



Dioxomolybdenum (VI) Compounds of Macrocyclic Schiff base Ligands: Preparation, Characterization and Antibacterial activity

SHIKHA KATIYAR¹, DEVENDRA PRATAP RAO^{2*}, NARENDRA KUMAR VERMA³,
AMIT KUMAR GAUTAM⁴, ASHISH VERMA⁵, CHANDRA PRAKASH SINGH⁶,
YASHVEER GAUTAM⁷ and VIJAY SHANKAR⁸

^{1,2,3,4,5}Department of Chemistry, Coordination Chemistry Laboratory, Dayanand Anglo-Vedic (PG) College, Kanpur-208001, U.P, India.

⁶Department of Chemistry, Mahatma Gandhi (PG) College, Gorakhpur- 273001, U.P, India

⁷Department of Chemistry, Pandit Prithi Nath (PG) College, Kanpur-208001, U.P, India.

⁸Department of Chemistry, B.S.N.V. (PG) College, Lucknow-226001, U. P., India.

*Corresponding author E-mail: devendraprataprao@yahoo.com

<http://dx.doi.org/10.13005/ojc/400104>

(Received: December 09, 2023; Accepted: January 29, 2024)

ABSTRACT

Using di-2-furanylethanedione and 5-bromo-3-methylbenzene-1,2-diamine we prepared a monomeric [MoO₂(SL)] with a Schiff base, as well as 4 different compounds using the formulation [MoO₂(MSL)]. We investigate how [MoO₂(SL)] reacts with 1,3-diketones. Several characterizations are discussed in this article, including molar conductance measurement, elemental analysis, UV-Vis, IR, NMR, and thermal measurements. Molybdenum has a six-coordination number. All five MoO₂(VI) compounds have distorted octahedral arrangements. Molybdenum octahedra have four N-atoms and two oxidized O-atoms. Against *S. aureus* and *S. typhi*, all synthesized compounds showed moderate activity. The chelation hypothesis is used to define the progression of the antibacterial task.

Keywords: Dioxomolybdenum(VI), 5-bromo-3-methylbenzene-1,2-diamine, Schiff base, Di-2-furanylethanedione, β-diketones, Macrocyclic compounds, Antibacterial activity.

INTRODUCTION

At least nine atoms are required for a macrocyclic compound, including all heteroatoms. This type of compound contains at least three donor atoms. Over the past half century, macrocyclic compounds have undergone considerable development¹⁻⁵. In coordination chemistry, N-atom-containing ligands and their compounds play an

important role. There have been various research papers published that explore metal compounds from physicochemical and biochemical perspectives and drive extensive applications⁶⁻¹¹. A transitional Schiff base formulation with vitamin B6 catalyzes transamination reactions using metal ions^{15,16}. In addition to their antifungal and antiviral properties, Schiff base compounds are also anti-inflammatory and antitumor¹²⁻²⁰.



Metalloproteins and enzymes contain positions of metal that can be modelled by Schiff base compounds in the bioinorganic field²¹. In comparison to the isolated ligand, the anticancer activity of various Schiff bases is greater for that particular metal compound²²⁻²⁹. Additionally, they remain fascinated by chemistry reactions and consumer electronics memory storage gadgets.

Extreme density ligands in transition metal compounds have different configurations and coordination numbers^{30,31}. The multiple oxidation states of molybdenum can allow it to be adaptable in this aspect. A coordination number may also range from 4 to 8³². Schiff base edifices can be produced for homogeneous and heterogeneous reactions by linking molybdenum compounds with ligands containing hetero atoms (N,O and S)³³⁻³⁹. There are a number of biological applications that can be achieved by MoO₂(VI) compounds because they have multidentate ligands. [MoO₄]²⁻ can readily be acquired in aqueous solution as Mo(VI). Solution concentration and pH can determine the concentration of the [MoO₄]²⁻ ion. A template for oxygen transfer has been shown to exist in the form of the [MoO₄]²⁻ ion. It has been shown that their oxygen transfer properties have a negative effect on the molybdenum oxotransferase mechanism⁴⁰⁻⁴³. It is known that several redox enzymes are fully oxidized. A cis-dioxomolybdenum moiety is associated with their active sites in such cases⁴⁴⁻⁴⁶.

Molybdenum is the only transition metal considered as a biometal that is essential for pathogenic microorganisms found in human, animal and vegetation pathogens^{47,48}. The biological and catalytic properties of Mo(VI) coordinate chemistry make it an active area of scientific research⁴⁹⁻⁵². A molybdenum molecule sets up the physiological functions of oxomolybdoenzymes⁵³⁻⁵⁵. It might be useful as a chelating agent since di-2-furanylethanedione is versatile. There could be Schiff base condensation between diamines and di-2-furanylethanedione due to its reactive carbonyl groups. In order to synthesize macrocyclic ligands, di-2-furanylethanedione plays an essential role.

Di-2-furanylethanedione has denticity

ligands, which can be synthesized from reaction of diamine with di-2-furanylethanedione under certain conditions. Through metal template impact, the synthesized compound undergoes cyclization with 1,3-diketones. It is possible to prepare and characterize them, and TGA, nmr, ir, UV-Vis spectroscopy, molar conductivity measurements, and elemental analysis have all supported their provisional structures.

EXPERIMENTAL

Materials

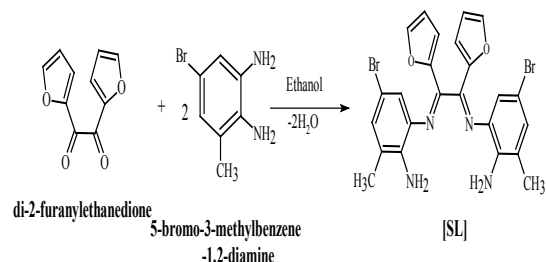
Chemists obtained from business resources prepared Schiff bases (ligands) and compounds using reagent grade chemicals. In addition to molybdenyl acetylacetonate, 5-bromo-3-methylbenzene-1,2-diamine, and di-2-furanylethanedione, 1,3-diketones were obtained from Aldrich without similar refinement.

Physical Measurements and Analytical Methods

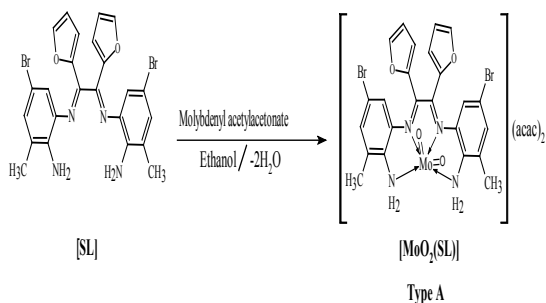
In Arunachal Pradesh, India, CHN analysers were used at important CRFs, including NERIST, Nirjuli, Itanagar, to examine C,H and N in the compounds. Nitrogen is assessed using Kjeldahl's method for synthesized compounds. Using a gravimetric technique, molybdenum was measured after decay of the compound⁵⁶. As barium sulfate was developed as a method for estimating sulfur, sulfur estimation progressed⁵⁷. In addition to sulfuric acid baths, general methods were used for determining uncorrected melting factors. A Labinda-UV 3000+ UV/Vis spectrophotometer at UPTTI Kanpur, U.P., India was used to compute the electronic absorption spectra of the compounds utilizing ethanol. At Indian Institute of Technology Kanpur, we recorded the infrared spectra of MoO₂(VI) compounds in KBr using Perkin-Elmer Spectrum models 10.03.06 and 18.03.06 spectrophotometers. On the JMM ECS-400 (JEOL) spectrometer, proton (¹H NMR) spectra of MoO₂(VI) compounds were obtained. An analysis of the temperature distribution of the [MoO₂(SL)] compound was carried out using the TG/DTA-SDT Q600 V 20.9 Built 20, USA thermal analyzer under a nitrogen atmosphere at temperatures between 50-900°C at a 10°C min⁻¹ heating rate.

