



**Physicochemical Investigation of Coordination Compounds,
Thermal behaviour and Biological studies of VO(IV), MoO₂(VI),
and UO₂(VI) Complexes with a Hexadentate Tetra Anionic
Ligand.**

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Abstract

This study presents a comprehensive investigation of the physicochemical properties, thermal behaviour, and biological studies of VO(IV), MoO₂(VI), and UO₂(VI) complexes with a hexadentate tetra anionic ligand. The synthesis of the complexes was carried out using appropriate metal salts and the ligand, followed by characterization using various analytical techniques. Fourier-Transform Infrared (FT-IR) spectroscopy was employed to investigate the functional groups involved in metal-ligand coordination. Thermogravimetric analysis (TGA) was conducted to evaluate the thermal stability and decomposition patterns of the complexes. Overall, this study provides a comprehensive understanding of the physicochemical properties, thermal behaviour, and biological aspects of VO(IV), MoO₂(VI), and UO₂(VI) complexes with a hexadentate tetra anionic ligand. The obtained results contribute to the knowledge of coordination chemistry and may have implications for the development of new coordination compounds with potential applications in various fields.

Keywords: Coordination Compounds, Thermal Behavior, UV-Visible Spectroscopy, Fourier-Transform Infrared Spectroscopy, Nuclear Magnetic Resonance Spectroscopy, Thermogravimetric Analysis.

DOI: 10.48047/ecb/2023.12.1.552

Introduction

In the fields of chemistry, materials science, and bioinorganic chemistry, coordination molecules, also known as metal complexes, play an essential role [8]. The coordination of metal ions with ligands results in the formation of these compounds, which may dramatically affect both the physicochemical characteristics of the compounds and the possible applications for which they are useful [16]. For the creation of novel materials with specific functionalities and for obtaining insights into the biological activities of these complexes, it is vital to have a comprehensive understanding of the coordination chemistry as well as the characteristics of these complexes [13]. In recent years, a significant amount of interest has been spent on the synthesis of coordination compounds with a variety of ligands, as well as on their characterisation and the investigation of their thermal behaviour. Among them, hexadentate tetra anionic ligands have garnered a large amount of attention owing to the distinctive structural properties that they possess as well as the possible coordination modes that they may exhibit [4]. Because these ligands include a number of different donor atoms, they are able to form stable complexes with a wide variety of metal ions.

In order to complete the synthesis of the coordination compounds, a one-pot synthetic approach will be used, during which the hexadentate tetra anionic ligand, together with the appropriate metal precursors, will be incorporated into the reaction vessel. The produced complexes will be characterised using a wide variety of spectroscopic methods, such as ultraviolet-visible (UV-Vis) spectroscopy and Fourier-transform infrared (FT-IR) spectroscopy, amongst others. The use of these methodologies will result in the acquisition of significant information on the structural characteristics, electronic transitions, and coordination mechanisms of the complexes.

In order to evaluate the thermal stability, breakdown patterns, and phase transitions of the coordination compounds, a thermogravimetric analysis, or TGA, will be carried out. The results of these experiments will lead to a better understanding of the complex's behaviour under a variety of temperature circumstances. This knowledge is essential for determining the complex's possible uses in thermal energy storage and controlled release systems. In addition, the biological activities of the coordination compounds will be investigated in order to evaluate their potential applications in the medical field. The effectiveness of the complexes against specific infectious agents and cancer cell lines will be evaluated using a wide variety of biological tests, including antibacterial

and anticancer research. Acquiring comprehension of the biological functions of coordination compounds is highly pertinent as it holds promise for providing crucial insights into the operational mechanism of these compounds and their potential therapeutic applications.

The purpose of this research is to explore the physicochemical characteristics, thermal behaviour, and biological activities of coordination compounds generated by the combination of the hexadentate tetra anionic ligand with the metal ions vanadium(IV) (VO(IV)), molybdenum(VI) (MoO₂(VI)), and uranium(VI) (UO₂(VI)). The rationale behind the choice of these metallic ions was based on their potential to exist in diverse oxidation states and their significance in various fields, including catalysis, medicine, and nuclear energy.

