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A REVIEW OF RESEARCH ON RECENT APPLICATIONS OF SCHIFF'S BASES

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Abstract
A broad class of organic compounds known as Schiff bases (SBs) are distinguished by the presence of carbon–nitrogen double bonds (–C=N–). They are generated by condensation processes, usually with the aid of solvents like methanol, between primary amines and aldehydes or ketones. The numerous biological actions of these substances, including their antibacterial, antifungal, antiviral, anti-inflammatory, and antioxidant qualities, have attracted a lot of research. Schiff bases are produced when primary amines react with aldehydes or ketones. They have antioxidants, antiviral, antibacterial, antifungal, and anti-inflammatory properties. In coordination chemistry, Schiff bases play a crucial role by creating stable metal complexes with different metal ions. Pharmaceuticals, agrochemicals, dyes, analytical chemistry, catalysis, energy storage, environmental applications, chemo-sensing, bio-sensing, and biomedical applications are just a few of the sectors that use Schiff bases. Because Schiff bases may form stable complexes with metal ions, they are essential for both organic and inorganic chemistry. Schiff bases with possible antiviral, antifungal, and antibacterial effects have been the subject of recent research. To improve knowledge of their synthesis procedures, synthetic schemes are developed.

Keywords: Schiff bases, Imines, Biological activities, Condensation Reaction, Synthesis, Review.

Introduction
Hugo Schiff, a German chemist, first mentioned Schiff bases in 1864 [i] These organic molecules are formed via condensation reactions between carbonyl compounds and primary amines General structure, R'-CR=N-R", where R, R', and R" can vary. R and R' can be alkyl, aryl, or heterocyclic structures with various substituents as shown in figure 1. The carbonyl group involved may be part of an aldehyde or ketone (>C=O). Schiff bases contain an azomethine (>C=N-) group, hence they are also known as azomethine or imine compounds [ii]. This reaction showcases the formation of a Schiff base (R-CH=N-R') along

with the release of water (H_2O). The condensation reaction between a primary amine and a carbonyl functional group to form a Schiff base can be represented as follows:

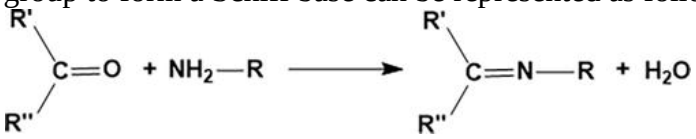


Figure 1: General Scheme of Schiff Base Formation)

Schiff bases are labeled into bidentate, tridentate, tetradentate, and polydentate ligands, that can form extraordinarily solid complexes with transition metallic ions [i] (Figure 2). Assuming they have got one of a kind practical group such as -OH, -NH2, or -SH, the resulting Schiff bases can act as mixed-donor ligands in bi-, tri-, tetra-, and better coordination modes [iii]. Multivalent Schiff base ligands without difficulty shape complexes with bidentate, tridentate, and tetra- or polydentate metallic ions at one of a kind oxidation state. Donor atoms (N, O, S) may be determined in bidentate ligands (N=N or O-N), tridentate ligands (NNN, ONO, NNS, or ONS), and tetradentate ligands (ONNO, NNNN, or NSNO) [iv].

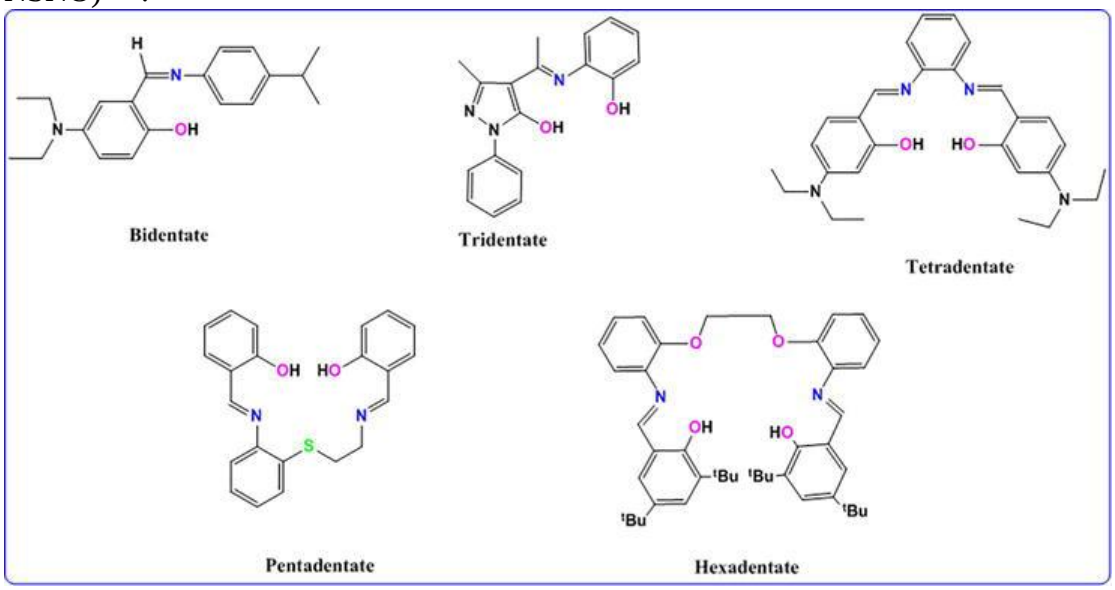


Figure 2. Structures of **Schiff bases**

Symmetrical and Asymmetrical Schiff Bases

The Schiff bases` excellent affinity for chelation in the direction of internal and non-internal transition metallic ions is hired to provide strong complexes. Unsymmetrical ligands, which do now no longer have a rotation or replicate axis of symmetry, bind to a steel ion with unique groups, at the same time as symmetrical ligands do now no longer [v]. It has been argued that unsymmetrical Schiff base ligands are advanced to their symmetrical opposite numbers because of their cap potential to extra as it should be expecting the geometry of metallic ion binding web sites in organic structures containing metal ions, in addition to their capacity to extra effortlessly integrate herbal and synthetic structural components.

