The Bioscan AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES 21(3): 549-561, 2026 www.thebioscan.com

# Preparation and Analysis of Mixed Ligand Lanthanum Complexes involving determination of their Physicochemical, Spectral, Thermal properties and Antibacterial Investigation.

**Digambar Patil[1*], Vishal Kamble[1], Jitendra Pawara[1], Hrishikesh Deokar[2] ,Kaustubh Mundhe[1]**

[1]Department of Chemistry, Changu Kana Thankur, Arts, Commerce and Science College, New Panvel, Maharashra, India.(Empowered Autonomous)

[2]Department of Chemistry, S.D.Arts,V.S.Apte Commerce and M.H.Mehta Science College, Palghar, Maharashtra, India.

DOI: https://doi.org/10.63001/tbs.2026.v21.i03.pp549-561

**KEYWORDS**
*Amino acids, ligand, complexes, antibacterial activity*

**Received on:**
30-06-2026
**Accepted on:**
25-07-2026
**Published on:**
31-07-2026

## Abstract

The mixed ligand lanthanum (III) metal complexes are prepared from ortho hydroxylbenzaldehyde oxime ( OHBO) and chemical compounds L-alanine, L-isoleucine, L-proline, L-phenylalanine. All complexes are off white in colour and stable solids. The non-electrolyte nature of all the new synthesized complexes confirmed by conductometric measurement. The infrared study of lanthanum complexes reveals the strong metal ligand bonding by the oxygen and nitrogen atoms in the complexes. magnetic susceptibility also shows that the mixed ligand complexes are paramagnetic nin nature. The differential thermal analysis and thermo gravimetric measurement indicates the presence of coordinated water molecules The high decomposition temperature of the complexes shows the strong metal ligand bonding within complex molecules. UV-Visible spectroscopy clears the intra ligand and LCMT transitions in the complexes. complexes are formed in 1:2:1 ratio indicating by Elemental analysis. Agar cup method and Tube dilution method are employed for antibacterial detection of lanthanum (III) metal complexes which indicates that complexes exhibit antibacterial activity against selected strains of bacterial

## Introduction

In the recent years, synthesis of complexes of transition and inner transition elements from two or more different ligands is the topic of interest for many researchers as the mixed ligand complexes have more stability. It is known that in the biological systems, these complexes play the crucial role.[1-2] There are numerous mixed ligand complexes which are studied as they are showing various biological activities like anticancer, antifungal, antibacterial [3-7] Large number of ligands containing different donor atoms like O,N are used for the synthesis of mixed ligand complexes to find their antidiabetic and antituberculosis activities[8-9] Mixed ligand complexes of lanthanides mainly cerium metal with amino acids are prepared and characterized and studied for their various biological activities like antibacterial, antimicrobial activities etc.[10-13] The amino

acids containing N,O,S donor atoms with the active groups like –NH2, --SH and –COOH have ability to form metal complexes, received lots of interest showing vital biological activities are also prepared and characterized.[14-17] The mixed ligand complexes also employed in various field like acts as catalyst in many reactions such as hydroformylation, reduction, oxidation, oxidative cleavage, decomposition of hydrogen peroxide etc. and thus get their share of attention. Preparation of cerium metal complexes, their characterization and antibacterial investigation have been also reported by many researchers.[18-20] Keeping these various facts in mind emerging through the literature survey, we reported here the synthesis of mixed ligand complexes of Cerium metal by using Salicylaldoxime as primary ligand and various amino acids L-Valine, L-Glycine, L-Hydroxy proline, L-Threonine as secondary ligands. All the complexes were characterized by Spectral and Physico-chemical methods. Determination of molar conductance, $p^H$ , magnetic susceptibility of the complexes as well as Elemental analysis, UV-Visible, FTIR spectral, Thermal analysis were carried out. Antibacterial investigation of the complexes also performed.

**Methodology**

**2.1 Materials :**

The compounds required , Lanthanum III)chloride heptahydrate, ortho hydroxylbenzaldehyde oxime ,L-alanine, L-isoleucine, L-proline, L-phenylalanine were purchased from S.D. Fine Chemicals, Mumbai, and taken for the synthesis of the mixed ligand complexes. The analytical grade solvents dimethyl sulphoxide, dimethyl formamide, acetone, ethanol were used and purified by using standard protocol.[21-22]

