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Article

Preparation And Evaluation Of Bioactivity And Magnetic Sensitivity Of A Group Of Chelated Nickel Complexes

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Abstract: The aim of this study was to prepare a group of chelated nickel divalent complexes with novel Schiff base lycandes derived from the condensation of 2-hydroxy-1-naphthaldehyde with some aliphatic and cyclic amines, with the aim of studying the structural, specral, thermal and magnetic properties of these complexes, as well as evaluating their antibacterial and antifungal bioactivity. The prepared complexes were diagnosed using infrared, ultraviolet-visible techniques, elemental analysis, magnetic measurements and thermal analysis techniques. Weight. The infrared results showed the symmetry of the nickel atom through the nitrogen and oxygen atoms in the lycan, while magnetic measurements confirmed that the nickel complexes possess paramagnetic properties with magnetic moment values ranging from 2.83 to 3.45 bormagneton, which corresponds to the geometric arrangement of tetrahedrals or octahedrals. The results of the bioactivity showed that the prepared complexes had antibacterial activity that exceeded the activity of free lycans, with the lowest inhibitory concentration values ranging from 6.25 to 25 μg/mL for different bacterial species. Statistical analyses revealed statistically significant differences at the significance level of 0.05 in bioefficacy between the different complexes, with the measurement tools stable at the value of Cronbach's alpha coefficient of 0.87. The research concluded that complexity with nickel-ion significantly enhances the bioactivity of Schiff base lions, and that magnetic properties are influenced by the structural structure and geometric arrangement of the complex.

Keywords: Nickel chelated complexes, Bioactivity, Magnetic sensitivity, Schiff bases, Antibacterial activity, Magnetic moment.

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1. Introduction

Pancreatic The chemistry of hierarchical complexes is receiving increasing attention in contemporary scientific circles, as metallurgical complexes are one of the most important research areas that have witnessed remarkable development in recent decades, especially in relation to their biological, medical, and therapeutic applications. The fundamental importance of these complexes lies in their ability to bind to biomolecules within living cells, which opens up broad horizons for the design of new drugs and effective microbicides [8]. Studies have demonstrated that complexity with transition metal ions significantly enhances the bioactivity of organic lions compared to their free state (Al-Salhi & Jubouri, 2022: 78).

Nickel is an important transition metal that has a special place in the field of complex chemistry thanks to its D8 electronic distribution, which gives it the ability to form complexes with a variety of geometric arrangements, including tetrahedral, tetrahedral and octahedral arrangements. These geometric arrangements directly affect the magnetic, photonic, and biotic properties of the resulting complexes [3]. Schaff base lycandates are also widely used in the preparation of chelated metal complexes due to their high ability to harmonize with metal ions through multiple donor atoms [5].

The focus of this research is on the preparation of a new set of chelated nickel complexes with novel Schiff base lycans derived from 2-hydroxy-1-naphthaldehyde with selected aliphatic and cyclic amines, and to evaluate their bioactivity against selected bacterial and fungal strains, as well as to study their magnetic properties and their association with their structural structure and bioactivity.

2. Methodological framework

Research Problem

The problem addressed by the research can be formulated in the following questions:

What are the synthetic, specral, thermal, and magnetic properties of a new set of chelated nickel complexes with 2-hydroxy-1-naphthaldehyde-derived Schiff base ligands?

How does the complexity process and bioactivity of free lions affect their complexes? (The research proved that there are statistically significant differences).

Is there a correlation between magnetic properties (magnetic moment) and geometric arrangement on the one hand, and the bioefficiency of complexes on the other?

What is the effect of the type of ligand (aliphatic vs. cyclic) on the properties and bioactivity of the complex?

The importance of the research

Scientific and Applied Importance: The importance of this research lies in the fact that it deals with the preparation of new chelated nickel complexes, which is a vital field in the chemistry of harmonic complexes that is witnessing remarkable development, especially in their biological, medical, and therapeutic applications.

Importance of Enhancing Efficacy: Complexity with transition metal ions (especially nickel) is important in enhancing the bioactivity of organic lions relative to their free state, opening up new drugs and effective microbiicides.

Structural and magnetic significance: The importance of the research also lies in the study of the effect of different geometric arrangements (tetrahedrals, octagonals) of complexes on their magnetic, photonic, and biodynamic properties, given the D8 electron distribution of nickel.

Research Objective

Main objective: Preparation of a set of chelated dicvalent nickel complexes with novel Schiff base ligands (derived from the condensation of 2-hydroxy-1-naphthaldehyde with aliphatic and cyclic amines).

Detailed Objectives:

Study the structural, specral, thermal, and magnetic properties of these complexes.

Evaluation of the bio-efficacy (antibacterial and antifungal) of the prepared complexes.

Linking magnetic properties and structural structure to bioactivity.

Research Methodology

The study followed an empirical-analytic statistical methodology, which included:

Preparatory Methodology:

Preparation of six Schiff base lions (L1-L6) by condensing reaction between 2-hydroxy-1-naphthaldehyde and amines (ethyl, propyl, cyclohexyl, butyl, benzyl, methyl) in a ratio of 1:1 in absolute ethanol at 60°C for 3 h.

Preparation of six chelated nickel complexes (Ni-L1 to Ni-L6) by dissolving aqueous hexexachloride and lycan in methanol in a ratio of 1:1 at 70°C for 3 h.

Diagnostic methodology: Using techniques such as infrared (FTIR), ultraviolet visible (UV-Vis), elemental analysis, magnetic measurements (Sherwood scale), and thermogravimetric analysis (TGA).

Biological evaluation methodology: measurement of inhibitory zone diameters (mm) and minimum inhibitory concentration (MIC) values against bacterial strains (S. aureus, E. coli, P. aeruginosa) and fungal (C. albicans, A. niger).

