

Original Article

# Synthesis and Characterization of New Cu(II) Complexes of ((2-Chloroquinolin-3-yl)methylene)-3-Methoxyaniline

Datta A. Patil<sup>1</sup>, Rajkumar U. Pokalwar<sup>2</sup>

<sup>1,2</sup>Department of Chemistry, Degloor College, Degloor, Maharashtra, India.

<sup>2</sup>Corresponding Author : [rajupokalwar@rediffmail.com](mailto:rajupokalwar@rediffmail.com)

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**Abstract** - A simple and efficient synthetic process was developed for preparing copper(II) complexes derived from the Schiff base ligand ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline. The ligand was synthesized through the condensation of equimolar 2-chloroquinolin-3-carbaldehyde and 3-methoxyaniline in ethanol under mild conditions. The obtained product has high purity within one hour. Subsequent reaction with copper(II) chloride in ethanol produced air-stable coordination complexes exhibiting various metal-to-ligand stoichiometries. Formation and purity were rigorously confirmed by multiple spectroscopic techniques, <sup>1</sup>H NMR verified the characteristic –CH=N– imine linkage via proton shifts; IR spectroscopy displayed bands indicative of C=N bond stretching and metal-ligand coordination vibrations; HRMS confirmed molecular structures through observed mass fragmentations ions. These outcomes highlight the method's simplicity, high efficiency, and reproducibility.

**Keywords** - 2-Chloroquinoline-3-carbaldehyde, Copper complexes, ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline, 3-methoxyaniline.

## 1. Introduction

This persistent emphasis highlights the adaptability of the quinoline platform as a fundamental chemical synthesis and translational drug development cornerstone. The ubiquity of quinoline units in a variety of natural products and their use as adaptable building blocks for the synthesis of pharmacologically powerful molecules are the driving forces behind recent advancements in the laboratory.[1] Quinoline derivatives are extensively researched for a variety of biological activities, including strong antimalarial [2] effects, anti-inflammatory,[3] anticancer,[4] antimicrobial, DNA-binding,[5] antibacterial,[6] Quinoline Schiff base complexes as anticancer, [7-8] anti-tuberculosis, [9] antihistamine, [10] antifungal, [11] anti-HIV, [12] antihypertensive, [13] and antiparasitic[14] properties. Quinoline scaffolds are also often used in the study of bioorganic and bioorganometallic processes. [15-16]

Beyond their biological significance, quinoline derivatives, particularly 2-chloroquinoline-3-carbaldehyde, serve as essential building blocks for a variety of scaffolds with significant medical applications. Meth-Cohn et al. pioneered its synthetic flexibility, allowing for easy functionalizations using nucleophilic substitutions and condensations to effectively access bioactive heterocycles.[1] A variety of nucleophiles, including amines, thiols, alkoxides, and carbon-based groups like enolates or organozinc compounds, can easily replace the 2-

chloro substituent in 2-chloroquinoline-3-carbaldehyde by nucleophilic aromatic substitution. This reactivity expands applications in medicinal chemistry by allowing the modular production of 2-substituted quinolines, such as Schiff bases, thioethers, and extended heterocycles.

The aldehyde group has also been converted into derivatives of acrylic acid, hydrazones, and oximes. A wide variety of fused quinoline systems, including thieno, pyridazino, tropono, pyrano, and fluoroquinolines, have been made possible by these and similar modifications.

This variation in the biological response profile has sparked researchers' interest in the various possible uses of the quinoline skeleton as an active moiety. Quinolines are special natural alkaloids that are important to the pharmaceutical business and may be found in many different synthetic and natural products [17].

In addition to these biological applications, quinolines are employed as photoinitiators, sensors, fluorescent dyes, photosensitizers, fluorescent probes, device components, and materials for nonlinear optics [18]. Additionally, hierarchical self-assembly of poly-substituted quinolines may generate a variety of meso and nano structures with enhanced photonic and electrical properties.