**2.2 Instrumentation :**

Electric conductance of all lanthanum complexes were measured by Equiptronics Autoranging Conductivity Meter Model No. EQ-667 by preparing 0.001 M solution of complexes in DMSO solvent. C, H and N content were measured on Elementar Unicube at Spring Testing Solutions Laboratory, Mumbai . Thermal behavior of the Lanthanum complexes were recorded in controlled nitrogen atmosphere on a TGA 5500 by water at Spring Testing Solutions Laboratory, Mumbai at the heating rate of 10◦C per minute on increasing temperature up to 900◦C. UV spectra of the all lanthanum complexes were recorded in $10^{-3}$ M solution in DMSO on Shimadzu UV/VIS-1900 spectrophotometer in the ultraviolet and visible region of 200 nm to 800 nm range. Shimadzu FT-IR spectrophotometer of IRAffinity$^{-1}$ was utilized to report the Infrared spectra of all the complexes in KBr disc in the region 4000-400

$cm^{-1}$ on Aligant Microlab Carry 630 IR instrument. Both Electronic absorption spectra and FTIR were measured at Spring Testing Solutions Laboratory, Mumbai .

**2.3 Synthesis of mixed ligand Complexes :**

The alcoholic solution (10 ml) of lanthanum (III) chloride heptahydrate (371 mg. 1mmol) was prepared. The alcoholic solution (10 ml) of ortho hydroxylbenzaldehyde oxime (OHBO) (274 mg, 2mmol) was mixed with constant stirring by using magnetic stirrer. Then all the reaction mixture was kept in boiling water bath for 20-30 minutes with stirring. Then to this hot reaction mixture , the aqueous solution of secondary ligand compound was added dropwise with constant stirring. The whole reaction mass was then heated for 10-15 minutes in a water bath at 50 °C. The lanthanum complex was then precipitated by raising the pH of reaction mixture.. The whole reaction mixture was cooled and solid complex was filtered then it was washed by water followed by using ethanol. All the complexes were air dried for 24 hours and utilized for further study

**2.4 Antibacterial Screening :**

**2.4.1 Tube Dilution Method**

This method was employed to determine the minimum inhibitory concentration (MIC) of complexes. mixed ligand Lanthanum (III) complexes were subjected to *in vitro* screening against the selected strains of bacteria S. aureus, C. diphtheriae, S. typhi and P. aeruginosa using Muller Hinton broth as the culture medium. Stock solution of concentration 1000 µg/cm3 was obtained by dissolving the test compound of 10 mg in 10 cm3 of DMSO solvent. After successfully preparing the stock solution, the various aliquots of 5, 10, 15, 20 to …., 250 µg/cm3 were obtained in test broth. Preparation of Bacterial inoculums in sterilized Muller Hinton broth and their incubation in refrigerator for 24 hrs. at $37^0$C was performed. Aliquots were then dispensed in borosilicate test tube of diameter 150 x 20 mm and the bacterial inoculums 0.1 cm3 of the desired bacterial strain (S. aureus, C. diphtheriae, S. typhi and P. aeruginosa) containing $10^6$ bacteria/cm3 was inoculated in the tube. The tubes were kept on a rotary shaker for 24 h at $37^0$C for incubation. On the next day, the presence or absence of the growth of the test organisms was observed to find the MIC of complexes. Tetracycline was used as standard control and MIC of tetracycline against selected strain of bacteria was compared with test compound.

**2.4.2 Agar Cup Method**

Lanthanum (III) metal were subjected to check their antibacterial activity against the selected

strains of bacteria, S. aureus, C. diphtheriae, the gram positive and S. typhi and P. aeruginosa gram negative bacteria using Agar Cup method. In this method, the petriplate filled with sterile nutrient agar containing desired strain of bacteria was poured to a height of about 5mm and then kept the plate as it to solidify the nutrient agar. After this, with help of sterile cork borer, a single cup having 8 mm diameter was cut from middle part of the plate and it was filled with the sample solution of 1000 µg/cm3 concentration. This test solution was allowed to spread in surrounding agar by keeping 10 minutes in refrigerator and the incubated for 24 h at 37 °C.

**Results and discussion**

**3.1 Preparation of complexes**

The lanthanum complexes synthesized as follows

$$LaCl_3.7H_2O + 2OHBO + HL \longrightarrow [La(OHBO)_2(L).2H_2O] + 3HCl + 5H_2O$$

Where, OHBO : ortho hydroxylbenzaldehyde oxime

HL : secondary ligand

**3.2 Physico-Chemical Properties of complexes**

The synthesized lanthanum metal mixed ligand complexes are off white in colour (Table No.1) and are non-hygroscopic in nature.

