

# Synthesis, Characterization and Antibacterial Evaluation of New Lanthanum(III) Complexes Containing Schiff Base and Amino Acid Ligands

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**Abstract:** A series of novel lanthanum (III) mixed ligand complexes of type  $[La(DBAP)_2(L) \cdot 2H_2O]$  have been successfully synthesized using a DBAP Schiff base obtained from condensation of 4-dimethylaminobenzaldehyde with 2-aminophenol as the primary ligand, along with L-alanine, L-serine, and L-leucine as secondary ligands. The synthesized La(III) metal chelates were systematically characterized through UV-Visible and FTIR spectroscopy, elemental analysis, magnetic susceptibility, and molar conductance measurements. The FTIR spectral studies confirmed the coordination of La(III) metal ion to DBAP Schiff base and amino acid through nitrogen and oxygen donor atoms respectively. The electronic absorption spectrum of La(III) metal complexes reveal characteristic intra-ligand transitions along with ligand-to-metal charge transfer (LMCT) transition. Magnetic studies established the diamagnetic behaviour of the complexes, in agreement with the  $4f^0$  electronic configuration of La(III), and conductivity measurements suggested their non-electrolytic nature. The antimicrobial activity of the synthesized Schiff base and its corresponding complexes was assessed against *Escherichia coli*, *Shigella sonnei*, *Staphylococcus aureus*, and *Bacillus subtilis* by employing the agar well diffusion technique. The results demonstrated that the synthesized La(III) metal complexes showed enhanced antibacterial activity in comparison with the uncoordinated ligand and the corresponding metal salt.

**Keywords:** Antibacterial activity, 2-aminophenol, Mixed ligand complex, Amino acids, 4-dimethylamino benzaldehyde

## 1. Introduction

Schiff bases have been extensively investigated in coordination and bioinorganic chemistry. Some transition metal complexes containing Schiff base ligands are well known for their antimicrobial, antifungal, antioxidant and anti-cancer activities [1-4]. Furthermore, mixed-ligand complexes of lanthanides with Schiff base ligands and amino acids have been reported to possess good antibacterial activity [5, 6]. Numerous mixed ligand complexes of lanthanum showed potent antibacterial activity [7-9]. The synthesis and characterization of mixed ligand complexes of transition metals with Schiff base derived from 4-dimethylamino Benzaldehyde with 2-aminophenol have also been extensively reported [10,11].

This research work describes the synthesis, coordination studies and biological evaluation of mixed ligand lanthanum(III) complexes with Schiff base derived from 4-dimethylaminobenzaldehyde and 2-aminophenol as the primary ligand and numerous amino acids (L-alanine, L-serine and L-leucine) as secondary ligands.

## II. MATERIAL

All reagents and solvents employed in the present study were of analytical grade. The chemicals used include lanthanum chloride heptahydrate ( $LaCl_3 \cdot 7H_2O$ ), ethanol ( $C_2H_5OH$ ), 2-aminophenol, dimethyl sulfoxide (DMSO), 4-



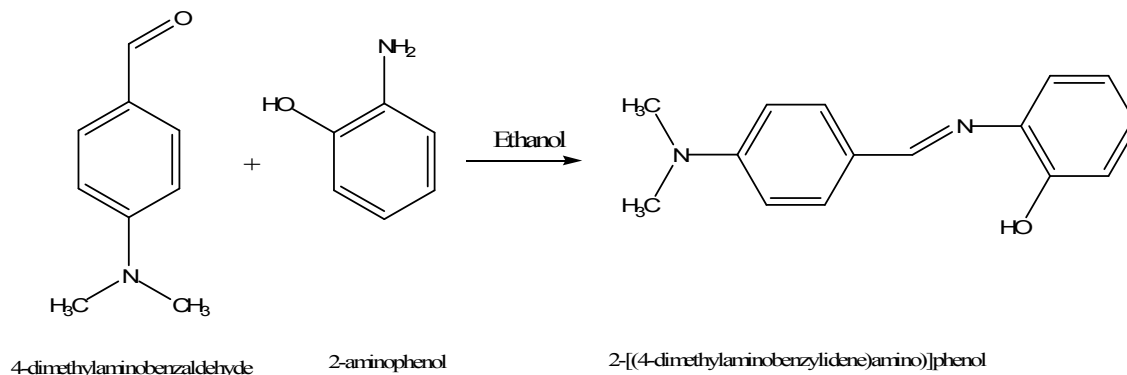
dimethylaminobenzaldehyde, L-alanine, L-serine, L-leucine and dimethylformamide (DMF). All chemicals were procured from Loba Chemie laboratory and used without further purification.

