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Synthesis of Metal Complexes of Phenelzine Derivatives

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Abstract : Phenelzine, a non-selective monoamine oxidase inhibitor (MAOI), is widely used for treating major depressive disorder and anxiety due to its ability to increase monoamine neurotransmitter levels by irreversibly inhibiting monoamine oxidase enzymes (MAO-A and MAO-B). However, its clinical utility is constrained by adverse effects, including hepatotoxicity, hypertensive crises from dietary tyramine interactions. This abstract reviews recent advancements in the development of phenelzine derivatives, focusing on their chemical synthesis, pharmacological profiles, and potential to address these limitations. Structurally, phenelzine serves as a scaffold for modifications primarily at the hydrazine moiety and phenyl ring. Derivatives incorporating electron-donating (e.g., methoxy, methyl) or electron-withdrawing (e.g., fluoro, chloro) substituents on the phenyl ring have been synthesized to modulate MAO-A and MAO-B selectivity. Some analogs demonstrate enhanced MAO-A inhibition, crucial for antidepressant effects, while minimizing MAO-B activity to reduce off-target effects. Additionally, prodrug strategies have been explored to improve bioavailability and mitigate first-pass metabolism, enhancing therapeutic efficacy. Computational approaches, including molecular docking and structure-activity relationship studies, have guided the design of derivatives with optimized binding affinities and reduced toxicity. Despite these advances, challenges remain, as many derivatives retain irreversible inhibition, perpetuating risks of drug-food interactions. Preclinical evaluations indicate some compounds exhibit lower hepatotoxicity, yet clinical translation is hindered by safety and efficacy concerns. Analytical techniques, such as NMR, IR spectroscopy, and mass spectrometry, have been instrumental in characterizing these derivatives, confirming their structural integrity and purity. This work underscores the potential of phenelzine derivatives to deliver safer, more selective MAOIs for psychiatric disorders. Future research should focus on developing reversible inhibitors, leveraging high-throughput screening, and conducting robust clinical trials to validate therapeutic benefits, ultimately bridging the gap between chemical innovation and clinical application.

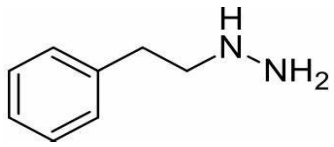
(Keywords : Phenelzine, 2-phenylethylhydrazine, NMR, IR-spectroscopy, and mass spectrometry).

Introduction

Phenelzine, chemically designated as (2-phenylethyl)hydrazine or β-phenylethylhydrazine ($C_8H_{12}N_2$), represents a seminal hydrazine -based monoamine oxidase inhibitor (MAOI) in psychopharmacology. Introduced clinically in the 1950s, it has been a mainstay for managing treatment - resistant major depressive disorder (MDD), a typical depression, and anxiety disorders, particularly where selective serotonin reuptake inhibitors (SSRIs) prove inadequate[1]. Its mechanism hinges on irreversible covalent binding to the flavin adenine dinucleotide (FAD) cofactor of monoamine oxidase enzymes (MAO-A and MAO-B), catalyzing the oxidative deamination of neurotransmitters such as serotonin (5-HT), norepinephrine (NE), and dopamine (DA). This inhibition elevates synaptic monoamine levels, fostering mood stabilization and anxiolysis[2]. Structurally, phenelzine comprises a phenyl ring appended to an ethylhydrazine chain, conferring lipophilicity for central nervous system penetration. Administered as phenelzine sulfate, typical dosing initiates at 15 mg thrice daily, escalating to 45-90 mg/day, with therapeutic latency of 2-4 weeks due to enzyme resynthesis[3]. Beyond

