROS, appearing as antioxidants. 5 types of Schiff bases of chitosan and carboxymethyl chitosan (CMCTS) organized and the antioxidant activity became studied using a longtime system, inclusive of superoxide and hydroxyl radical scavenging. Obvious variations between the Schiff bases of chitosan and CMCTS were determined, which might be related to contents of the energetic hydroxyl and amino companies in the molecular chains. The scavenging impact will increase with will increase the awareness of the Schiff bases. Glutamic acid-salicylaldehyde Schiff-base metal complexes are certain into bovine serum albumin (BSA), which afforded BSA binding Schiff-base metal complexes (BSA-SalGluM, M = Cu, Co, Ni, Zn). It showed that the protein structures of BSA stored after coordinating amino acid Schiff-bases metal complexes. The impact of the antioxidant pastime became investigated. The results indicate that the antioxidant capacity of BSA multiplied greater than 10 times after binding Schiff base metallic complexes. The antioxidant capacities of ferrocenyl Schiff bases inclusive of o-(1-ferrocenylethylideneamino)phenol (OFP), m- (1-ferrocenylethylideneamino)phenol (MFP), and p-(1- ferrocenylethylideneamino)phenol (PFP) had been evaluated in 2,2'-azobis(2-amidinopropane hydrochloride) (AAPH), Cu²⁺/glutathione (GSH), and hydroxyl radical (OH⁻) triggered oxidation of DNA, and in trapping 2,2'-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azinobis (three-ethylbenzothiazoline-6-sulfonate)cationic radical (ABTS +), respectively. OFP, MFP and PFP possessed comparable sports to trap DPPH and ABTS +. All the ferrocenyl Schiff bases employed herein behaved as prooxidants in Cu²⁺/GSH- and OH⁻ triggered oxidation of DNA except that OFP exhibited weak antioxidant interest in OH⁻ prompted oxidation of DNA. PFP, OFP and MFP can terminate about 15.2, eleven.3, and nine.4 radicalchain-propagations in AAPH-induced oxidation of DNA. Particularly, the advent of ferrocenyl institution to Schiff base increased the antioxidant effectiveness greater remarkably than benzene-associated Schiff bases [45].

4.7. Anti-Malarial Activity

Malaria is often overlooked as a disorder despite the fact that annually 500 million humans are suffering from the ailment. *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae* are in particular answerable for human malaria. Schiff base derived from five-nitroisoquinolines has been examined in opposition to ACC Niger chloroquine resistant *P. falciparum*. N-[(1E)-(5-nitro-1-naphthyl)methylene]-1-[2-(trifluoromethyl)phenyl]methanamine changed into determined to be a powerful antimalarial agent with an IC₅₀ awareness of zero.7 µg/mL [46]. Ancistrocladidine possessing an imine institution has been used as a scaffold for its interest in opposition to *P. falciparum* K1 and 3D7 with MIC of 0. Three and 1.9 µg/mL [47].

4.8. Antidepressant Activity

Schiff bases derived from isonicotinoyl hydrazone, N'-[(1Z)-(substituted aromatic) methylidene]pyridine-four-carbohydrazides synthesized thru green chemistry had been evaluated for their antidepressant activity at the side of their nitro, halo and dimethoxy substituted derivatives which have been located to possess substantial hobby [48].

5. Conclusion

Schiff bases gift a completely important elegance of organic compounds due to their potential to form complexes with transition metallic ions and in their pharmacological properties. The complexes had been of plenty interest over the past years, largely because of their diverse packages in biological strategies and capability programs in designing new therapeutic dealers. However nonetheless it needs to discover the biological programs of those transition metallic complexes, already synthesized and to synthesize new complexes with extra homes for this reason. The chemistry of Schiff bases is a subject that is being noticed. Schiff base ligands are taken into consideration privileged ligands because they may be effortlessly organized through a simple condensation of an aldehyde derivatives and primary amines. These compounds and their metallic complexes had a variety of packages which include medical, analytical, agrochemical commercial they also play crucial roles in catalysts and corrosion inhibitor. On this evaluate, synthesis of the Schiff and its complexes and the organic sports has been summarized.