### III. METHODS

The CHN contents of the synthesized mixed ligand La(III) complexes were determined using a Thermo Finnigan elemental analyser. Infrared spectra were recorded in the range 4000–400  $\text{cm}^{-1}$  using KBr pellet discs on an FT-IR spectrophotometer. Electronic absorption spectra were obtained using a Shimadzu UV-Vis 1800 spectrophotometer. Magnetic susceptibility of the chelates was determined by the Gouy balance technique, using  $\text{Hg}[\text{Co}(\text{SCN})_4]$  as the standard reference compound for calibration. The molar conductance of the synthesized metal complexes was measured at a concentration of 0.001 M in DMF using an Equiptronics auto-ranging conductivity meter.

#### SYNTHESIS OF SCHIFF BASE

The Schiff base ligand (DBAP), was synthesized via a condensation reaction between 4-dimethylaminobenzaldehyde (0.02 M, 2.98 g) and 2-aminophenol (0.02M, 2.18g) in equal volume ( $25\text{cm}^3$ ) of ethyl alcohol. The reaction mixture was refluxed under continuous stirring for 1 hour. The obtained yellow solid product was isolated by filtration, washed with cold ethanol, and dried under vacuum. The synthesis of the Schiff base ligand (DBAP) is illustrated in Scheme 1.



Scheme 1: Synthesis of Schiff base (DBAP) ligand

#### SYNTHESIS OF MIXED-LIGAND LANTHANUM(III) COMPLEXES

An ethanolic solution of the Schiff base ligand (20 mL, 0.001 mol; 0.481 g) was added drop wise to an aqueous solution of lanthanum(III) chloride heptahydrate (10 mL, 0.001 mol; 0.372g) under constant magnetic stirring. After complete addition, an aqueous solution of the respective amino acid (10 mL, 0.001 mol) was introduced slowly into the reaction mixture.

The pH of the solution was carefully adjusted to approximately 8.5 by gradual addition of dilute ammonium hydroxide solution to facilitate complex formation. The resulting mixture was refluxed for about 2 hours to ensure complete coordination. Upon cooling to room temperature, a reddish-brown solid separated out. The precipitated complex was filtered, washed several times with ethanol to remove residual impurities, and dried under reduced pressure. The obtained precipitate of lanthanum (III) complexes were subjected to various spectroscopic studies to establish their structure. Additionally, their antibacterial activity was investigated using standard microbiological assays.

#### ANTIBACTERIAL SCREENING

The antibacterial potential of the synthesized La(III) metal complexes was examined by employing the agar well diffusion technique against *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, and *Shigella sonnei*. Mueller–Hinton agar medium was sterilized, inoculated with freshly prepared bacterial suspensions, and dispensed aseptically



into sterile Petri dishes. After solidification of the medium, uniform wells (8 mm in diameter) were created using a sterile cork borer. Test samples were dissolved in dimethylformamide (DMF) to obtain a concentration of 1 mg/mL, and an appropriate volume of each solution was carefully introduced into the respective wells under aseptic conditions. The inoculated plates were then incubated at 37 °C for 24 h. Following incubation, the antimicrobial efficacy of the complexes was assessed by measuring the diameter of the clear inhibition zones formed around each well. Tetracycline served as the standard drug to compare the antibacterial performance of the synthesized metal complexes.

#### IV. RESULT AND DISCUSSION

The synthesis reaction of lanthanum (III) metal complexes incorporating the DBAP Schiff base and various amino acids is shown below.



Where, DBAP = 2-[(4-(dimethyl amino)benzylidene amino)]phenol, HL = L-alanine/ L-serine/ L-leucine.

The lanthanum (III) mixed-ligand complexes were isolated as reddish-brown crystalline solids. The synthesized chelates displayed limited solubility in polar aprotic solvents such as DMF and DMSO, whereas they were insoluble in water and in most conventional organic solvents. All complexes decomposed at comparatively elevated temperatures, reflecting the formation of thermally stable coordination compounds. The molar conductance values recorded in DMF were found to be low, signifying the non-electrolytic nature of the complexes in solution.

The elemental (CHN) analytical results (Table 1) were found to be consistent with the calculated values, thereby supporting a 1:2:1 stoichiometric proportion of metal to Schiff base and amino acid ligands. These findings are in accordance with the proposed molecular formula,  $[\text{La}(\text{DBAP})_2(\text{L}) \cdot 2\text{H}_2\text{O}]$ , for the synthesized lanthanum(III) mixed-ligand complexes.