Homoleptic and heterolytic Schiff base metal complexes

Schiff base metal complexes. The number one difference among homoleptic and heterolytic complexes is that homoleptic complexes have equal ligands related to a metallic center. In contrast, heterolytic complexes have at least one wonderful ligand coupled to the complex`s metallic center [vi] (Figure 3) .

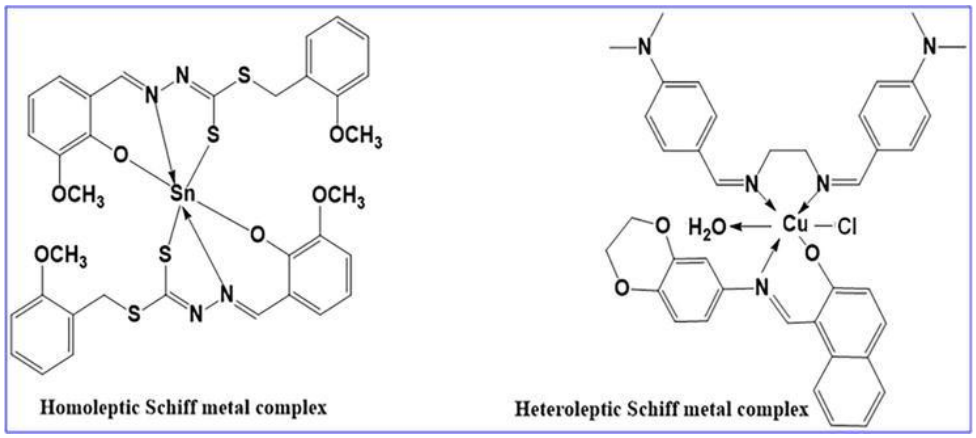


Figure 3. Homoleptic and heterolytic Schiff base metal complexes

Mononuclear and polynuclear Schiff base metal complexes

A single metallic atom or ion is present in the simplest form of a Schiff base metal complex, surrounded by monodentate, bidentate, tridentate, and polydentate ligands. Polynuclear Schiff base metallic complexes are attributed to the presence of or greater metallic atoms, or ions, coordinated inside a single coordination sphere. The atoms can be related together through direct metallic-metallic bonds, bridging ligands, or all those things. As flexible ligands, Schiff bases shape diverse polynuclear metallic complexes which include homonuclear and heteronuclear. These bendy ligands have the capacity to behave as monodentate, bidentate, or polydentate, and that they may be engineered to provide mononuclear, binuclear, or polynuclear metallic-organic frameworks. It is feasible to alternate the unclarity of Schiff base complexes; for example, it's miles feasible to synthesize both mono- or binuclear complexes the use of almost equal ligands and artificial [vii]approaches for each form of complexes (Figure 4).

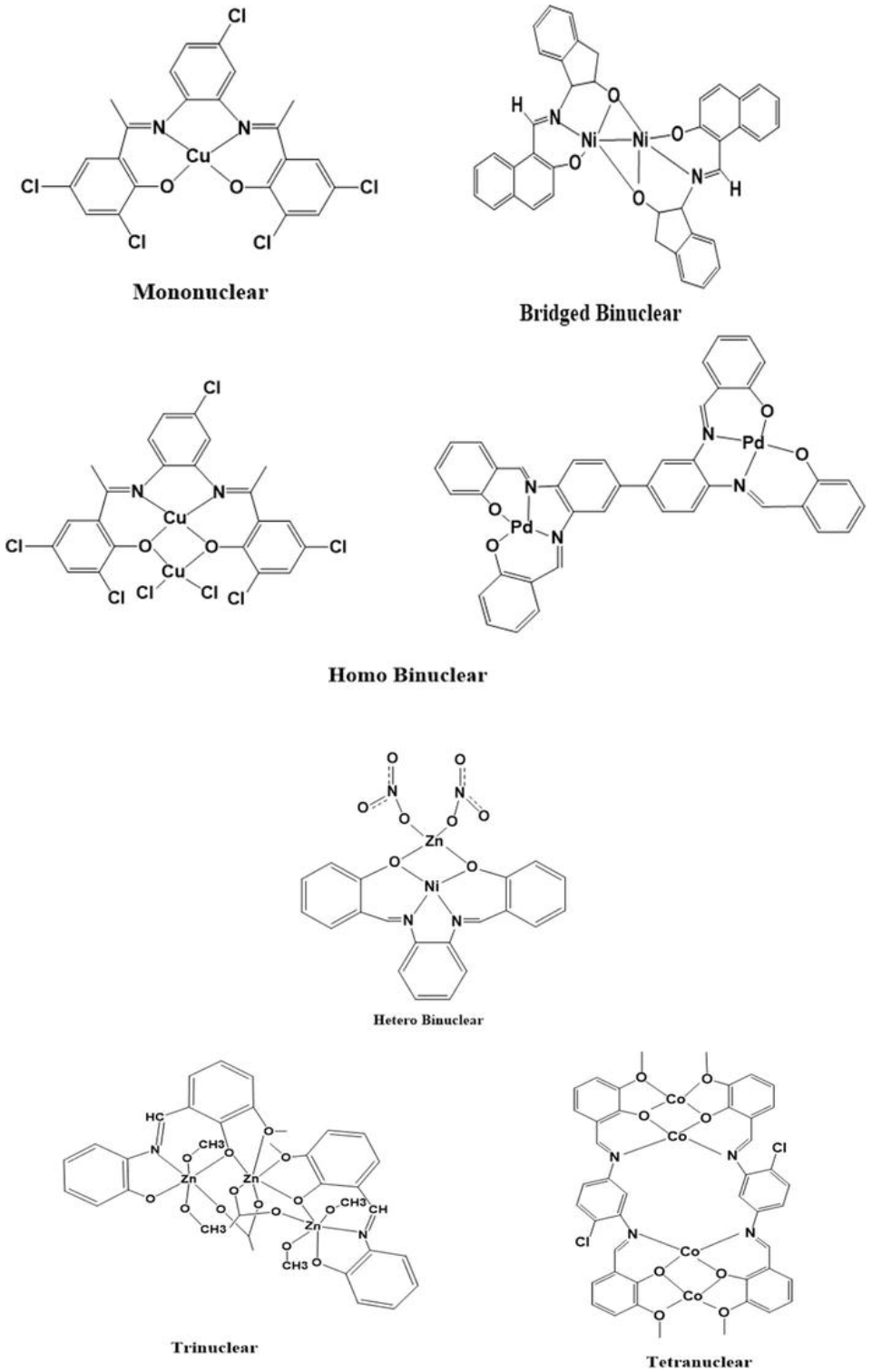
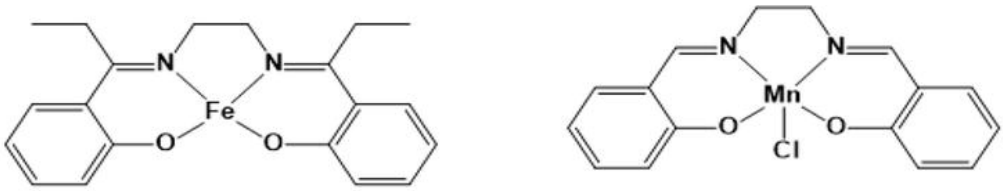