Preparation of molybdenum(VI) compounds containing ligands that result from condensation of di-2-furanylethanedione and 5-bromo-3-methylbenzene-1,2-diamine with 1,3-diketones.

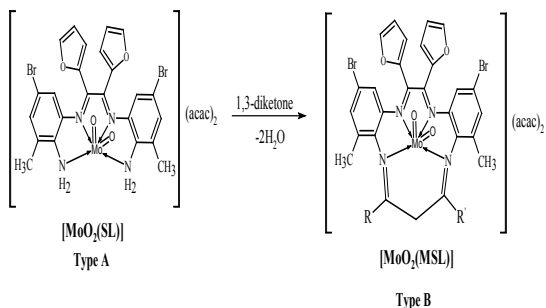
Schemes 1, 2 and 3 show how to synthesize $[\text{MoO}_2(\text{MSL})]$. Drop-wise addition of molybdenyl acetylacetonate (1.6307 g, 5 mmol) in ethanol (50 mL) was followed by the addition of di-2-furanylethanedione (0.9506 g, 5 mmol) in 50 mL ethanol and 5-bromo-3-methylbenzene-1,2-diamine (2.0106 g, 10 mmol) in 50 mL ethanol. The solution turns brown after 3 h of slight reflux in the reaction mixture. After filtering, ethanol was used to wash the solid product, and silica gel was used to isolate the solid under vacuum. In order to check the purity of the compound, the TLC method was used. As a result, the yield increased to 48% (type A). 3D structures of the Schiff base ligand (SL) and parent compound $[\text{MoO}_2(\text{SL})]$ are given in Figure 1 and 2.



Scheme 1. Synthesis of Schiff base ligand (SL)



Scheme 2. Synthesis of $[\text{MoO}_2(\text{SL})]$



Scheme 3. Synthesis of $[\text{MoO}_2(\text{MSL})]$

Where, SL = di-2-furanylethanedione+ 5-bromo-3-methylbenzene-1,2-diamine; MSL = in the presence of dioxmolybdenum(VI) cation, macrocyclic ligands are synthesized by condensation of SL with 1,3-diketones.

MSL¹: 2R = CH₃, R' = CH₃; MSL²: R = C₆H₅, R' = CH₃; MSL₃: R = C₄H₉S, R' = CF₃; MSL⁴: R = C₆H₅, R' = C₆H₅

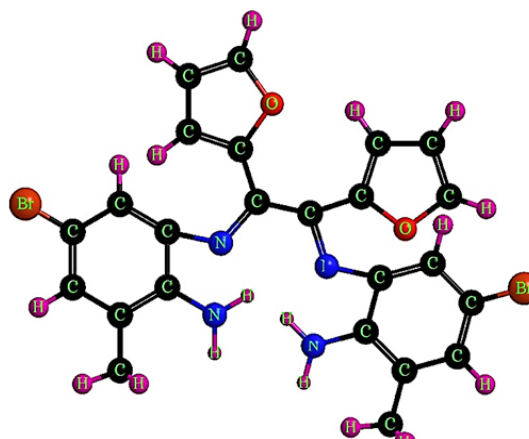


Fig. 1. 3D structure of Schiff base ligand (SL)

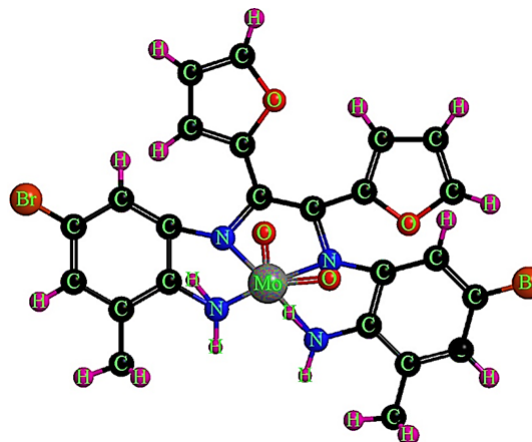


Fig. 2. 3D structure of parent compound $[\text{MoO}_2(\text{SL})]$

Upon addition of 1,3-diketones to ethyl alcohol suspension of Kind A, a uniform reaction was observed after three hours. Here we used 1,3-diketones like 4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedione, 1,3-diphenyl-1,3-propanedione, 2,4-pentanedione or 1-phenyl-1,3-butanedione (1:1) to produce yellow solid macrocyclic stable products (type B). A TLC test is performed to verify the purity of macrocyclic compounds.

Where,

Table 1: Schiff base ligands and compounds: physical and analytical data

| Compound | Formula | F.W. | Yield (%) | m.p. (°C) | % of Element, Calcd./(found) | | | | |
|--|--|---------|-----------|-----------|------------------------------|----------------|------------------|------------------|----------------|
| | | | | | C | H | N | Mo | S |
| SL | C ₂₄ H ₂₀ Br ₂ N ₄ O ₂ | 556.26 | 65 | 120 | 51.82 (51.74) | 3.62 (3.60) | 10.07 (10.00) | -- | -- |
| [MoO ₂ (SL)] | C ₃₄ H ₃₄ Br ₂ N ₄ MoO ₈ | 882.41 | 55 | 118 | 46.27 (46.20) | 3.88 (3.78) | 6.34 (6.38) | 10.87 (10.80) | -- |
| [MoO ₂ (MSL ₁)] | C ₃₉ H ₃₈ Br ₂ N ₄ MoO ₈ | 946.52 | 50 | 130 | 49.49 (49.40) | 4.05 (4.00) | 5.92 (6.86) | 10.14 (10.9) | -- |
| [MoO ₂ (MSL ₂)] | C ₄₄ H ₄₀ Br ₂ N ₄ MoO ₈ | 1008.59 | 45 | 155 | 52.40 (52.33) | 4.00 (3.96) | 5.56 (5.32) | 9.51 (9.46) | -- |
| [MoO ₂ (MSL ₃)] | C ₄₂ H ₃₈ Br ₂ N ₄ MoO ₈ F ₃ S | 1071.59 | 45 | 125 | 47.05 (46.90) | 3.57 (3.50) | 5.22 (5.15) | 8.95 (8.89) | 2.99 (2.95) |
| [MoO ₂ (MSL ₄)] | C ₄₉ H ₄₂ Br ₂ N ₄ MoO ₈ | 1070.66 | 50 | 132 | 54.97 (54.94) | 3.95 (3.91) | 5.23 (5.20) | 8.96 (8.90) | -- |

SL= Di-2-furanylethanedione has been transformed into a Schiff base by condensation with 5-bromo-3-methylbenzene-1,2-diamine; Ligand MSL¹ synthesized via condensation of SL with 2,4-pentanedione to form a macrocyclic Schiff base; Ligand MSL² synthesized via condensation of SL with 1-phenyl-1,3-butanedione to form a macrocyclic Schiff base; Ligand MSL³ synthesized via condensation of SL with 4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedione to form a macrocyclic Schiff base; Ligand MSL⁴ synthesized via condensation of SL with 1,3-diphenyl-1,3-propanedione to form a macrocyclic Schiff base.