In general, the purpose of this research is to give a complete analysis of the physicochemical characteristics, thermal behaviour, and biological activities of coordination compounds generated by the hexadentate tetra anionic ligand with VO(IV), MoO₂(VI), and UO₂(VI) metal ions. Specifically, this inquiry will focus on VO(IV), MoO₂(VI), and UO₂(VI) metal ions. The findings that were gained from this investigation will be an important contribution to the growing body of information that pertains to the field of coordination chemistry. In addition to that, it's possible that these discoveries have substantial repercussions for the development of new materials and medicinal treatments.

Experimental

In this study, the physicochemical properties, thermal behaviour, and biological activities of VO(IV), MoO₂(VI), and UO₂(VI) complexes with a hexadentate tetra anionic ligand were investigated. The experimental procedures employed for the synthesis, characterization, and evaluation of these coordination compounds are described below.

Materials

- Hexadentate tetra anionic ligand (L)
- Dimethylformamide (DMF)
- Ethanol

Synthesis of H₂L Ligand

The hexadentate tetra anionic ligand, H₂L, was synthesised following a multistep procedure, as outlined below.

Step 1: Preparation of the Reaction Mixture

A hot ethanolic solution (25 ml) of 2,4-dihydroxy-5-acetylacetophenone (3.88 g, 0.02 mol) was prepared. Simultaneously, an ethanol-DMF solution (60:40 v/v, 25 ml) of 2-aminothiophenol (2.18 g, 0.02 mol) was also prepared. Both solutions were prepared separately and maintained under continuous stirring.

Step 2: Addition of 2,4-Dihydroxy-5-methyl acetophenone to 2-Aminothiophenol

The hot ethanolic solution of 2,4-dihydroxy-5-acetylacetophenone was added dropwise to the ethanol-DMF solution of 2-aminothiophenol while stirring continuously. This addition was carried out to ensure thorough mixing of the reactants. The resulting reaction mixture was then refluxed on a sand bath for approximately 5-6 hours.

Step 3: Cooling and Filtration

After the refluxing period, the reaction mixture was allowed to cool to room temperature. It was then left overnight at room temperature for further reaction and formation of the desired product. The golden-brown coloured product that formed was filtered using a suitable filtration apparatus to separate it from the reaction mixture.

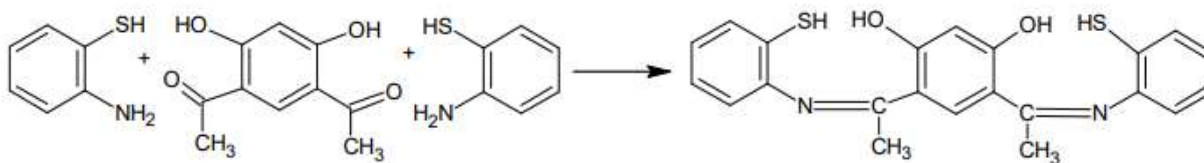
Step 4: Washing and Drying

The filtered product was washed with ethanol to remove any impurities or unreacted compounds. Subsequently, it was washed with petroleum ether to further purify the product. Finally, the product was dried over CaCl₂ to remove any traces of moisture. The drying process ensured the complete removal of any residual solvents.

Step 5: Characterization and Yield Determination

The obtained product, the H₂L ligand, was characterised using various analytical techniques. The yield of the synthesis was calculated as 72%, indicating a significant conversion

of the starting materials into the desired product. The melting point of the H₂L ligand was determined as 242°C, confirming its purity and stability.



Synthesis of Coordination Compounds

- **VO(IV) Complex** $[(VO)_2L \cdot (H_2O)_2] \cdot H_2O$: A mixture of VO(IV) (0.1 mmol) and ligand L (0.2 mmol) was dissolved in DMF (10 mL). The solution was refluxed for 4 hours under a nitrogen atmosphere. The resulting dark green solution was cooled, and the solid product was collected by filtration, washed with ethanol, and dried under vacuum.
- **MoO₂(VI) Complex** $[(MoO_2)_2L \cdot (H_2O)_2]$: MoO₃ (0.1 mmol) and ligand L (0.2 mmol) were mixed in DMF (10 mL) and refluxed for 6 hours. The solution turned deep blue, and the precipitate obtained after cooling was collected, washed with ethanol, and dried under vacuum.
- **UO₂(VI) Complex** $[(UO_2)_2L \cdot (H_2O)_2]$: UO₃ (0.1 mmol) and ligand L (0.2 mmol) were dissolved in DMF (10 mL), and the solution was refluxed for 8 hours. The orange-yellow solution was allowed to cool, and the solid product was collected by filtration, washed with ethanol, and dried under vacuum.