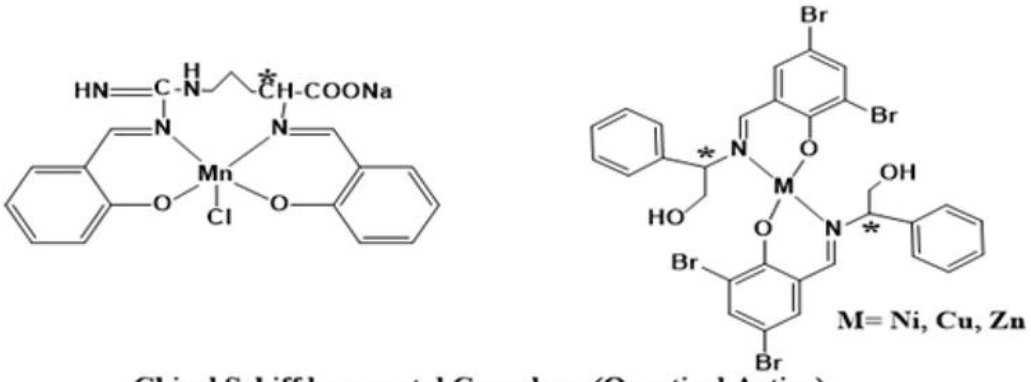
Figure 4. Mononuclear and polynuclear Schiff base metal complexes

Achiral and chiral Schiff base metal complexes

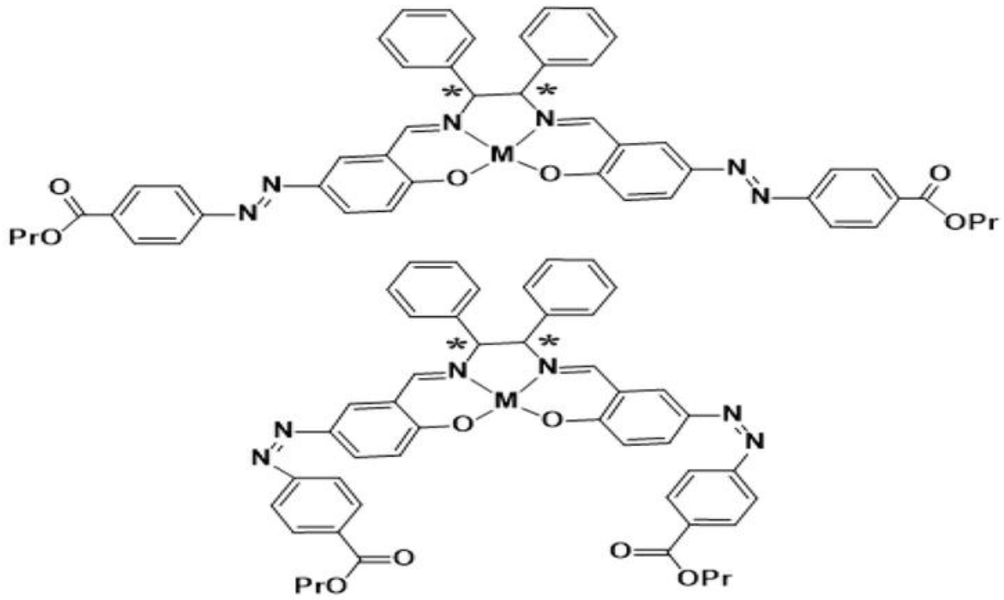
A chiral Schiff base metallic complicated isn't superimposable with its own reflect photo due to the fact the two systems aren't same in all respects. The reflect photo of an achiral Schiff base steel complicated is same to the complicated itself and may be superimposed on it. The phenomena of optical interest have historically been described in phrases of asymmetry and dissymmetry; however, the time chirality has outdated those in advance classifications. Chiral entities exist as species with the identical chemical constitution. The most effective manner they may be distinguishable from each other is that they have got the other configuration of an item and the reflective photo of that thing. Chemical compounds may be stated to be stereoisomers if their chemical constitutions are identical, however their spatial preparations in their atoms are different. Chiral refers to the assets of molecules that forestall them from being added into twist of fate with their reflect copies with the aid of using the usage of [viii] stiff motions (Figure 5).