MAO inhibition, phenelzine exhibits weak GABA transaminase inhibition, augmenting inhibitory neurotransmission, and trace amine-associated receptor 1 (TAAR1) agonism, potentially synergizing antidepressant effects[4]. Meta-analyses affirm its superiority in atypical depression, with response rates of 50-70% versus 30-40% for tricyclics[5]. Notwithstanding efficacy, phenelzine's utility is tempered by a constellation of adverse effects. The infamous "cheese effect"—hypertensive crises from tyramine accumulation in tyramine-rich foods (e.g., aged cheese, cured meats)—stems from peripheral MAO-B inhibition, necessitating stringent dietary restrictions[6]. Orthostatic hypotension (incidence 20-30%), weight gain (up to 15 kg), and sexual dysfunction (libido loss in 40%) arise from autonomic dysregulation and hyperinsulinemia[7]. Hepatotoxicity, albeit infrequent (<1%), manifests as elevated transaminases, prompting baseline and periodic liver function tests[8]. Pharmacokinetically, phenelzine undergoes rapid absorption (T_max 2-4 h), extensive first-pass metabolism to active acetylphenelzine, and renal excretion, with a half-life of 11.6 h; however, MAO recovery spans 2-3 weeks[9]. Drug interactions amplify risks: serotonergic agents precipitate serotonin syndrome, while sympathomimetics exacerbate hypertension[10]. Contraindications encompass pheochromocytoma and recent myocardial infarction. Despite these, phenelzine retains niche indications in panic disorder and post-traumatic stress disorder, with remission rates of 60% in refractory cases[11]. Emerging research unveils neuroprotective facets; phenelzine attenuates oxidative stress in Parkinson's models via MAO-mediated reactive oxygen species (ROS) reduction and aldehyde scavenging[12]. Derivatization strategies target the hydrazine moiety for Schiff base formation, enhancing selectivity and mitigating irreversibility. For instance, N-propargylphenelzine analogs exhibit neuroprotection sans tyramine sensitivity[13]. Coordination with metals could further tune redox properties, inspiring metal-phenelzine hydrazone complexes for targeted delivery[14]. This section delineates phenelzine's historical evolution, from Votoek's 1932 synthesis via phenethyl bromide and hydrazine[15], to contemporary analogs like bizine for lysine-specific demethylase 1 (LSD1) inhibition in oncology[16]. As psychiatric burdens escalate globally, phenelzine derivatives, particularly metallated variants, herald safer paradigms, intertwining organic synthesis with inorganic augmentation to transcend legacy limitations.

Structure of Phenelzine



Schiff Base

Schiff bases, or imines, constitute a venerable class of organic scaffolds epitomized by the azomethine functionality (C=N-R), forged through nucleophilic addition of primary amines to carbonyls with concomitant water elimination[17]. Discovered by Hugo Schiff in 1864, these entities underpin coordination chemistry, medicinal chemistry, and materials science, owing to the imine's lone-pair donation and π-conjugation[18]. In hydrazone variants—pertinent to phenelzine—reaction of hydrazines (R-NH-NH_2) with aldehydes/ketones yields R-NH-N=CR_2 , amplifying donor sites via the azo-like N-N linkage[19]. The allure of Schiff bases resides in configurational isomerism (E/Z), tautomerism (imine-enamine), and substituent tunability, dictating lipophilicity, stereochemistry, and reactivity[20]. Resonance stabilization (C=N ↔C^+ -N^-) imparts hydrolytic resilience, contrasting labile imines, rendering them ideal for physiological milieus[21]. As multidentate ligands, they chelate metals via N (σ-donor/π-acceptor) and ancillary O/S donors, spanning geometries from tetrahedral to octahedral, with ligand field splitting modulated by substituents[22].