Quinoline-based scaffolds have developed into versatile platforms for the development of selective colorimetric and fluorescent chemosensors due to their



exceptional  $\pi$ -reactive qualities, conjugation, nitrogen donor sites, and modifiable photophysical properties. [19]

Schiff bases, also known as anils, imines, or azomethines, are condensation products that result from the nucleophilic addition of primary amines to aldehydes or ketones together with the removal of water. They are extremely useful in coordination chemistry and pharmaceutical applications because of their characteristic structural motif, the azomethine (C=N) functionality, which provides unique reactivity and coordination characteristics. Numerous investigations [20,21] have shown that the azomethine group's chemical reactivity and biological activity are significantly influenced by the lone pair of electrons on the  $sp^2$ -hybridized nitrogen atom. Schiff bases are regarded as effective chelating agents because of their high coordinating abilities through the (C=N) group, simplicity of synthesis, and structural diversity [22–23]. Schiff base ligands' flexibility and the wide range of biological, analytical, and commercial uses for their metal complexes have made this field of study a pillar of contemporary coordination chemistry. With crucial roles in bioinorganic modeling, biomedical treatments, supramolecular assemblies, catalysis, materials science, separation processes, and the synthesis of structurally new molecules, this subject has grown significantly.

Schiff bases coupled with metal-forming complexes, especially with copper, have demonstrated a variety of biological activities, including antibacterial and antifungal effects [24–25]. Their metal complexes have been extensively studied for potential anticancer and herbicidal properties [26], and they are often used as models for biologically relevant systems. For example, *o*-phenylenediamine-based Schiff bases exhibit clinically relevant properties [27], while isatin-derived Schiff bases have shown antiviral, anti-HIV, antiprotozoal, and anthelmintic activities [28], along with notable anticonvulsant and other pharmacological effects [29]. Certain copper–Schiff base complexes have been identified as potent antiviral agents [30], and Schiff bases derived from 4-dimethylaminobenzaldehyde have demonstrated antibacterial activity. Moreover, Schiff bases have found applications in medicine as anti-inflammatory agents and antibody-related therapeutics [31].

It is necessary to construct and explore structurally defined copper(II) complexes obtained from strategically functionalized quinoline-based Schiff bases in order to understand the effect of substituent electronics on metal coordination behavior.

In the present study, novel copper(II) complexes were synthesized using the Schiff base ligand ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline, generated via condensation of 2-chloroquinoline-3-carbaldehyde and 3-methoxyaniline, and subsequently employed as a platform to explore structure coordination relationships. Particularly with regard to the effects of the electron-donating methoxy

substituent on ligand field strength, the structural stabilization provided by the 2-chloro substituent, and the structure–coordination relationship analysis in a medicinal inorganic chemistry context, copper(II) complexes derived specifically from ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline have not been thoroughly studied. This work investigates the synergistic interplay of the quinoline pharmacophore, the labile 2-chloro handle, and the methoxy-substituted aniline moiety, probing their influence on coordination geometry, stability, and potential bioactivity in medicinal inorganic chemistry.