Achiral Schiff base metal Complexes



Chiral Schiff base metal Complexes(Opectical Active)



Trans and Cis Schiff base metal complexes

.**Figure 5.** Achiral, chiral, trans and cis Schiff base metal complexes

Application of Schiff bases and its metal complexes

Synthetic methods of Schiff bases

Schiff base ligands, a category of molecules having imine groups, have grown in recognition because of their physiological and pharmacological properties. They are a captivating elegance of chelating marketers able to coordinate metallic ions in a complex, that is used to

mimic organic processes. Much research had been carried out on synthesizing Schiff bases [ix]. Schiff bases had been organized the usage of traditional and inexperienced artificial methods (Figure 6).

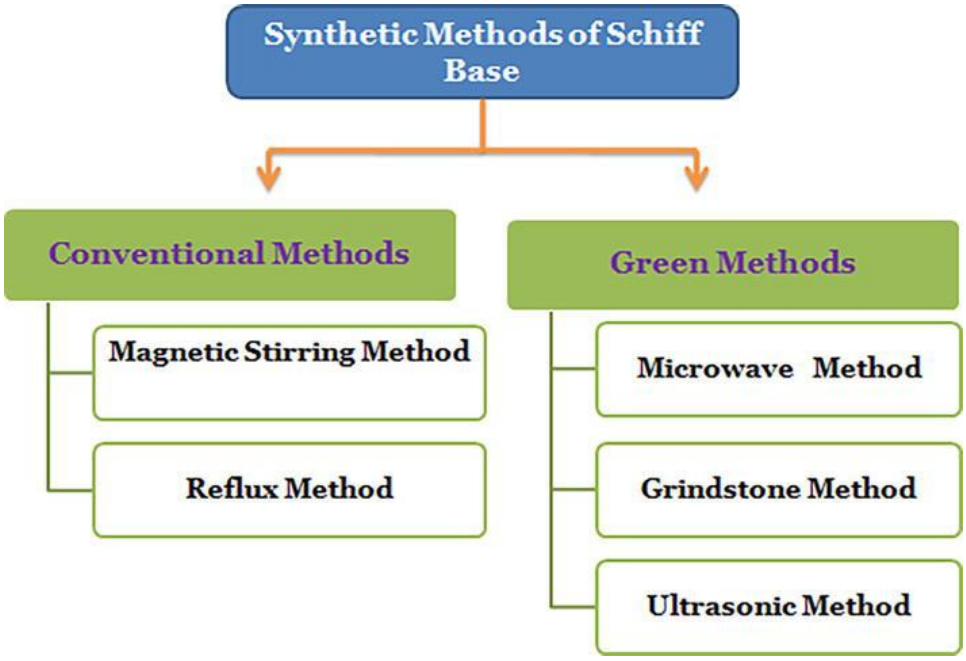
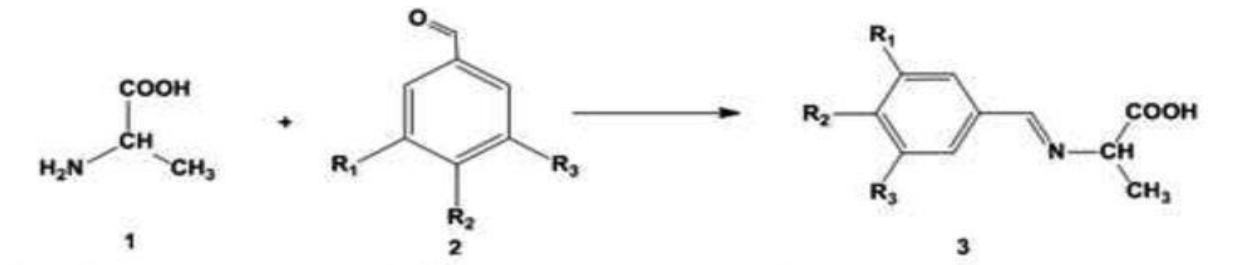


Figure 6. Synthetic methods of Schiff bases

Heat is required in many condensation processes, and conventional reaction conditions often involve heating the reactants in a metal, oil, or sand bath for hours or even days. The traditional manner entails refluxing or stirring distinctive aldehydes or ketones with diverse varieties of number one amines. Green chemistry refers to the equipment and strategies that offer sizeable environmental and economic blessings over traditional artificial methods. It depicts that the present day in inexperienced chemistry has prompted a brand-new call for natural synthesis wherein wonderful response environments ought to be located, lowering the use of dangerous natural solvents or poisonous chemicals. Green methods ought to enhance selectivity, lessen response time, and simplify product isolation over traditional methods. Microwave-assisted synthesis of Schiff bases has been done without solvent or low-solvent conditions and decreases response time drastically, improves conversion, and from time to time will increase selectivity. Since the improvement of solvent much less microwave synthesis of Schiff bases, it has turn out to be the maximum famous and easy method for those reactions and is utilized in diverse applications. Many researchers said the use of microwave-assisted synthesis of diverse varieties of Schiff bases and their derivatives. The grindstone method response creates neighborhood warmth with the aid of grinding substrate crystals and reagent with a mortar and pestle. Grinding begins off evolved reactions with the aid of using transmitting a tremendously small amount of power via friction. In a few circumstances, an aggregate and reagent shape a glassy substance. Such reactions are easy to handle, remove pollutants, are tremendously less expensive to operate, and can be taken into consideration [x] in a crystal are prepared tightly and regularly, solid-nation reactions are extra green and selective than answer reactions [xi]. The synthesis of amino acid Schiff bases (3) in water with the aid of using the response of variously substituted fragrant aldehydes/heterocyclic aldehydes (2) and dl -alanine amino acid (1) stirring at room temperature (technique A) the use of grindstone chemistry (technique B), microwave irradiation (technique C), and traditional heating (technique D). Studies evaluating the

instances required to synthesize 4 wonderful Schiff bases below 4 distinctive situations discovered that at the same time as technique B (grindstone) had a higher product yield, it additionally took drastically longer than strategies A, C, and D., i.e., Product yields ranged from seventy two to 78% after being subjected to grinding for 30–35 mins accompanied with the aid of using leaving the response aggregate overnight (8 hr.). Product yields of 69–73% were achieved in 40–45 minutes when the reactants were stirred in water at room temperature (15–20°C). Microwave irradiation (technique C) and everyday heating (technique D) had been extensively utilized to synthesize compounds. In 5–6 mins, yields of 70–seventy-two% had been completed below microwave irradiation, that's a great deal faster than grinding (technique B). The maximum yield and shortest response time had been each completed with the aid of using the use of Method C (Figure 7)