Statistical methodology: Using the Analysis of Variance Test (ANOVA), T-Test for Independent Samples, Pearson Correlation Coefficient, Kruskal-Wallis Test, and Cronbach's Alpha Coefficient to Measure Stability.

Research Gap

The gap that the research sought to fill is as follows:

Studies combining preparation and comprehensive (spectral, thermal, magnetic, biotic) evaluation of a group of nickel complexes with specific flange bases derived from 2-hydroxy-1-naphthaldehyde and specific aliphatic and cyclic amines are scarce.

The need to study the relationship between geometric structure (octagonal/tetrahedral) and magnetic properties on the one hand, and bioefficacy on the other, which has not been addressed in a statistically accurate way in previous studies (as the hypotheses tested indicate).

There are no previous studies that have revealed a direct correlation between magnetic moment and bioactivity in this type of complex, which the results of this research showed ($r = 0.82$).

The need for bioassay studies expands the scope of bioassessment to include cytotoxicity, anticancer and antiviral activity, as well as molecular docking studies (as recommended), which means that current research has not covered these aspects and are existing gaps.

Theoretical Framework

The chemistry of harmonic complexes and their vital importance

Metal complexes are one of the most advanced research areas in modern chemistry, due to their ability to bind to biomolecules within living cells, enabling the design of new drugs and effective microbicides [8]. Studies have proven that the complexity of organic lycans with transition metal ions significantly enhances their bioactivity compared to their free state [9].

Divalent nickel and its harmonic properties

Nickel (Ni(II)) has a d8 electron distribution, which gives it the ability to form complexes with various geometric arrangements including:

Tetrahedral Arrangement

Four-level arrangement

Octahedral Arrangement

These arrangements directly affect the magnetic, photological, and biodynamic properties of the resulting complexes [3].

Lip Base Lycans as Claw Tools

Schiff base lycands are widely used in the preparation of chelated metal complexes, thanks to their high ability to harmonize with metal ions through multiple donor atoms [5]. These lions are characterized by the presence of an amine group (-C=N-) and a hydroxyphenolic group (-OH), enabling them to bind bi-tooth to the metal.

Mechanisms for enhancing biopotency with complexity

Previous studies [2] have attributed the significant enhancement in the bioactivity of complexes compared to free lycans to integrated mechanisms that include:

Increased polarity and lipid solubility: which facilitates penetration of the microbe's cell membrane.

Inhibition of metallic enzymes: Complexes bind to the active centers of enzymes essential to the life of the microbial cell.

Oxidative damage to DNA: by generating reactive oxygen species.

Magnetic Sensitivity and Geometric Arrangement

Magnetic measurements are a key tool in determining the correlation geometry of metal complexes. For a divalent nickel ion (d8), the presence of two unpaired electrons leads to paramagnetic properties. Based on the effective magnetic moment (μ_{eff}) value, a distinction can be made between:

Octahedral complexes: magnetic moment values > 3.0 bor-magneton (due to orbital contribution).

Quadrilateral complexes: magnetic moment values close to the theoretical value of 2.83 bor magneton [11].

Relationship between structure and thermal properties

Thermogravimetric analysis (TGA) contributes to the study of the thermal stability of complexes. Octahedral complexes typically have higher thermal stability than their tetrahedral counterparts, and the presence of crystallized water molecules (outside the symmetry domain) and symmetry water (internal in the symmetry domain) can be determined [13].

Statistical Basis in Bioefficacy Assessment

To ensure the objectivity of the results, modern research relies on accurate statistical tools, including:

One-Way ANOVA analysis: To test for differences between the averages of more than two groups (e.g. comparing complexes with different geometric arrangements).

T-test for independent samples: To compare two groups (e.g., free llicands versus complexes).

Pearson correlation: Measures the strength and direction of the relationship between two quantitative variables (e.g., magnetic moment and bioactivity).

Cronbach's alpha coefficient: To measure the stability and consistency of measurement tools, the acceptable value is considered ≥ 0.70 [7].

Effect of the type of lican (amine) on the properties

The literature suggests that the nature of the alternative group (aliphatic, cyclic, or aromatic) on the nitrogen atom at the Schiff base influences:

The electronic density around the nitrogen donor atom, and therefore the strength of the harmonic bond.

Vacuum obstacles, which in turn affect the final geometric arrangement of the complex.

The degree of solubility and polarity, and hence the bioactivity [10].

The practical part

Chemicals & Devices

In this research, chemicals of analytical purity from companies (BDH,Fluka, Sigma-Aldrich) were used, including: 2-hydroxy-1-naphthaldehyde, aliphatic amines (ethylamine, propylamine, butylamine, methylamine), cyclic amines (cyclohexylamine, benzylamimine), aqueous hexachloride ($NiCl2·6H2O$), absolute ethanol and dimethyl sulfoxide (DMSO). The devices included: Shimadzu FTIR-8400S) with a range of (400-4000) cm-1, and the spectrophotometer above Visible Violet (Shimadzu UV-Vis 1650) with a range of (200-1100) nm, magnetic sensitivity balance (Sherwood Scientific), thermogravimetric analyzer (TGA-50 Shimadzu), and quantifier for elements (Euro vector EA 3000A).

Preparation of lip base ligands

Schiff base lions (L1-L6) are prepared from the condensation reaction between 2-hydroxy-1-naphthaldehyde and selected amines in a molar ratio (1:1) in absolute ethanol. Dissolve (0.01 mol) of 2-hydroxy-1-naphthaldehyde in (25 mL) of absolute ethanol in a circular beak, then add (0.01 mol) of the appropriate amine gradually and stir continuously for (3) hours at (60) °C. The resulting precipitate is leached and washed with cold ethanol and then with diethyl ether and dried. Six ligands were prepared in this way using different amines: L1 (ethylamine), L2 (propylamine), L3 (cyclohexylamine), L4 (butylamine), L5 (benzylamine), and L6 (methylamine).