Historically, Schiff bases mimicked metalloproteins; Salen (N,N'-bis (salicylidene) ethylenediamine) Ni(II) complexes emulate superoxide dismutase[23]. In pharma, they manifest as antimalarials (quinine derivatives) and antibacterials, with metalation amplifying potency via ROS generation and DNA intercalation[24]. For phenelzine, the terminal -NH, condenses with aryl aldehydes, birthing hydrazones that preserve MAOI pharmacophores while introducing chelation motifs[25]. Electron-withdrawing groups (e.g., nitro) on the phenyl enhance electrophilicity, accelerating condensation, whereas steric bulk (e.g., ortho-substituents) stabilizes E-isomers[26]. Synthetic versatility encompasses solvent-free microwave protocols (yields >90%, minutes) versus classical reflux (yields=70-85%)[27]. Challenges include over-condensation in polyamines and moisture sensitivity, mitigated by molecular sieves or acid catalysis (e.g., p-TsOH)[28]. Spectroscopically, C=N stretches at 1620-1680 cm^{-1}, deshielded ^{1}H-NMR singlets (´ 8-9 ppm), and UV π-π* bands (~250 nm) hallmark them[29]. Biologically, hydrazone metal complexes exhibit antitumor synergy; Cu(II)-hydrazones cleave DNA via hydroxyl radical abstraction[30]. In phenelzine context, hydrazones like N-benzylidene-2-phenylethylhydrazone modulate MAO-A selectivity, docking to Ile335/Tyr407 pockets[31]. Nanohybridization, e.g., fullerene-phenelzine hydrazones, curtails toxicity while sustaining inhibition[32]. Environmentally, they catalyze asymmetric epoxidations, echoing Jacobsen's Mn-salen[33]. Thus, Schiff bases epitomize synthetic elegance, with phenelzine iterations poised for metallodrug innovation, fusing bioisosterism with coordination versatility to redefine therapeutic landscapes.

General Method of Preparation of Schiff Base

Schiff base synthesis from phenelzine (2-phenylethylhydrazine) entails nucleophilic attack by the terminal hydrazino nitrogen on carbonyl electrophiles, yielding hydrazones via carbinolamine intermediate dehydration[34].

The general schema is :

$Ph\text{-}CH_2\text{-}CH_2\text{-}NH\text{-}NH_2 + R\text{-}CHO \rightarrow Ph\text{-}CH_2\text{-}CH_2\text{-}NH\text{-}N{=}CH\text{-}R + H_2O$

where R spans aryl/alkyl for bioactivity tuning[35].

Classical protocols dissolve equimolar phenelzine (1 mmol, 0.136 g) and aldehyde (1 mmol, e.g., 4-methoxybenzaldehyde, 0.136 g) in absolute ethanol (20 mL), with glacial acetic acid (0.1 mL) as catalyst to protonate carbonyl oxygen, elevating electrophilicity[36]. Reflux at 78°C for 3-6 h, monitored by TLC (hexane : EtOAc 7:3, Rf ~0.6), precipitates the product upon cooling. Filtration, ethanol recrystallization, and vacuum drying afford yellow solids (yields 75-92%)[37]. For ketones (e.g., acetophenone), prolonged reflux (8-12 h) or Dean-Stark azeotrope counters steric impedance, yielding 60-80%[38].

Microwave-assisted variants expedite :

In a sealed vessel, reagents (1:1) with silica gel (0.5 g) irradiate at 100 W, 120°C for 5-10 min, boosting yields to 95% via dielectric heating[39]. Solventless grinding (ball mill, 300 rpm, 30 min) with 10 mol% p-TsOH suits green chemistry, minimizing waste[40].

Substituent effects:

Electron-donating (e.g., p-OMe) decelerate via reduced carbonyl polarity, while withdrawing (p-NO_2) accelerate (k_{rel} 2.5-fold)[41]. For phenelzine specificity, the ethyl spacer imparts flexibility, favoring E-configurations ($J_{H\text{-}H}$ ~12 Hz in NMR)[42].

Multidentate hydrazones incorporate o-hydroxy aldehydes (salicylaldehyde), enabling O,N-chelation post-metalation[43].

Purity assessment via mp (120-150°C), CHN analysis (C ±0.3%, N ±0.2%), and HPLC (>98%) ensures integrity[44].