According to elemental analysis (Table 1), metal and ligand are in a 1:1 stoichiometry.

Antibacterial activity assay

Several bacterial strains were tested *in vitro* for their antibacterial activity, including *S. aureus*, *B. subtilis*, *E. aerogene* and *S. typhi* utilizing an agar-well diffusion process⁵⁸⁻⁶⁰. Antibacterial activity of Doxycycline became the same as that of other antibiotics. Agar media were drilled with 6 mm-diameter holes using a metallic borer. All bacterial suspensions were adjusted to a density of 3x10⁵ colony-forming units per mL. Agar was expanded with standardized suspensions. In the examined sample, 300 g mL⁻¹ of the produced compounds were dissolved in 1% DMSO. Each well was filled with the examined samples. DMSO and Doxycycline (0.05%) were packed in the rest of the wells. Upon incubation at 355°C for 30 h growth inhibition is tested.

RESULTS AND DISCUSSION

Infrared spectra

Through an *in-situ* procedure, dioxomolybdenum(VI) was produced by refluxing a mixture of di-2-furanylethanedione, 5-bromo-3-methylbenzene-1,2-diamine, and molybdenyl acetylacetonate in aqueous ethanol in a 1:2:1 ratio, which resulted in macrocyclic compounds as shown in the scheme. Several infrared bands were observed for the isolated ligands and the MoO₂(VI) compounds. Table 2 highlights these bands. A macrocyclic compound with N-atoms of the group azomethine bonded to molybdenum has been demonstrated by lowering C=N absorption frequencies⁶¹⁻⁶⁴. In isolated ligands, >C=N absorption appears at 1665 cm⁻¹ in spectrum bands between 1610-1650 cm⁻¹⁶¹⁻⁶³. It could be assigned to the Mo-N vibration around 490-570 cm⁻¹, which is not related to free ligands⁶⁵. Di-2-furanylethanedione forms a strong bond with diamines due to the presence of two >C=N bands around 1710 cm⁻¹^{66,67}. Dioxomolybdenum(VI) compounds and their isolated ligands exhibit compound infrared spectra due to various ring vibrations and C-H vibrations. An asymmetric (N-H) and symmetric (N-H) wide band is targeted at 3430 and 3060 cm⁻¹, respectively. There is no difference between [MoO₂(SL)] and [MoO₂(MSL)] because the NH group is absent. This implies the NH group is not involved in the bonding process⁶⁸. Among dioxomolybdenum(VI) compounds, d-orbital is used most often for bonding, forming preferentially

cis-dioxo groups. In dioxomolybdenum(VI) compounds, cis-[MoO₂]²⁺ demonstrates asymmetric and symmetric stretching vibrations at 896-910 cm⁻¹ and 962-970 cm⁻¹ as a result of C_{2v} symmetry⁶⁹. There are two infrared spectral bands at these wavelengths that are associated with $\nu_{\text{asym(O=Mo=O)}}$ and $\nu_{\text{sym(O=Mo=O)}}$ vibrations respectively⁶⁹⁻⁷⁶. In comparison to $\nu_{\text{sym(O=Mo=O)}}$, $\nu_{\text{asym(O=Mo=O)}}$ vibrations are lower^{77,78}. On the outer coordination sphere,

the acetylacetonate group can be observed in the bands around 1555-1570 cm⁻¹ and 1465-1482 cm⁻¹, which correspond to the C=O and C=C vibrations, respectively⁷⁹. The macrocyclic compounds exhibit an equal pattern of infrared spectral bands. A method of cyclizing 1,3-diketones by containing amino groups on the carbonyl group, the asymmetrically and symmetrically stretching vibrations of terminal amino groups disappear^{79,80}.

Table 2: Schiff base ligand and dioxomolybdenum compounds IR spectral bands (ν/cm⁻¹)

| Compound | ν of | | | | | | | |
|--|-------|------|-----------------------|-----------------------|-----------------------------|----------------------------|--------------------------|-------------------------|
| | C=N | Mo-N | C=O _(acac) | C=C _(acac) | $\nu_{\text{asym(O=Mo=O)}}$ | $\nu_{\text{sym(O=Mo=O)}}$ | $\nu_{\text{asym(N-H)}}$ | $\nu_{\text{sym(N-H)}}$ |
| SL | 1660m | --- | --- | --- | --- | --- | 3325br | 3133br |
| [MoO ₂ (SL)] | 1610s | 490m | 1570m | 1465s | 901s | 965s | 3430br | 3060br |
| [MoO ₂ (MSL ₁)] | 1642m | 555s | 1565s | 1480m | 905m | 965s | | |
| [MoO ₂ (MSL ₂)] | 1650s | 562s | 1560s | 1472s | 910m | 970m | | |
| [MoO ₂ (MSL ₃)] | 1630s | 570m | 1555m | 1470m | 904m | 972m | | |
| [MoO ₂ (MSL ₄)] | 1645m | 530s | 1563s | 1470s | 896s | 965s | | |

In the range of 4000-400 cm⁻¹, all spectra were recorded with KBr

¹H NMR spectra

All NMR signals are given in Table 3. All MoO₂(VI) compounds as well as the ligand were analyzed using ¹H NMR in DMSO-D₆. It is possible that SL contains signal because of NH₂ at δ (5.32), which is also found in [MoO₂(SL)], at δ (7.20) but not in other macrocyclic compounds, which suggests the presence 1,3-diketones that are present in

cyclization⁸⁴⁻⁸⁶. For isolated ligands and molybdenum compounds, the ten protons are multiplets within the range δ (7.84-6.53). About δ 7.25 peaks appeared for the protons of aromatic rings. In the preparation of the macrocyclic compound, two types of azomethine are offered which appear to result in these chemical shifts. It is possible that peak at δ 2.33 is be due to CH₃ attached to an aryl group.

Table 3: Dioxomolybdenum compounds and ligand ¹H NMR Spectral Data (in δ ppm)

| Compound | HC-Ar | N-H | H ₃ C-Ar | =C-CH ₃ | -CH ₂ | HC-furan | HC- thienyl |
|--|----------------|---------|---------------------|--------------------|------------------|----------------|-----------------------|
| SL | 7.12 2H7.17 2H | 5.32 4H | | 2.12 6H | -- | 6.54 4H7.84 2H | -- |
| [MoO ₂ (SL)] | 7.32 2H7.40 2H | 7.20 4H | | 2.33 6H | -- | 6.54 4H7.84 2H | -- |
| [MoO ₂ (MSL ₁)] | 7.32 2H7.40 2H | -- | 2.33 6H | 0.87 6H | 1.05 2H | 6.54 4H7.84 2H | -- |
| [MoO ₂ (MSL ₂)] | 7.32 4H7.40 5H | -- | 2.33 6H | 0.87 3H | 1.05 2H | 6.54 4H7.84 2H | -- |
| [MoO ₂ (MSL ₃)] | 7.32 2H7.40 2H | -- | 2.33 6H | 0.87 3H | 1.05 2H | 6.54 4H7.84 2H | 7.01 1H7.15 1H7.53 1H |
| [MoO ₂ (MSL ₄)] | 7.32 6H7.40 8H | -- | 2.33 6H | -- | 1.05 2H | 6.54 4H7.84 2H | -- |