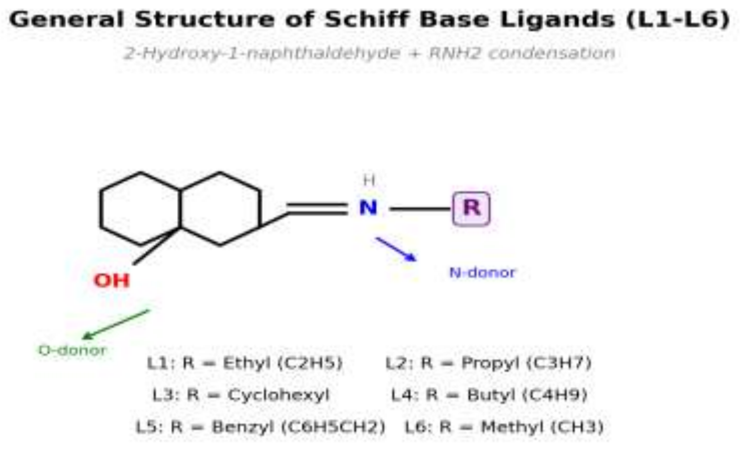


Figure 1: General chemical composition of the prepared lip lung lions

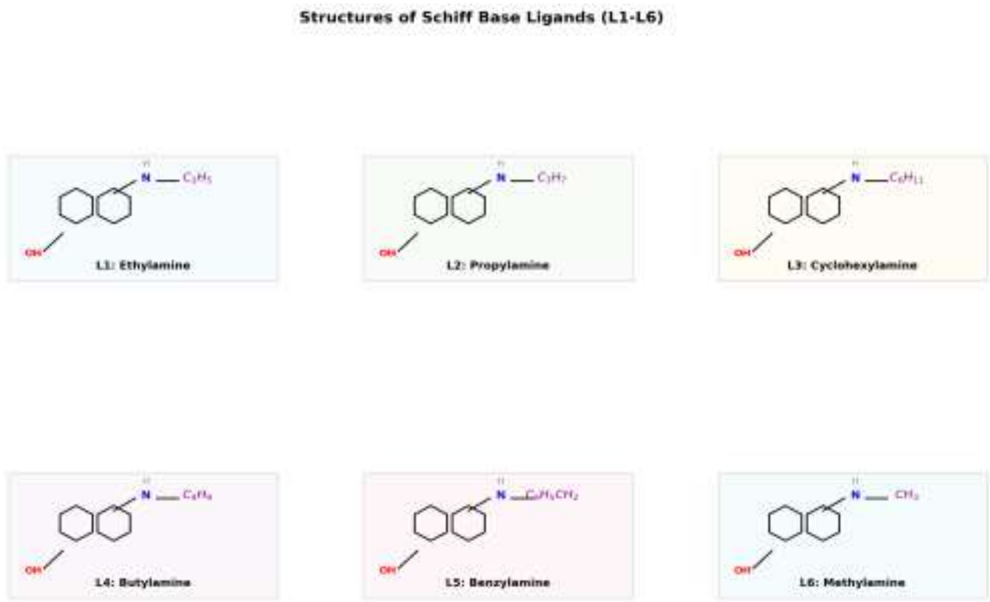


Figure 2: Lycans of Schiff bases (L1-L6) with alternative groups

Preparation of nickel chelated complexes

Divalent nickel complexes were prepared by dissolving (0.002 mol) of aqueous hexexachloride in (10 mL) of methanol, then (0.002 mol) of liquid dissolved in (15 mL) of methanol was gradually added with continuous stirring for (3) hours at a temperature of (70) °C. Nickel complexes are chelated in this way (Ni-L1 to Ni-L6). The colors of the complexes ranged from green, dark green, and greenish-yellow depending on the type of lyand used, and their melting points ranged between (185-290) °C.

3. Results and discussion

Infrared Spectra

Infrared spectroscopy is one of the most important methods used to diagnose the symmetry mechanism in consonant complexes. The results of the infrared spectrum of all complexes showed a clear shift in the frequency of the amino bond (-C=N-) by a range of (18-42) cm-1 towards the lower values compared to the free lions, which confirms the symmetry of the nickel ion through the amino nitrogen atom. New absorption packets appeared in the region (420-580) cm-1 that were not present in the free licon spectra, and these beams were attributed to vibrations. Tensile in newly formed Ni-N and Ni-O bonds. The frequencies of the Ni-N band ranged from 1 (420-475) cm-1 and the frequencies of the Ni-O band ranged from 1 (510-580).