**Table No. 1 :**

| Complex | Empirical Formula | Molecular Weight | Colour |
|---|---|---|---|
| $[La(OHBO)_2(Ala).2H_2O]$ | $LaC_{17}H_{22}O_8N_3$ | 535 | off white |
| $[La(OHBO)_2(Pro).2H_2O$ | $LaC_{19}H_{24}O_8N_3$ | 561 | off white |
| $[La(OHBO)_2(Iso).2H_2O$ | $LaC_{20}H_{28}O_8N_3$ | 577 | off white |
| $[La(OHBO)_2(Phe).2H_2O$ | $LaC_{23}H_{26}O_8N_3$ | 611 | off white |

Table No.2 indicates the temperature of decomposition of all lanthanum complexes which are in the rage of 245-260 which shows that there is strong Metal-ligands bonding within the complexes.as well as they are also insoluble in common organic solvents like ethanol , acetone, methanol etc. but in the solvents like DMSO and DMF, complexes are partially miscible.

**Table No-2:**

| Complex | Decomposition Temp. (°C) | pH |
|---|---|---|
| $[La(OHBO)_2(Ala).2H_2O]$ | 255 | 6.95 |
| $[La(OHBO)_2(Pro).2H_2O$ | 260 | 7.03 |
| $[La(OHBO)_2(Iso).2H_2O$ | 250 | 6.98 |
| $[La(OHBO)_2(Phe).2H_2O$ | 245 | 7.06 |

Table No-3 explains the molar conductance of lanthanum complexes and room temperature magnetic susceptibility of all complexes. The molar conductance values are in the range of 0.0024 to 0.0017 Mhos $cm^2$ $mol^{-1}$ showing that the all lanthanum complexes are nonelectrolyte in nature.[23] The elemental analysis data of complexes given in the Table No-3 which confirms that the general formula of lanthanum complexes is 1:2:1 [24] The room temperature effective magnetic moment of all the lanthanum (III) complexes shows that all complexes are Diamgnetic in nature.[25]

**Table No-3 :**

| **Complex** | **Elemental Analysis Found (Calculated)** | | | | **Molar Conductance (Mhos $cm^2$ $mol^{-1}$)** | **Magnetic Nature** |
|---|---|---|---|---|---|---|
| | % C | % H | % N | % M | | |
| $[La(OHBO)_2(Ala).2H_2O]$ | 38.08 (38.13) | 4.10 (4.11) | 7.83 (7.85) | 25.96 (25.98) | 0.0024 | Diamagnetic |
| $[La(OHBO)_2(Pro).2H_2O]$ | 40.62 (40.64) | 4.25 (4.27) | 7.43 (7.48) | 24.73 (24.77) | 0.0028 | Diamagnetic |
| $[La(OHBO)_2(Iso).2H_2O]$ | 41.56 (41.59) | 4.82 (4.85) | 7.25 (7.27) | 24.06 (24.09) | 0.0021 | Diamagnetic |
| $[La(OHBO)_2(Phe).2H_2O]$ | 45.15 (45.18) | 4.24 (4.25) | 6.86 (6.87) | 22.71 (22.75 | 0.0017 | Diamagnetic |

**Electronic absorption spectra of the complexes :**

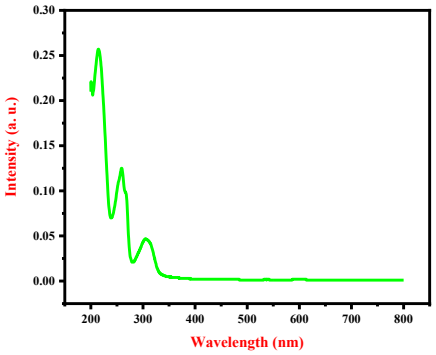
The electronic spectra of prepared complexes were measured in DMSO solvent.

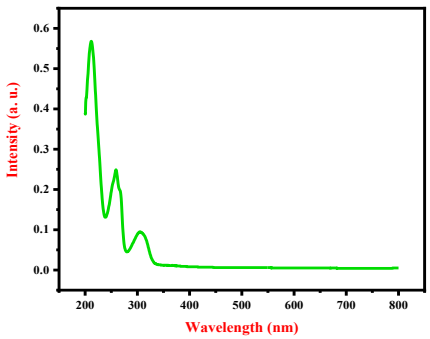
In the UV-visible spectra, many amino acids shows peak below 200 nm transitions.[26]. These bands are appear to higher wavelength region in the all the complexes showing π→π* transitions and charge transfer transitions in the complexes from ligand to metal ion and vice versa.