UV-Visible spectra

These spectra were measured in ethanol, and they are consistent with the strength energy level scheme suggested by the tetradentate tetraaza ligand and dioxomolybdenum(VI) compounds⁸¹⁻⁸³. Tetradentate ligands and dioxomolybdenum(VI) compounds exhibit similar spectra. With the Mo(VI) ion having no d-electron, it is no longer expected to show pure d-d absorption bands. All molybdenum compounds can also be explained as charge transfer transitions between their nitrogen and molybdenum d-orbitals [N(π)→d(Mo)]. A dioxomolybdenum(VI) compound containing nitrogen donor atoms exhibits

homogeneous UV-Vis spectra. Strong absorption bands during the UV-Vis spectrum of those compounds is identified at 292 nm and at 311 nm, which may be attributed to intraligand transitions and n→π*/π→π* transitions. The band between 380 nm and 395 nm appears to be caused by N(π)→d(Mo). Transition ²B₂→²A₁ (d_{xy}→d_{x²-y²}) may be covered within other bands and is ideal to facilitate charge transfer between the molybdenum LUMO and the ligand HOMO. Energy level schemes for these compounds have been provided by Ballhausen-Gray diagrams. Each compound's electronic spectrum has an octahedral distortion⁸⁷.

Magnetic and molar conductance measurements

As for d^0 configuration, it is not necessary to mention that dioxomolybdenum(VI) compounds are diamagnetic. Due to the absence of electrons in d-orbitals, no d-d transitions are determined for those compounds. The molar conductivities (Λ_m) of all molybdenum compounds in DMF at the ca. 10^{-3} M endorse 1:1 sort electrolytes. Those compounds have molar conductance ranging from 90 to $110 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$. As predicted by the schemes, the molar conductance values on top of the compounds of dioxomolybdenum(VI) type (A) and macrocyclic type (B) suggest tentative shapes.

Thermogravimetric analyses

Thermogravimetric curve (TG Curve) of the compound presented in Fig. 3 reveals that the compound has decomposed in one step. At a temperature of 279 about 83% weight loss has been observed which is due to loss of Schiff ligand and acetylacetonate moiety (calculated weight 83.1%). At 281, the residue left is 16.3% which corresponds to MoO_3 . Weight percent left at 324 is 14.48 and is attributed to MoO_2 .

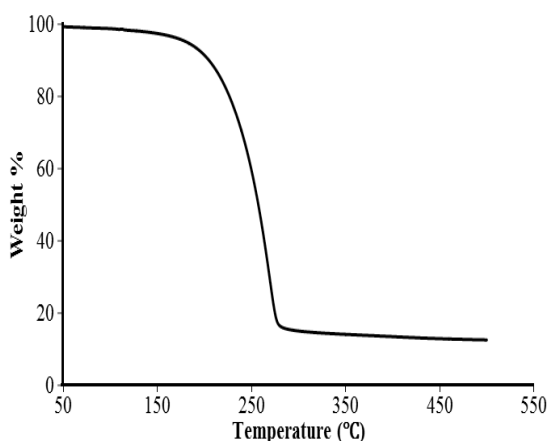


Fig. 3. TG thermograph of $[\text{MoO}_2(\text{SL})]$

Antibacterial activity

As can be seen in Table 4, the dioxomolybdenum(VI) compounds exhibit

antimicrobial activity. It was tried against a variety of bacteria, including *S. aureus*, *B. subtilis*, *E. aerogenes*, and *S. typhi*, using the synthesized dioxomolybdenum(VI) compounds. Chelation hypothesis can be used to explain the improvement of dioxomolybdenum(VI) compounds' antibacterial properties^{79,80}. A doxycycline remedy is used as the reference material. Many of the compounds were found to have low or modest activity against *S. aureus* and *S. typhi*.

Using Eq 1 as a starting point, we calculate the percentage of inhibition effect based on the positive control.

$$\% \text{ inhibition effect} = \frac{\text{extract inhibition halo diameter}}{\text{positive control inhibition halo diameter}} \times 100 \quad (1)$$

^aIn vitro diffusion method using cups and wells conc. $300 \mu\text{g mL}^{-1}$ in solvent DMSO; Inhibition zone (mm): 23-26 = strong activity; 15-18 = moderate activity; 19-22 = good activity; an antibiotic drug of reference is doxycycline.

InChI

InChI=1S/C₂₄H₂₀Br₂N₄O₂/c1-13-9-15(25)11-17(21(13)27)29-23(19-5-3-7-31-19)24(20-6-4-8-32-20)30-18-12-16(26)10-14(2)22(18)28/h3-12H,27-28H2,1-2H3/b29-23+,30-24+

InChI key of compound

VWNWPFYNPOEBGW-HCTXVVGCHSA-N

SMILES Notation

Brc4cc(\N=C(\C(=N)c1cc(Br)cc(C)c1N)\c2ccc(O)c3ccc(O)c(N)c(C)c4

LogP

5.50+/- 0.67

Table 4: Antibacterial activities^a

| Compound | <i>S. aureus</i> | <i>E. aerogenes</i> | <i>S. typhi</i> | <i>B. subtilis</i> | Doxycycline |
|--------------------------------|------------------|---------------------|-----------------|--------------------|-------------|
| $[\text{MoO}_2(\text{SL})]$ | 17 | 20 | 17 | 21 | 26 |
| $[\text{MoO}_2(\text{MSL}_1)]$ | 13 | 20 | 18 | 20 | 24 |
| $[\text{MoO}_2(\text{MSL}_2)]$ | 13 | 19 | 17 | 22 | 25 |
| $[\text{MoO}_2(\text{MSL}_3)]$ | 14 | 19 | 19 | -- | 24 |
| $[\text{MoO}_2(\text{MSL}_4)]$ | 16 | 17 | -- | 22 | 23 |

CONCLUSION

These compounds haven't been crystallized yet, so their crystal structures are unavailable. The [MoO₂(SL)] and [MoO₂(MSL)] compounds can be represented using the above elemental and spectral studies. The antibacterial activity of these compounds has been tested. We demonstrate the formation of dioxin derivatives from dioxomolybdenum(VI) Schiff bases. The Schiff base condensation was confirmed using a flexible chelator with two carbonyl groups, di-2-furanylethanedione. As a result of their reaction with 1,3-diketones, macrocyclic products are formed. Distorted octahedron surrounding Mo. Di-2-furanyledione and diamines are used to condense Schiff bases in ethanol medium. Tetradentate bonds are formed between azomethine nitrogen atoms and metal ions in Schiff bases. One metal ion is present in each ligand molecule. Compounds prepared have been shown to have six coordinated

distorted octahedral shapes and a mononuclear six coordination.

ACKNOWLEDGMENT

It would be appreciated if the authors could thank the BoM-Secretary, D.A-V. Post-Graduate College, Kapur for the opportunity to look at the work in a laboratory setting. Fortuitously, UPTTI Kanpur India supplies analytical facilities.