**TABLE 1 : THE PHYSICOCHEMICAL AND ELEMENTAL ANALYTICAL DATA OF La(III) COMPLEXES.**

Complex	M. P (°C)	Color	Empirical Formula	Formula Weight (g)	Elemental Analysis (%)			
					La Obs (Cal.)	C Obs (Cal.)	H Obs (Cal.)	N Obs (Cal.)
$[\text{La}(\text{DBAP})_2(\text{Ala}) \cdot 2\text{H}_2\text{O}]$	210	Reddish Brown	$\text{C}_{33}\text{H}_{40}\text{LaN}_5\text{O}_6$	741.61	18.70 (18.73)	53.40 (53.45)	5.42 (5.44)	9.45 (9.44)
$[\text{La}(\text{DBAP})_2(\text{Ser}) \cdot 2\text{H}_2\text{O}]$	230	Reddish Brown	$\text{C}_{33}\text{H}_{40}\text{LaN}_5\text{O}_7$	757.61	18.32 (18.33)	52.30 (52.32)	5.29 (5.32)	9.26 (9.24)
$[\text{La}(\text{DBAP})_2(\text{Leu}) \cdot 2\text{H}_2\text{O}]$	225	Reddish Brown	$\text{C}_{36}\text{H}_{46}\text{LaN}_5\text{O}_6$	783.69	17.70 (17.72)	55.19 (55.17)	5.89 (5.92)	8.90 (8.94)

(Ala= L-alanine, Ser = L-serine, and Leu = L-leucine)

#### FTIR SPECTROSCOPIC STUDY OF THE COMPLEXES

The FT-IR spectra of the synthesized lanthanum mixed-ligand complexes (Table 2) display a broad band in the region 3327–3355  $\text{cm}^{-1}$ , which can be attributed to the stretching vibration of coordinated water molecules [11,12]. In contrast, the spectra of the uncoordinated amino acids exhibit characteristic absorptions at 2960–3066  $\text{cm}^{-1}$  and 3427–3462  $\text{cm}^{-1}$  corresponding to the stretching modes of the carboxylate ( $\text{COO}^-$ ) and amino ( $\text{NH}_2$ ) groups, respectively. Upon complexation, the disappearance of the distinct  $\text{COO}^-$  band along with the merging of the  $\text{NH}_2$  stretching band into the broad water-related absorption suggests coordination through both the carboxylate oxygen and amino nitrogen atoms.

The azomethine ( $-\text{HC}=\text{N}-$ ) stretching vibration, observed at 1583  $\text{cm}^{-1}$  in the free Schiff base ligand, undergoes a slight shift to 1581–1587  $\text{cm}^{-1}$  in the complexes, indicating the participation of the imine nitrogen in metal binding. Additionally, the appearance of new bands in the ranges 594–597  $\text{cm}^{-1}$  and 452–461  $\text{cm}^{-1}$  absent in the spectra of the free ligands, are assignable to M–O and M–N stretching vibrations, respectively. Collectively, these spectral features



substantiate the coordination of lanthanum through oxygen and nitrogen donor atoms derived from the azomethine and hydroxyl functionalities, leading to chelate formation. The FT-IR spectra of the La(III) complexes and uncoordinated Schiff base ligand, are depicted in Figures 1–4.

**TABLE 2: IR SPECTRAL DATA OF SYNTHESIZED LANTHANUM MIXED-LIGAND COMPLEXES**

Sr. No.	Complex	FT-IR Peaks (cm <sup>-1</sup> )					
		$\nu$ O-H	$\nu$ COO A. A.	$\nu$ NH <sub>2</sub> A. A.	$\nu$ C=N (SB)	$\nu$ M-N	$\nu$ M-O
1	Schiff base (DBAP)	3342	-	-	1583	-	-
2	L-alanine	-	3041	3462	-	-	-
3	L-serine	-	3066	3448	-	-	-
4	L-leucine	-	2960	3427	-	-	-
5	[La(DBAP) <sub>2</sub> (Ala)2H <sub>2</sub> O]	3355	-	-	1587	461	597
6	[La(DBAP) <sub>2</sub> (Ser). 2H <sub>2</sub> O]	3337	-	-	1581	452	596
7	[La(DBAP) <sub>2</sub> (leu)2H <sub>2</sub> O]	3327	-	-	1584	453	594

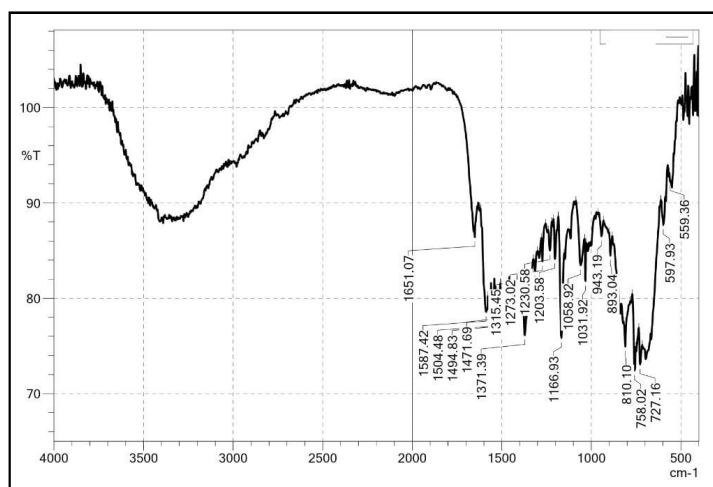


Figure 1. FTIR Spectra of [La(DBAP)<sub>2</sub>(Ala)<sub>2</sub>H<sub>2</sub>O]