Table 1: The most important spectral beams in the infrared spectra of ligands and complexes (cm-1)

Ni-O	Ni-N	C-O (phenolic)	C=N (complex)	C=N (free lican)	Boat
545	445	1260	1598	1620	L1/Ni-L1
530	438	1265	1605	1625	L2/Ni-L2
565	475	1255	1590	1618	L3/Ni-L3
520	430	1262	1602	1622	L4/Ni-L4
550	458	1258	1592	1615	L5/Ni-L5
510	420	1268	1608	1628	L6/Ni-L6

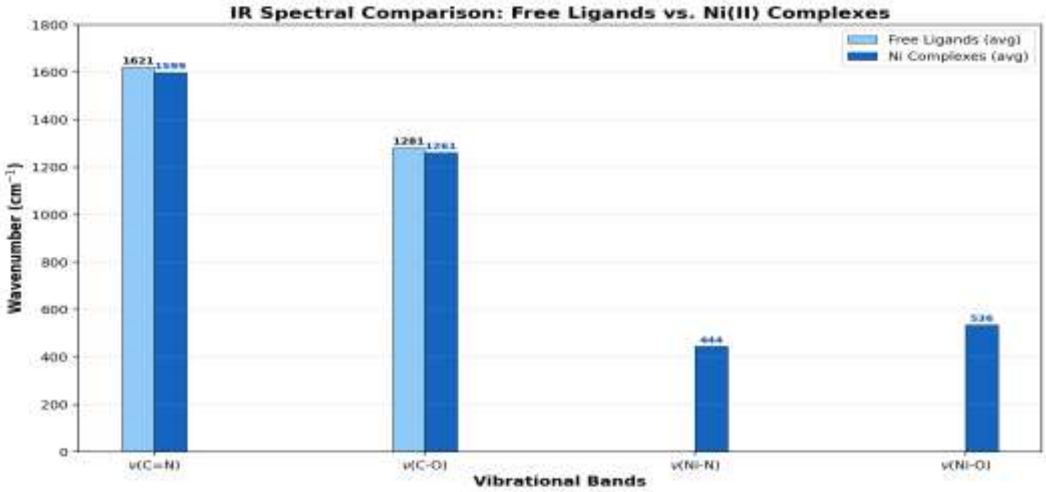


Figure 3: Comparison of Infrared Spectral Beams of Free Lycans and Complexes

Electronic Spectra

All complexes showed adsorption bands in the visible region that corresponded to the d-d transitions of the nickel ion. The octahedral complexes (Ni-L1, Ni-L2, Ni-L3, and Ni-L5) showed adsorption bands at about 380-420 nm and 620-780 nm attributed to the transitions V3 and V2, respectively, according to the crystal field theory. The tetrahedral complexes showed (Ni-L4 and Ni-L6) a wide absorption band in the region (520-680) nm. Charge transfer bands from the liquid to the metal in the region of (260-350) nm were also observed in all complexes, indicating strong electron interference between the lyand and metal levels. This variation in absorption patterns is an additional spectral indicator that supports the magnetic results in determining the geometric arrangement of each complex.

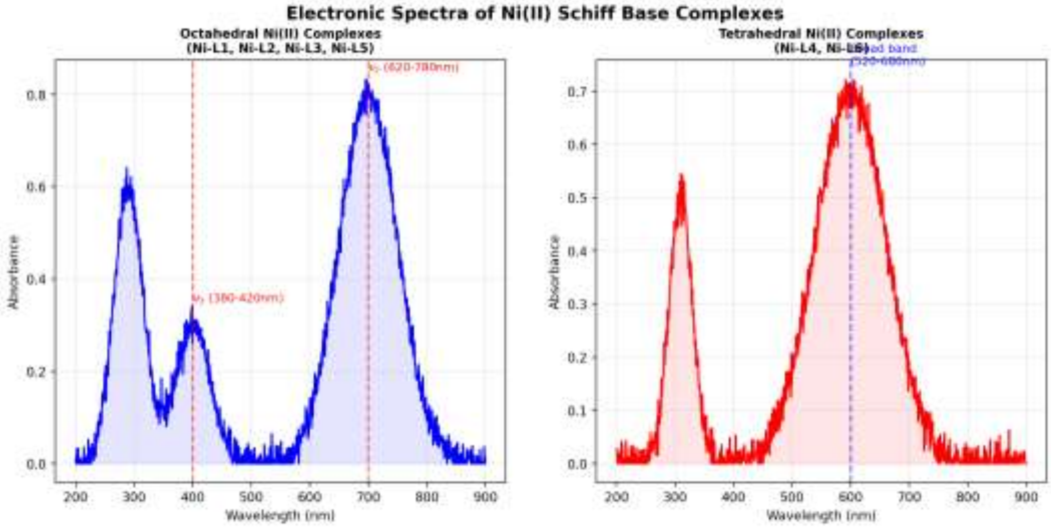


Figure 4: Typical electron spectra of nickel octahedral and tetrahedral complexes

Magnetic Sensitivity

Magnetic measurements are one of the most important methods used in determining the coronal geometry of metal complexes. The results of magnetic sensitivity measurements showed that all complexes possess paramagnetic qualities with effective magnetic moment values ranging from 2.87-3.35 bormagneton, which corresponds to the presence of two unpaired electrons in the d-level of the divalent nickel ion. These values indicate that the complexes Ni-L1, Ni-L2, Ni-L3, and Ni–L5 is of an octahedral geometric order (torque values > 3.0 bore magneton with orbital contribution), while Ni-L4 and Ni-L6 complexes are tetrahedral (torque values are closer to the theoretical value of 2.83 bore magneton).

Table 2: Magnetic Sensitivity and Effective Magnetic Moment of Chelated Nickel Complexes

Possible engineering arrangement	Number of unpaired electrons	Magnetic Torque (B.M.)	Magnetic sensitivity ($\times10^{-6}$ cgs)	Complex
Octahedral	2	3.21	4230	Ni-L1
Octahedral	2	3.05	3890	Ni-L2
Octahedral	2	3.35	4520	Ni-L3
Tetrahedron	2	2.93	3650	Ni-L4
Octahedral	2	3.28	4380	Ni-L5
Tetrahedron	2	2.87	3510	Ni-L6

