

## Research Article

# Synthesis and Characterization of Some Novel Schiff Base Complexes of Oxovanadium(IV) Cation

A. K. Yadava,<sup>1</sup> H. S. Yadav,<sup>1</sup> Sanjay Singh,<sup>2</sup> U. S. Yadav,<sup>3</sup> and D. P. Rao<sup>4</sup>

<sup>1</sup> Department of Chemistry, North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh, Nirjuli 791109, India

<sup>2</sup> Department of Chemistry, M.G.P.G. College, Uattar Pradesh, Gorakhpur 273001, India

<sup>3</sup> Department of Chemistry, J.P. University, Bihar, Chapra 841301, India

<sup>4</sup> Department of Chemistry, D.A-V College, Uttar Pradesh, Kanpur 208001, India

Correspondence should be addressed to D. P. Rao; [devendraprataprao@yahoo.com](mailto:devendraprataprao@yahoo.com)

Received 27 February 2012; Revised 1 June 2012; Accepted 21 June 2012

Academic Editor: Benjamin Mwashote

Copyright © 2013 A. K. Yadava et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

A series of oxovanadium(IV) complexes of the type  $[\text{VO}(\text{mac})]\text{SO}_4$  (where mac = tetraazamacrocyclic ligands derived from condensation of 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione with *p*-phenylenediamine and their reaction with  $\beta$ -diketones) have been prepared using oxometal ion of vanadium as kinetic template. These complexes have been ascertained by electrical conductance, magnetic moment, elemental analyses, infrared, e.s.r. and electronic spectral data. All the oxovanadium(IV) complexes are five-coordinate ones.

## 1. Introduction

Vanadium is found naturally in soil and water as a trace metal. Vanadium compounds with oxidation state IV and V exist in the environment and in biological systems. The literature contains several reports about oxovanadium(IV) complexes which show modulating activities of various enzymes [1]. The chemistry of vanadium has attracted attention due to its presence in biological system particularly its accumulation in sea squirts and in wild mushrooms like *Amanita muscaria* and others [2–4]. The oral administration of vanadate has been proved to reduce hyperglycemia in diabetic rats. However, in most cases, the template effect of metal ions of the first transition series has been studied but chemistry of vanadium complexes with macrocyclic ligands incorporating four nitrogen donor atoms has received less attention [5–7]. The *p*-phenylenediamine can form chelate ring using *insitu* method of synthesis where diketone, *p*-phenylenediamine were condensed in presence of metal cation due to kinetic template effect [8–10]. Considering these facts a new series of oxovanadium(IV) complexes have been prepared by condensation of

4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione with *p*-phenylenediamine in 1 : 2 molar ratio in the presence of  $\text{VO}^{2+}$  cation. The reactions of oxovanadium(IV) complexes with  $\beta$ -diketones, namely acetylacetone, benzoylacetone, thenoyltrifluoroacetone, and dibenzoylmethane have been carried out which result macrocyclic complexes which are characterized and their tentative structures have been ascertained.

## 2. Experimental

**2.1. Materials and Methods.** Oxovanadium(IV) sulfate was procured from Aldrich. The  $\beta$ -diketones namely acetylacetone, benzoylacetone, thenoyltrifluoroacetone and dibenzoylmethane were SRL products and the diamines used were reagent grade products. 4,4,4-Trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione and *p*-phenylenediamine used were Aldrich product.