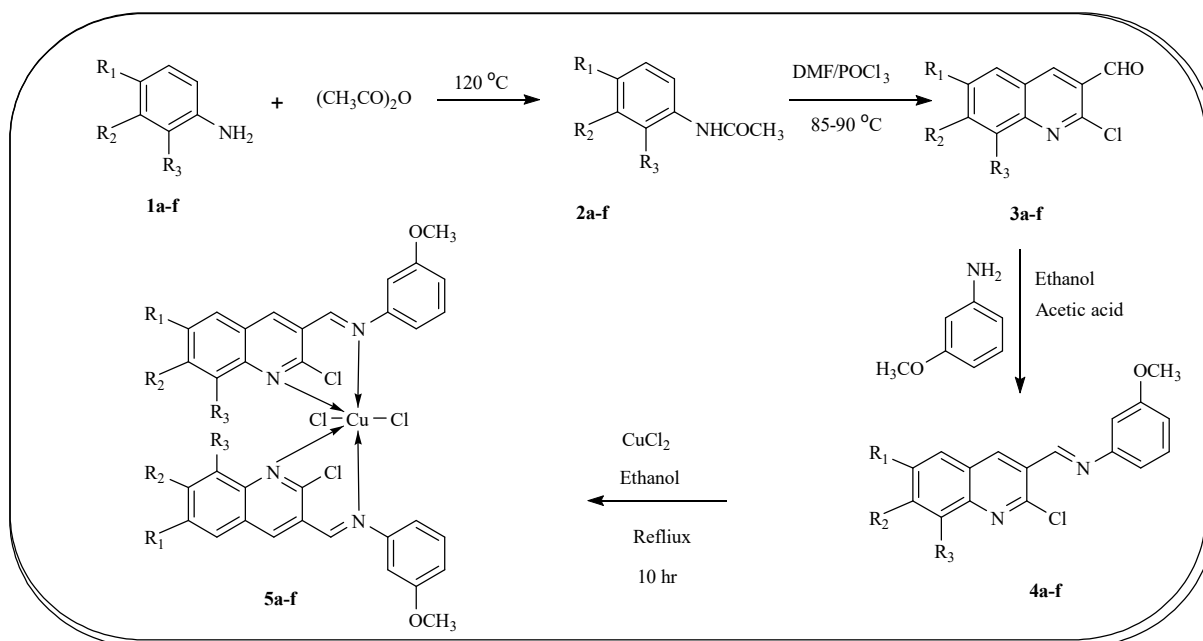
## 2. Results and Discussion

The current work focuses on the synthesis of new copper complexes of ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline, using 2-chloroquinoline-3-carbaldehyde and 3-methoxyaniline as starting materials (Scheme I). A series of Schiff base ligands (4a-f) was initially synthesized by condensing substituted 2-chloroquinoline-3-carbaldehydes (3a-f) with 3-methoxyaniline in the presence of acetic acid, using ethanol as the solvent at room temperature. The reactions went successfully, producing the intended complex in high yields of 95–98% (Table 1, entries 1–6). The synthesized ligands (4a-f) were then reacted with copper(II) chloride under reflux conditions in ethanol to generate copper complexes (5a-f). These complexation processes were performed in 10 hr, resulting in high yields of 86–88% (Table 1, entries 7–12). The reproducibility of the synthesis of the copper complex is confirmed by repeating the experiment three times, and it is observed that the yield of the end product remains the same, 87% (Table 1, entries 13, (5a)).

Chemical structures of freshly synthesized substances were verified using IR,  $^1H$  NMR, and mass spectroscopy. The azomethine (C=N) group was identified in the IR spectra by a distinct absorption band at 1620–1680  $cm^{-1}$ . Metal-chloride (M-Cl) and metal-nitrogen (M-N) linkages were identified in bands ranging from 420 to 600  $cm^{-1}$ . A peak at 2860  $cm^{-1}$  indicated N-H stretching, whereas a band at 2924  $cm^{-1}$  represented C-H stretching vibrations. This is in the agreements with the reported values, [32–34] which thus confirms the formation of Schiff base and metal ligand linkage bond in the synthesized compounds.

## 3. Materials and Methods

2-Chloroquinoline-3-carbaldehyde[1] was produced in the lab using a previously described process.[1–4] Unless otherwise noted, Spectrochem, Avra Chemicals, and S.D. Fine Chem provided all solvents and reagents. Melting points were obtained in open capillary tubes at atmospheric pressure and are uncorrected.  $^1H$  NMR spectra were obtained using a Bruker AVANCE NEO 500 MHz spectrometer, with DMSO- $d_6$  as the solvent and Tetramethyl Silane (TMS) as the internal standard. The IR spectra were acquired with a Shimadzu FTIR spectrometer. The produced compounds' molecular ion peaks were captured to confirm the High-Resolution Mass Spectra (HRMS).