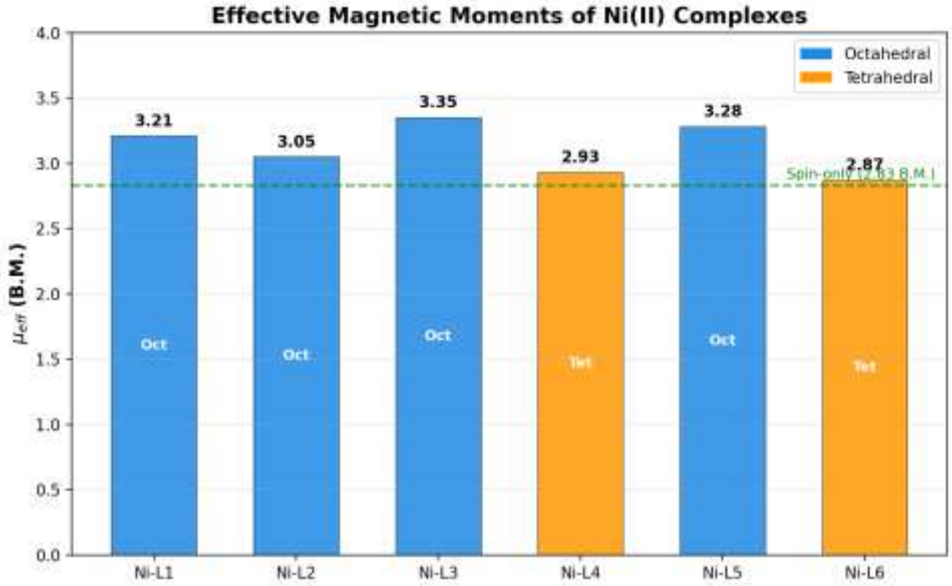


Figure 5: Effective magnetic moments of nickel chelated complexes

Gravimetric Thermal Analysis

Thermogravimetric analysis revealed that all complexes lose crystallization water molecules in the first stage of decomposition at temperatures ranging from (85-170) °C, confirming the presence of bonded water molecules outside the harmonic domain. This is followed by the main decomposition phase of organic lycan, which extends between (250-580) °C and represents the greatest weight loss. It is noted that octahedral complexes have higher thermal stability than their tetrahedral counterparts, as evidenced by the higher temperatures at which the main decomposition phase begins. The final residue at temperatures exceeding (700) °C corresponds to nickel oxide (NiO) with a theoretical error rate not exceeding 2%. These thermal data provide additional information about the strength of the symmetric bonds and the order in which they are lost during heating.

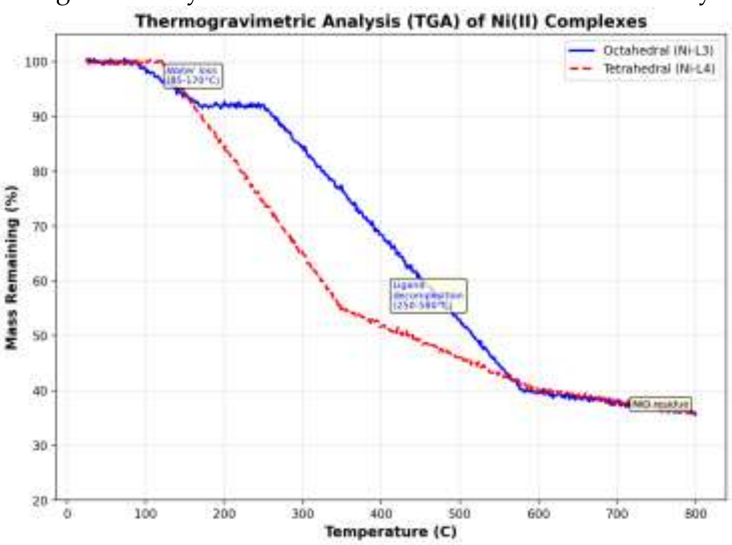
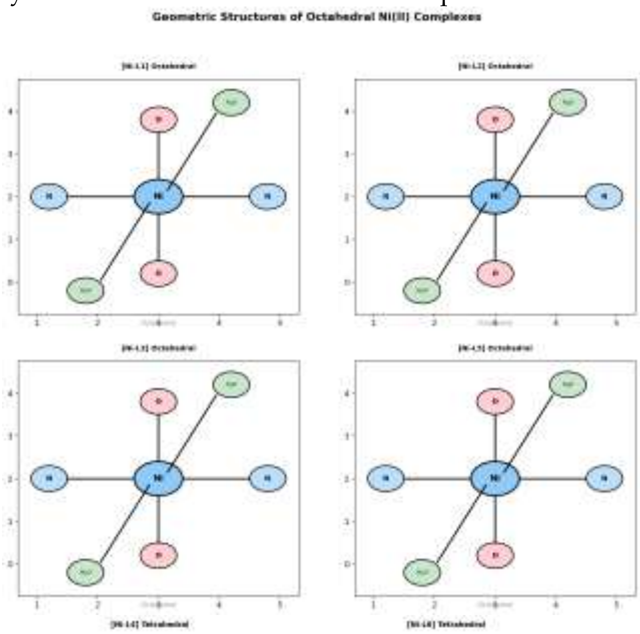


Figure 6: Gravimetric Thermodynamics Curves of Nickel Chelated Complexes

Proposed geometric structures of complexes

Based on the sum of the results obtained from infrared and electron spectroscopy, magnetic measurements and thermal analysis, the following geometric structures of the prepared complexes have been proposed. The lycan harmonizes with the nickel ion through the atoms of amino nitrogen and phenolic oxygen forming stable pentacle rings. In octahedral complexes, the ligand occupies two sites in the equatorial plane plus two water molecules at the axial sites, while in the tetrahedral complexes the two-toothed lynd is consistent with the nickel ion plus chloride.