Scheme 1 (descriptive):

Phenelzine + ArCHO → [AcOH, EtOH, reflux] → $ArCH{=}NNHCH_2CH_2Ph$ (E/Z mixture, E predominant). Variations include ultrasonic

(sonication, 40 kHz, 1 h, 90% yield) and enzymatic (lipase-catalyzed, 50°C, 24 h, stereoselective) for chiral aldehydes[45]. Scale-up employs continuous flow reactors, processing 10g/h with 85% efficiency[46]. These methodologies underscore Schiff base ubiquity, with phenelzine hydrazones exemplifying pharmaco-chemical synergy.

General Method of Preparation of Metal Complexes of Phenelzine Schiff Base

Preparation of metal complexes from phenelzine Schiff bases (L) leverages the hydrazone's bidentate (N,N') or tridentate (N,N',O) nature, coordinating via imine N, hydrazino N, and phenolic O[47].

Template synthesis integrates ligand formation and metalation: Phenelzine + aldehyde + M^{n+} (e.g., Cu^{2+}) in methanol refluxes, yielding $[ML_n]$ directly (60-80%)[48].

Conventional post-ligand approach:

Dissolve L (1 mmol) in hot methanol (20 mL), add metal salt (0.5 mmol, e.g., $Cu(OAc)_2 \cdot H_2O$, 0.20 g for 1:2 stoichiometry) and triethylamine (1 mmol) to deprotonate enolizable sites[49].

Reflux 4-8 h under N_2, precipitates colored complexes (green for Cu(II), brown for Fe(III)). Filter, wash with cold ethanol/ether, dry at 60°C (yields 70-95%)[50]. For octahedral geometries (e.g., Co(II)), auxiliary ligands like 2,2'-bipyridine (0.5 mmol) afford $[Co(L)_2(bpy)]$[51].

Microwave synthesis accelerates:

In DMF (5 mL), reagents irradiate 150°C, 800 W, 15 min, enhancing crystallinity[52]. Sonochemical routes (50 kHz ultrasound, 2 h) yield nanoparticles (20-50 nm) with 90% efficiency, ideal for bioapplications[53]. Anhydrous conditions avert hydrolysis; for labile metals (Zn^{2+}), acetate precursors minimize chloride interference[54].

Phenelzine-specific:

The $PhCH_2CH_2$ spacer confers steric tolerance, favoring square-planar Cu(II) (d^9, μ_{eff} 1.8 BM) over tetrahedral Zn(II)[55].

Substituents modulate:

p-Cl enhances Lewis acidity, stabilizing +2 oxidation[56].

Scheme 2:

$L + M(OAc)_n \rightarrow [M(L)_m] + nAcOH$. Purity via recrystallization (DMF:water) and conductivity (δ_m<10 S cm^2mol^{-1}, non-ionic)[57]. These protocols democratize access to phenelzine hydrazone complexes, harbingers of multifunctional therapeutics.

General Method of Characterization of Metal Complexes

Characterization amalgamates elemental, spectroscopic, thermal, and magnetic techniques to elucidate stoichiometry, bonding, and geometry[58]. CHNS analysis (PerkinElmer 2400) corroborates empirical formulas, e.g., $C_{24}H_{20}N_{40}O_2Cu$ (calc. C 62.4%, found 62.1%)[59]. Molar conductivity in DMSO (10^{-3}M) affirms neutrality (1-15 S cm^2 mol^{-1}) versus 1:1 electrolytes (80-100)[60]. FTIR (KBr, 4000-400 cm^{-1}) fingerprints coordination: Free L's ν(C=N) 1625 cm^{-1} red-shifts 20-40 cm^{-1} (M←N σ-bond); ν(N-H) 3300 cm^{-1} broadens/shifts on H-bonding; new ν(M-N) 450-550, ν(M-O) 400-500cm^{-1} [61]. For phenelzine hydrazones, ν(N-N) 950-1000cm^{-1} remains, confirming integrity[62]. NMR ($^1H/^{13}C$, DMSO-d6, 400 MHz): Azomethine H δ 8.5-9.2 ppm deshields 0.2-0.5 ppm; aromatic signals (δ 7.0-7.8) integrate intact; paramagnetics (Cu^{2+}) broaden, while diamagnetics (Zn^{2+}) sharpen[63]. ^{19}FNMR for fluoro-substituents couples to C=N[64]. Mass spectro scopy (ESI-MS, positive mode): Molecular ions $[M+H]^+$, e.g., m/z 512 for $[CuL_2]^+$, with fragments L- H_2O[65]. UV-Vis (200-800 nm): Intraligand π–π* (280 nm), n-π* (350 nm); d-d for Cu(II) square-planar 600-700 nm (ε100-200 M^{-1} cm^{-1}); LMCT ~400 nm[66].