Schiff Bases	Methods							
	Stirring		Refluxed		Microwave		Grindstone	
	Time (Min.)	%Yield	Time (Min.)	%Yield	Time (Min.)	%Yield	Time (Min.)	%Yield
3a	40	69	60	63	6	71	35	74
3b	45	71	60	60	5	72	30	76
3c	40	71	60	60	5	70	35	72
3d	40	72	60	64	6	70	30	73
3e	45	72	60	62	5	72	30	78
3f	40	71	60	62	6	71	30	78

3a, R_1=H, R_2= OCH_3, R_3=H
3b, R_1=H, R_2= OCH_3, R_3=OH
3c, R_1=H, R_2= Cl, R_3=H
3d, R_1=H, R_2= OCH_3, R_3=H
3e, R_1=H, R_2= OCH_3, R_3=OCH_3
3f, R_1=OCH_3, R_2= OCH_3, R_3=OCH_3

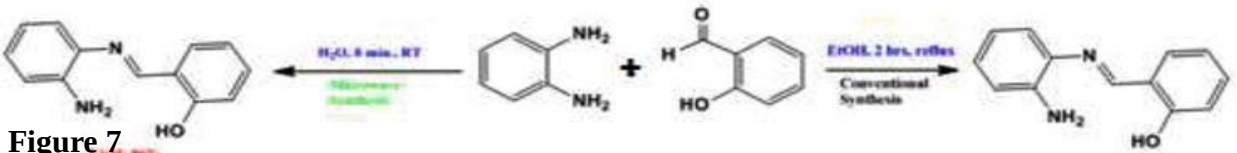


Figure 7

Methods	Time	%Yield
Conventional Method	2h	65
Microwave Assisted Method	8min.	96

Synthesis of Schiff bases 3a–3f with different methods and comparisons [xii] Sonication is using excessive strength to excite debris for diverse purposes. Ultrasonics with frequencies extra than 20 kHz is commonly hired in a method called ultrasonication [xiii]. In the laboratory, it's far usually used with an ultrasonic tubtub or probe; this equipment is called a sonicator. A new technique for synthesizing Schiff bases below catalyst-unfastened ultrasonic irradiation situations has been observed, yielding 92% as compared to the modern-day approach 84% yield [xiv]. They observed a green and environmentally pleasant approach for Schiff base synthesis in an aqueous answer the use of ultrasonic irradiation conditions and therefore no catalyst. Several studies discovered how exceptionally inexperienced synthesis strategies may want to purpose a particular condensation method to arise preferentially. When against answer-primarily based totally synthesis, mechanochemical synthesis has the benefit of ease of set-up and excessive yields [xv] Most Schiff bases have stated greater notable ligation with metallic ions due to a lone pair of electrons in those compounds. The variety of

transition and different metallic ions complexes had been synthesized using novel Schiff base ligands [xvi]

Classification of Schiff bases and their metal complexes

By coordinating the d-block metallic ion with the electron-donating ligand atom, a complicated is created that modifies the metallic`s steric and electric properties. By doing so, the metallic ion`s reactivity is stabilized and regulated, that is especially useful for ions at better oxidation states wherein they're much less stable. Auxiliary ligands, or Schiff bases, are compounds that alter the shape and reactivity of a transition metallic ion inner a complicated. On the alternative hand, they do now no longer incur any irreversible modifications, not like reactive ligands. Atoms like nitrogen, sulfur, or oxygen can act as donors within side the coordination process. [xvii].

Application of Schiff bases and its metal complexes

Schiff bases and their metallic complexes discover big use in numerous industries and applications, which include the meals industry, the agrochemical industry, the dye industry, analytical chemistry, catalysis, electricity storage, environmental, chemo-sensing, bio-sensing, nanotechnology, and biomedical applications [xviii].

Catalysis

Catalytic interest is improved in each homogeneous and heterogeneous reactions through Schiff base steel complexes. The ligands, coordination sites, and steel ions hired in every compound decide its hobby. Many one-of-a-kind reactions, which include polymerization, ring-starting polymerization, oxidation, epoxidation, allylic alkylation, discount of ketones, hydrazination of acetophenones, the Michael addition reaction, the decomposition of hydrogen peroxide, the annulation reaction, the Heck reaction, the carbonylation reaction, and the Diels-Alder reaction, had been used to severely compare the catalytic hobby of metallic complexes. There is large capability for Schiff base ligands for use as metallic complexes in catalysis because of their easy synthesis technique and warmth stability. The catalytic interest of Schiff base complexes differed significantly relying at the shape and type of ligands used [xix]

Dye industry

The dyeing approach employs an extensive variety of Schiff bases and complexes, a lot of that have been synthesized, investigated, and hired as mordants [xx]. As a dye, transition metallic complexes which include iron (III), nickel (II), cobalt (II), and copper (II) complexes, amongst others, were organized from loads of Schiff bases and hired to supply loads of transition metallic complexes. Aldehyde corporations that consist of azo dyestuff are recognized to synthesize many azomethine linkages that comprise azo dyes because of condensation with primer amines. The fabric enterprise makes use of those dyestuffs to colour loads of materials. Outside the fabric sector, the field of photochemistry locations a good-sized emphasis on the usage of azo dyes that consist of the amine group. The Schiff base on fluorene confirmed acceptable residences inclusive of sensitivity to pH, in addition to warmth and colour stability. For creating a water-primarily based totally ink, it confirmed promise as a purposeful pigment material [xxi]