**Table No. 4 : Electronic Absorption Spectra of lanthanum complexes**

| **Complex** | **λ (nm)** | **ν (cm-1 )** | **Proposed Assignments** |
|---|---|---|---|
| $[La(OHBO)_2(Ala).2H_2O]$ | 210 | 47619 | π→π* |
| | 252 | 39682 | n → π* |
| | 315 | 31746 | Charge-transfer |
| $[La(OHBO)_2(Pro).2H_2O$ | 220 | 45454 | π→π* |
| | 255 | 39215 | n → π* |
| | 312 | 32051 | Charge-transfer |

| | | | |
|---|---|---|---|
| $[La(OHBO)_2(Iso).2H_2O$ | 215 | 46512 | π→π* |
| | 259 | 38610 | n → π* |
| | 306 | 32680 | Charge-transfer |
| $[La(OHBO)_2(Phe).2H_2O]$ | 211 | 47393 | π→π* |
| | 259 | 38610 | n → π* |
| | 308 | 32467 | Charge-transfer |

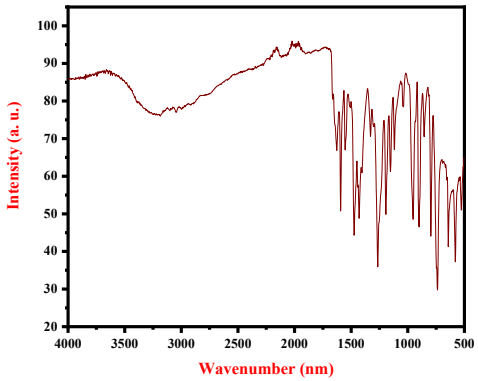


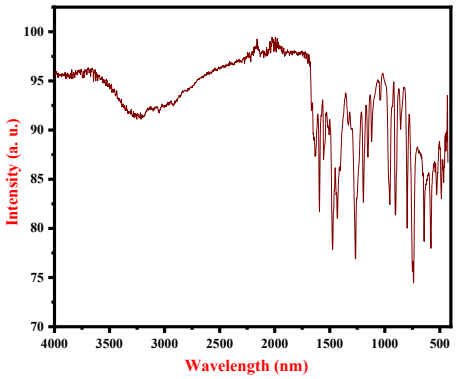

**IR spectra of Lanthanum Complexes :**

The primary ligand ortho hydroxylbenzaldehyde oxime shows band at 3550 $cm^{-1}$ which is due to the phenolic –OH group. For free oxime –OH group, the band obtained in the range of 3225 to 3360 $cm^{-1}$. The absence of band at 3550 $cm^{-1}$ in the all the synthesized lanthanum complexes confirms the deprotonation of OH group and coordination of phenolic oxygen with lanthanum metal in the synthesized complexes. The band for free oxime group has been present in the all the lanthanum complexes and not involved in the bond formation. The shift of frequency of C=N stretching vibrations to lower range of 1590-1593 $cm^{-1}$ confirms that the oxime group of primary ligand bonded through nitrogen to central metal lanthanum in all the complexes. The strong band obtained in the region between 952-956 $cm^{-1}$ in all lanthanum complexes is due to C-O stretching vibrations. However the strong bands observed in the range of wavelength 1265 - 1267 $cm^{-1}$ and weak bands ranging from 1474 $cm^{-1}$ -1472 $cm^{-1}$ are ascribed for COO – asymmetric vibration modes and symmetric vibration modes respectively in the all complexes. It confirms that metal and acid group of secondary ligand coordinated through oxygen atom. The band in the range of 1593-1591 $cm^{-1}$ and 1628-1615 $cm^{-1}$ are due to N-H stretching vibrations in all the lanthanum complexes which also signify that the secondary ligand amino acids also bonded to lanthanum metal in the all complexes. The medium bands observed in the range of 579-585 $cm^{-1}$ and 643-644 $cm^{-1}$ are mainly assigned to M-N and M-O stretching vibrations. This

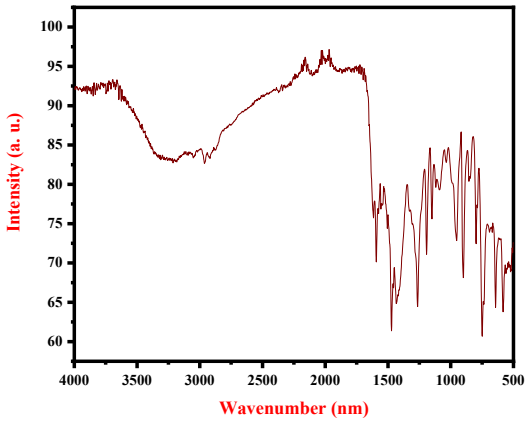
provides bonding with oxygen and nitrogen of the both ligands.[27-28]




[La(OHBO)$_2$(Ala).2H$_2$O]




[La(OHBO)$_2$(Pro).2H$_2$O]




[La(OHBO)$_2$(Iso).2H$_2$O]