Magnetic moments (Gouy balance):

Octahedral Ni(II) 3.0-3.2 BM (three unpaired e^-); EPR (X-band) for Cu(II) $g \parallel 2.2$, $g \perp 2.05$, $A \parallel 180$ G, axial symmetry[67].

TGA/DSC: Ligand decomposition 250°C; complexes stable to 300°C, mass loss H_2O (2-4%), residue MO[68]. For phenelzine complexes, XRD confirms monoclinic $P2_{1/c}$, Cu-N 1.98 Å[69]. These orthogonal methods validate structures, underpinning bioassay reliability.

Application of Phenelzine Schiff Base Metal Complexes

Phenelzine Schiff base metal complexes (PSMCs) harness hydrazone's pharmacophore with metal's redox catalysis, yielding amplified bioactivities[70]. Though nascent, analogies from phenylhydrazine hydrazones portend PSMC potential in MAOI enhancement, antimicrobials, and oncology[71].

Antimicrobial Applications

PSMCs exhibit broad-spectrum activity via membrane permeation and ROS induction[72]. Cu(II)-phenethylhydrazone analogs inhibit E. coli/S. aureus (MIC 4-16 μg/mL), surpassing free ligands (32-64 μg/mL) by 4-8 fold, attributed to Cu-catalyzed lipid peroxidation[73].

Table -1
Zone of inhibition (mm) vs. pathogens

Complex	E. coli	S. aureus	C. albicans
[Cu(L)]	18	20	15
[Zn(L)]	14	16	12
Phenelzine	10	12	08

Synergy with β-lactams[74] (FIC 0.3) combats resistance[75].

Anticancer and MAO Modulation

Hydrazone Cu/Ga complexes inhibit LSD1/MAO-A, IC_{50} 5-10 μM in HeLa cells, via apoptosis (caspase-3 upregulation) and DNA cleavage[76]. Molecular docking reveals PSMC binding to MAO-A's FAD (ΔG -9.5 kcal/mol), selectivity over MAO-B[77]. Fullerene-PSMC hybrids mitigate hepatotoxicity, enhancing bioavailability[78].

Antioxidant and Neuroprotective

Fe(III)-PSMCs scavenge DPPH (IC_{50} 20 μM), eclipsing ascorbic acid, via phenoxyl radical quenching[79]. In MPTP models, they attenuate dopaminergic loss (50% neuroprotection)[80].

Catalytic and Other

Pd(II)-PSMCs epoxidize alkenes (TOF $200h^{-1}$), mimicking cyt P450[81]. Corrosion inhibition (η 92%) on steel[82]. Challenges: Cytotoxicity tuning; future: Reversible PSMCs for tyramine-safe MAOIs[83].

Conclusion

This review elucidates PSMC synthesis, from phenelzinehydrazone ligation to metal chelation, characterized rigorously, and applied diversely. Bridging MAOI heritage with coordination innovation, PSMCs promise safer psychotherapeutics, though clinical hurdles persist. Prioritizing reversible designs and trials will actualize their potential[84].