Scheme-1: Synthesis of copper complexes of ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline

## 4. General Procedure

### 4.1. Preparation of ligand ((2-chloro-6-methylquinolin-3-yl)methylene)-3-methoxyaniline (4b)

To a stirred solution of 2-chloro-6-methylquinoline-3-carbaldehyde (1.02 g, 5 mmol) and 3-methoxyaniline (0.53 g, 5 mmol) in absolute EtOH (20 mL) was added glacial AcOH (4 drops). The mixture was stirred at RT for 1 h. The precipitated imine was collected by filtration, washed with cold EtOH (5 mL), and dried under reduced pressure to afford ((2-chloro-6-methylquinolin-3-yl)methylene)-3-methoxyaniline. The product was used directly in the next step without further purification.

### 4.2. Preparation of Copper complex of ((2-chloro-6-methylquinolin-3-yl)methylene)-3-methoxyaniline (5b)

A clear solution was prepared by heating a stirred solution of ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline (0.59 g, 2 mmol) in 10 mL of ethanol. This was followed by a gradual addition of a copper chloride solution (0.25 g, 2 mmol) in 10 mL of ethanol, stirring constantly. After heating the reaction mixture to reflux, the reaction progress was monitored by TLC using an 8:2 hexane: ethyl acetate solvent solution. The mixture was cooled to room temperature when the process was finished, which took 10 hr. The required product was obtained by filtering, washing with ethanol, and drying the resultant solid.

The compound was fully characterized by IR,  $^1\text{H}$  NMR, and mass spectroscopy.

#### 4.2.1. Copper complex of ((2-chloro-7-methylquinolin-3-yl)methylene)-3-methoxyaniline (5b)

IR ( $\text{cm}^{-1}$ )

445 (-M-Cl); 466 (-N-M); 1632 (-C=N); 2866 (-N-H); 2936 (-C-H);

$^1\text{H}$  NMR (DMSO,  $\delta$ ppm)

2.35 (s, 3H, -CH<sub>3</sub>), 3.51 (s, 3H, -OCH<sub>3</sub>), 7.26 – 7.30 (s, 4H, Ar-H), 7.72 (d, 1H, Ar-H), 7.89 (d, 1H, Ar-H), 7.98 (s, 1H, Ar-H), 8.90 (s, 1H, H-C=N), 8.99 (s, 1H, Ar-H).

HRMS

756.16 (m+1) m/z.

A similar procedure was applied for the preparation of compounds (5a-f) using an appropriate quantity of reagents.

#### 4.2.2. Copper complex of ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline (5a)

IR ( $\text{cm}^{-1}$ )

438 (-M-Cl); 452 (-N-M); 1615 (-C=N); 2852 (-N-H); 2919 (-C-H).

$^1\text{H}$  NMR (DMSO,  $\delta$ ppm)

3.48 (s, 3H, -OCH<sub>3</sub>), 7.22 – 7.25 (s, 4H, Ar-H), 7.61 (d, 1H, Ar-H), 7.68 (d, 1H, Ar-H), 7.82 (d, 1H, Ar-H), 7.92 (d, 1H, Ar-H), 8.88 (s, 1H, H-C=N), 8.92 (s, 1H, Ar-H).

HRMS

727.12 (m+1) m/z.

#### 4.2.3. Copper complex of ((2-chloro-7-methylquinolin-3-yl)methylene)-3-methoxyaniline (5c)

IR ( $\text{cm}^{-1}$ )

4223 (-M-Cl); 457 (-N-M); 1628 (-C=N); 2883 (-N-H); 3020 (-C-H).

$^1\text{H}$  NMR (DMSO,  $\delta$ ppm)

2.32 (s, 3H, -CH<sub>3</sub>), 3.53 (s, 3H, -OCH<sub>3</sub>), 7.23 – 7.33 (s, 4H, Ar-H), 7.65 (d, 1H, Ar-H), 7.92 (s, 1H, Ar-H), 7.95 (s, 1H, Ar-H), 8.86 (s, 1H, H-C=N), 8.91 (s, 1H, Ar-H).