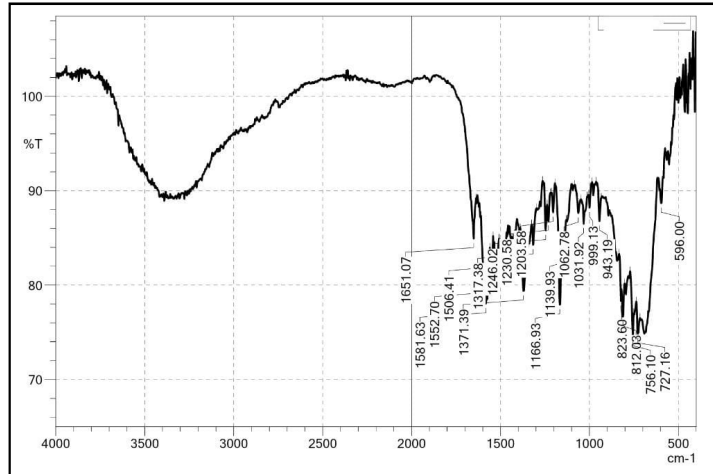


Figure 2. FTIR Spectra of [La(DBAP)<sub>2</sub>.(Ser)<sub>2</sub>H<sub>2</sub>O]

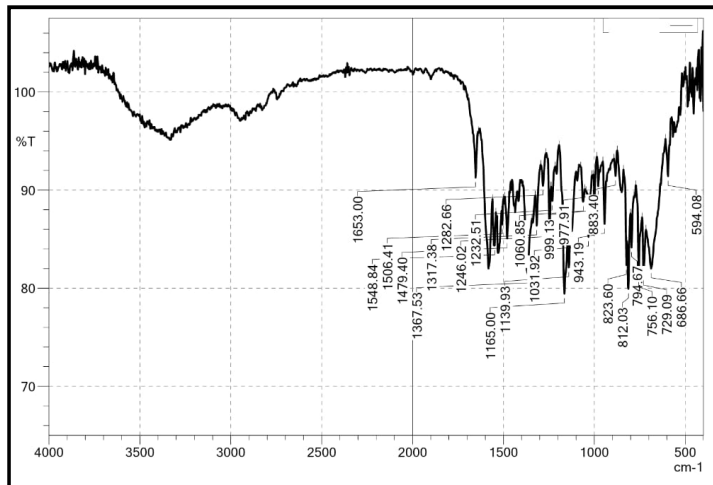


Figure 3. FTIR Spectra of [La(DBAP)<sub>2</sub>.(Leu)<sub>2</sub>H<sub>2</sub>O]

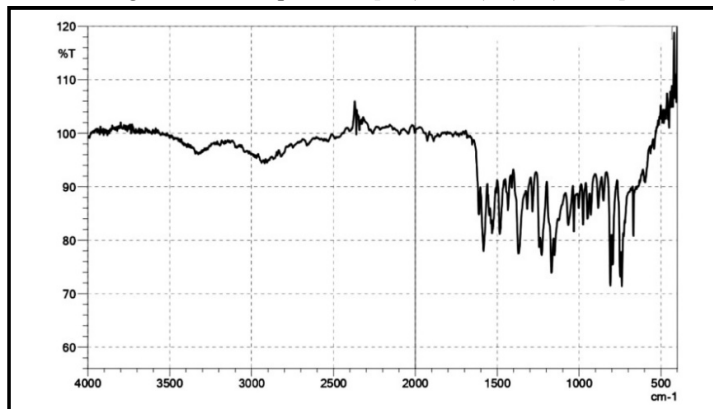


Figure 4. FTIR Spectra of Schiff base (DBAP)