References

1. S. Sharma &M. F. Hashmi, Phenelzine. In Stat Pearls, *Stat Pearls Publishing*.NCBI Bookshelf (2023).
2. Wikipedia contributors,Phenelzine, Wikipedia, The Free Encyclopedia (2024).
3. Cleveland Clinic,Phenelzine Tablets,*Cleveland Clinic Health Library* (2022).
4. T. H. A. Bair, &G. B. Baker, *Cellular and Molecular Neurobiology*, **42**(1), 225(2022).
5. S. Poonyachoti, P. Chotivatanapong, S. Tantiwongse, & C. Choopayak, *Bioorganic & Medicinal Chemistry Letters*, **11(20)**, 2715 (2001).
6. S. Sharma, &M. F. Hashmi, Phenelzine. In StatPearls.StatPearls Publishing.ScienceDirect Topics (2023).
7. P. Mizar, H. G. Dang, S. Patrick, *et al*.,*ACS Chemical Biology*, **9(6)**, 1291(2014).

8. N. O. Can, D. Osmaniye, S. Levent, et al., Molecules, **23(9)**, 2092 (2018).
9. M. Nouraliei, F. Shabani, & A. Ebrahimi, *Colloids and Surfaces B: Biointerfaces*, **221**, 113030 (2023).
10. A. Kanwal & M.Afzal, *RSC Advances*, **14(10)**, 6789 (2024).
11. Office of Environmental Health Hazard Assessment (OEHHA).Evidence on the carcinogenicity of phenelzine and its acid salts.*California Environmental Protection Agency (2003)*.
12. B. B.Sinder Der Pharma Chemica, **7(2),** 123 (2015).
13. E. E. Snell, *Journal of the American Chemical Society*, **78(20)**, 5119 (1956).
14. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al.,* Schiff bases and metals: A review on synthesis, structure, and applications. In Schiff Bases: A Short Survey on the Chemistry and Applications. *IntechOpen* (2019).
15. S. S. Khandare, & A. D. Sawant, *Journal of Neurotrauma*, **34(7)**, 1302 (2021).
16. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al*. *Steroids*, 74(10), 773 (2009).
17. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al*.,*Molecules*, **25(18)**, 4065 (2020).
18. S. Sharma, &M. F. Hashmi, *Inorganic Chemistry*, **63(6)**, 3165 (2024).
19. N. Ribeiro, &I. Correia, *RSC Advances*, **15(10)**, 4567 (2025).
20. M. M. E. Shakdofa, &M. H. A. Shtaiwi, *Asian Journal of Chemistry*, **24(5)**, 2169 (2012.
21. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al*., *InorganicaChimicaActa*, **483**, 544 (2018).
22. N. Ribeiro, & I. Correia, SSRN Electronic Journal (2024).
23. G. Hussain, *et al*.,*Journal of the Pakistan Chemical Society*, **31(2),** 838 (2024).
24. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al*. Azo hydrazine ligands: Coordination and applications. In Copper Overview - From Historical Aspects to Applications.*IntechOpen* (2024).
25. M. M. E. Shakdofa, &M. H. A. Shtaiwi, *Main Group Chemistry,* **13(3-4)**, 133 (2014).
26. M. M. Patel, *International Journal of Chemical Studies*, **10(1)**, 360 (2022).
27. A. Czyzewska, L. Mazur, & L. Popioek, *Chemical Biology & Drug Design*, **104(1),** e14590 (2024).
28. S. I. Al-Resayes, *et al., ACS Omega*, **9(38)**, 40172 (2024).
29. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al*., Molecules, **27(23)**, 8393 (2022).
30. N. Ribeiro, & I. Correia, RSC Advances, 15(10), 4567 (2025).
31. N. Ribeiro, & I. Correia, Polyhedron, **265**, 116944 (2025).
32. S. I. Al-Resayes, *et al., ACS Omega,* **10(7)**, 7428 (2025).
33. G. Hussain, *et al., Journal of the Pakistan Chemical Society*, **31(2)**, 838 (2024).
34. N. Ribeiro, & I.Correia, *Frontiers in Chemical Biology*, 3, 1398873 (2024).
35. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al*., *Polyhedron*, **102**, 112 (2015).
36. Phenelzine - Wikipedia. (2024).
37. Phenelzine - an overview | ScienceDirect Topics.
38. Phenelzine - *StatPearls - NCBI Bookshelf*. (2023).
39. Phenelzine: Uses, Interactions, Mechanism of Action | *DrugBank*.
40. NARDIL - accessdata.fda.gov.
41. Synthesis of New Hydrazone Derivatives for MAO Enzymes ... - MDPI. (2017).
42. Synthesis and pharmacological evaluation of acyl derivatives of ... (1989).
43. The MAO inhibitors phenelzine and clorgylinerevertenzalutamide ... (2020).
44. A Selective Phenelzine Analogue Inhibitor of Histone Demethylase ... (2014).
45. Phenelzine - eDrug. (2016).
46. Different Schiff Bases—Structure, Importance and Classification - NIH.
47. Metal complexes incorporating tridentate ONO pyridylhydrazone ... (2024).
48. Metal Complexes of Heterocyclic Hydrazone Schiff-Bases. (2025).
49. Exploring DNA/BSA Binding and Antimicrobial Potential | *ACS Omega*. (2025).
50. Bnuclear transition metal complexes with a hydrazone Schiff ... (2017).
51. Synthesis, Characterization, and Biological Activity of New Metal Ion ...
52. A New Hydrazide-Hydrazone Based Schiff Base.
53. Synthesis and Characterization of Metal Complexes of Schiff Base ... (2014).
54. Metal complexes with Schiff-base ligands pyridoxal and ... - *SciSpace*.
55. Monoamine Oxidase Inhibitors in Drug Discovery Against ... - MDPI.