**Antibacterial studies:**

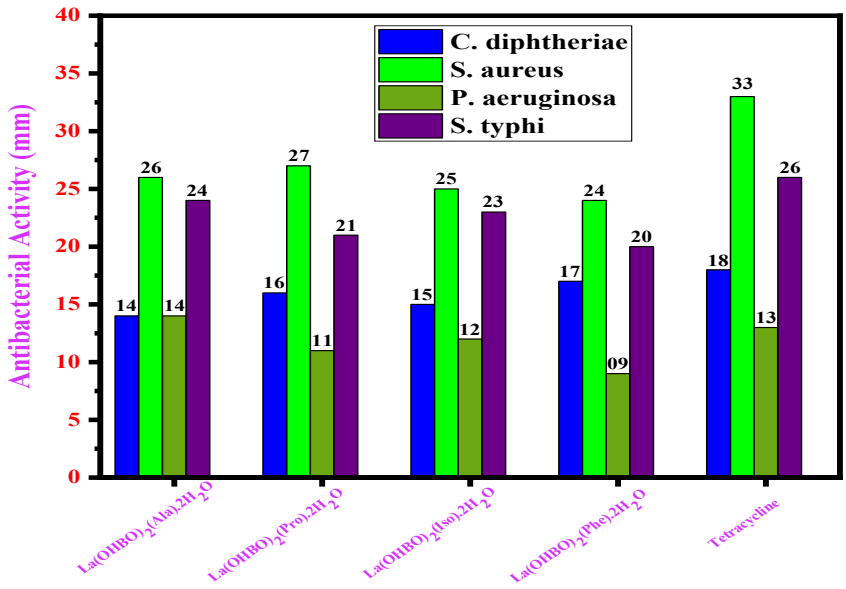
The diameter of the zone inhibition (mm) was used to compare the antibacterial behavior of the complexes. It confirms that all complexes exhibit biological activity by inhibiting the growth of microorganisms. The lanthanum Complexes were more sensitive against bacterial strain S. aureus and S. typhi as compared to C. diphtheria and P. aeruginosa. It was found that lanthanum metal complexes showing more activity to stop the growth of bacteria than ligands.[29] The MIC) of the ligand, metal salt and cerium complexes was lie in the range of 100-200 µg/mL, 75-200 µg/mL and 10-35 µg/mL respectively. Due to chelation, metal complexes inhibit the growth of bacteria as it lowers the polarity of metal ions in the complexes and increases hydrophobic property and helps to permeate through the lipid layers of microorganism.

**Table No.- 5 : Antibacterial results of synthesized Lanthanum (III) Complexes by Agar Cup Method**

| Sr. No. | Complex | Antibacterial Activity (mm) with | | | |
|---|---|---|---|---|---|
| | | *C. diphtheriae* | *S. aureus* | *P. aeruginosa* | *S. typhi* |
| 1. | $[La(OHBO)_2(Ala).2H_2O]$ | 14 | 26 | 14 | 24 |
| 3. | $[La(OHBO)_2(Pro).2H_2O$ | 16 | 27 | 11 | 21 |
| 4. | $[La(OHBO)_2(Iso).2H_2O$ | 15 | 25 | 12 | 23 |
| 5. | $[La(OHBO)_2(Phe).2H_2O$ | 17 | 24 | 09 | 20 |
| 6. | Tetracycline | 18 | 33 | 13 | 26 |

**Table 07: MIC (µg/mL) data of prepared Lanthanum (III) Complexes**

| Complex | MIC (µg/mL) | | | |
|---|---|---|---|---|
| | *C. diphtheriae* | *S. aureus* | *P. aeruginosa* | *S. typhi* |
| $[La(OHBO)_2(Ala).2H_2O]$ | 30 | 15 | 35 | 15 |
| $[La(OHBO)_2(Pro).2H_2O$ | 35 | 10 | 25 | 20 |
| $[La(OHBO)_2(Iso).2H_2O$ | 30 | 15 | 30 | 10 |
| $[La(OHBO)_2(Phe).2H_2O$ | 35 | 15 | 25 | 15 |
| $LaCl_3 \cdot 7H_2O$ | 160 | 80 | 200 | 75 |
| OHBO ligand | 200 | 100 | 180 | 130 |
| Tetracycline | 2.0 | 1.5 | 8.0 | 1.5 |