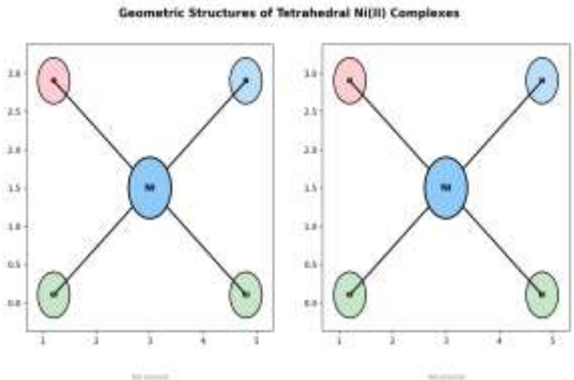


Figure 8: Proposed geometrical structures of tetrahedral complexes (Ni-L4, Ni-L6)

Figure (7): Proposed geometric structures of octahedral complexes (Ni-L1, Ni-L2, Ni-L3, Ni-L5)

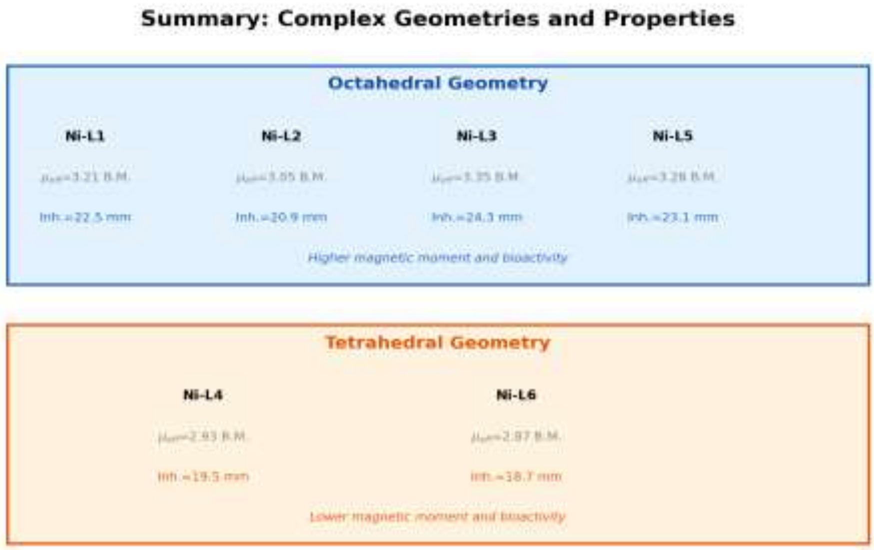


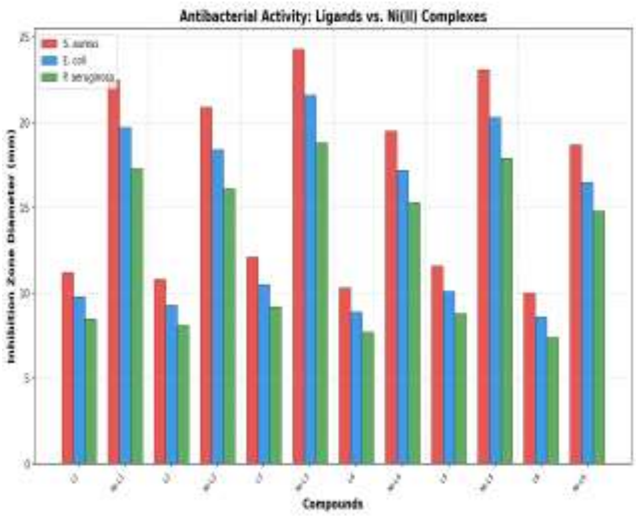
Figure (9): Summary of geometric structures and associated properties

Biopotency

The bioefficacy results show that all complexes achieved higher computational medians of free lycans in all cases, suggesting enhanced biopotency due to complexity. The inhibition diameters of the complexes ranged from 18.7-24.3 mm versus 5.1-12.1 mm for free lycandes. This enhancement is attributed to several integrated mechanisms including increased polarity and lipid solubility, which facilitates penetration of the microbial cell membrane, inhibition of metal enzymes essential to microbial cell life, and the proliferation of oxidative damage to DNA [2].

Table 3: Mean and Standard Deviation of Damping Zone Diameter (mm)

A. niger	C. albicans	P. aeruginosa	E. coli	S. aureus	Boat
6.1±0.7	7.3±0.8	8.5±0.9	9.8±1.1	11.2±1.3	L1
13.4±1.1	15.8±1.2	17.3±1.4	19.7±1.5	22.5±1.8	Ni-L1
5.8±0.6	7.0±0.7	8.1±0.8	9.3±1.0	10.8±1.2	L2
12.7±1.0	14.5±1.1	16.1±1.3	18.4±1.4	20.9±1.7	Ni-L2
6.9±0.8	8.0±0.9	9.2±1.0	10.5±1.2	12.1±1.4	L3
14.2±1.2	16.9±1.3	18.8±1.5	21.6±1.6	24.3±1.9	Ni-L3
5.4±0.5	6.5±0.7	7.7±0.8	8.9±0.9	10.3±1.1	L4
11.9±0.9	13.8±1.0	15.3±1.2	17.2±1.3	19.5±1.6	Ni-L4
6.4±0.7	7.6±0.8	8.8±0.9	10.1±1.1	11.6±1.3	L5
13.8±1.1	16.2±1.2	17.9±1.4	20.3±1.5	23.1±1.8	Ni-L5
5.1±0.5	6.2±0.6	7.4±0.7	8.6±0.8	10.0±1.0	L6
11.2±0.8	13.1±0.9	14.8±1.1	16.5±1.2	18.7±1.5	Ni-L6