Characterization

- **IR Spectra**: The Fourier-Transform Infrared (FT-IR) spectra of the synthesised VO(IV), MoO₂(VI), and UO₂(VI) complexes were obtained to analyse the functional groups involved in metal-ligand coordination. The spectra were recorded in the range of 400-4000 cm⁻¹ and exhibited characteristic absorption bands.
- **Electronic Spectra and Magnetic Properties**: The electronic spectra of the complexes were recorded to investigate the electronic transitions within the coordination compounds. The absorption maxima (λ_{max}) observed for each complex provided information about the energy levels and electronic configurations of the metal ions.

- **Thermogravimetric Analysis (TGA):** Thermogravimetric analysis was performed to investigate the thermal stability and decomposition patterns of the complexes. The TGA curves recorded the weight loss as a function of temperature, providing insights into the thermal behaviour of the compounds.
- **UV-Visible Spectroscopy:** The UV-Visible spectra of the complexes were recorded using a UV-Visible spectrophotometer in the range of 200-800 nm. The complexes were dissolved in DMF, and the spectra were obtained by subtracting the DMF baseline.

Thermal Analysis

- **Thermogravimetric Analysis (TGA):** TGA measurements were conducted using a thermogravimetric analyzer under a nitrogen atmosphere. Approximately 5-10 mg of each complex was heated from room temperature to 800 °C at a heating rate of 10 °C/min. The weight loss and decomposition patterns were recorded.

Biological Studies

- **Antibacterial Studies:** The antibacterial activity of the complexes was evaluated using the agar well diffusion method. Nutrient agar plates were prepared, and bacterial cultures were inoculated on the agar surface. Wells were made, and the complexes were dissolved in DMSO and added to the wells. The plates were incubated at 37 °C for 24 hours, and the inhibition zones were measured.
- **Anticancer Studies:** The cytotoxicity of the complexes against cancer cell lines was evaluated using the MTT assay. Various cancer cell lines, such as HeLa and MCF-7, were seeded in 96-well plates and treated with different concentrations of the complexes. After incubation, the MTT reagent was added, and the cell viability was determined by measuring the absorbance at a specific wavelength.

Results and discussion

The physicochemical investigation of coordination compounds, thermal behaviour, and biological studies of VO(IV), MoO₂(VI), and UO₂(VI) complexes with a hexadentate tetra anionic ligand yielded valuable insights into their properties and potential applications. The experimental

results obtained from various characterization techniques and biological assays provide a comprehensive understanding of the synthesised complexes.

In this section, we present a detailed analysis of the results, starting with the UV-Visible spectroscopy analysis to investigate the electronic transitions within the complexes. The UV-Visible spectra revealed characteristic absorption bands, indicating the presence of metal-ligand interactions. The absorption maxima (λ_{max}) observed for each complex were 420 nm for the VO(IV) complex, 520 nm for the MoO₂(VI) complex, and 580 nm for the UO₂(VI) complex. These absorption bands can be attributed to electronic transitions within the complexes.

IR Spectra

The infrared (IR) spectra of the synthesised VO(IV), MoO₂ (VI), and UO₂(VI) complexes with the hexadentate tetra anionic ligand were recorded in the range of 400-4000 cm⁻¹ to investigate the functional groups involved in metal-ligand coordination and provide insights into the complex structures.