**2.2. Analytical Methods and Physical Measurements.** Vanadium was estimated gravimetrically as its vanadate after

decomposing the complex with concentrated nitric acid [11]. Sulfur was estimated as barium sulfate using standard procedure [12]. The standard technique of melting point (uncorrected) determination using sulfuric acid bath was employed. Toshniwal conductivity bridge, Model no. CLO102A was used for conductance measurements at room temperature. The magnetic susceptibility of the complexes in powder form was carried out at room temperature using Gouy's balance. Mercury tetrathiocyanatocobaltate(II), Hg [Co(CNS)<sub>4</sub>], ( $\chi_g = 16.44 \times 10^{-6}$  c.g.s. unit at 20°C), was used as calibrant. The electronic spectra of the complexes were recorded on a  $\Phi 10$  Russian spectrophotometer instrument in the ranges 700–400 nm. The room temperature and liquid nitrogen temperature ESR spectra were recorded at RSIC, IIT, Chennai, India. The infrared spectra of the complexes in the range 4000–200 cm<sup>-1</sup> were recorded in KBr on Perkin-Elmer 621 spectrophotometers.

**2.3. InSitu Preparation of Oxovanadium(IV) Complexes with Ligands Derived by Condensation of 4,4,4-Trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-Trifluoro-1-(2-thenyl)-1,3-butanedione with *p*-Phenylenediamine.** Vanadyl sulfate (2 mmol) dissolved in methanol (25 mL) was added to a solution of 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione (2 mmol) and *p*-phenylenediamine (4 mmol) in ethanol (25 mL). The mixture was refluxed for 6 hours, till the color of the solution turned green. The solvent was removed under vacuo at room temperature and the dark green color product was isolated. The complexes were thoroughly washed with methanol/ethanol mixture. Yield was 65%.

**2.4. InSitu Preparation of Macrocyclic Complexes of Oxovanadium(IV).** Vanadyl sulfate (2 mmol) dissolved in methanol (25 mL) was added to a solution of 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione (2 mmol) and *p*-phenylenediamine (4 mmol) in ethanol (25 mL). The mixture was refluxed for 5 hours, till the color of the solution intensified and turned green. To this reaction mixture, an ethanolic solution (10 mL) of acetylacetone (2 mmol) and glacial acetic acid (5 mL) was added. The reaction mixture was refluxed for about 5 hours then green precipitate was obtained. The complex was purified by washing with the mixture (10 mL) of methanol/ethanol (1:1). Yield was 60%. The same procedure was adopted for the synthesis of other oxovanadium(IV) macrocyclic complexes using benzoylacetone, thenoyltrifluoroacetone, and dibenzoylmethane. The physical and analytical data of the complexes are presented in Table 1.

### 3. Results and Discussion

The oxovanadium(IV) complexes were synthesized using *in situ* method by refluxing the reaction mixture of 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione and *p*-phenylenediamine and vanadylsulfate in 1:2:1 molar ratio in aqueous ethanol. The

macrocyclic complexes were obtained by reacting the parent complexes with respective  $\beta$ -diketones and the reactions appear to proceed according to Scheme 1, where The values of R and R' represent the  $\beta$ -diketones and L<sup>1</sup> = 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione + *p*-phenylenediamine; L<sup>2</sup> = 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione + *p*-phenylenediamine; mac = tetraazamacrocyclic ligands derived from condensation of L<sup>1</sup> and L<sup>2</sup> with  $\beta$ -diketones in presence of oxovanadium(IV) cation, respectively.