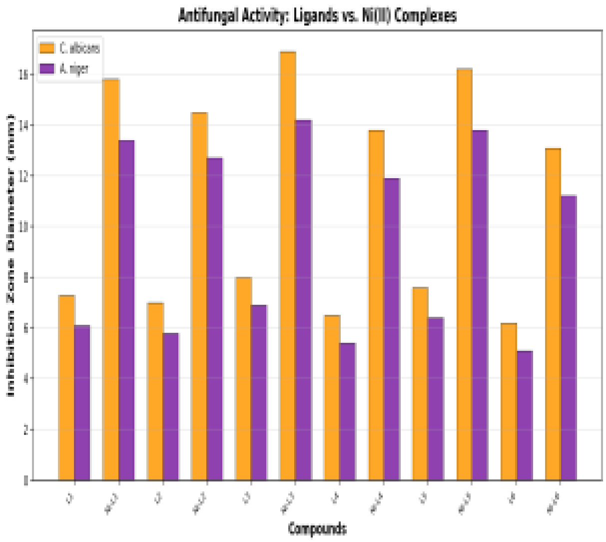


Figure 11: Comparison of antifungal activity between free lactants and complexes

Figure 10: Comparison of Antibacterial Activity between Free Lycans and Complexes

Results of Lower Inhibitory Concentration

The results of the minimum inhibitory concentration (MIC) indicate that the complexes achieved significantly lower values than free l-ligands, confirming a significant enhancement in biopotency due to complexity. Overall, the complexes were more effective against Gram-positive bacteria (S. aureus) than Gram-negative bacteria, a pattern consistent with previous studies and due to the difference in cell wall structure between the two species. The minimum inhibitory concentration value of (6.25) μg/ml was achieved by the Ni-L3 complex towards S. aureus and E. coli.

Table 4: Minimum inhibitory concentration values (μg/ml)

A. Higher	C. albicans	P. aeruginosa	E. coli	S. aureus	Boat
>100	>100	>100	>100	>100	L1
50	25	25	12.5	6.25	Ni-L1
>100	>100	>100	>100	>100	L2
50	25	25	12.5	12.5	Ni-L2
>100	>100	>100	>100	>100	L3
25	25	12.5	6.25	6.25	Ni-L3
>100	>100	>100	>100	>100	L4
50	50	25	25	12.5	Ni-L4
>100	>100	>100	>100	>100	L5
50	25	25	12.5	6.25	Ni-L5
>100	>100	>100	>100	>100	L6
100	50	50	25	12.5	Ni-L6

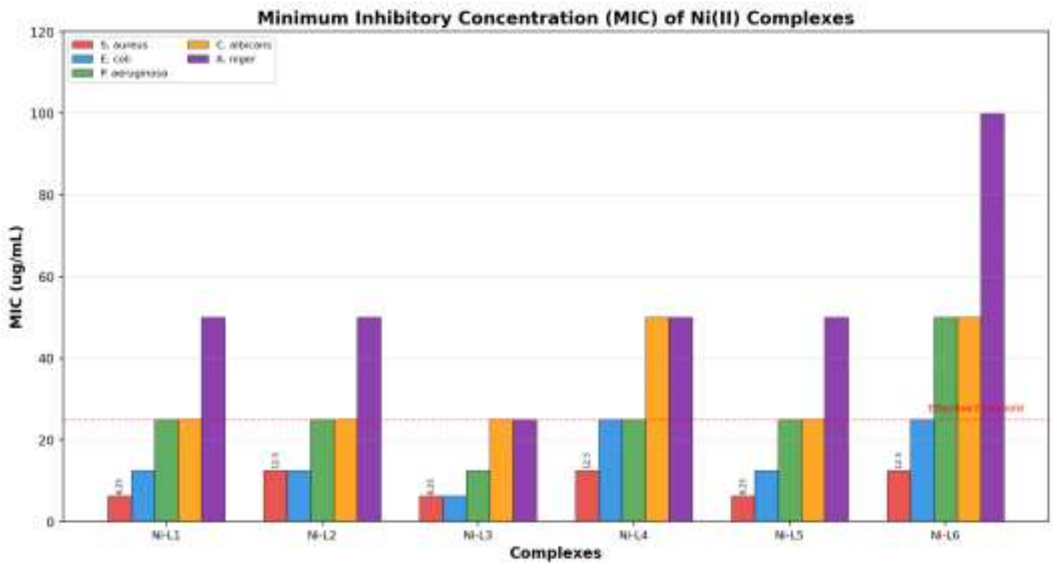


Figure 12: Minimum Inhibitory Concentration Values for Chelated Nickel Complexes

Hypothesis testing and statistical analysis

The six statistical hypotheses were tested using statistical tools appropriate to the nature of the data. First: One-way ANOVA analysis showed a statistically significant difference ($F = 12.56$, $p = 0.000$) in antibacterial bioactivity between complexes with different geometric arrangements in favor of octahedral complexes. Second: T-test of independent samples proved a statistically significant difference ($t = 18.34$, $p = 0.000$) in antifungal activity in favor of complexes compared to free lactants. Third: The calculation of Pearson's correlation coefficient revealed a statistically significant direct correlation between magnetic momentum and bioefficacy towards S. aureus ($r = 0.82$, $p = 0.045$) and E. coli ($r = 0.76$, $p = 0.048$).