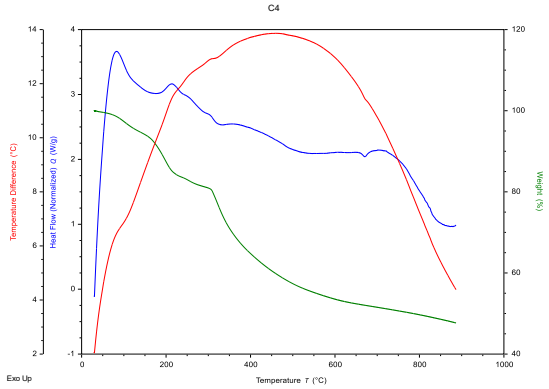

**Thermal Study of the complexes :**

The thermal study of the synthesized complexes was carried by using DTA and TG analysis in the controlled atmosphere of

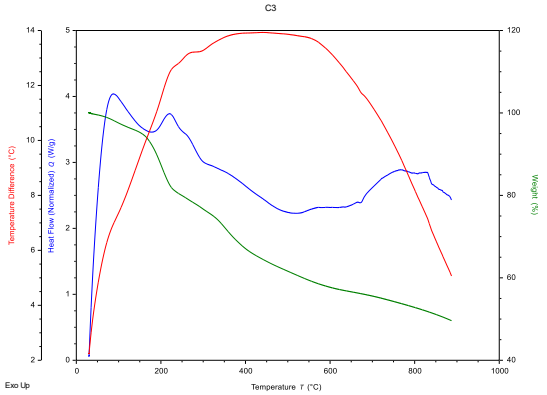
nitrogen gas with the constant heating rate of 10 o C / minute .All complexes were heated upto 900$^0$C and the thermogram curve was got to exhibit three decomposition curves indicating that there was gradual weight loss in the complex as the temperature has been raised. All the lanthanum complexes showing similar behavior in the TG, DTA study. First loss has been observed in the range of 10-240$^0$C which due to the coordinated water molecules. Second loss in the weight of complex seen in the range of 250-390$^0$C due to loss of secondary ligand. The final loss in the weight observed in the range of 400-750$^0$C due to simultaneous loss of two hydroxylbenzaldehyde oxime ligand. After this, TG-DTA curve shows straight line confirming the end of decomposition of mixed ligand lanthanum complexes.

**Table No.8 : Data of Thermal analysis of complexes :**

| Complex | Temp. Range (°C) | Loss in Weight due to |
|---|---|---|
| [La(OHBO)$_2$(Ala).2H$_2$O] | 15-230 | Two water molecules |
| | 255-395 | Amino acid |
| | 400-755 | Two OHBO molecules |
| [La(OHBO)$_2$(Pro).2H$_2$O] | 10-240 | Two water molecules |
| | 260-390 | Amino acid |
| | 400-750 | Two OHBO molecules |
| [La(OHBO)$_2$(Iso).2H$_2$O] | 28-230 | Two water molecules |
| | 250-400 | Amino acid |
| | 410-740 | Two OHBO molecules |
| [La(OHBO)$_2$(Phe).2H$_2$O] | 20-220 | Two water molecules |
| | 245-405 | Amino acid |
| | 405-760 | Two OHBO molecules |

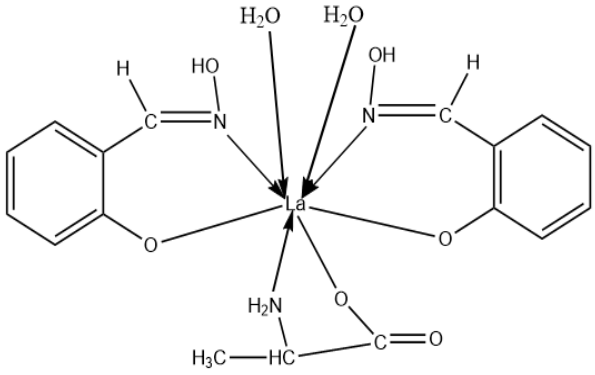



[La(OHBO)$_2$(Iso).2H$_2$O]

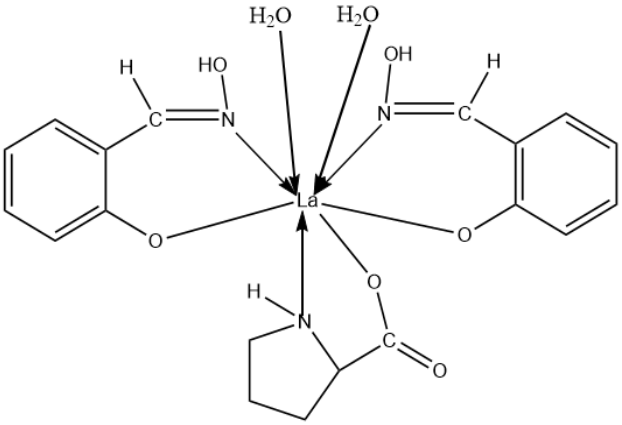



[La(OHBO)$_2$(Phe).2H$_2$O]