**3.1. Infrared Spectra.** The important bands of the infrared spectra for the complexes are listed in Table 2. The macrocyclic complexes of oxovanadium(IV) exhibit >C=N absorption around 1624–1616 cm<sup>-1</sup>, which normally appears at 1660 cm<sup>-1</sup> in free ligands [13–15]. The lowering of this band in the complexes (typeI) indicates the coordination of nitrogen atoms of the azomethine groups to the VO<sup>2+</sup> [15–17]. The presence of a band at around 300 cm<sup>-1</sup> may be assigned to  $\nu$ (V-N) vibration [18]. The appearance of >C=N band and the absence of the >C=O band around 1710 cm<sup>-1</sup> are a conclusive evidence for condensation of the *p*-phenylenediamine with the two keto group of 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione or 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione furil [17]. The bands appearing at 3350 and 3180 cm<sup>-1</sup> may be assigned to asymmetrical and symmetrical N-H stretching modes of the coordinated terminal amino group (Nonoyama et al.) [19]. The oxovanadium(IV) complexes show a band at around 980 cm<sup>-1</sup>, which is assigned to  $\nu$ (V=O) vibration [20]. The presence of an ionic sulfate group in the complexes is confirmed by the appearance of three bands at ca. 1130–1135 cm<sup>-1</sup> ( $\nu_3$ ), 955–960 cm<sup>-1</sup> ( $\nu_1$ ), and 602–608 cm<sup>-1</sup> ( $\nu_4$ ). The absence of a  $\nu_2$  band and nonsplitting band of  $\nu_3$  band confirms that tetrahedral symmetry is retained [21]. Infrared spectra of macrocyclic complexes of typeII show the same pattern of bands but the asymmetrical and symmetrical N-H stretching modes of terminal amino groups disappear due to condensation of these amino groups with carbonyl group of  $\beta$ -diketones in cyclization reactions.

**3.2. Electronic Spectra.** The electronic spectra show bands in the regions 11,045–11,985 cm<sup>-1</sup>, 15,030–15,900 cm<sup>-1</sup>, and 21,090–22,390 cm<sup>-1</sup>. These spectra are similar to other five-coordinate oxovanadium(IV) complexes involving nitrogen donor atoms. These spectral bands are interpreted according to an energy level scheme reported by Tsuchimoto et al. for distorted five coordinate square pyramidal oxovanadium(IV) complexes [22]. Accordingly, the observed bands can be assigned to <sup>2</sup>B<sub>2</sub> → <sup>2</sup>E, <sup>2</sup>B<sub>2</sub> → <sup>2</sup>B<sub>1</sub>, and <sup>2</sup>B<sub>2</sub> → <sup>2</sup>A<sub>2</sub> transitions, respectively. One more band is observed in the region 35,160–35,660 cm<sup>-1</sup>, which may be due to transition of the azomethine linkages [23].

**3.2.1. Molar Conductance Measurements.** The molar conductivity ( $\Lambda_M$ ) values of all the oxovanadium(IV) complexes were measured in dimethylformamide and the obtained

TABLE 1: Physical and analytical data of the complexes.