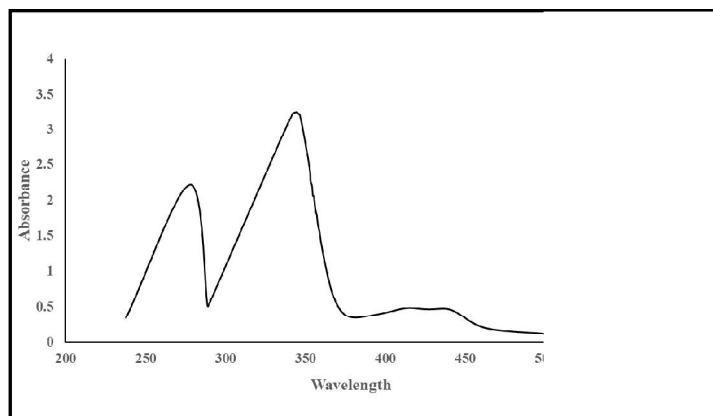


### UV-VISIBLE SPECTROSCOPIC STUDY

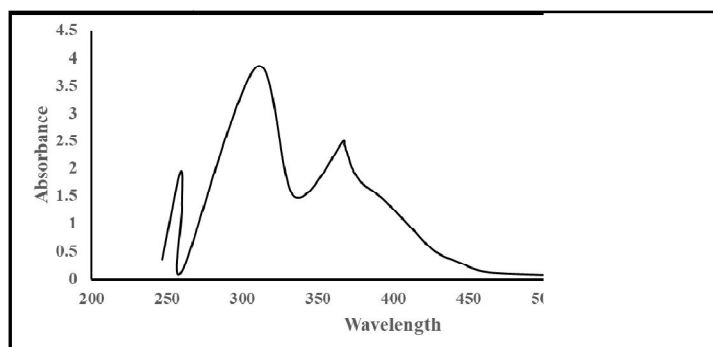
UV-Visible spectrum of synthesized Lanthanum complexes were obtained in DMF solution at a concentration of  $1 \times 10^{-3}$  M. As summarized in Table 3 and Figures 5–7, the spectra display three distinct absorption maxima located within the ranges 261–277 nm, 339–345 nm, and 426–426 nm. The high-energy bands are attributed to intra-ligand  $\pi \rightarrow \pi^*$  and  $n \rightarrow \pi^*$  transitions, while the lower-energy bands are assigned to ligand-to-metal charge transfer (LMCT) transitions [13,14].

**TABLE 3 : UV-VISIBLE SPECTROSCOPIC DATA OF LANTHANUM COMPLEXES.**

Complex	$\nu$ ( $\text{cm}^{-1}$ )	$\lambda$ (nm)	Assignments
[La(DBAP) <sub>2</sub> .(Ala).2H <sub>2</sub> O]	3610.10	277	$\pi \rightarrow \pi^*$
	2898.55	345	$n \rightarrow \pi^*$
	2409.63	415	L→M
[La(DBAP) <sub>2</sub> (Ser.)2H <sub>2</sub> O]	3773.58	265	$\pi \rightarrow \pi^*$
	2923.97	342	$n \rightarrow \pi^*$
	2375.29	421	L→M
[La(DBAP) <sub>2</sub> .(Leu)2H <sub>2</sub> O]	3831.41	261	$\pi \rightarrow \pi^*$
	2949.85	339	$n \rightarrow \pi^*$
	2347.41	426	L→M



**Figure 5. UV-Vis. Spectra of [La(DBAP)<sub>2</sub>.(Ala).2H<sub>2</sub>O]**



**Figure 6. UV-Vis. Spectra of [La(DBAP)<sub>2</sub>.(Ser).2H<sub>2</sub>O]**



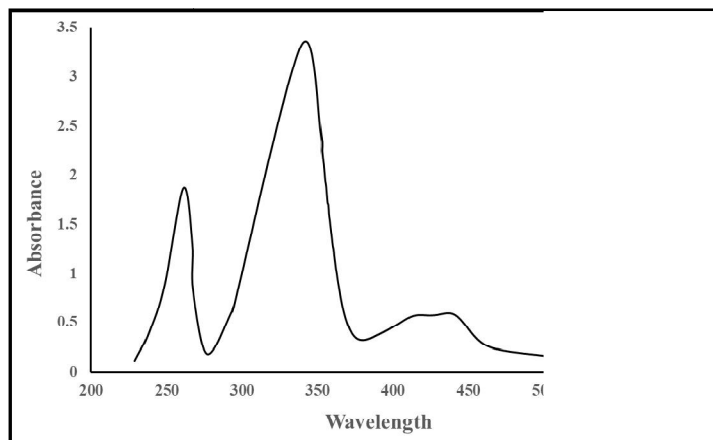


Figure 7. UV-Vis. Spectra of  $[La(DBAP)_2.(Leu).2H_2O]$

#### MAGNETIC SUSCEPTIBILITY AND CONDUCTANCE INVESTIGATIONS

Magnetic susceptibility measurements performed on the synthesized La(III) complexes, after applying appropriate diamagnetic corrections, indicated the absence of unpaired electrons, thereby confirming their diamagnetic character[15]. Furthermore, molar conductance measurements in DMF at a concentration of 0.001 M exhibited very low conductivity values in the range of 0.130–0.270 Mho  $cm^2 mol^{-1}$  (Table 4). These results suggest that the all La(III) complexes behave as non-electrolytes in solution [16].