Food industry

Various studies corporations have lately focused on generating herbal novel and energetic substances for meals packaging applications. Because in their antibacterial action, chitosan-derived Schiff base movies evolved won't best enhance the protection of such ingredients and consequently prolong their shelf life, however, additionally offer a taste this is well-prevalent via way of means of the consumer. Schiff`s base (SB) changed zirconium dioxide bolstered PLA bio-composite movie serves as an exchange packing cloth to update unmarried waste synthetic substances that pollute the environment. For energetic packaging applications, Schiff base (SB) changed polylactic acid (PLA) movie can offer advanced barrier and antifungal qualities [xxii, xxiii].

4.4 Agrochemical industry

Metal complexes with numerous Schiff base ligands have attracted the eye of chemists in current years because of their agricultural applications, together with pesticidal, nematicide, and insecticidal. Unsymmetrical Schiff bases glyoxal salicylaldehyde succinic acid dihydrazide and its Ni(II), Co(II), Zn(II), and Cu(II) complexes had been synthesized and studied; at more concentrations, they show enormous insecticidal action [xxiv] H2L [2, 2′-[(1E, 2E)-ethane-1,2- diylidenedi (E) azanylylidene] dibenzenethiol] and its new Zn(II), Ni(II) metallic complexes had been hired as insect repellent agents [xxv]. Coumarin-primarily based totally Schiff base and its earth metallic complexes [xxvi] had been used to deal with pests (Tribolium castaneu) and worms (Meloidogyne incognita)

Analytical applications

These are used to investigate number one amines, carbonyl compounds, and useful groups. In complexes, azomethine bonds are fashioned via complicated formation reactions or modifications of their spectroscopic homes because of pH and solvent variations (pH of solvent polarity indicators). Schiff bases are a wonderful service for the selective and green extraction of sure steel ions. They are famous for his or her powerful chelating capabilities. Schiff bases extract steel ions, crucial in regulating heavy metallic pollution. *N*, *N* -bis(3-methylsalicylidene)-ortho-phenylene diamine, Schiff base utilized in spectrophotometric detection of nickel. The method has been used effectively to quantify hint portions of nickel in natural meals samples Schiff bases are famed for his or her capacity to shape complexes and function correct chelating ligands. They had been extensively hired as analytical reagents because of their ligation property. [xxvii]. Schiff base products of salicylaldehyde are used in gravimetric and spectrophotometric analyses. Additionally, the same reagent was recently used for the spectrophotometric detection of Ni(II) at trace levels. Cu^{2+} ions were detected using the fluorescent 4-(1-phenyl-1-methylcyclobutane-3-yl)-2-(2-hydroxy-5-bromobenzylidene) aminothiazole Schiff base. This chemical sensor operates in the visible region, has a wide dynamic range, and can be used over a broad pH range. [xxviii]

Energy storage

There is a resurgence of interest in the search for efficient, clean, and sustainable energy sources (such as wind and solar), as well as modern energy conversion and storage technologies, due to the rapid growth of the global economy, the depletion of fossil fuels, and increasing environmental pollution. Energy garage technology is greater critical in our lives because the solar does now no longer shines at nighttime and the wind does now no longer blow all the time. Currently, there is lots of hobby in electric power garage technology together with batteries and electrochemical capacitors (supercapacitors). Recent studies have proven that natural oligomeric Schiff bases and electroactive polymeric (linear or

hyperbranched) Schiff bases carry out satisfactorily as bad electrodes (anodes) in sodium-ion batteries [xxix].

Lithium-ion batteries have additionally made use of nitrogen-wealthy carbon nanosheets produced with the aid of using the Schiff base response in a molten salt answer as anode materials [xxx, xxxi]. The linear polymeric Schiff bases advanced with the aid of using Armand et al [xxxii], resulting from the condensation of fragrant dialdehydes with aliphatic and fragrant diamines accomplished nicely as anodes for sodium-ion batteries. Polymeric Schiff bases also are produced with the aid of using combining terephthalic-aldehyde, phenylenediamine, and polyether amine blocks, ensuing in polymers with excessive adhesive characteristics that may be used as redox-energetic binders for sodium-ion anodes. Similarly, Zhang et al [xxxiii] advanced any other ImCOF (Imine bonds containing covalent organic frameworks) that accomplished once more as an anode fabric for lithium-ion batteries derived from 2,4,6-triaminopyrimidine and terephthalaldehyde.

Environmental applications

Most firms worldwide need copper, silver, lead cadmium, aluminum and cobalt. These metals can be present in nearly all dairy products. Their widespread prevalence in industrial processes, chronic metal contamination from occupational contact, and health risks associated with these metals necessitate their identification and control in biological and dietary samples. Metals are used in electroplating, alloy production, and battery manufacturing. As a result, excessive metal concentrations have been discovered in diverse water sources, soil, and plants. Products such as cigarettes, beers, oils, and supplements necessitate metals][monitoring and quality control [xxxiv]

Metal corrosion has a tremendous impact on the national economy and critical safety and pollution issues. Although many inhibitors have good inhibitory properties, they are insufficient for environmental protection and sustainable development initiatives for various reasons (such as difficulty in degradation, toxicity or high-temperature resistance). Stable, efficient, and ecologically friendly inhibitors are the inhibitors of the future. Many inhibitors, including imidazolines, Mannish bases, and Schiff bases, contain heteroatoms (N, S, O) or chemical interactions with electrons (p bonds). N, O, and S heteroatoms, as well as unsaturated >C=N- bonds, can create strong and durable corrosion-inhibiting adsorption films on metal surfaces, demonstrating outstanding inhibitory effects. At the same time, Schiff base compounds are attractive to researchers due to their inexpensive cost, ease of synthesis and purification, strong water solubility, and low toxicity [xxxv]

Chemo-sensing applications

Schiff base-primarily based totally fluorescent probes have currently been invented for detecting and tracking several unsafe analytes in organic systems. Schiff base compounds with nitrogen-oxygen-wealthy coordination as a receptor site offer a solid platform for fluorescence sensing with significant, seen colour shifts. Detecting steel ions with numerous mechanisms in a correct pattern the use of Schiff base-primarily based totally sensors is attractive currently. In the latest decade, Schiff base probes primarily based totally on fluorescence live-mobileular imaging had been used to come across steel ions inclusive of Co2+, Cu2+, Zn2+, Hg2+, Ag+, Al3+, and ClO− ions [xxxvi, xxxvii].