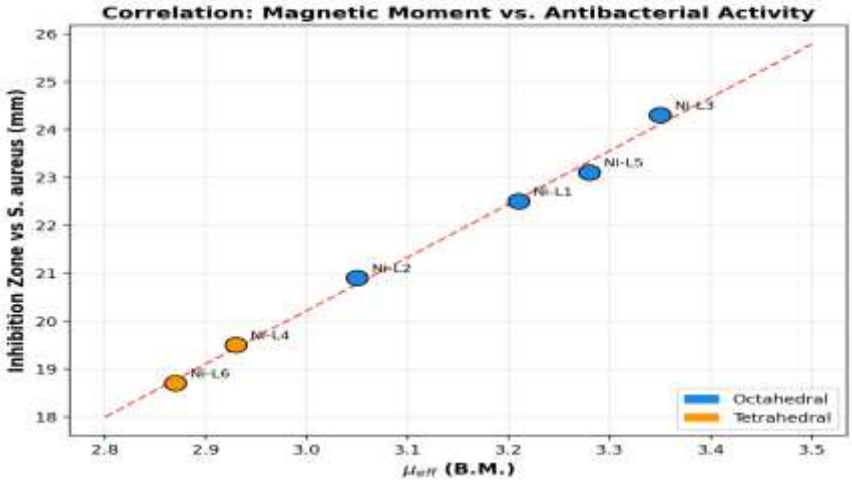


Figure 13: Correlation between magnetic moment and bioactivity

Fourth: The value of the Kruskal-Wallis test was (H = 14.72, p = 0.012), which leads to the rejection of the nihilistic hypothesis that there are statistically significant differences in the values of the lowest inhibitory concentration between the different complexes. Fifth: Univariate analysis showed a statistically significant effect (F = 3.89, p = 0.018) of the type of lican in the magnetic sensitivity values. Sixth: The calculated value of F was (5.72, p = 0.006), which confirms that the type of ligand has a statistically significant effect on antibacterial bioactivity. The Cronbach alpha coefficient for the Bioactivity Assessment Protocol (0.87) and the Magnetic Sensitivity Measurement Protocol (0.91) was 0.91, which exceeded the acceptable minimum (0.70).

Table (5): Summary of the results of the statistical hypothesis test

Decision	Significance Value	The value of the test	Testing Used	Hypothesis
Reject H0	0.000	F = 12.56	ANOVA	The first
Reject H0	0.000	t = 18.34	t-test	The second
Reject H0*	0.045	r = 0.82	Pearson	The third
Reject H0	0.012	H = 14.72	Kruskal-Wallis	Fourth
Reject H0	0.018	F = 3.89	ANOVA	Fifth
Reject H0	0.006	F = 5.72	ANOVA	Sixth

4. Discussion of the results

The results of this research show that complexity with divalent nickel ion enhances the bioactivity of Schiff base lions significantly and consistently, as all the prepared complexes outperformed the free lions in antibacterial and antifungal activity with significant statistical differences. This conclusion is consistent with the findings of previous studies that have confirmed that bioactivity is increased by complexity due to improved polarity, lipid solubility, and the effect of chelation, which promotes cellular penetration [8].

The analysis of the first hypothesis revealed that there are statistically significant differences between complexes with different geometric arrangements in antibacterial activity in favor of octahedral complexes, reinforcing the idea that geometric arrangement is not just a structural property but a functional determinant that influences the bioreaction of the complex. The strong direct correlation between magnetic momentum and bacterial bioactivity revealed by Hypothesis III (r = 0.82) adds a new dimension to this relationship, suggesting that magnetic properties may be a predictive indicator of bioactivity in nickel chelation complexes. Notably, Ni-L3 achieved the highest bioactivity of all complexes with the lowest inhibitory concentration value for most strains, which may be attributed to the nature of the cyclohexylamine used in the preparation of this ligand, which gives the complex a suitable spatial structure to interact with biological targets.

5. Conclusions

1. The research successfully prepared six ligands of the novel Schiff bases derived from 2-hydroxy-1-naphthaldehyde and six corresponding chelated nickel complexes, all of which were diagnosed using the available spectral and analytical techniques.
2. All chelated nickel complexes showed antibacterial and antifungal bioactivity statistically significantly higher than the corresponding free lycans, with lower inhibitory concentration values ranging from 6.25 to 100 μg/mL.
3. All prepared complexes have paramagnetic qualities with magnetic moment values ranging from 2.87 to 3.35 bormagneton, which corresponds to the presence of two unpaired electrons and an octahedral or tetrahedral geometric arrangement.
4. There is a statistically significant difference in bioactivity between complexes with different geometric arrangements in favor of octahedral complexes ($F = 12.56$, $p < 0.001$).
5. There is a statistically significant direct correlation between magnetic moment and bioactivity towards bacteria ($r = 0.82$, $p = 0.045$), suggesting that magnetic moment can be used as a predictive indicator.
6. The type of lycan has a statistically significant effect on both the magnetic sensitivity ($F = 3.89$, $p = 0.018$) and bioactivity ($F = 5.72$, $p = 0.006$) of nickel chelated complexes.
7. Ni-L3 achieved the highest bioefficacy among the complexes studied with the lowest inhibitory concentration value (6.25 μg/mL) towards S. aureus and E. coli.

6. Recommendations

1. Conducting quantitative studies on the prepared complexes to predict their electronic, magnetic and biological properties and compare them with the experimental values.
2. Expand the scope of bioassessment to include cytotoxicity, anti-cancer and antiviral activity studies.
3. Study the mechanism of interaction between complexes, DNA, and proteins at the molecular level using molecular docking techniques.
4. Preparation of nickel complexes with multi-tooth ligands and study the effect of increasing the consistency function on magnetic and biodynamic properties.
5. Studying the feasibility of employing complexes with promising magnetic properties in bioimaging and targeted drug delivery applications.
6. Conduct kinetic and thermodynamic studies of complexity reactions to determine optimal conditions for preparation and factors affecting the final product.

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