Funding

As part of this work, we received support from the Directorate of Higher Education, Uttar Pradesh, Prayagraj (Degree Vikas/225-232/2021-2022 dated 01 April 2021).

Conflict of Interest

Financial interests of the authors are not in conflict.

REFERENCES

1. Healy, M.D.S.; Rest, A.J. Template reactions. *Advances Inorganic Chemistry and Radiochemistry.*, **1978**, *21*, 1-40, [https://doi.org/10.1016/S0065-2792\(08\)60277-0](https://doi.org/10.1016/S0065-2792(08)60277-0).
2. Sergienko, V.S.; Abramenko, V.L.; Gorbunova, Y.E. Dioxomolybdenum (VI) Complexes with R1-Substituted Salicylidene Allylimines (Hl n): Synthesis and Structure. Crystal Structure of [MoO 2 (L 1 2](R 1= H). *Russian Journal of Inorganic Chemistry.*, **2018**, *63*, 28-33, <https://doi.org/10.1134/S003602361801014X>.
3. Melson, G.A. Coordination Chemistry of Macrocyclic Compounds. Plenum Press, NY., **1979**.
4. Lindoy L.F.; Busch, D.H. *Preparative Inorganic Reactions.*, **1971**, *6*, 1.
5. Lindoy, L.F.; Busch, D.H. Metal ion-controlled syntheses of novel five-coordinate zinc and cadmium complexes containing a helical coordination geometry and their template reaction to form complexes of a pentadentate macrocyclic ligand. *Inorganic Chemistry.*, **1974**, *13*(10), 2494-2498, <https://doi.org/10.1021/ic50140a037>.
6. Luo, X.F.; Hu, X.; Zhao, X.Y.; Goh, S.H.; Li, X.D. Miscibility and interactions in blends and complexes of poly(4-methyl-5-vinylthiazole) with proton-donating polymers, *Polymer.*, **2003**, *44*(18), 5285-5291, [https://doi.org/10.1016/S0032-3861\(03\)00578-0](https://doi.org/10.1016/S0032-3861(03)00578-0).
7. Murthy, A.S.N.; Reddy, A.R. Electronic absorption spectroscopic studies of enolimine-ketoamine equilibria in Schiff bases. *Journal of Chemical Sciences.*, **1981**, *90*(6), 519-526, <https://www.ias.ac.in/article/fulltext/jcsc/090/06/0519-0526>
8. Razakantoanina, V.; Phung, N.K.P.; Jaureguiberry, G. Antimalarial activity of new gossypol derivatives, *Parasitology Research.*, **2000**, *86*(8), 665-668, <https://doi.org/10.1007/pl00008549>.
9. Royer, R.E.; Deck, L.M.; Vander T.J.; Jagtm, Synthesis and anti-HIV activity of 1,1'-dideoxygossypol and related compounds, *Journal of Medicinal Chemistry.*, **1995**, *38*(13), 2427-2432, <https://doi.org/10.1021/jm00013a018>.
10. Flack, M.R.; Pyle, R. G.; Mullen, N.M. Oral gossypol in the treatment of metastatic adrenal cancer. *Journal of Clinical Endocrinology Metabolism.*, **1993**, *76*, 1019-1024, <https://doi.org/10.1210/jcem.76.4.8473376>.
11. Baumgrass, R.; Weiwad, M.; Erdmann, F. Reversible inhibition of calcineurin by the polyphenolic aldehyde, gossypol, *The Journal of Biological Chemistry.*, **2001**, *276*(51), 47914-47921, <https://doi.org/10.1074/jbc.m103273200>

12. Al-Shihri, A.S.M.; Abdel Fattah, H.M. Thermogravimetric and Spectroscopic characterization of trivalent lanthanide chelates with some Schiff base. *Journal of Thermal Analysis Calorimetry.*, **2003**, *71*(2), 643-649, <https://doi.org/10.1023/A:1022880615841>.
13. Raman, N.; Sakthivel, A.; Rajasekaran K. Synthesis and spectral characterization of antifungal sensitive Schiff base transition metal complexes. *Mycobiology.*, **2007**, *35*(3), 150-153, <https://doi.org/10.4489/MYCO.2007.35.3.150>.
14. Creaven, B.S.; Czeglédi, E.; Devereux, M.; Enyedy, E.A.; Kia, A.F.A.; Karcz, D.; Kellett, A.; McClean, S.; Nagy, N.V.; Noble, A.; Rockenbauer, A.; Szabó-Plánka, T.; Walshab, M. Biological activity and coordination modes of copper(II) complexes of Schiff base-derived coumarin ligands. *Dalton Transactions.*, **2010**, *39*, 10854-10865, <https://doi.org/10.1039/c0dt00068j>.
15. Doctor, V.M.; Oro, J. Mechanism of non-enzymatic transition reaction between histidine and alphaoxoyglutaric acid. *Journal of Biochemistry.*, **1969**, *112*(5), 691-697, <https://doi.org/10.1042/bj1120691>.
16. El-Gammal, O.A.; El-Reash, G.M.A.; Goama, H.E. Mononuclear Cr(III), Mn (II), and Fe(III) complexes derived from new ONO symmetrical flexible hydrazone: synthesis, spectral characterization, optical band gap and DFT computational study. *Letters in Applied Nano Bio Science.*, **2019**, *8*(4), 743-753, <https://doi.org/10.33263/LIANBS84.743753>.
17. Jarrahpour, A.; Khalili, D.; De Clercq, E.; Salmi, C.; Brunel, J.M. Synthesis, antibacterial, antifungal and antiviral activity evaluation of some new bis-Schiff bases of isatin and their derivatives. *Molecules.*, **2007**, *12*, 1720-1730, <https://doi.org/10.3390/12081720>.
18. Bharti, S.K.; Patel, S.K.; Nath, G.; Tilak, R.; Singh, S.K. Synthesis, characterization, DNA cleavage and *in vitro* antimicrobial activities of copper(II) complexes of Schiff bases containing a 2,4-disubstituted thiazole. *Transition Metal Chemistry.*, **2010**, *35*, 917-925, <https://doi.org/10.1007/s11243-010-9412-8>.
19. Manjunatha, M.; Naik, V. H.; Kulkarni, A.D.; Patil, S.A. DNA cleavage, antimicrobial, antiinflammatory anthelmintic activities, and spectroscopic studies of Co(II), Ni(II), and Cu(II) complexes of biologically potential coumarin Schiff bases. *Journal of Coordination Chemistry.*, **2011**, *64*(24), 4264-4275, <https://doi.org/10.1080/00958972.2011.621082>.
20. Amer, S.; El-Wakiel, N.; El-Ghamry, H. Synthesis, spectral, antitumor and antimicrobial studies on Cu(II) complexes of purine and triazole Schiff base derivatives. *Journal of Molecular Structure.*, **2013**, *1049*, 326-335, <https://doi.org/10.1016/j.molstruc.2013.06.059>.
21. Ohashi, M.; Koshiyama, T.; Veno, T.; Yanase, M.; Fujii, H.; Watanabe, Y. Preparation of artificial metalloenzymes by insertion of Chromium(III)Schiff base complexes in to apomyoglobin mutants. *Angewandte Chemie International Edition.*, **2003**, *42*(9), 1005-1008, <https://doi.org/10.1002/anie.200390256>.
22. Dongfang, X.U.; Shuzhi, M.A.; Guangying, D.V.; Qizhuang, H.E.; Dazhi, S. Synthesis, characterization and anticancer properties of rare earth complexes with Schiff base and O-phenanthroline. *Journal of Rare Earths.*, **2008**, *26*(5), 643-647, [https://doi.org/10.1016/S1002-0721\(08\)60153-2](https://doi.org/10.1016/S1002-0721(08)60153-2).
23. Uddin, N.; Rashid, F.; Ali S.; Tirmizi S.A.; Ahmad, I.; Zaib, S.; Zubair, M.; Diaconescu, P.L.; Tahir, M.N.; Jamshed, I.; Haider, A. Synthesis, characterization, and anticancer activity of Schiff bases. *Journal of Biomolecular Structure and Dynamics.*, **2019**, *38*(11), 3246-3259, <https://doi.org/10.1080/07391102.2019.1654924>.
24. Etain, S.E.H.; Abd El-Aziz, D.M.; Abd El-Zaher, E.H.; Ali, E.A. Synthesis spectral, antimicrobial and antitumor assessment of Schiff base derived from 2-aminobenzothiazol and its transition metal complexes. *Spectrochim. Acta. Molecular and Biomolecular Spectroscopy.*, **2011**, *79*(5), 1331-1337, <https://doi.org/10.1016/j.saa.2011.04.064>.
25. Cozzi, P.G. Metal-Salen Schiff base complexes in catalysis: practical aspects. *Chemical Society Reviews.*, **2004**, *33*, 410-421, <https://doi.org/10.1039/b307853c>.
26. Singh, R.K.; Kukrety, A.; Saxena, R.C.; Thakre, G.D.; Atray, N.; Ray, S.S. Novel triazine Schiff base-based cationic gemini surfactants: Synthesis and their evaluation as Antiwear, antifriction, and anticorrosive additives in polyol. *Industrial and Engineering Chemistry Research.*, **2016**, *55*(9), 2520-2526, <https://doi.org/10.1021/acs.iecr.5b04242>.