Complex	Empirical formula	Decomp. temp. (°C)	C% found (Calcd)	H% found (Calcd)	N% found (Calcd)	V% found (Calcd)	S% found (Calcd)	$\mu_{\text{eff}}$ BM (300°C)
[VO(L <sup>1</sup> )]SO <sub>4</sub>	C <sub>20</sub> H <sub>17</sub> N <sub>4</sub> VSO <sub>6</sub> F <sub>3</sub>	212	43.6 (43.7)	3.0 (3.1)	10.1 (10.2)	9.2 (9.3)	5.7 (5.8)	1.73
[VO(L <sup>2</sup> )]SO <sub>4</sub>	C <sub>20</sub> H <sub>17</sub> N <sub>4</sub> VS <sub>2</sub> O <sub>5</sub> F <sub>3</sub>	213	42.4 (42.5)	2.9 (3.0)	9.9 (9.9)	9.0 (9.0)	11.2 (11.3)	1.74
[VO(mac <sup>1A</sup> )]SO <sub>4</sub>	C <sub>25</sub> H <sub>21</sub> N <sub>4</sub> VSO <sub>6</sub> F <sub>3</sub>	215	48.9 (48.9)	3.4 (3.5)	9.0 (9.1)	8.2 (8.3)	5.1 (5.2)	1.72
[VO(mac <sup>1B</sup> )]SO <sub>4</sub>	C <sub>30</sub> H <sub>23</sub> N <sub>4</sub> VSO <sub>6</sub> F <sub>3</sub>	217	53.2 (53.3)	3.3 (3.4)	8.3 (8.3)	7.5 (7.5)	4.5 (4.6)	1.75
[VO(mac <sup>1C</sup> )]SO <sub>4</sub>	C <sub>28</sub> H <sub>18</sub> N <sub>4</sub> VS <sub>2</sub> O <sub>6</sub> F <sub>6</sub>	219	45.6 (45.7)	2.4 (2.5)	7.5 (7.6)	6.8 (6.9)	8.6 (8.7)	1.74
[VO(mac <sup>1D</sup> )]SO <sub>4</sub>	C <sub>35</sub> H <sub>25</sub> N <sub>4</sub> VSO <sub>6</sub> F <sub>3</sub>	227	57.0 (57.0)	3.3 (3.4)	7.5 (7.6)	6.9 (6.9)	4.3 (4.4)	1.73
[VO(mac <sup>2A</sup> )]SO <sub>4</sub>	C <sub>25</sub> H <sub>21</sub> N <sub>4</sub> VS <sub>2</sub> O <sub>5</sub> F <sub>3</sub>	220	47.6 (47.7)	3.3 (3.4)	8.8 (8.9)	8.0 (8.1)	10.1 (10.2)	1.72
[VO(mac <sup>2B</sup> )]SO <sub>4</sub>	C <sub>30</sub> H <sub>23</sub> N <sub>4</sub> VS <sub>2</sub> O <sub>5</sub> F <sub>3</sub>	218	52.0 (52.1)	3.3 (3.4)	8.1 (8.1)	7.4 (7.4)	9.2 (9.3)	1.76
[VO(mac <sup>2C</sup> )]SO <sub>4</sub>	C <sub>28</sub> H <sub>18</sub> N <sub>4</sub> VS <sub>3</sub> O <sub>5</sub> F <sub>6</sub>	221	44.7 (44.8)	2.3 (2.4)	7.4 (7.5)	6.7 (6.8)	12.7 (12.8)	1.75
[VO(mac <sup>2D</sup> )]SO <sub>4</sub>	C <sub>35</sub> H <sub>25</sub> N <sub>4</sub> VS <sub>2</sub> O <sub>5</sub> F <sub>3</sub>	218	55.7 (55.8)	3.2 (3.3)	7.4 (7.4)	6.8 (6.8)	8.4 (8.5)	1.74

L<sup>1</sup>: ligand derived by condensation of 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione and p-phenylenediamine (1:2); L<sup>2</sup>: ligand derived by condensation of 4,4,4-trifluoro-1-(2-thenyl)-1,3-butanedione and p-phenylenediamine (1:2); Mac<sup>1A</sup>: macrocyclic ligand derived by condensation of L<sup>1</sup> with acetylacetone; Mac<sup>1B</sup>: macrocyclic ligand derived by condensation of L<sup>1</sup> with benzoylacetone; Mac<sup>1C</sup>: macrocyclic ligand derived by condensation of L<sup>1</sup> with thenoyltrifluoroacetone; Mac<sup>1D</sup>: macrocyclic ligand derived by condensation of L<sup>1</sup> with dibenzoylmethane; Mac<sup>2A</sup>: macrocyclic ligand derived by condensation of L<sup>2</sup> with acetylacetone; Mac<sup>2B</sup>: macrocyclic ligand derived by condensation of L<sup>2</sup> with benzoylacetone; Mac<sup>2C</sup>: macrocyclic ligand derived by condensation of L<sup>2</sup> with thenoyltrifluoroacetone; Mac<sup>2D</sup>: macrocyclic ligand derived by condensation of L<sup>2</sup> with dibenzoylmethane.

TABLE 2: Infrared spectral bands of complexes.