TABLE 4: ELECTRICAL CONDUCTANCE AND MAGNETIC SUSCEPTIBILITY DATA OF La(III) COMPLEXES

Complex	( $X_m$ )	( $X_g$ )	$\mu_{eff}$ (B.M.)	( $\Delta m$ ) (Mhos $cm^2 mol^{-1}$ )
$[La(DBAP)_2.(Ala)2H_2O]$	$- 0.260 \times 10^{-3}$	$- 0.350 \times 10^{-6}$	Diamagnetic	0.000240
$[La(DBAP)_2.(Ser.)2H_2O]$	$- 0.257 \times 10^{-3}$	$- 0.339 \times 10^{-6}$	Diamagnetic	0.000110
$[La(DBAP)_2.(Leu)2H_2O]$	$- 0.282 \times 10^{-3}$	$- 0.360 \times 10^{-6}$	Diamagnetic	0.000130

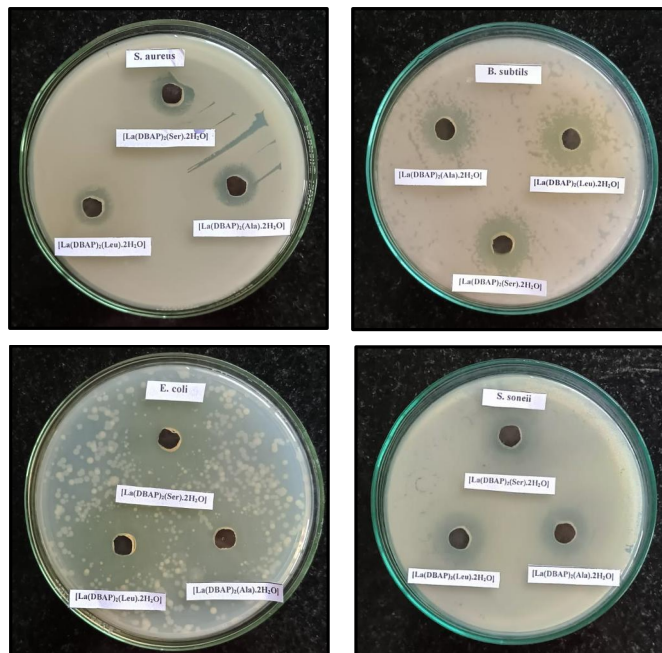
#### ANTIBACTERIAL ACTIVITY

The antibacterial activity of the synthesized lanthanum(III) complexes was tested using the agar cup method. The compounds were evaluated against *Shigella sonnei*, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus subtilis* to determine their antibacterial effectiveness. The results of the agar cup method (Table 5 and Figure 8) indicated that all synthesized lanthanum complexes showed greater sensitivity against *B. subtilis* and *E. coli* compared to *S. aureus* and *S. sonnei*. The increased antibacterial activity of lanthanum complexes can be explained by the chelation effect. When the ligand binds to the metal ion, the overall polarity of the metal decreases. At the same time, the complex becomes more lipophilic. This increase in lipophilicity helps the compound to pass more easily through the lipid membrane of microorganisms, resulting in better antibacterial activity [17-19].



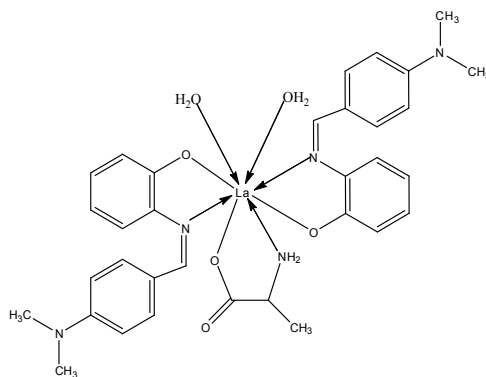
**TABLE 5: ANTIMICROBIAL EFFECTIVENESS OF MIXED-LIGAND La(III) COMPLEXES (MM)**

Sr. No.	Complexes	Zone of Inhibition in mm			
		<i>S. Aureus</i>	<i>B. subtilis</i>	<i>S. sonnei</i>	<i>E. coli</i>
1	[La(DBAP) <sub>2</sub> (Ala).2H <sub>2</sub> O]	15	25	20	25
2	[La(DBAP) <sub>2</sub> (Ser). 2H <sub>2</sub> O]	14	24	20	27
3	[La(DBAP) <sub>2</sub> (Leu).2H <sub>2</sub> O]	16	23	19	27



**Figure 8. Zone of Inhibition of synthesized lanthanum complexes**

From the physical properties and spectral analysis data, the proposed structures of the reported mixed-ligand complexes of lanthanum are illustrated in Figures 9, 10 and 11 respectively.