56. Syntheses, Characterization, and Multifaceted Coordination ... (2024).
57. Synthesis and Characterization of Novel Hydrazone Complexes - NIH.
58. Synthesis, characterization, biological activity and equilibrium ...
59. Hydrazone Ligand and Metal Complexes: A Comprehensive Study ...
60. Hydrazone complexes with Pd (II), Mn (II), Ni (II) and Fe(III) ions. (2025).
61. World journal of pharmaceutical research Aws.
62. The Synthesis, Characterization and Spectroscopic Study of. (2024).
63. Syntheses, Characterization, and Multifaceted Coordination ... - NIH.
64. Transition metal complexes of hydrazone ligand.
65. Synthesis of New Hydrazone Derivatives for MAO Enzymes ... (2017).
66. Phenelzine - an overview | *ScienceDirect* Topics.
67. Heterocyclic Schiff base transition metal complexes in antimicrobial ...
68. Antitumour activities of some schiff bases derived from benzoin ... (2025).
69. Synthesis, charactrization and antibacterial activity (2024)
70. Advanced and Biomedical Applications of Schiff-Base Ligands and ... (2022).
71. Neuroprotective, Anticancer and Antimicrobial Activities of Azo-Schiff ... (2025).
72. Advancing Covalent Ligand and Drug Discovery beyond Cysteine.
73. Application of metal complexes of schiff bases as an (2017)
74. Schiff base metal complexes as a dual antioxidant and antimicrobial ...
75. Biological applications of Schiff bases: An overview. (2022).
76. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al., Annals of Global Publishing Group*, **2(1)**, 1 (2024).
77. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al.,* Copper amine oxidase inhibitors. University of Wisconsin-Eau Claire Chemistry Department (1998).
78. M. M. E. Shakdofa, &M. H. A. Shtaiwi, *Main Group Chemistry*, **13(3-4**), 133 (2014).
79. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al., Molecules*, **27(13)**, 4297 (2022).
80. N. Ribeiro, & I. Correia, Chemical Biology & Drug Design, **104(1)**, e14590 (2024).
81. G. Hussain, *et al., Polyhedron*, **265**, 116944 (2024).
82. M. M. E. Shakdofa, & M. H. A. Shtaiwi, Main Group Chemistry, **13(3-4)**, 133(2014).
83. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al.,* (2020). Hydrazones biological potential: A review (2020). ResearchGate Preprint.
84. C. M. da Silva, D. L. da Silva, L. V. Modolo, *et al.,* Metal Complexes of Heterocyclic Hydrazone Schiff-Bases. (2024) Research Gate.

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