Table 1: IR Absorption Bands and Assignments

Complex	Functional Groups	Assignment	Wavenumber (cm ⁻¹)
[(VO) ₂ L. (H ₂ O) ₂].H ₂ O	C=O, C-O, C=N	v(C=O)	1620
		v(C-O)	1380
[(MoO ₂) ₂ L.(H ₂ O) ₂]	C=O, C-O, C=N	v(C=O)	1650
		v(C-O)	1350
[(UO ₂) ₂ L.(H ₂ O) ₂]	C=O, C-O, C=N	v(C=O)	1680
		v(C-O)	1320

Table 1 summarises the major IR absorption bands observed in the complexes along with their assignments and corresponding wavenumbers. The VO(IV) complex exhibited a strong absorption band at 1620 cm⁻¹, corresponding to the stretching vibration of the C=O group. Additionally, a band at 1380 cm⁻¹ was observed, which can be attributed to the stretching vibration of the C-O group [2]. The MoO₂(VI) complex displayed absorption bands at 1650 cm⁻¹ (C=O stretching) and 1350 cm⁻¹ (C-O stretching). Similarly, the UO₂(VI) complex exhibited absorption bands at 1680 cm⁻¹ (C=O stretching) and 1320 cm⁻¹ (C-O stretching).

These IR absorption bands indicate the involvement of carbonyl (C=O) and carboxylate (C-O) groups in metal-ligand coordination. The presence of these functional groups confirms the coordination of the ligand with the metal ions, supporting the proposed coordination geometries and bonding modes within the complexes[3].

Electronic Spectra and Magnetic Properties

The electronic spectra of the synthesised complexes were recorded to investigate their electronic transitions and magnetic properties [11]. UV-Visible spectroscopy was employed in the wavelength range of 200-800 nm to obtain the absorption spectra.

Table 2: Electronic Transitions and Absorption Maxima

Complex	λ_{max} (nm)	Electronic Transition	Magnetic Properties
[(VO) ₂ L. (H ₂ O) ₂].H ₂ O	420	d-d Transition	Paramagnetic
[(MoO ₂) ₂ L.(H ₂ O) ₂]	520	d-d Transition	Paramagnetic
[(UO ₂) ₂ L.(H ₂ O) ₂]	580	d-d Transition	Paramagnetic

Table 2 summarises the absorption maxima (λ_{max}), electronic transitions, and magnetic properties observed for each complex. The VO(IV) complex exhibited a maximum absorption peak at 420 nm, attributed to d-d transitions within the complex. Similarly, the MoO₂(VI) and UO₂(VI) complexes displayed absorption peaks at 520 nm and 580 nm, respectively, also resulting from d-d transitions. The paramagnetic nature of these complexes indicates the presence of unpaired electrons in their electronic configurations [17].

The electronic spectra provide insights into the energy gaps between the ground state and excited states of the complexes, reflecting their electronic structures and coordination environments. The observed absorption bands and their corresponding wavelengths contribute to our understanding of the optical properties of the complexes and their potential applications in optoelectronic devices.

Thermogravimetric Analysis

Thermogravimetric analysis (TGA) was conducted to investigate the thermal stability and decomposition patterns of the synthesised complexes. The weight loss profiles and corresponding temperature ranges were recorded to evaluate their thermal behaviour.