**Figure 9: Proposed structure of [La(DBAP)<sub>2</sub>(Ala).2H<sub>2</sub>O]**



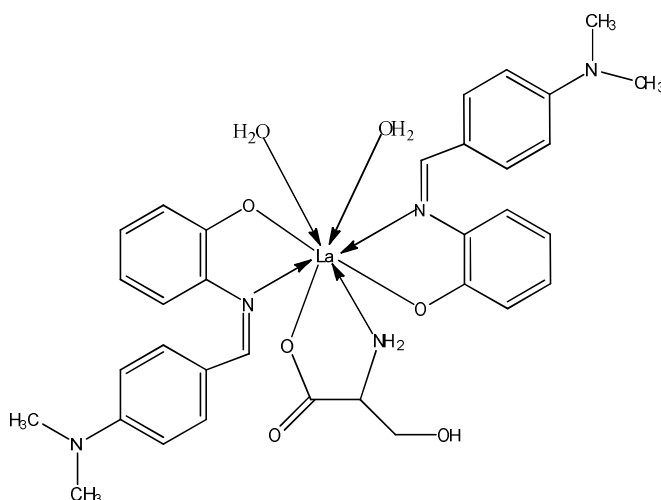


Figure 10: Proposed structure of  $[La(DBAP)_2(Ser) \cdot 2H_2O]$

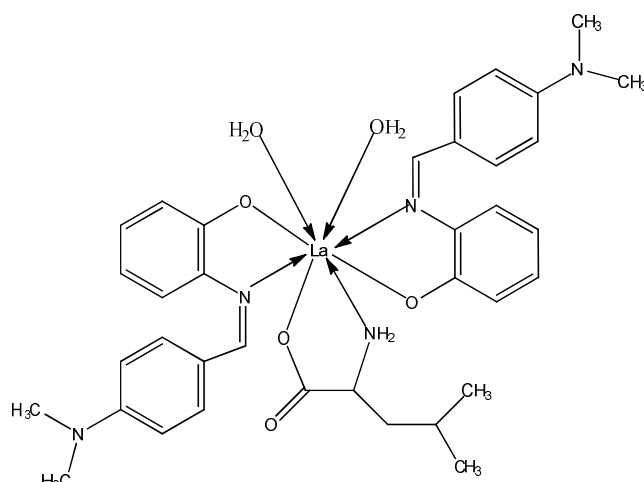


Figure 11: Proposed structure of  $[La(DBAP)_2(Leu) \cdot 2H_2O]$

## V. CONCLUSIONS

In conclusion, we have successfully synthesized a new mixed-ligand lanthanum(III) complexes containing a Schiff base (DBAP) and amino acids. The synthesized new complexes were characterized different physical and spectroscopic methods. Spectral analysis confirmed that both the Schiff base and amino acid molecules coordinated to the lanthanum ion through Nitrogen & Oxygen donor atoms respectively. The overall results suggest that the lanthanum (III) ion has an eight-coordinate arrangement. Furthermore, the molar conductivity studies showed that synthesized La(III) complexes behave as non-electrolytes in solution. The synthesized complexes exhibited better antibacterial activity than the free ligands, indicating that coordination of ligand with the metal ion enhances their biological activity. Overall, the investigation provides useful information about the synthesis of new lanthanum mixed-ligand complexes and their possible applications in bioinorganic and medicinal chemistry research.