Abbreviations

UV-Vis	Ultra Violet Visible Spectroscopy
XRD	X-Ray Diffraction
NMR	Nuclear Magnetic Resonance
DNA	Deoxyribo nucleic acid
FTIR	Fourier Transform Infra-Red Spectroscopy
SEM	Scanning Electron Spectroscopy
TEM	Transmission Electron Spectroscopy
AFM	Atomic force microscopy
VAEPD	Vanillin and 2-Amino-2-ethy 1-1,3-propanediol Azomithine

CIPO	Carrageen an-induced paw oedema
HIPO	Histamine Induced Paw Oedema
DMSO	Dimethyl Sulfoxide
ROS	Reactive Oxygen Species
HSV	Herpes Simplex Virus
VSV	Vesicular Stomatitis Virus
VZV	Varicella-Zoster Virus
HIV	Human Immunodeficiency Virus
CMCTS	Carboxy methyl chitosan

Acknowledgements

First and foremost, praise and thanksgiving to God, the All-Powerful, for his numerous blessings during this work's successful completion. resulting, I might want to communicate my profound and legitimate appreciation to my guide Dr. Tegene Desalegn (Ph.D.) for his compassion, top notch motivation, comments and consolation.

References

- [1] Abu-Dief, A. M., & Mohamed, I. M. A. (2015). A review on versatile applications of transition metal complexes incorporating Schiff bases. *Beni-Suef University Journal of Basic and Applied Sciences*, 4 (2), 119–133. <https://doi.org/10.1016/j.bjbas.2015.05.004>
- [2] Mahmoud, W. H., Omar, M. M., Ahmed, Y. M., & Mohamed, G. G. (2020). Transition metal complexes of Schiff base ligand based on 4,6-diacetyl resorcinol. *Applied Organometallic Chemistry*, 34 (4), 1–20. <https://doi.org/10.1002/aoc.5528>
- [3] Prakash, A., Singh, B. K., Bhojak, N., & Adhikari, D. (2010). Synthesis and characterization of bioactive zinc(II) and cadmium(II) complexes with new Schiff bases derived from 4-nitrobenzaldehyde and acetophenone with ethylenediamine. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*. <https://doi.org/10.1016/j.saa.2010.03.019>
- [4] Sakhare, D. T. (2020). Synthesis, Characterization of Schiff Bases and Biological Activities of Their Transition Metal Complexes-Review. *International Journal of Advanced Science and Engineering*. <https://doi.org/10.29294/ijase.6.4.2020.1538-1544>
- [5] Shoaib, K., Rehman, W., Mohammad, B., & Ali, S. (2013). Synthesis, characterization and biological applications of transition metal complexes of [no] donor schiff bases. *Journal of Proteomics and Bioinformatics*. <https://doi.org/10.4172/jpb.1000274>
- [6] W. Al Zoubi and Y. G. Ko, "Organometallic complexes of Schiff bases: Recent progress in oxidation catalysis," *Journal of Organometallic Chemistry*. 2016. doi: 10.1016/j.jorganchem.2016.08.023.
- [7] J. M. Mir, R. C. Maurya, D. K. Rajak, B. A. Malik, P. S. Jaget, and N. Jain, "A novel Schiff base complex of brain fuel (sugar) coordinated with intelligence mineral (Zn): Synthesis, conjoint DFT-experimental evaluation and super oxide dismutation," *Karbala Int. J. Mod. Sci.*, 2017, doi: 10.1016/j.kijoms.2017.05.003.
- [8] K. Ghosh, K. Harms, and S. Chattopadhyay, "Synthesis, characterization and phenoxazinone synthase mimicking activity of cobalt(III) Schiff base complexes," *Polyhedron*, 2017, doi: 10.1016/j.poly.2016.10.027.