4.9 Bio-sensing applications

Within cells, Schiff base compounds were used as biosensors for H_2O_2, glucose, and Oncomarker CA-a hundred twenty-five CA-125 [xxxviii]. Evaluation of the sensitivity and specificity of the gold Schiff base complicated-doped sol gel nano optical sensor for the detection of CA-a hundred twenty five in ovarian most cancers affected person samples became completed and as compared to outcomes received from samples taken from healthful

ladies serving as a manage group Sheta M. Sheta et al. [xxxix] created an ultrasensitive approach of detecting human creatinine the usage of a cerium(III)-isatin Schiff base complicated as an optical sensor

Biomedical applications

Schiff bases and their metallic complexes have several packages in numerous biomedical prescription drugs along with antimicrobial, anti-malarial, anticancer, antiviral, anti-inflammatory, antioxidant, anticonvulsant, anti-anthelmintic, bioprinting, tissue regenerating, enzyme inhibition and drug delivery. In organic systems, the azomethine nitrogen of Schiff bases serves as a binding site for metallic ions to connect to numerous biomolecules along with proteins and amino acids for anti-germ activity. Our bodies` Schiff bases catalyzed many metabolic occasions withinside the shape of enzymes which might be lively in opposition to sure bacteria. Several research had been carried out to enhance the bio-features of Schiff bases and their metallic complexes. Schiff bases can combat cancer, fungus, germs, ulcers, and viruses, relying on which transition metallic ions they contain [xl].

Conclusion:

Schiff bases are essential compounds in chemistry with a wide range of applications due to their ability to form stable complexes and their diverse biological activities. Their synthesis, classification, and industrial applications make them significant in various fields of chemistry and industry.

REFERENCES

i Shalin Kumar DNDPS. Applications of metal complexes of Schiff bases-A review. J Sci Ind Res (India) 2009,181–190.

ii Abbas SA, MM, FA, NS and IZ. Abbas, S.A., Munir, M., Fatima, A., NahSynthesis, Characterization and Biocidal Studies of Some Transition Metal Complexes Containing Tetra Dentate and Neutral Bi Dentate Schiff Base. Electronic. Journal of Life Science, 2010, 1, 37-40.

iii Xiang Dong Liu MKASTE. Accelerating effects of N-aryl-N′, N′-dialkyl ureas on epoxy-dicyandiamide curing system. Journal of Polymer Science Part A: Polymer Chemistry Volume 2009; 5298–5305.

iv X. Du XYu, JPol.Sci. Accelerating effects of N-aryl-N′, N′-dialkyl ureas on epoxy-dicyandiamide curing system. Part A: Polymer Chemistry, 1997, 35, 3249

v Hassan AS AANENAMGA-OM. Hassan AS, Askar AA, Nossier ES, Naglah Antibacterial evaluation, in silico characters and molecular docking of Schif bases derived from 5-aminopyrazoles. Molecules 2019, **24**(17),3130.

vi Chaudhary NK GB. Chaudha Coordination chemistry, antibacterial screening, and in silico ADME study of mononuclear NiII and CuII complexes of asymmetric Schiff Base of streptomycin and aniline. Journal of Chemistry 2022,1-14.

vii Cheng LX TJLHJXDFYJZB. Antioxidant And antiproliferative activities of hydroxyl-substituted Schiff bases. Bioorg Med Chem Lett 2022**, 20**(8),2417–2420.

viii Yadav M SSDJ. Designing, spectroscopic characterization, biological screening and antioxidant activity of mononuclear transition metal complexes of bidentate Schiff base hydrazones. Journal of Chemical Sciences 2021,**133**(1),1-22.

ix Mitter Steiner M FFBHMMZN. Ultrasound-assisted synthesis of pyrimidines and their fused derivatives: A review. Ultrasonics Sonochemistry. A review

Ultrasonics Sonochemistry 2021, 79,105683.

x Singh A GHBPGAK. Singh A, Novel thioether Schiff base transition metal complexes: Design, synthesis, characterization, molecular docking, computational, biological and catalytic studies. Applied Organometallic Chemistry 2022,**36**,66-73.

xi Dhingra N SJSHL. Synthesis, spectroscopy, and density functional theory of organotin and organosilicon complexes of bioactive ligands containing nitrogen, sulfur donor atoms as antimicrobial agents: In vitro and in silico studies. Dalton Transactions 2022,51,8821-8831.

xii Shukla M KHSDS. Comparative study of the Schiff bases by conventional and green method and antimicrobial activity. International Journal of Materials Sciences 2017,**12**(1),71-76.

xiii Nikpassand M FLSS. An efficient and green synthesis of novel azo Schiff base and its complex under ultrasound irradiation. Oriental Journal of Chemistry 2013, **29**(3),1041-1046.

xiv Satheesh CE SKPKPKRHANM. Half-sandwich Ru (II) complexes containing (N, O) Schiff base ligands: Catalysts for base-free transfer hydrogenation of ketones. Applied Organometallic Chemistry 2019,**33**(10), e5111.