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## REFERENCES

- [1]. F.S. Nworie, F.I. Nwabue, N.I. Elom and S.O. Eluu, "Schiff bases and schiff base metal complexes: from syntheses to applications", *J. basic appl. Res. Biomed.*, 2(3), 295-305, 2016.
- [2]. R. Malav and S. Ray, "Recent advances in the synthesis and versatile applications of transition metal complexes featuring Schiff base ligands", *RSC*, 15, 22889-22914, 2025.
- [3]. M. Chinnasamy, N. Venkatesh, P. Marimuthu, G. Sathiyam, S. Ali Alfarbi, G. Venkatesan, "Synthesis, characterization, and biological evaluation of novel bioactive Schiff base metal complexes and their molecular docking studies", *J. Environ. Chem. Eng.*, 13(2), 115835, 2025.
- [4]. S. N. Unki, V. Kumar, A. Kalabandi and M. R. Karekal, "Synergistic Antimicrobial and Antioxidant Effects of Indole Schiff Base-Metal (II) Complexes: A Dual Approach", *Chem Biodivers.*, 22(11), 1-13, 2025.
- [5]. B. Shyni, J. P. Remiya and T.S. Sikha, "Synthesis, Characterization and Applications of Some Lanthanide(III) Complexes with Schiff Base Derived from L-Valine and Vanillin", *Asian J. Chem.*, 36(7), 2024.
- [6]. Shatha M. H. Obaid, "Synthesis, Spectral and Antibacterial Activity of Mixed Ligand from Lanthanum (III) Complexes of Schiff Base Ligand with Some Amino Acids", *JGPT*, 11(03), 88-99, 2019.
- [7]. B. D. Aghav and R. S. Lokhand, "Study of the ternary complexes of lanthanum with 2, 3-dimethyl-1-phenyl-4-salicylidene-3-pyrazolin-5-one and some Amino Acids", *J. Chem. Pharm. Res.*, 8(6), 380-386, 2016.
- [8]. G. A. Thakur, U. N. Dhaigude and P. B. Thakur, "Synthesis, Spectral Characterization and Antibacterial Studies of Mixed Ligand La (III) and Ce (III) Complexes Derived From 1-nitroso-2-naphthol and Some Amino Acids", *Orient. J. Chem.*, 36(4), 632-639, 2020.
- [9]. G. A. Thakur, U. N. Dhaigude And S. S. Patil, "Some mixed ligand complexes of Lanthanum (III) Using 1-Nitroso-2-naphthol and amino acids", *Asian J. Chem.*, 30(7), 1585-1589, 2018.
- [10]. M. M. El-ajaily, A. A. Maihub, U. K. Mahanta, G. Badhei, R. K. Mohapatra and P. K. Das, "Mixed Ligand Complexes Containing Schiff Bases And Their Biological Activities: A Short Review", *Rasayan J. Chem.*, 11(1), 166-174, 2018.
- [11]. F. S. Alassbaly, A. A. Maihub, S. F. Ben-Gweirif, M. M. El-ajaily and T. H. Al-Noor, "Chelation Trends and Antibacterial Activity of Some Mixed Ligand Chelates", *Saudi J. Pathol. Microbiol.*, 1(2), 29-35, 2016.
- [12]. M. M. El-ajaily, N. S. Al-barkil and A. A. Maihub, "Mixed Schiff Bases Chelates: Synthesis and Spectroscopic Investigation", *Asian J. Adv. Basic Sci.*: 4(2), 123-130, 2016.
- [13]. V. Sathiyarayanan, P. V. Prasath, P. C. Sekhar, K. Ravichandran, D. Easwaramoorthy, F. Mohammad, H. A. Al-Lohedan, Won Chun Oh, and S. Sagadevan, "Docking and in vitro molecular biology studies of p-anisidine-appended 1-hydroxy-2-acetonaphthone Schiff base lanthanum(III) complexes", *RSC Adv.*, 10, 16457-16472, 2020.
- [14]. R. J. Wani, A. Hussain, M. Ud Din Sheikh, M. N. Bukhari, M. Fatima and G. Ali, "Synthesis of mono and hetero-bi nuclear lanthanum (III) and europium (III) complexes", *J Mater. Sci: Mater Eng.*, 20(64), 1-16, 2025.
- [15]. S. Patil, B. Langi, M. Gurav and D. Patil, "Studies of Mixed Ligand Lanthanum Complexes: Synthesis, Spectral Interpretations and Antibacterial Study", *J. Pharm. Res. Int.*, 3(37), 161-174, 2021.



- [16]. M. Gopal and S. Sasi, Synthesis and Structural Characterization of Lanthanum(III) Complexes of 4-Nitrosoantipyrine”, *Asian J. Chem.*, 33(3), 617-621, 2021.
- [17]. N. Kumar, R. Kaushal and P. Awasthi, “Transition Metal Complexes as Antibacterial Agents: An Overview”, *J. Fluoresc.*, 35(10), 10445-10461, 2025.
- [18]. S. A. Al-Harbi, M. S. Bashandy and H. M. Al-Saidi, A. A. Ahmed Emara and S. M. Abd El-Gilil, “Spectroscopic properties, anti-colon cancer, antimicrobial and molecular docking studies of silver(I), manganese(II), cobalt(II) and nickel(II) complexes for 2-amino-4-phenylthiazole derivative”, *Eur. J. Chem.*, 7(4), 421-430, 2016.
- [19]. M. Abu-Dief, T. El-Dabea, R. M. El-Khatib, A. Abdou, M. Abd El Aleem Ali Ali El-Remaily, “Development of New Mixed Cu(II) Chelate Based on 2- Benzimidazolylguanidine and Phenanthroline Ligands: Structural Elucidation, Biological Evaluation, DFT and Docking Approaches”, *Sohag J. Sci.*, 9(2), 174-185 2024.