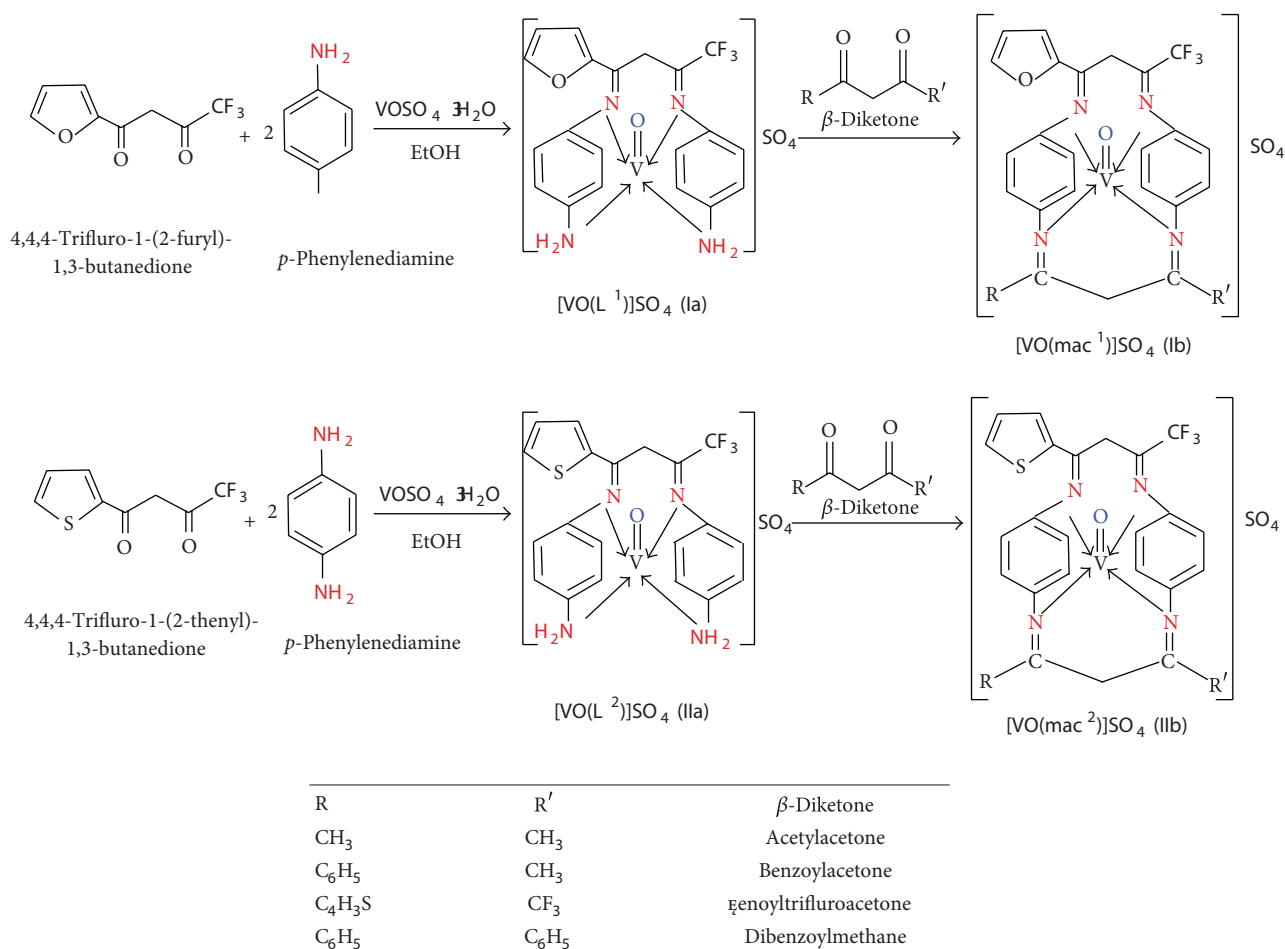
Complex	Bands (cm <sup>-1</sup> )							
	$\nu$ (>C=N)	$\nu$ (V-N)	$\nu$ (V=O)	$\nu_3$ of SO <sub>4</sub> <sup>2-</sup>	$\nu_1$ of SO <sub>4</sub> <sup>2-</sup>	$\nu_4$ of SO <sub>4</sub> <sup>2-</sup>	$\nu_{\text{asym}}$ (N-H)	$\nu_{\text{sym}}$ (N-H)
[VO(L <sup>1</sup> )]SO <sub>4</sub>	1616	304	980	1133	955	604	3348	3181
[VO(L <sup>2</sup> )]SO <sub>4</sub>	1622	301	981	1132	958	603	3350	3180
[VO(mac <sup>1A</sup> )]SO <sub>4</sub>	1620	304	980	1134	960	606		
[VO(mac <sup>1B</sup> )]SO <sub>4</sub>	1624	303	982	1133	958	608		
[VO(mac <sup>1C</sup> )]SO <sub>4</sub>	1622	302	981	1132	958	606		
[VO(mac <sup>1D</sup> )]SO <sub>4</sub>	1624	304	982	1133	956	603		
[VO(mac <sup>2A</sup> )]SO <sub>4</sub>	1622	302	981	1132	956	604		
[VO(mac <sup>2B</sup> )]SO <sub>4</sub>	1624	303	980	1134	958	606		
[VO(mac <sup>2C</sup> )]SO <sub>4</sub>	1622	304	980	1133	960	604		
[VO(mac <sup>2D</sup> )]SO <sub>4</sub>	1620	301	981	1135	958	602		