HRMS

756.08 (m+1) m/z.

4.2.4. Copper complex of ((2-chloro-8-methylquinolin-3-yl)methylene)-3-methoxyaniline (5d)  
IR ( $\text{cm}^{-1}$ )

4328(-M-Cl); 461 (-N-M); 1615 (-C=N); 2852 (-N-H); 2972(-C-H).

$^1\text{H NMR}$  (DMSO,  $\delta\text{ppm}$ )

2.27 (s, 3H, -CH<sub>3</sub>), 3.49 (s, 3H, -OCH<sub>3</sub>), 7.21 – 7.28 (s, 4H, Ar-H), 7.65 (d, 1H, Ar-H), 7.80 (d, 1H, Ar-H), 7.90 (s, 1H, Ar-H), 8.92 (s, 1H, H-C=N), 8.92 (s, 1H, Ar-H).

HRMS

756.11 (m+1) m/z.

4.2.4. Copper complex of ((2-chloro-6-methoxyquinolin-3-yl)methylene)-3-methoxyaniline (5e)  
IR ( $\text{cm}^{-1}$ )

434 (-M-Cl); 456 (-N-M); 1622 (-C=N); 2928 (-N-H); 2985 (-C-H);

$^1\text{H NMR}$  (DMSO,  $\delta\text{ppm}$ )

2.38 (s, 3H, -CH<sub>3</sub>), 3.42 (s, 3H, -OCH<sub>3</sub>), 3.50 (s, 3H, -OCH<sub>3</sub>), 7.29 – 7.38 (s, 4H, Ar-H), 7.68 (d, 1H, Ar-H), 7.85

(d, 1H, Ar-H), 7.88 (s, 1H, Ar-H), 8.93 (s, 1H, H-C=N), 8.95 (s, 1H, Ar-H)

HRMS

788.09 (m+1) m/z.

4.2.5. Copper complex of ((2-chloro-7-methoxyquinolin-3-yl)methylene)-3-methoxyaniline (5f)  
IR ( $\text{cm}^{-1}$ )

442 (-M-Cl); 480 (-N-M); 1624 (-C=N); 2872 (-N-H); 2931 (-C-H).

$^1\text{H NMR}$  (DMSO,  $\delta\text{ppm}$ )

2.38 (s, 3H, -CH<sub>3</sub>), 3.46 (s, 3H, -OCH<sub>3</sub>), 3.58 (s, 3H, -OCH<sub>3</sub>), 7.24– 7.35 (s, 4H, Ar-H), 7.62 (d, 1H, Ar-H), 7.78 (d, 1H, Ar-H), 7.85 (s, 1H, Ar-H), 8.89 (s, 1H, H-C=N), 8.96 (s, 1H, Ar-H).

HRMS

788.12 (M+1) m/z.

Table 1. Data on newly synthesized compounds

Entry	Compound	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Reaction Time (min)	Yield(%)	Melting Point(°C)
1	4a	H	H	H	10	95	161-163
2	4b	CH <sub>3</sub>	H	H	10	95	169-171
3	4c	H	CH <sub>3</sub>	H	10	96	138-140
4	4d	H	H	CH <sub>3</sub>	10	95	149-151
5	4e	OCH <sub>3</sub>	H	H	10	95	132-134
6	4f	H	OCH <sub>3</sub>	H	10	97	145-147
7	5a	H	H	H	10 hr	87	229-231
8	5b	CH <sub>3</sub>	H	H	10 hr	88	232-234
9	5c	H	CH <sub>3</sub>	H	10 hr	85	245-247
10	5d	H	H	CH <sub>3</sub>	10 hr	88	257-259
11	5e	OCH <sub>3</sub>	H	H	10 hr	86	244-246
12	5f	H	OCH <sub>3</sub>	H	10 hr	88	235-237

In this work, a series of novel copper (II) complexes derived from the Schiff base ligand ((2-chloroquinolin-3-yl)methylene)-3-methoxyaniline were efficiently synthesized. The process began with the condensation reaction between 2-chloroquinolin-3-carbaldehyde and 3-methoxyaniline under mild conditions to form the imine ligand in high yield, which was then coordinated to copper(II) ions using simple metal salt exchange in polar solvents.