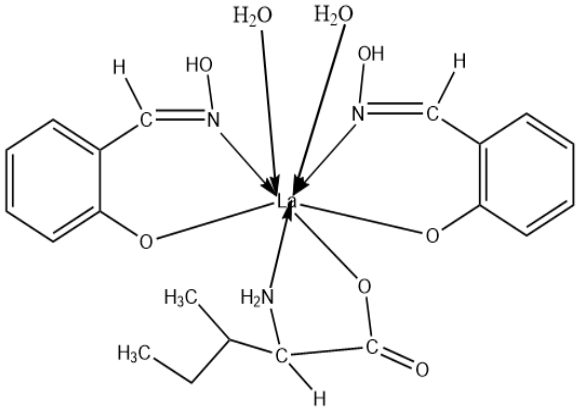
Hence the proposed structures of La(III) metal mixed ligand complexes are as following-



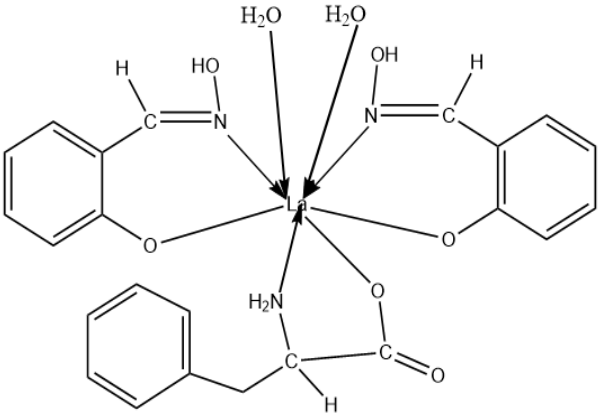
[La(OHBO)$_2$(Ala).2H$_2$O]



[La(OHBO)$_2$(Pro).2H$_2$O]



[La(OHBO)$_2$(Iso).2H$_2$O]



[La(OHBO)$_2$(Phe).2H$_2$O]

**Conclusion**

We have successfully synthesized mixed ligand complexes of Lanthanum (III) metal of type [La(OHBO)$_2$(L).2H$_2$O] using Ligands containing N.O donor atoms Complexes were off white in color and stable at room temperature. Molar conductance of all complexes was very low indicating that the

complexes are non-electrolyte in nature. The detail IR study of lanthanum complexes clears that lanthanum metal bonding taking place through the N-and O-donor atoms of the primary and secondary ligands. The ultra-violet study of all the complexes signify that there is intra ligand and charge transfer transitions in the synthesized complexes. All the lanthanum metal complexes has high decomposition temperature values which confirms that it has strong metal ligand bonding. The Differential thermal analysis and thermo gravimetric analysis which indicates gradual weight loss in the lanthanum complexes confirming the presence of water molecules and ligands in the complexes. Magnetic study of new synthesized complexes shown that all complexes are diamagnetic in nature. Hence lanthanum complexes has proposed coordination number eight. The antimicrobial study of complexes shows that complexes were more active against the strain of bacterial S. typhi and S. aureus as compared to bacterial strain C. diphtheria and P. aeruginosa.

**ACKNOWLEDGMENT**

Authors are acknowledge to Thakur Infraprojects Private Limited (TIPL), Panvel, Navi Mumbai for providing funding to this research project (TIPL/CSR/25/2023-24). Authors are also grateful to Changu Kana Thakur Arts, Commerce and Science college, New Panvel (Empowered Autonomous) for continuous support and encouragement for completing research project work.

**COMPETING INTERESTS**

Authors have declared that they have no conflict of interest.

**REFERENCES**

1. Islam MS, Uddin MM. J Bangladesh Chem. Soc. 1992; 5(2):212.
2. Pannala V, Raju RM. Orient J chem. 2005; 22(2):39.
3. Panchal PK, Patel MN, Synthesis, Structural Characterization, and Antibacterial Studies of Some Mixed-Ligand First Row d-Transition Metal Complexes, Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry. 2004;34(7):1277–1289.
4. Ekennia AC, Onwudiwe DC, Ume C, Ebenso EE, Mixed Ligand Complexes of N-Methyl-N-phenyl Dithiocarbamate, Synthesis, Characterisation, Antifungal Activity, and Solvent Extraction Studies of the Ligand, Bioinorganic Chemistry and Applications. 2015;1–10.
5. Khan BT, Bhatt J, Najmuddin K,

Synthesis, antimicrobial, and antitumor activity of a series of palladium(II) mixed ligand complexes. Journal of Inorganic Biochemistry. 1991;44(1):55–63.