27. Sathya, N.; Raja, G.; Padma; Priya, N.; Jayabalakrishnan C. Ruthenium(II) complexes incorporating tridentate schiff base ligands: Synthesis, spectroscopic, redox, catalytic and biological properties. *Applied Organometallic Chemistry*, **2010**, *24*(5), 366-373, <https://doi.org/10.1002/aoc.1621>.
28. Arun, V.; Sridevi, N.; Robinson, P.P.; Manju, S.; Yusuff, K.K.M. Ni(II) and Ru(II) Schiff base complexes as catalysts for the reduction of benzene. *Journal of Molecular Catalysis A: Chemical*, **2009**, *304*(1-2), 191-198, <https://doi.org/10.1016/j.molcata.2009.02.011>.
29. Segura, J. L.; Mancheño, M. J.; Zamora, F. Covalent organic frameworks based on Schiff-base chemistry: synthesis, properties and potential applications. *Chemical Society Review*, **2016**, *45*, 5635-5671, <https://doi.org/10.1039/c5cs00878f>.
30. Yadava, H.D.S.; Sengupta, S.K; Tripathi, S.C. Syntheses and spectroscopic studies on dioxouranium(VI), oxovanadium(IV) and oxozirconium(IV) complexes with tetradentate macrocyclic ligands. *Inorganica Chimica Acta*, **1987**, *128*, 1-6, [https://doi.org/10.1016/S0020-1693\(00\)84685-X](https://doi.org/10.1016/S0020-1693(00)84685-X).
31. Sergienko, V.S.; Abramenko, V.L.; Surazhskaya, M.D. Intracomplex Dioxomolybdenum (VI) Compounds with Alcoholimines of Aromatic o-Hydroxyaldehydes. Crystal Structure of 2-Hydroxynaphthylidene Monoethanolimine (H₂L) and Solvated Complex [MoO₂(L)•C₅H₅N]. *Russian Journal of Inorganic Chemistry*, **2020**, *65*, 495-501, <https://doi.org/10.1134/S0036023620040166>.
32. Crans, D.C. Fifteen years of dancing with vanadium. *Pure and Applied Chemistry*, **2005**, *77*(9), 1407-1527, <http://dx.doi.org/10.1351/pac200577091497>.
33. Bagherzadeh, M.; Amini, M.; Parastar, H. Synthesis, X-ray structure and oxidation catalysis of a oxido-peroxido molybdenum(VI) complex with a tridentate Schiff base ligand. *Inorganic Chemistry Communications*, **2012**, *20*, 86-89, <https://doi.org/10.1016/j.inoche.2012.02.023>.
34. Moradi-Shoeili, Z.; Zare.; M.; Bagherzadeh, M.; Kubicki, M.; Boghaei, D.M. Preparation and structure of zinc complexes containing pincer ligands and their application for Knoevenagel condensation in water. *Journal of Coordination Chemistry*, **2015**, *68*(2), 548-559, <https://doi.org/10.1080/00958972.2014.978308>.
35. Bagherzadeh, M.; Amini, M.; Parastar, H. Synthesis, X-ray structure and oxidation catalysis of a oxido-peroxido molybdenum(VI) complex with a tridentate Schiff base ligand. *Inorganic Chemistry Communication*, **2012**, *20*, 86-89, <https://doi.org/10.1016/j.inoche.2012.02.023>.
36. Aziz, A.A.A. Synthesis, spectroscopic characterization, thermal studies, catalytic epoxidation and biological activity of chromium and molybdenum hexacarbonyl bound to a novel N₂O₂ Schiff base. *Journal of Molecular Structure*, **2010**, *979*(1-3), 77-85, <https://doi.org/10.1016/j.molstruc.2010.06.004>.
37. Chakravarthy, R.D.; Suresh, K.; Ramkumar, V.; Chand, D.K. New chiral molybdenum complex catalyzed sulfide oxidation with hydrogen peroxide. *Inorganica Chimica Acta*, **2011**, *376*(1), 57-63, <https://doi.org/10.1016/j.ica.2011.05.033>.
38. Rayati, S.; Rafiee, N.; Wojtczak, A. cis-Dioxomolybdenum(VI) Schiff base complexes: Synthesis, crystal structure and catalytic performance for homogeneous oxidation of olefins. *Inorganica Chimica Acta*, **2012**, *386*, 27-35, <https://doi.org/10.1016/j.ica.2012.02.005>.
39. Rao, D.P. A review on versatile applications of novel Schiff bases and their metal complexes. *Letters in Applied Nano Bio Science*, **2019**, *8*(4), 675-681. <https://doi.org/10.33263/LIANBS84.675681>.
40. Pushie, M.J.; George, G.N. Spectroscopic studies of molybdenum and tungsten enzymes. *Coordination Chemistry Review*, **2011**, *255*(9-10), 1055-1084, <https://doi.org/10.1016/j.ccr.2011.01.056>.
41. Gautam, R.K.; Singh, C.P.; Prasad S.P.; Saxena, R.; Rao, D.P. Synthesis and antibacterial activity of novel molybdenum complexes with macrocyclic Schiff base derived from furanylethanedione. *Asian Journal of Chemistry*, **2019**, *31*, 2607-2612, <https://doi.org/10.14233/ajchem.2019.22242>.