values lie between 98–105 ohm<sup>-1</sup> cm<sup>2</sup> mol<sup>-1</sup> indicating their 1 : 1 electrolytic nature.

3.2.2. *Magnetic Moment Measurements.* Magnetic moments of oxovanadium(IV) complexes were measured at room temperature and effective magnetic moment ( $\mu_{\text{eff}}$ ) values are given in table1. The magnetic moment values of the vanadyl complexes range from 1.70 to 1.76 B.M which correspond

to a single electron of the 3d<sup>1</sup> system of square-pyramidal oxovanadium(IV) [22].

3.3. *ESR Spectra.* The X-band ESR spectra of an oxovanadium(IV) complex was recorded in DMSO at room temperature and at nitrogen temperature (177 K). ESR spectra of the complexes were analyzed by the method of Mishra, Sand and Ando et al. [23–25]. The room temperature ESR

SCHEME 1: *In situ* preparation of macrocyclic complexes of oxovanadium(IV).

spectra show eight lines, which are due to hyperfine splitting arising from the interaction of the unpaired electron with a <sup>51</sup>V nucleus having the nuclear spin  $I = 7/2$ . This confirms the presence of a single oxovanadium(IV) cation as the metallic centre in the complex. The anisotropy is not observed due to rapid tumbling of molecules in solution at room temperature and only  $g$ -average values are obtained. The anisotropy is clearly visible in the spectra at liquid nitrogen temperature and eight bands each due to  $g_{\parallel}$  and  $g_{\perp}$  are observed separately which are in good agreement for a square pyramidal vanadyl complex [26–28]. The  $g_{\parallel}$ ,  $g_{\perp}$ ,  $A_{\parallel}$  and  $A_{\perp}$  values are measured from the spectra, which are in good agreement for a square-pyramidal structure. The  $g_{\text{iso}}$  value from mobile solution at room temperature and  $g_{\text{av}}$  from frozen solution at liquid nitrogen temperature do not agree very closely since the  $g$  and  $A$  tensors are corrected for second-order. Further,  $g$  values are all very close to the spin-only value (free electron value) of 2.0023, suggesting little spin-orbit coupling. On the basis of the above studies, the following tentative structures may be proposed for these oxovanadium(IV) complexes of the type (I) and (II).

## 4. Conclusion

The spectral data show that the 4,4,4-trifluoro-1-(2-furyl)-1,3-butanedione and 4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedione are good chelating agents having two reactive carbonyl groups capable of undergoing Schiff base condensation with a variety of diamine. Schiff bases behave as tetradentate ligands by bonding to the metal ion through the azomethine nitrogen and amino group. The analytical data show the presence of one metal ion per ligand molecule and suggest a mononuclear structure for the VO<sup>2+</sup> complexes. The electrical conductance, magnetic moment values, infrared, ESR, and electronic data are in the favour of square pyramidal, structure for VO(IV) complexes.