The target complexes exhibited excellent stability and were comprehensively characterized by  $^1\text{H NMR}$  (confirming -CH=N- formation), IR spectroscopy (revealing C=N and M-N/M-O vibrations), and mass spectrometry (verifying molecular compositions). These findings validate a reproducible synthetic protocol, highlighting the potential of such halogenated quinoline complexes in catalysis, antimicrobial agents, and advanced materials.

## 5. Conclusion

A series of structurally validated Cu(II) complexes derived from a chloroquinoline-based Schiff base ligand was successfully synthesized and thoroughly characterized. Detailed spectral interpretation confirms azomethine formation and nitrogen coordination to copper. The work highlights the structural role of chloro substitution in stabilizing the coordination framework. These findings expand the understanding of quinoline-based copper complexes and provide a foundation for future exploration in catalysis, antimicrobial screening, and materials applications.

Further studies involving single-crystal X-ray analysis and biological evaluation are recommended to strengthen structure-activity correlations. This work establishes an efficient route for such quinoline-based complexes with potential applications in bioactivity, catalysis, and materials science.

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## References

- [1] Otto Meth-Cohn, Bramha Narine, and Brian Tarnowski, "A Versatile New Synthesis of Quinolines and Related Fused Pyridines, Part 5. The Synthesis of 2-Chloroquinoline-3-Carbaldehydes," *Journal of the Chemical Society, Perkin Transactions 1*, pp. 1520-1530, 1981. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [2] Kirandeep Kaur et al., "Quinolines and Structurally Related Heterocycles as Antimalarials," *European Journal of Medicinal Chemistry*, vol. 45, no. 8, pp. 3245-3264, 2010. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [3] Rizk Elsayed Khidre, Bakr Fathy Abdel-Wahab, and Farid Abdel-Rehem Badria, "New Quinoline-based Compounds for Analgesic and Anti-inflammatory Evaluation," *Letters in Drug Design & Discovery*, vol. 8, no. 7, pp. 640-648, 2011. [[Google Scholar](#)] [[Publisher Link](#)]
- [4] Wafaa M. Abdou, Rizk E. Khidre, and Azza A. Kamel, "Elaborating on Efficient Anti-Proliferation Agents of Cancer Cells and Anti-Inflammatory-Based N-Bisphosphonic Acids," *Archiv der Pharmazie*, vol. 345, no. 2, pp. 123-136, 2012. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [5] Brahmam Medapi et al., "Design and Synthesis of Novel Quinoline-Aminopiperidine Hybrid Analogues as Mycobacterium Tuberculosis DNA GyraseB Inhibitors," *Bioorganic & Medicinal Chemistry*, vol. 23, no. 9, pp. 2062-2078, 2015. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [6] N.C. Desai, G.M. Kotadiya, and A.R. Trivedi, "Studies on Molecular Properties Prediction, Antitubercular and Antimicrobial Activities of Novel Quinoline based Pyrimidine Motifs," *Bioorganic & Medicinal Chemistry Letters*, vol. 24, no. 14, pp. 3126-3130, 2014. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [7] Rajkumar U. Pokalwar et al., "Synthesis and Antibacterial Activities of  $\alpha$ -Hydroxyphosphonates and  $\alpha$ -Acetyloxyphosphonates Derived from 2-Chloroquinoline-3-Carbaldehyde," *Arkivoc*, pp. 196-204, 2006. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [8] Shreelekha Adsule et al., "Novel, Schiff base Copper Complexes of Quinoline-2-Carboxaldehyde as Proteasome Inhibitors in Human Prostate Cancer Cell," *Journal of Medicinal Chemistry*, vol. 49, no. 24, pp. 7242-7246, 2006. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [9] Rangappa S. Keri, and Siddappa A. Patil, "Quinoline: A Promising Antitubercular Target," *Biomedicine & Pharmacotherapy*, vol. 68, no. 8, pp. 1161-1175, 2014. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [10] Ambika Srivastava, Mrityunjay K. Singh, and R.M. Singh, "Pyrazolo-fused Quinoline Analogues: Synthesis of 1H-pyrazolo [3, 4-b] Quinolines and 3-Amino-1H-Pyrazolo [3, 4-b] Quinolines from 3-Formyl and 3-cyano-2-Chloroquinolines," *Indian Journal of Chemistry. Sect. B: Organic Chemistry, Including Medical Chemistry*, vol. 45, no. 1, pp. 292-296, 2006. [[Google Scholar](#)]
- [11] P. Sah, S.P. Garg, and S.R. Nautiyal, "Some New Biologically Active Quinoline Analogues," *Indian Journal of Heterocyclic Chemistry*, vol. 7, no. 3, pp. 201-204, 1998. [[Google Scholar](#)]
- [12] Nafees Ahmed et al., "Synthesis and Anti-HIV Activity of Alkylated Quinoline 2, 4-Diols," *Bioorganic & Medicinal Chemistry*, vol. 18, no. 8, pp. 2872-2879, 2010. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [13] Heinz H. Pertz, H. Christian Milhahn, and Eckart Eich, "Cycloalkanecarboxylic Esters Derived from Lysergol, Dihydrolysergol-I, and Elymoclavine as Partial Agonists and Antagonists at Rat 5-HT<sub>2A</sub> Receptors: Pharmacological Evidence that the Indolo[4,3-fg]quinoline System of the Ergolines Is Responsible for High 5-HT<sub>2A</sub> Receptor Affinity," *Journal of Medicinal Chemistry*, vol. 42, no. 4, pp. 659-668, 1999. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [14] Vladimir V. Kouznetsov et al., "Target-Oriented Synthesis of Antiparasitic 2-Hetaryl Substituted Quinolines based on Imino Diels-Alder Reactions," *Letters in Drug Design & Discovery*, vol. 4, no. 4, pp. 293-296, 2007. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [15] Kazuhiko Nakatani, Shinusuke Sando, and Isao Saito, "Improved Selectivity for the Binding of Naphthyridine Dimer to Guanine-Guanine Mismatch," *Bioorganic & Medicinal Chemistry*, vol. 9, no. 9, pp. 2381-2385, 2001. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [16] Emon Barua et al., "Characterization of Mechanical and Micro-architectural Properties of Porous Hydroxyapatite Bone Scaffold using Green Microalgae as Binder," *Arabian Journal for Science and Engineering*, vol. 44, pp. 7707-7722, 2019. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [17] Gajendra S. Thakur et al., "Traditional and Sustainable Methods for the Synthesis of Quinoline Derivatives as Anticancer Agents (2019-Present): A Comprehensive Review," *Anti-Cancer Agents in Medicinal Chemistry*, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [18] Mahdiyeh Davoodi, Mahnaz Farahi, and Moeteza Shiri, "Ni-Schiff base Complex Supported on FSM-16 as a Novel Efficient Nanocatalyst to Synthesize Quinolone-3-Carbonitrile Derivatives," *Journal of Molecular Structure*, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]