42. Rao, C.P.; Sreedhara, A.; Rao, P.V.; Verghese, M.B.; Rissanen, K.; Kolehmainen, E.; Lokanath, N.K.; Sridhar, M.A.; Prasad, J.S. Syntheses, structure, reactivity and species recognition studies of oxo-vanadium(V) and -molybdenum(VI) complexes. *Journal of the Chemical Society.*, **1998**, *14*, 2383-2394, <https://doi.org/10.1039/A801226A>.
43. Hahn, R.; Herrmann, W.A.; Artens, G.R.J. Kleine, M. Biologically relevant metal coordination compounds: MoVIO₂ and nickel(II) complexes with tridentate aromatic Schiff bases. *Polyhedron.*, **1995**, *14*(20-21), 2953-2960, [https://doi.org/10.1016/0277-5387\(95\)00133-D](https://doi.org/10.1016/0277-5387(95)00133-D).
44. Mendel, R.R. Molybdenum: biological activity and metabolism. *Dalton Transaction.*, **2005**, *21*, 3404-3409, <https://doi.org/10.1039/B505527J>.
45. Sigel, A.; Sigel, H. Metal Ions in Biological Systems, Molybdenum and Tungsten: Their Roles in Biological Processes, Marcel Dekker, NY. **39**, **2002**.
46. Maurya, R.C.; Shukla, B.; Pandey, A. Synthesis, magnetic and spectral studies of some cis-dioxomolybdenum(VI) complexes derived from N, O- and N₂O²⁻ type Schiff bases. *Indian Journal of Chemistry.*, **2002**, *41A*(3), 554-559, URI: <http://hdl.handle.net/123456789/29016>.
47. Rousso, I.; Friedman, N.; Sheves, M.; Ottolenghi, M. pKa of the protonated Schiff base and aspartic 85 in the bacteriorhodopsin binding site is controlled by a specific geometry between the two residues. *Biochemistry.*, **1995**, *34*, 12059-12065, <https://doi.org/10.1021/bi00037a049>
48. Bassov, T.; Sheves, M. Alteration of pKa of the bacteriorhodopsin protonated Schiff base. A study with model compounds. *Biochemistry.*, **1980**, *25*(18), 5249-5258, <https://doi.org/10.1021/bi00366a040>.
49. Mimoum, H.; Roch, I.S.D.; Sajus, L. Epoxydation des olefines par les complexes peroxydiques covalents du molybdene-VI. *Tetrahedron.*, **1970**, *26*(1), 37-50, [https://doi.org/10.1016/0040-4020\(70\)85005-0](https://doi.org/10.1016/0040-4020(70)85005-0).
50. Conte, V.; Furia, F.D. Catalytic oxidations with hydrogen peroxide as oxidant, Kluwer Academic Publisher, Berlin., **1992**.
51. Mimoum, H.; Saussine, L.; Daire, E.; Postel, M.; Fisher, J.; Weiss, R. Vanadium(V) peroxy complexes. New versatile biomimetic reagents for epoxidation of olefins and hydroxylation of alkanes and aromatic hydrocarbons. *Journal of American Chemistry Society.*, **1983**, *105*(10), 3101-3110, <https://doi.org/10.1021/ja00348a025>
52. Nair, M.L.H.; Thankamani, D. Synthesis and characterization of oxomolybdenum (V) and dioxomolybdenum (VI) complexes with schiff base derived from isonicotinoylhydrazide. *Indian Journal of Chemistry.*, **2009**, *48A*(9), 1212-1218, URI: <http://hdl.handle.net/123456789/6010>.
53. Garner, G.D. Molybdenum, special topics in Comprehensive Coordination Chemistry. *Wilkinson G, Ed., Pergamon press, Oxford.*, **1987**, *6*, 1421.
54. Niasari, M.S.; Davar, F.; Bazarganipour, M. Synthesis, characterization and catalyticoxidation of para-xylene by a manganese(III) Schiff base complex on functionalized multi-wall carbon nanotubes (MWNTs). *Dalton Transactions.*, **2010**, *39*, 7330-7337, <https://doi.org/10.1039/B923416K>.
55. Ambroziak, K.; Beleck, R.M.; He, Y.; Saha, B.; Sherrington, D.C. Investigation of batch alkene epoxidations catalyzed by polymer-supported Mo(VI) complexes. *Industrial and Engineering Chemistry Research.*, **2009**, *48*(7), 3293-3302, <https://doi.org/10.1021/ie801171s>.
56. Vogel, A.I. *A Text book of quantitative Inorganic analysis* 4th ed., Longmans Green Co. Ltd., London, **1978**.
57. Vogel, A.I. *A Text book of practical organic chemistry* 4th ed., Longmans Green Co. Ltd., London, **1978**.
58. Simmons, A. *Practical medical microbiology* 14th ed, Churchill Livingstone, Edinberg, **1996**, *11*, 163,
59. Collee, J.G.; Duguid, J.P.; Frase, A.G.; Marmion, B.D. *Practical medical microbiology*, Churchill Livingstone, New York, **1989**.
60. Nag, P.; Sharma, D. Synthesis, characterization and anticandidal activity of dioxomolybdenum(VI) complexes of the type [MoO₂{ON=C(CH₃)Ar}₂] and [MoO₂{OC(R)CHC(R')=NC₆H₅}₂]. *Heliyon.*, **2019**, *5*(5), E01729, <https://doi.org/10.1016/j.heliyon.2019.e01729>