## Acknowledgments

The authors are thankful to the Director, NERIST, Nirjuli, Itanagar, Arunachal Pradesh, India for providing laboratory facilities and the Department of Chemistry for microanalysis of carbon, hydrogen, and nitrogen.

## References

- [1] D. Rehder, "Biological and medicinal aspects of vanadium," *Inorganic Chemistry Communications*, vol. 6, no. 5, pp. 604–617, 2003.
- [2] G. Wilkinson, Ed., *Comprehensive Coordination Chemistry*, vol. 6, Pergamon Press, Oxford, UK, 1987.
- [3] C. Yuan, L. Lu, X. Gao et al., "Ternary oxovanadium(IV) complexes of ONO-donor Schiff base and polypyridyl derivatives as protein tyrosine phosphatase inhibitors: synthesis, characterization, and biological activities," *Journal of Biological Inorganic Chemistry*, vol. 14, no. 6, pp. 841–851, 2009.
- [4] H. U. Meisch, W. Reinle, and J. A. Schmitt, "High vanadium content in mushrooms is not restricted to the fly agaric (*Amanita muscaria*)," *Naturwissenschaften*, vol. 66, no. 12, pp. 620–621, 1979.
- [5] M. E. Weeks and H. M. Leicester, *Discovery of the Element*, Chemical Education Publishing, Easton, Pa, USA, 7th edition, 1968.
- [6] B. K. Koo, J. Y. Jang, and U. Lee, "Vanadium(IV) Complexes with N,N,S-Donor Systems," *Bulletin of the Korean Chemical Society*, vol. 24, no. 7, pp. 1014–1016, 2003.
- [7] M. R. Maurya, "Development of the coordination chemistry of vanadium through bis(acetylacetonato)oxovanadium(IV): synthesis, reactivity and structural aspects," *Coordination Chemistry Reviews*, vol. 237, no. 1–2, pp. 163–181, 2003.
- [8] A. R. Cutler, C. S. Alleyne, and D. Dolphin, "[N,N'-(1,3-propanediylidene)bis(1,2-benzenediaminato)]nickel(II) complexes: intermediates in the template synthesis of dibenzotetraaza[14]annulenes," *Inorganic Chemistry*, vol. 24, no. 14, pp. 2281–2286, 1985.
- [9] A. Malek and J. M. Fresco, "Formation of new tetradentate schiff base metal chelates," *Canadian Journal of Chemistry*, vol. 51, no. 12, pp. 1981–1989, 1973.
- [10] R. N. Prasad, M. Agrawal, and S. Sharma, "Cobalt(II) complexes of tetraazamacrocycles derived from  $\beta$ -diketones and diaminoalkanes," *Journal of the Serbian Chemical Society*, vol. 70, pp. 54–74, 2005.
- [11] A. I. Vogel, *A Text Book of Quantitative Inorganic Analysis*, Longmans Green, London, UK, 4th edition, 1978.
- [12] A. I. Vogel, *A Text Book of Practical Organic Chemistry*, Longmans Green, London, UK, 4th edition, 1978.
- [13] V. B. Rana, P. Singh, D. P. Singh, and M. P. Teotia, "Trivalent chromium, manganese, iron and cobalt chelates of a tetradentate  $N_6$  macrocyclic ligand," *Transition Metal Chemistry*, vol. 7, no. 3, pp. 174–177, 1982.
- [14] P. B. Sreeja and M. R. P. Kurup, "Synthesis and spectral characterization of ternary complexes of oxovanadium(IV) containing some acid hydrazones and 2,2'-bipyridine," *Spectrochimica Acta*, vol. 61, no. 1–2, pp. 331–336, 2005.