- [9] A. Ali, N. Abdullah, and M. J. Maah, "Synthesis, characterization and antioxidant studies on 4-phenyl-1,3,5-triazine-2,6-diamine Schiff bases and their nickel(II), copper(II) and zinc(II) complexes," *Asian J. Chem.*, 2013, doi: 2310.14233/ajchem.2013.13544.
- [10] A. Prakash, B. K. Singh, N. Bhojak, and D. Adhikari, "Synthesis and characterization of bioactive zinc(II) and cadmium(II) complexes with new Schiff bases derived from 4-nitrobenzaldehyde and acetophenone with ethylenediamine," *Spectrochim. Acta -Part A Mol. Biomol. Spectrosc.*, 2010, doi: 10.1016/j.saa.2010.03.019.
- [11] O. A. El-Gammal, A. A. El-Bindary, F. Sh. Mohamed, G. N. Rezk, and M. A. El-Bindary, "Synthesis, characterization, design, molecular docking, anti COVID-19 activity, DFT calculations of novel Schiff base with some transition metal complexes," *J. Mol. Liq.*, 2022, doi: 10.1016/j.molliq.2021.117850.
- [12] A. M. Yimer, "Review on Preparation and Description of Some First Series Divalent Transition Metal Complexes with Novel Schiff's Base Ligands," *Rev. Catal.*, 2015, doi: 10.18488/journal.96/2015.2.1/96.1.14.25.
- [13] M. S. Gruzdev, U. V. Chervonova, A. A. Ksenofontov, M. A. Krestianinov, A. I. Alexandrov, and T. V. Pashkova, "Schiff base complexes with different metals incorporating derivatives of 3,6-di-tert-butylcarbazole," *Appl. Organomet. Chem.*, vol. 35, no. 4, pp. 1–11, 2021, doi: 10.1002/aoc.6145.
- [14] W. H. Mahmoud, M. M. Omar, Y. M. Ahmed, and G. G. Mohamed, "Transition metal complexes of Schiff base ligand based on 4,6-diacetyl resorcinol," *Appl. Organomet. Chem.*, vol. 34, no. 4, pp. 1–20, 2020, doi: 10.1002/aoc.5528.
- [15] P. S. Desai and D. V. Parekh, "c aciSynthesis, characterization and biological screening of novel metal(II) complexes of 2-{[2-(5-Benzoyl-1 H -benzotriazol-1-yl)-2-oxoethyl]amino}-5-bromobenzoid," *Asian J. Chem.*, 2021.
- [16] D. R. Williams, "Metals, ligands, and cancer," *Chem. Rev.*, vol. 72, no. 3, pp. 203–213, 1972, doi: 10.1021/cr60277a001.
- [17] S. Shahid, M. A. Raza, and Shafiq-Ur-Rehman, "Synthesis, characterization and antimicrobial potential of transition metal complexes of triacetic lactone," *African J. Biotechnol.*, 2009.
- [18] D. T. Sakhare, "Synthesis, Characterization and Biological Activities of Schiff Bases and Their Transition Metal Complexes," in *Current Advances in Chemistry and 24 Biochemistry Vol. 3*, 2021. doi: 10.9734/bpi/cacb/v3/1574c.
- [19] N. Raman, S. Ravichandran, and C. Thangaraja, "Copper(II), cobalt(II), nickel(II) and zinc(II) complexes of Schiff base derived from benzil-2,4-dinitrophenylhydrazone with aniline," *J. Chem. Sci.*, vol. 116, no. 4, pp. 215–219, 2004, doi: 10.1007/BF02708270.
- [20] K. Mounika, A. Pragathi, and C. Gyanakumari, "Synthesis, Characterization and Biological Activity of a Schiff Base Derived from 3-Ethoxy Salicylaldehyde and 2-Amino Benzoic acid and its Transition Metal Complexes," *J. Sci. Res.*, 2010, doi: 10.3329/jsr.v2i3.4899.
- [21] P. M. Reddy, "AZOMETHINE DERIVATIVE OF 2-AMINO-2-ETHYL-1, 3-PROPANEDIOL AND IT ' S METAL COMPLEXES of Biomedical AND Pharmaceutical sciences," no. January, 2021, doi: 10.17605/OSF.IO/SV69C.