- [19] Sandeep Yadav et al., "Synthesis, Properties, and Applications of Aminoquinoline-Derived Schiff Bases and Their Metal Complexes," *Russian Journal of Bioorganic Chemistry*, vol. 52, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [20] A. Elmali, M. Kabak, and Y. Elerman, "The Rapid Synthesis of Schiff's bases without Solvent under Microwave Irradiation," *Journal Molecular Structure*, 2000. [[Google Scholar](#)]
- [21] P.R. Patel, B.T. Thaker, and S. Zele, "Preparation and Characterisation of Some Lanthanide Complexes Involving a Heterocyclic Beta-diketone," *Indian Journal of Chemistry. Section A: Inorganic, Bio-inorganic, Physical, Theoretical and Analytical Chemistry*, vol. 38, no. 6, 1999. [[Google Scholar](#)] [[Publisher Link](#)]
- [22] Carol M. Metzler, Allen Cahill, and David E. Metzler, "Equilibriums and Absorption Spectra of Schiff Bases," *Journal of the American Chemical Society*, vol. 102, no. 19, pp. 6075-6082, 1980. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [23] Gerald O. Dudek, and Emily Pitcher Dudek, "Spectroscopic Study of Keto-enol Tautomerization in Phenol Derivatives," *Chemical Communications (London)*, vol. 19, pp. 464-466, 1965. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [24] Nursen Sari et al., "Antibacterial Activites of Some New Amino Acid-Schi Bases," *Gazi University Journal of Science*, vol. 16, no. 2, pp. 283-288, 2010. [[Google Scholar](#)]
- [25] Manjusha Verma et al., "Anticonvulsant Activity of Schiff bases of Isatin Derivatives," *Acta Pharmaceutica*, vol. 54, no. 1, pp. 49-56, 2004. [[Google Scholar](#)] [[Publisher Link](#)]
- [26] Sulekh Chandra, "EPR and Electronic Spectral Studies on Copper," *Journal of the Indian Chemical Society*, vol. 81, no. 3, pp. 203-206, 2004. [[Google Scholar](#)]
- [27] Anish Mohindru, Joyce M. Fisher, and Marco Rabinovitz, "Bathocuproine Sulphonate: A Tissue Culture-compatible Indicator of Copper-mediated Toxicity," *Nature*, vol. 303, pp. 64-65, 1983. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [28] S.N. Pandeya et al., "Synthesis and Screening for Anti-HIV Activity of Some N-Mannich Bases of Isatin Derivatives," *Chemotherapy*, vol. 45, no. 3, pp. 192-196, 1999. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [29] Dr. Wolfgang Sawodny, and Manfred Riederer, "Addition Compounds with Polymeric Chromium (II)-Schiff base Complexes," *Angewandte Chemie International Edition in English*, vol. 16, no. 12, pp. 859-860, 1977. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [30] A. Bottcher et al., "Irreversible Enzymatic Inhibition by Cobalt Chelate Complexes," *Journal of Inorganic Biochemistry*, vol. 59, no. 2-3, pp. 221-221, 1995. [[Google Scholar](#)]
- [31] George J.P. Britovsek et al., "Imine Versus Amine Donors in Iron-based Ethylene Polymerisation Catalysts," *European Journal of Inorganic Chemistry*, vol. 2001, no. 2, pp. 431-437, 2001. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [32] Sulekh Chandra, and Rajiv Kumar, "Synthesis and Spectral Studies on Mononuclear complexes of Chromium(III) and Manganese(II) with 12-Membered Tetradentate N<sub>2</sub>O<sub>2</sub>, N<sub>2</sub>S<sub>2</sub> and N<sub>4</sub> Donor Macrocyclic Ligands," *Transition Metal Chemistry*, vol. 29, pp. 269-275, 2004. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [33] Raziye Arab Ahmadi, and Saeid Amani, "Synthesis, Spectroscopy, Thermal Analysis, Magnetic Properties and Biological Activity Studies of Cu(II) and Co(II) Complexes with Schiff Base Dye Ligands," *Molecules*, vol. 17, no. 6, pp. 6434-3448, 2012. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [34] Mohammad Shakir et al., "Template Synthesis and Physicochemical Studies of 14-Membered Functionalized Pendant Arm Schiff-Base Macrocyclic Complexes of Co(II), Ni(II), Cu(II), and Zn(II): DNA Binding Studies on a Cu(II) Complex," *Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry*, vol. 41, no. 8, pp.1056-1062, 2011. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]