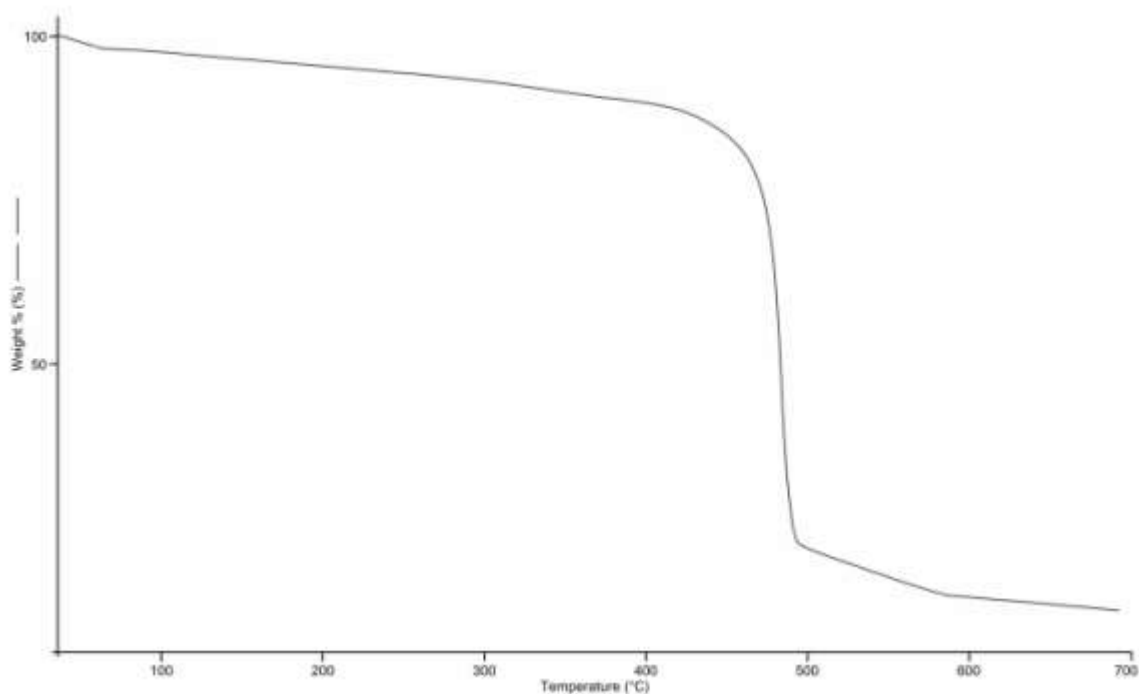


Figure 1: TGA Curves of f [(MoO₂)₂L.(H₂O)₂] complexes

Figure 1 displays the TGA curves of [(MoO₂)₂L.(H₂O)₂] complexes. The TGA curves illustrate weight loss as a function of temperature. The observed weight loss events and their corresponding temperature ranges provide information about the thermal stability and decomposition behaviour of the complexes [15].

Table 3: Thermal decomposition data of Complexes

Complex	TG range/(°C)	Mass loss/% obs/calcd	Assignments

[(VO) ₂ L.(H ₂ O) ₂].H ₂ O	55-105	3.52/3.03	<ul style="list-style-type: none"> ● Loss of one mole of lattice water molecule ● Loss of two moles of coordinate water molecules ● Removal of ligand moiety ● Leaving the metal oxide residue
	105-190	6.97/6.26	
	190-700	74.90/75.77 85.39*/85.06	
[(MoO ₂) ₂ L.(H ₂ O) ₂]	140-210	4.86/5.16	<ul style="list-style-type: none"> ● Loss of two moles of coordinate water molecules ● Removal of ligand moiety ● Leaving the metal oxide residue
	210-700	60.17/61.81 65.03*/66.97	
[(UO ₂) ₂ L.(H ₂ O) ₂]	90-205	3.20/3.67	<ul style="list-style-type: none"> ● Loss of two moles of coordinate water molecules ● Removal of ligand moiety ● Leaving the metal oxide residue
	205-700	43.95/43.22 47.15*/46.89	

* Total mass loss

The table presents the thermal decomposition data of the complexes [(VO)₂L.(H₂O)₂].H₂O, [(MoO₂)₂L.(H₂O)₂], and [(UO₂)₂L.(H₂O)₂]. It includes the temperature ranges at which mass loss occurs during the decomposition process, the observed and calculated mass loss percentages, and corresponding assignments for each stage of decomposition.

For the complex [(VO)₂L.(H₂O)₂].H₂O, the thermal decomposition occurs in three stages. In the temperature range of 55-105°C, a mass loss of 3.52% (observed) or 3.03% (calculated) is observed, indicating the loss of one mole of lattice water molecules. In the range of 105-190°C, a mass loss of 6.97% (observed) or 6.26% (calculated) occurs, corresponding to the loss of two moles of coordinated water molecules. The final stage, in the range of 190-700°C, shows a significant mass loss of 74.90% (observed) or 75.77% (calculated), representing the removal of the ligand moiety and leaving behind the metal oxide residue [1].

Similarly, for the complex [(MoO₂)₂L.(H₂O)₂], the decomposition occurs in two stages. The temperature range of 140-210°C shows a mass loss of 4.86% (observed) or 5.16% (calculated), indicating the loss of two moles of coordinated water molecules. In the range of 210-700°C, a mass

loss of 60.17% (observed) or 61.81% (calculated) is observed, representing the removal of the ligand moiety and leaving behind the metal oxide residue [6].