xv Otani N FTKNHTAT. Synthesis of amino acid derivative Schiff base copper (II) complexes by microwave and wet mechanochemical methods. Journal of the Indian Chemical Society 2021,**98**(1). 234-238.

xvi Singh A GHBPGAK. Novel thioether Schiff base transition metal complexes: Design, synthesis, characterization, molecular docking, computational, biological and catalytic studies. Applied Organometallic Chemistry 2022, 36,66-73.

xvii Puzari A BDDPB. Pd (II) complexes with multidentate Schiff base ligands: Synthesis, catalysis, and antibacterial properties. Monatshefte für Chemie-Chemical Monthly 2022, 153,435-442.

xviii Maiti SK BABPCABB. Binuclear chiral Ni (II) complex of tridentate OON chiral Schiff base ligand, 1-((E)-(((1S, 2R)-2-hydroxy-2, 3-dihydro-1H-inden-1-yl) imino) methyl) naphthalen-2-ol. Journal of Coordination Chemistry 2020,**73**(1),67-86.

xix Gupta KC SAK. Catalytic activities of Schiff base transition metal complexes. Coordination Chemistry Reviews 2008,**252**(12-14),1420-1450.

xx Abuamer KM MAE-AMEAA-KMAMA. The role of aromatic Schiff is based in dye techniques. International Journal of Organic Chemistry 2014, 4,7-15.

xxi Kazemnejadi M DKAMH. Synthesis and characterization of Schiff-base polymer derived from 2, 5-dichloroaniline and 2-hydroxybenzaldehyde. Journal of Iranian Chemical Communication 2017, **5**(3),237-363.

xxii Natesan S SJSAK. Design and development of Schiff's base (SB)-modified polylactic acid (PLA) antimicrobial film for packaging applications. Polymer Bulletin 2022,**79**(7),4627-4646.

xxiii Mr SN SAKPKA. Schiff's base (SB) modified zirconium dioxide reinforced PLA bio-composite film for industrial packaging applications. Composites Communications 2021,**25**,100750.

xxiv Singh S. Synthesis, spectroscopic studies and pesticidal activity of transition metal complexes with unsymmetrical Schiff base. Indian Journal of Biochemistry and Biophysics (IJBB) 2021, **58**(6),565-571.

xxv Karmakar I MSMA. Evaluation of antimicrobial and insect repellent properties

of two novel zinc (II), and nickel (II) complexes containing a tetradentate Schiff Base. Journal of Integrated Science and Technology 2015,**3**(2),60-67.

xxxvi Kapoor P SRFN. Coordination chemistry of rare earth metal complexes with coumarin-based imines: Ecofriendly synthesis, characterization, antimicrobial, DNA cleavage, pesticidal, and nematocidal activity evaluations. Journal of Coordination Chemistry 2012, **65**(2),262-277.

xxxvii Fakhari AR KANH. Synthesis and analytical application of a novel tetradentate N2O2 Schiff as a chromogenic reagent for determination of nickel in some natural food samples. Talanta 2005, **66**(4),813-817

xxxviii Aksuner N HEYICA. A highly sensitive and selective fluorescent sensor for the determination of copper (II) based on a Schiff base. Dyes and Pigments 2009, **83**(2),211-217.

xxxix López-Herraiz M C-MEC-GJCJRTAM. Oligomeric-Schiff bases as negative electrodes for sodium ion batteries: Unveiling the nature of their active redox centers. Energy & Environmental Science 2015,**8**(11),3233-3241.

xxx Castillo-Martínez E C-GJAM. Polymeric Schiff bases as low-voltage redox centers for sodium-ion batteries. Angewandte Chemie International Edition 2014,**53**(21),5341-5345.

xxxi Yang X ZXHYJJTHWD. Nitrogen-enriched hierarchically porous carbon materials fabricated by graphene aerogel templated Schiff-base chemistry for high performance electrochemical capacitors. Polymer Chemistry 2015,**6**(7),1088

xxxii Chen H ZYXCCMDHZX. Two π-conjugated covalent organic frameworks with long-term Cyclability at high current density for lithium ion battery. . Chemistry A European Journal 2019, **25**(68),15472-15476.

xxxiii Oiye ÉN RMKJTMBM. Electrochemical sensors containing Schiff bases and transition metal complexes to detect analytes of forensic, pharmaceutical and environmental interest. A review Critical Reviews in Analytical Chemistry 2019**,49**(6),488-509.

xxxiv Wei W LZLCHGHJZS. Synthesis, characterization and corrosion inhibition behavior of 2-aminofluorene bis-Schiff bases in circulating cooling water. . RSC Advances 2020,**10**(30),17816-17828.

xxxv Yuan C LXWYLLZMA. triazole Schiff base-based selective and sensitive fluorescent probe for Zn2+: A combined experimental and theoretical study. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 2016,154, 215-219.

xxxvi Bharali B THPPDDK. A new Schiff Base based fluorescent sensor for Al (III) based on 2-Hydroxyacetophenone and O-Phenylenediamine. Journal of Fluorescence 2020, **30**(4), 751-757.

xxxvii Abou-Omar MN AMAHAM. Boukherroub R, Mohamed EH. Novel optical biosensor based on a nano-gold coated by Schiff base doped in sol/gel matrix for sensitive screening of on co marker CA-125. ACS Omega 2021,**6**(32), 20812-20821.

xxxviii Sheta SM AMSHE-GES. A novel cerium (iii)–isatin Schiff base complex: Spectrofluorometric and DFT studies and application as a kidney biomarker for ultrasensitive detection of human creatinine. RSC Advances 2020,**10**(10), 5853-5863.

xxxix Sharma S MRSRFN. Synthesis, characterization, antimicrobial, and DNA cleavage evaluation of some organotin (IV) complexes derived from ligands

containing the 1H-indole-2, 3-dione moiety. Main Group Metal Chemistry 2016,**39**(1-2),31-40.

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