6. Rajendiran V, Karthik R, Palaniandavar M., Periasamy, et al., Mixed-Ligand Copper(II)- phenolate Complexes: Effect of Coligand on Enhanced DNA and Protein Binding, DNA Cleavage, and Anticancer Activity, Inorganic Chemistry. 2007;46(20):8208– 8221.
7. Sunil S. Patil, Ganesh A. Thakur, ManzoorM. Shaikh , Synthesis, Characterization, and Antibacterial Studies of Mixed Ligand Dioxouranium Complexes with 8-Hydroxyquinoline and Some Amino Acids, International Scholarly Research Network, 2011, 168539 , 1-6.
8. Naglah AM, Al-Omar MA, Kalmouch A, et al., Synthesis, characterization and antidiabetic effects of vanadyl(II) adenosine monophosphate amino acid mixed-ligand complexes, Future Medicinal Chemistry. 2019;11(03):193-210.
9. Altaf M, Stoeckli-Evans H, Cuin A, et al., Synthesis, crystal structures, antimicrobial, antifungal and antituberculosis activities of mixed ligand silver(I) complexes, Polyhedron. 2013;62:138–147.
10. G.A. Thakur, U.N. Dhaigude And P.V. Bhise, Asian Journal of Chemistry,2018,30(11),2467-2471.
11. Maharudra Kekare , Vikas Vaidya , Jagdish Thakur, International Journal of Science and Research (IJSR),2015, 4(1),1361-1366.
12. B. D. Aghav, S. K. Patil and R. S. Lokhande, Advances in Applied Science Research, 2015, 6(12):37-43
13. Ganesh Anant Thakur1, Uttam Narayan Dhaigude and Pramod Bhagawan Thakur, Orient. J. Chem., 2020,Vol. 36(4), 632-639.
14. Enass J Waheed, Shatha MH Obaid, and Abbas Ali Salih Al-Hamdani, Research Journal of Pharmaceutical, Biological and Chemical Sciences, 2019, 10(2),1624-1641.
15. Alya Khider Abbas, Baghdad Science Journal, 2016, 13(2s), 128-142.
16. Sobel S., Haigney A., Kim M., Kim D., Theophall G.,Nuñez J.,Williams D.,Hickling B. and Sinacori J. 2010. The complexation of aqueous metal ions relevant to biological applications. 2. Reactions of copper(II) citrate and copper(II) succinate with selected amino acids, Chemical Speciation and

Bioavailability, 22(2), 109-114.

17. Paláčková H.,Vinklárek J.,Holubová J., Císařová I. and Erben M. 2007. The interaction of antitumor active vanadocene dichloride with sulfur-containing amino acids, Journal of Organometallic Chemistry, 792(17), 3758-3764.
18. Sakr, S.H.; Elshafie, H.S.; Camele, I.; Sadeek, S.A. Molecules., 2018, 23, 1-17.
19. Islam MS, Uddin MM. J Bangladesh Chem. Soc. 1992; 5(2):212.
    Pannala V, Raju RM. Orient J chem. 2005; 22(2):39
20. Islam MS, Uddin MM. J Bangladesh Chem. Soc. 1992; 5(2):212.
21. Pannala V, Raju RM. Orient J chem. 2005; 22(2):39.
22. Islam MS, Uddin MM. J Bangladesh Chem. Soc. 1992; 5(2):212.
23. Kekare M, Vaidya VV, Thakur J, Studies and Synthesis of Biologically Active Mixed Ligand Cerium (III) Complexes, International Journal of Science and Research (IJSR). 2015;4(1):1361-1366.
24. G.A. Thakur1, U.N. Dhaigude and P.V. Bhise, Asian J. Chem., 2018, 30(11), 2467-2471
25. Kekare, M.; Vaidya, V.; Thakur, J. Int. J. Sci. Res., 2015, 4, 1361-1366.
26. Pannala V, Raju RM. Orient J chem. 2005; 22(2):39.
27. Panchal PK, Patel MN, Synthesis, Structural Characterization, and Antibacterial Studies of Some Mixed-Ligand First Row d-Transition Metal Complexes, Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry. 2004;34(7):1277–1289.
28. Ekennia AC, Onwudiwe DC, Ume C, Ebenso EE, Mixed Ligand Complexes of N-Methyl-N-phenyl Dithiocarbamate, Synthesis, Characterisation, Antifungal Activity, and Solvent Extraction Studies of the Ligand, Bioinorganic Chemistry and Applications. 2015;1–10.
29. Panchal PK, Patel MN, Synthesis, Structural Characterization, and Antibacterial Studies of Some Mixed-Ligand First Row d-Transition Metal Complexes, Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry. 2004;34(7):1277–1289.