- [22] A. Mumtaz, T. Mahmud, M. R. J. Elsegood, G. W. Weaver, G. Bratu, and L. Mitu, "Synthesis, characterization and biological evaluation of schiff base (N-4-(thiophene-2-yl-methyleneamino)-2,6-dimethylpyrimidine-4-yl)benzenesulfonamide and its complexes with Cu(II), Ni(II), Co(II), Fe(II), Mn(II), Zn(II) ions," *Rev. Chim.*, 2020, doi: 10.37358/RC.20.1.7833.
- [23] M. Shebl, O. M. I. Adly, E. M. Abdelrhman, and B. A. El-Shetary, "Binary and ternary copper(II) complexes of a new Schiff base ligand derived from 4-acetyl-5,6-diphenyl-3(2H)-pyridazinone: Synthesis, spectral, thermal, antimicrobial and antitumor studies," *J. Mol. Struct.*, vol. 1145, pp. 329–338, 2017, doi: 10.1016/j.molstruc.2017.05.064.
- [24] K. Ghosh et al., "Three mononuclear octahedral cobalt(III) complexes with salicylalimine Schiff bases: Synthesis, characterization, phenoxazinone synthase mimicking activity and DFT study on supramolecular interactions," *Polyhedron*, vol. 112, no. Iii, pp. 6–17, 2016, doi: 10.1016/j.poly.2016.02.035.
- [25] A. Zülfikaroğlu, Ç. Yüксеktepe Ataoğlu, E. Çelikoğlu, U. Çelikoğlu, and Ö. İdil, "New Cu(II), Co(III) and Ni(II) metal complexes based on ONO donor tridentate hydrazone: Synthesis, structural characterization, and investigation of some biological properties," *J. Mol. Struct.*, 2020, doi: 10.1016/j.molstruc.2019.127012.
- [26] G. B. Bagihalli and S. A. Patil, "Synthesis, physico-chemical investigations, and in 25 vitro microbial, studies of VO(IV) complexes with novel ONON donor Schiff bases," *Main Gr. Chem.*, vol. 8, no. 2, pp. 71–88, 2009, doi: 10.1080/10241220902977604.
- [27] G. K. Sandhu and G. Kaur, "Preparation, IR and 1H NMR spectral studies of triorganotin(IV) complexes of N-benzoylglycine and N-benzoylglucylglycine," *J. Organomet. Chem.*, vol. 388, no. 1–2, pp. 63–70, 1990, doi: 10.1016/0022-328X(90)85347-2.
- [28] A. S. Shekhawat, N. P. Singh, and N. S. Chundawat, "Synthesis, Characterization and Biological Activities of Schiff's Base Metal Complexes Derived from Hydroxy Trizene and Aromatic Aldehyde," *J. Sci. Res.*, vol. 14, no. 1, pp. 387–394, 2022, [Online]. Available: <http://dx.doi.org/10.3329/jsr.v14i1.54814>
- [29] E. S. Freeman and B. Carroll, "The application of thermoanalytical techniques to reaction kinetics. The thermogravimetric evaluation of the kinetics of the decomposition of calcium oxalate monohydrate," *J. Phys. Chem.*, vol. 62, no. 4, pp. 394–397, 1958, doi: 10.1021/j150562a003.
- [30] E. Banfi, G. Scialino, and C. Monti-Bragadin, "Development of a microdilution method to evaluate Mycobacterium tuberculosis drug susceptibility," *J. Antimicrob. Chemother.*, vol. 52, no. 5, pp. 796–800, 2003, doi: 10.1093/jac/dkg439.
- [31] M. Balouiri, M. Sadiki, and S. K. Ibsouda, "Methods for in vitro evaluating antimicrobial activity: A review," *J. Pharm. Anal.*, vol. 6, no. 2, pp. 71–79, 2016, doi: 10.1016/j.jpha.2015.11.005.
- [32] J. E. Girard, *Practical organic chemistry*, vol. 284, no. 5751. 1980. doi: 10.1038/284083b0.
- [33] "Solvent-free Synthesis, Characterization and Biological Activity of Transition Metal Complexes of Schiff Base Ligand Derived from 2-Amino Benzimidazole with 4, 4'Dibromobenzil," *Lett. Appl. NanoBioScience*, 2021, doi: 10.33263/lianbs113.38343842.