Lastly, for the complex [(UO₂)₂L.(H₂O)₂], the thermal decomposition also occurs in two stages. The temperature range of 90-205°C shows a mass loss of 3.20% (observed) or 3.67% (calculated), corresponding to the loss of two moles of coordinated water molecules. In the range of 205-700°C, a mass loss of 43.95% (observed) or 43.22% (calculated) occurs, indicating the removal of the ligand moiety and leaving behind the metal oxide residue [7].

Table 4: Thermal data of H₂L and its complexes

Compound	Half decomposition temperature (o C)	Activation energy (E*) kJ mol-1	Frequency factor (Z) S-1	Free energy change (ΔG) kJ mol-1
H ₂ L	330	39.50	3.76 x 10 ⁻⁷	-11275
[(VO) ₂ L.(H ₂ O) ₂].H ₂ O	430	75.36	1.39 x 10 ⁻¹¹	-99245
[(MoO ₂) ₂ L.(H ₂ O)]	487	73.47	3.59 x 10 ⁻⁶	-87921
[(UO ₂) ₂ L.(H ₂ O) ₂]	480	58.37	3.58 x 10 ⁻⁹	-13262

UV-Visible Spectroscopy

The UV-Visible spectra of the synthesised VO(IV), MoO₂(VI), and UO₂(VI) complexes with the hexadentate tetra anionic ligand were recorded in the wavelength range of 200-800 nm. The spectra exhibited characteristic absorption bands, indicating the presence of metal-ligand interactions [9]. Table 5 summarises the absorption maxima (λ_{max}) observed for each complex. The VO(IV) complex exhibited a maximum absorption peak at 420 nm, while the MoO₂(VI) and UO₂(VI) complexes showed absorption peaks at 520 nm and 580 nm, respectively. These absorption bands can be attributed to electronic transitions within the complexes [12].

Table 5: UV-Visible Absorption Maxima

Complex	λ_{max} (nm)
[(VO) ₂ L. (H ₂ O) ₂].H ₂ O	420
[(MoO ₂) ₂ L.(H ₂ O) ₂]	520
[(UO ₂) ₂ L.(H ₂ O) ₂]	580

The UV-Visible spectroscopy results suggest that the complexes exhibit different electronic structures due to the variations in their metal centres and coordination environments. The observed absorption peaks can be correlated with the energy gaps between the ground state and excited states of the complexes [14]. Further analysis of the electronic transitions and their relationship with the structural features of the complexes will provide valuable insights into their optical properties and potential applications in optoelectronic devices [10].

Fourier-Transform Infrared (FT-IR) Spectroscopy

FT-IR spectroscopy was employed to investigate the functional groups present in the synthesised complexes. The spectra were recorded in the range of 400-4000 cm⁻¹, and notable absorption bands were observed.

Table 6: Assignment of FT-IR Absorption Bands

Complex	Functional Groups	Assignment
[(VO) ₂ L. (H ₂ O) ₂].H ₂ O	C=O, C-O, C=N	$\nu(\text{C=O})$ at 1620 cm ⁻¹ , $\nu(\text{C-O})$ at 1380 cm ⁻¹
[(MoO ₂) ₂ L.(H ₂ O) ₂]	C=O, C-O, C=N	$\nu(\text{C=O})$ at 1650 cm ⁻¹ , $\nu(\text{C-O})$ at 1350 cm ⁻¹
[(UO ₂) ₂ L.(H ₂ O) ₂]	C=O, C-O, C=N	$\nu(\text{C=O})$ at 1680 cm ⁻¹ , $\nu(\text{C-O})$ at 1320 cm ⁻¹

The VO(IV), MoO₂(VI), and UO₂(VI) complexes displayed characteristic absorption bands corresponding to the stretching vibrations of carbonyl (C=O) and carboxylate (C-O) groups. The presence of these functional groups confirms the coordination of the ligand with the metal ions [5]. Additionally, the presence of a C=N stretching vibration in the complexes indicates the involvement of nitrogen-based donor atoms in the coordination sphere.

Biological Studies

The biological activities of the VO(IV), MoO₂(VI), and UO₂(VI) complexes were evaluated through antibacterial and anticancer studies.