61. Rana, V.B.; Singh, P.; Singh, D.P.; Teotia, M.P. Trivalent chromium, manganese, iron and cobalt chelates of a tetradentate N6 macrocyclic ligand. *Transition Metal Chemistry*, **1982**, *7*, 174-177, <https://doi.org/10.1007/BF01035836>.
62. Chandra, S.; Sharma, K.K. Synthesis and characterization of copper(II) complexes of a macrocyclic ligand. *Transition Metal Chemistry*, **1983**, *8*, 1-3, <https://doi.org/10.1007/BF00618784>.
63. Malik, W.U.; Bembi, R.; Singh, R. Preparation and characterisation of some new 12- and 14-membered dibenzotetraaza macrocyclic complexes of iron(III). *Inorganica Chimica Acta*, **1983**, *68*, 223-228, [https://doi.org/10.1016/S0020-1693\(00\)88965-3](https://doi.org/10.1016/S0020-1693(00)88965-3).
64. Głowiak, T.; Jerzykiewicz, L.; Sobczak, J.M.; Ziótkowski, J.J. New insights into the chemistry of oxomolybdenum(VI) complexes with N-salicylidene-2-aminoethanol. *Inorganica Chimica Acta*, **2003**, *356*, 387-392, [https://doi.org/10.1016/S0020-1693\(03\)00301-3](https://doi.org/10.1016/S0020-1693(03)00301-3).
65. Ferraro, J.R. Low frequency vibrations of inorganic and coordination compounds. Plenum, New York., **1971**.
66. Dyer, J.R. Applications of absorption spectroscopy of organic compounds. Prentice-Hall, Inc., Englewood Cliffs, NJ, **1965**.
67. Singh, S.; Yadav, H.S.; Yadava, A.K.; Rao, D.P. Synthesis and characterization of oxovanadium(IV) complexes with tetradentate Schiff base ligands having thenil as precursor molecule. *Current Research in Chemistry*, **2011**, *3*, 106-113, <https://doi.org/10.3923/crc.2011.106.113>.
68. Willis, L.J.; Loehr, T.M.; Miller, K.F.; Bruce, A.E.; Stiefel, E.I. Raman and infrared spectroscopic studies of dioxomolybdenum(VI) complexes with cysteamine chelates. *Inorganic Chemistry*, **1986**, *25*, 4289-4293, <https://doi.org/10.1021/ic00243a045>.
69. Ceylan, B.I.; Kurt, Y.D.; Ulkuseven, B. Synthesis and characterization of new dioxomolybdenum(VI) complexes derived from benzophenone-thiosemicarbazone (H₂L). Crystal structure of [MoO₂L(PrOH)]. *Journal of Coordination Chemistry*, **2009**, *62*, 757-766, <https://doi.org/10.1080/00958970802339669>
70. S.N. Rao, K.N. Munshi, N.N. Rao, M.M. Bhadbhade, E. Suresh. Synthesis, spectral and X-ray structural characterization of [cis-MoO₂(L)(solv)](L= salicylidene salicyloyl hydrazine) and its use as catalytic oxidant. *Polyhedron*, **1999**, *18*, 2491-2497, [https://doi.org/10.1016/S0277-5387\(99\)00139-4](https://doi.org/10.1016/S0277-5387(99)00139-4).
71. El-Medani, S.M.; Aboaly, M.M.; Abdalla, H.H.; Ramadan, R.M. Reactions of Group 6 Metal Carbonyls with Salicylaldehyde Hydrazone. *Spectroscopy Letter*, **2004**, *37*(6), 619-632, <https://doi.org/10.1081/SL-200037610>.
72. Zhu, X.W. Synthesis, crystal structures and catalytic property of dioxomolybdenum(VI) complexes derived from tridentate Schiff bases. *Acta Chimica Slovenica*, **2018**, *65*, 939-945, <https://doi.org/10.17344/acsi.2018.4607>.
73. Maurya, R.C.; Chourasia, J.; Martin, M.H.; Roy, S.; Sharma, A.K.; Vishwakarma, P. Dioxomolybdenum(VI) chelates of bioinorganic, catalytic, and medicinal relevance: Studies on some cis-dioxomolybdenum(VI) complexes involving O, N-donor 4-oximino-2-pyrazoline-5-one derivatives. *Arabian Journal of Chemistry*, **2015**, *8*(3), 293-306, <https://doi.org/10.1016/j.arabjc.2011.01.010>.
74. Wang, X.; Zhang, X.M.; Liu, H.X. Synthesis, characterization and crystal structure of cis-dioxomolybdenum(VI) complexes of the Schiff base Girard reagent (T) salt. *Journal of Coordination Chemistry*, **1994**, *33*, 223-228, <https://doi.org/10.1080/00958979408024280>
75. Mahmoudi, H.; Bagherzadeh, M.; Ataie, S.; Kia, R.; Heydar Moravej, S.; Zare, M.; Raithby, P.R.; Ferlin, F.; Vaccaro, L. Synthesis and X-ray crystal structure of a molybdenum(VI) Schiff base complex: Design of a new catalytic system for sustainable olefin epoxidation. *Inorganica Chimica Acta*, **2020**, *511*, 119775, <https://doi.org/10.1016/j.ica.2020.119775>.
76. Rao, D.P.; Yadav, H.S.; Yadava, A.K.; Singh, S.; Yadav, U.S. Syntheses and spectroscopic studies on macrocyclic complexes of dioxomolybdenum(VI) with furil as precursor. *E-Journal of Chemistry*, **2012**, *9*, 497-503, <https://doi.org/10.1155/2012/205123>.
77. Cotton, F.A.; Wilkinson, G.; Murillo, C.A.; Bochmann, M. *Advanced Inorganic Chemistry*, 6th ed., Wiley, New York, **1999**, *18*, 944-947.
78. Nakamoto, K. Infrared and Raman Spectra of inorganic and co-ordination compounds. New York: Wiley, **1978**, <https://doi.org/10.1002/0470027320.s4104>

79. Gehrke, H.; Veal, J. Acetylacetonate complexes of molybdenum(V) and molybdenum(VI). *Inorganica Chimica Acta.*, **1969**, *3*, 623-627, [https://doi.org/10.1016/S0020-1693\(00\)92563-5](https://doi.org/10.1016/S0020-1693(00)92563-5).
80. Yadav, H.S. Synthesis of spectroscopic studies of oxovanadium(IV) complexes with 16- and 18-membered macrocyclic ligands. *Polyhedron.*, **1993**, *12*, 313-317, [https://doi.org/10.1016/S0277-5387\(00\)81729-5](https://doi.org/10.1016/S0277-5387(00)81729-5).
81. Rao, D.P.; Yadav, H.S.; Yadava, A.K.; Singh, S.; Yadav, U.S. In-situ preparation of macrocyclic complexes of dioxomolybdenum(VI) involving a heterocyclic precursor. *Journal of Coordination Chemistry.*, **2011**, *64*, 293-299, <https://doi.org/10.1080/00958972.2010.544037>.
82. Sakata, K.; Kuroda, M.; Yanagida, S.; Hashimoto, M. Preparation and spectroscopic properties of oxovanadium(IV) and dioxomolybdenum(VI) complexes with tetraaza[14] annulenes containing pyridine rings. *Inorganica Chimica Acta.*, **1989**, *156*, 107-112, [https://doi.org/10.1016/S0020-1693\(00\)90375-X](https://doi.org/10.1016/S0020-1693(00)90375-X).
83. Gautam, R.K.; Singh, C.P.; Kumar, D.; Rao, D.P. New Insights into the Chemistry of cis-Dioxomolybdenum(VI) Schiff base complexes with macrocyclic ligands. *Chemical Science Transactions.*, **2019**, *8*(4), 467-476, <https://doi.org/10.7598/cst2019.1594>.
84. Garg, R.; Saini, M.K.; Fahmi, N.; Singh, R.V. Spectroscopic and biochemical studies of some manganese(II), oxovanadium(V) and dioxovanadium(VI) complexes S/O and N donor agents synthesized under microwave conditions. *Transition Metal Chemistry.*, **2006**, *31*, 362-367, <https://doi.org/10.1007/s11243-005-0001-1>.
85. Gautam, R.K.; Singh, C.P.; Saxena, R.; Rao, D.P. Synthesis and studies of some cis-MoO₂(VI) complexes with nitrogen donor macrocyclic ligands. *European Chemical Bulletin.*, **2019**, *8*, 387-393, <http://dx.doi.org/10.17628/ecb.2019.8.387-393>.
86. Kahroic, E.; Molcanov, K.; Tusek-Bozic, L.; Kojic-Prodic, B. New complexes of Mo(V) with Schiff bases: Crystal structure of butylammonium di- μ -oxo- μ -acetato-bis[(N-butylsalicylideneiminato-N,O)oxomolybdenum(V)] benzene, acetic acid solvate. *Polyhedron.*, **2006**, *25*(12), 2459-2464, <https://doi.org/10.1016/j.poly.2006.02.008>.
87. Ballhausen, C.J.; Gray, H.B. The electronic structure of the vanadyl ion. *Inorganic Chemistry.*, **1962**, *1*, 111-122, <https://doi.org/10.1021/ic50001a022>.