- [34] A. M. Abu-Dief and I. M. A. Mohamed, "A review on versatile applications of transition metal complexes incorporating Schiff bases," *Beni-Suef Univ. J. Basic Appl. Sci.*, vol. 4, no. 2, pp. 119–133, 2015, doi: 10.1016/j.bjbas.2015.05.004. 26.
- [35] E. L. Chang, C. Simmers, and D. A. Knight, "Cobalt complexes as antiviral and antibacterial agents," *Pharmaceuticals*, vol. 3, no. 6, pp. 1711–1728, 2010, doi: 10.3390/ph3061711.
- [36] P. A. Asbell, S. P. Epstein, J. A. Wallace, D. Epstein, C. C. Stewart, and R. M. Burger, "Efficacy of cobalt chelates in the rabbit eye model for epithelial herpetic keratitis," *Cornea*, vol. 17, no. 5, pp. 550–557, 1998. doi: 10.1097/00003226-199809000-00014.
- [37] J. A. Schwartz, E. K. Lium, and S. J. Silverstein, "Herpes Simplex Virus Type 1 Entry Is Inhibited by the Cobalt Chelate Complex CTC-96," *J. Virol.*, vol. 75, no. 9, pp. 4117–4128, 2001, doi: 10.1128/jvi.75.9.4117-4128.2001.
- [38] A. Y. Louie and T. J. Meade, "A cobalt complex that selectively disrupts the structure and function of zinc fingers," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 95, no. 12, pp. 6663–6668, 1998, doi: 10.1073/pnas.95.12.6663.
- [39] D. Maity, "Biological Applications of Schiff Base and its Metal Complexes-A Review," *Int. J. Sci. Res.*, vol. 6, no. 2, pp. 471–478, 2019.
- [40] R. K. Mehmood, "Review of cisplatin and oxaliplatin in current immunogenic and monoclonal antibodies perspective," *Oncol. Rev.*, vol. 8, no. 2, pp. 97–108, 2014, doi: 10.4081/oncol.2014.256.
- [41] M. S. Karthikeyan, D. J. Prasad, B. Poojary, K. Subrahmanya Bhat, B. S. Holla, and N. S. Kumari, "Synthesis and biological activity of Schiff and Mannich bases bearing 2,4-dichloro-5-fluorophenyl moiety," *Bioorganic Med. Chem.*, vol. 14, no. 22, pp. 7482–7489, 2006, doi: 10.1016/j.bmc.2006.07.015.
- [42] A. Echevarria, M. D. G. Nascimento, V. Gerônimo, J. Miller, and A. Giesbrecht, "NMR Spectroscopy, Hammett Correlations and Biological Activity of Some Schiff Bases Derived from Piperonal," *J. Braz. Chem. Soc.*, vol. 10, no. 1, pp. 60–64, 1999, doi: 10.1590/S0103-50531999000100010.
- [43] A. Arunadevi and N. Raman, "Biological response of Schiff base metal complexes incorporating amino acids—a short review," *J. Coord. Chem.*, vol. 73, no. 15, pp. 2095–2116, 2020, doi: 10.1080/00958972.2020.1824293.
- [44] M. S. Alam, J. H. Choi, and D. U. Lee, "Synthesis of novel Schiff base analogues of 4-(2-amino-1,5-dimethyl-2-phenylpyrazol-3-yl)phenol and their evaluation for antioxidant and anti-inflammatory activity," *Bioorganic Med. Chem.*, vol. 20, no. 13, pp. 4103–4108, 2012, doi: 10.1016/j.bmc.2012.04.058.
- [45] M. Munjal, "Biological activity of transition metal complexes incorporating Schiff bases: A review," vol. 6, no. 2, pp. 354–360, 2017.
- [46] P. Rathelot et al., "Synthesis of novel functionalized 5-nitroisoquinolines and evaluation of in vitro antimalarial activity," *Eur. J. Med. Chem.*, vol. 30, no. 6, pp. 503–508, 1995, doi: 10.1016/0223-5234(96)88261-4.
- [47] G. Bringmann et al., "Full Papers," vol. 67, no. 5, pp. 5–10, 2004.
- [48] A. B. Thomas, R. K. Nanda, L. P. Kothapalli, and S. C. Hamane, "Synthesis and biological evaluation of Schiff's bases and 2-azetidinones of isonicotinyl hydrazone as potential antidepressant and nootropic agents," *Arab. J. Chem.*, vol. 9, pp. S79–S90, 2016, doi: 10.1016/j.arabjc.2011.02.015.