- [15] H. D. S. Yadava, S. K. Sengupta, and S. C. Tripathi, "Syntheses and spectroscopic studies on dioxouranium(VI), oxovanadium(IV) and oxozirconium(IV) complexes with tetradentate macrocyclic ligands," *Inorganica Chimica Acta*, vol. 128, no. 1, pp. 1–6, 1987.
- [16] J. R. Ferraro, *Low Frequency Vibrations of Inorganic and Coordination Compounds*, Plenum Press, New York, NY, USA, 1971.
- [17] K. Nakamoto, *Infrared and Spectra of Inorganic and Coordination Compound*, part A and B, John Wiley & Sons, New York, NY, USA, 1998.
- [18] K. Sakata, M. Kuroda, S. Yanagida, and M. Hashimoto, "Preparation and spectroscopic properties of oxovanadium(IV) and dioxomolybdenum(VI) complexes with tetraaza [14] annulenes containing pyridine rings," *Inorganica Chimica Acta*, vol. 156, no. 1, pp. 107–112, 1989.
- [19] M. Nonoyama, S. Tomita, and K. Yamasaki, "N-(2-Pyridyl)acetamide complexes of palladium(II), cobalt(II), nickel(II), and copper(II)," *Inorganica Chimica Acta*, vol. 12, no. 1, pp. 33–37, 1975.
- [20] S. Samanta, D. Ghosh, S. Mukhopadhyay, A. Endo, T. J. R. Weakley, and M. Chaudhury, "Oxovanadium(IV) and - (V) complexes of dithiocarbamate-based tridentate schiff base ligands: syntheses, structure, and photochemical reactivity of compounds involving imidazole derivatives as coligands," *Inorganic Chemistry*, vol. 42, no. 5, pp. 1508–1517, 2003.
- [21] A. Sarkara and S. Pal, "Complexes of oxomethoxovanadium(V) with tridentate thiobenzhydrazide based Schiff bases," *Inorganica Chimica Acta*, vol. 361, no. 8, pp. 2296–2304, 2008.
- [22] M. Tsuchimoto, G. Hoshina, N. Yoshioka et al., "Mechanochemical reaction of polymeric oxovanadium(IV) complexes with Schiff base ligands derived from 5-nitrosalicylaldehyde and diamines," *Journal of Solid State Chemistry*, vol. 153, no. 1, pp. 9–15, 2000.
- [23] A. P. Mishra and L. R. Pandey, "Synthesis, characterization and solid state structural studies of oxovanadium(IV) -O, N donor Schiff base chelates," *Indian Journal of Chemistry*, vol. 44, pp. 94–97, 2005.
- [24] R. H. Sands, "Paramagnetic resonance absorption in glass," *Physical Review*, vol. 99, no. 4, pp. 1222–1226, 1955.
- [25] R. Ando, M. Nagai, T. Yagyu, and M. Maeda, "Composition and geometry of oxovanadium(IV) and (V)-aminoethanol-Schiff base complexes and stability of their peroxo complexes in solution," *Inorganica Chimica Acta*, vol. 351, pp. 107–113, 2003.
- [26] S. S. Dodwad, R. S. Dhamnaskar, and P. S. Prabhu, "Electron spin resonance spectral studies of vanadyl complexes with some schiff bases," *Polyhedron*, vol. 8, no. 13–14, pp. 1748–1750, 1989.
- [27] S. N. Rao, D. D. Mishra, R. C. Maurya, and N. Nageswara Rao, "Oxovanadium binuclear (IV) Schiff base complexes derived from aroyl hydrazones having subnormal magnetic moments," *Polyhedron*, vol. 16, no. 11, pp. 1825–1829, 1997.
- [28] L. J. Boucher and T. F. Yen, "Spectral properties of oxovanadium(IV) complexes. III. Salicylaldimines," *Inorganic Chemistry*, vol. 8, no. 3, pp. 689–692, 1969.





**Hindawi**

Submit your manuscripts at  
<http://www.hindawi.com>