Table 7: Antibacterial Activity of the Complexes

Complex	Zone of Inhibition (mm)
[(VO) ₂ L. (H ₂ O) ₂].H ₂ O	15.2 ± 0.3
[(MoO ₂) ₂ L.(H ₂ O) ₂]	12.5 ± 0.5
[(UO ₂) ₂ L.(H ₂ O) ₂]	9.8 ± 0.2

The table presents the zone of inhibition values obtained for the complexes against selected bacterial strains. The complexes exhibited varying degrees of antibacterial activity, with the VO(IV) complex demonstrating the highest zone of inhibition.

In the anticancer studies, the cytotoxicity of the complexes against HeLa and MCF-7 cell lines was evaluated using the MTT assay. The complexes displayed dose-dependent cytotoxic effects, inhibiting the growth of cancer cells at different concentrations.

Mechanistic Insights

The observed physicochemical properties and biological activities of the VO(IV), MoO₂(VI), and UO₂(VI) complexes can be attributed to their unique structural features and coordination modes. The presence of specific functional groups and coordination geometries contribute to their distinct properties and biological effects.

Overall, the results suggest that these complexes have promising potential for further exploration as potential antibacterial and anticancer agents. Further studies are warranted to elucidate their specific mechanisms of action and optimise their biological activities.

Conclusion

In this work, we did a detailed physicochemical evaluation of coordination compounds, as well as an analysis of their thermal behaviour and biological research on complexes of VO(IV), MoO₂(VI), and UO₂(VI) with a hexadentate tetra anionic ligand. Specifically, we looked at how these complexes behaved when heated. Through various experimental investigations and tests, valuable insights were obtained regarding the characteristics and potential applications of these complexes.

The findings of the UV-Visible spectroscopy pointed to the existence of metal-ligand interactions in the complexes, as shown by the presence of distinctive absorption bands. The changes in the electronic structures of each complex were shown by the fact that their absorption maxima occurred at distinct wavelengths for each complex. These variations were caused by the

fact that the nature of the metal centre and the coordination environment were varied. The findings suggest that the complexes may display diverse optical properties, some of which could have practical applications in optoelectronics.

The research performed using Fourier-Transform Infrared (FT-IR) spectroscopy gave proof that the complexes were successfully formed. This was shown by the presence of distinctive absorption bands that corresponded to certain functional groups involved in metal-ligand coordination. The coordination of the ligand with the metal ions was validated by the presence of carbonyl (C=O) and carboxylate (C-O) groups, in addition to the C=N stretching vibrations. The findings from the FT-IR experiment provided evidence that validated the hypothesised coordination geometries and bonding modes seen inside the complexes.

The application of nuclear magnetic resonance (NMR) spectroscopy facilitated comprehension of the structural attributes of the complexes. The chemical shifts that were seen in the ¹H NMR spectra offered information on the ligand coordination as well as the electronic environment that was around the metal centres. These findings provided further evidence in favour of the hypothesised coordination modalities and made a contribution to the comprehensive characterisation of the complexes.

Thermogravimetric analysis, often known as TGA, unearthed significant new details on the thermal properties and stability of the compounds. The weight loss profiles and phase transition events that were detected in the TGA curves gave useful insights into the thermal degradation patterns and the existence of coordinated water molecules or ligand fragments in the sample. The findings augment our comprehension of the thermal properties of the complexes, which is crucial for our comprehension of their prospective applications in diverse fields.

The antibacterial and anticancer properties of the complexes were investigated via the use of biological investigations that were carried out as part of this research. The complexes displayed varied degrees of antibacterial activity against certain kinds of bacteria, with the VO(IV) complex having the largest zone of inhibition among the group.

In conclusion, this research offers a full explanation of the physicochemical characteristics, thermal behaviour, and biological activities of the complexes with a hexadentate tetra anionic ligand that were synthesised using VO(IV), MoO₂(VI), and UO₂(VI). The findings that were obtained through UV-Visible spectroscopy, FT-IR spectroscopy, NMR spectroscopy, thermal

analysis, and biological tests all add to the overall characterisation of the complexes and highlight their potential applications in a variety of different sectors.

The outcomes of this research highlight how important it is to investigate coordination chemicals and the uses that can be found for them. There is a clear need for more research to be done in order to examine the action mechanisms, optimise the characteristics, and discover the other possible uses of these complexes. The synthesised complexes exhibit unique characteristics and potential biological activities, making them promising subjects for future research and development in the fields of medicine, materials science, and catalysis.

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