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NEW INSIGHTS INTO THE CHEMISTRY OF OXOVANADIUM(IV) AND ZIRCONIUM (IV) COMPLEXES WITH TRIDENTATE COORDINATING LIGAND

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ABSTRACT

New Oxovanadium(IV) and zirconium (IV) complexes were synthesized with tridentate ligand and characterized by elemental analysis, molar conductance measurements, molecular weight determinations, IR, electronic, and ^{1}H NMR studies. The Oxovanadium(IV) complex is non-electrolyte whereas zirconium(IV) complex is 1:2 electrolytes in nature and may be formulated as$[(VOL)_2SO_4]$ and $[ZrL_2]Cl_2$ respectively, where L = ethyl 2-{[(2*E*,3*Z*)-4-hydroxypent-3-en-2-ylidene]amino}-4,5,6,7-tetrahydro-1-benzothiophene-3-carboxylate. The analytical data showed that the Schiff base ligand acts as tridentate toward metal ions via the azomethine nitrogen, ester carbonyl and enolic oxygen atom. Spectral studies and magnetic susceptibility measurement reveals square pyramidal geometry for VO (IV) and octahedral structure for Zr (IV) complex. These metal complexes also exhibited antibacterial activity against pathogenic strains causing urinary tract infections.

KEY WORDS: Oxovanadium(IV), zirconium (IV), Tridentate, Antibacterial.

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INTRODUCTION

The interest in the construction of Schiff-base co-ordination complexes by reacting transition metal ions with multidentate ligand has been constantly growing over the past years [1-3],and thus there is a continued increasein theknowledge of molecular self-assembly, metal-ligand complexation and disposition of metal binding sites. By understanding these areas, new improved systems related to the fields of catalysis, supramolecular chemistry, and bioengineering can be achieved. A large number of Schiff bases and their complexes have been studied due to their anomalous properties such as ability to reversibly bind the oxygen, catalytic activity in the hydrogenation of olefins, photochromic properties and complexing ability towards some toxic biological activity and biological modeling application[4-8]. There have also been reports of antimicrobial activities of these complexes towards various pathogenic and non-pathogenic micro-organisms [9-12]. It will be of pharmacological advantage if these complexes are used as an antibacterial agent, as it is difficult for the micro-organisms to gain resistance to complex molecules. In this era where we face threats in the form of Multi drug resistant pathogens evolving into super bugs like Extended Spectrum β-lactamase (ESBL) and Metallo-β-lactamase (MBL) producers capable of hydrolyzing β-lactam antibiotics, screening of antimicrobial properties of these complexes will provide a novel approach in the field of pharmacy[13].In a continuation of our investigation of the transition metal complexes of ethyl 2-{[(2*E*,3*Z*)-4-hydroxypent-3-en-2-ylidene]amino}-4,5,6,7-tetrahydro-1-benzothiophene-3-carboxylate we report here a study of the complexes of oxovanadium(IV) and zirconium(VI)complexes of Schiff bases derived from ethyl 2-amino-4, 5, 6, 7 tetrahydrobenzo (b) thiophene 3-carboxylate which were condensed with (3*Z*)-4-hydroxypent-3-en-2-one. The Schiff bases and their metal complexes have been characterized by various spectroscopic and analytical studies and further screened for their antimicrobial activities.

MATERIALS AND METHODS

All chemicals used in the project work were of AR grade and was recrystallized while the solvents were purified and double distilled before use. Zirconium content was determined as ZrO_2 whereas Vanadium content was determined as silver vanadate by the standard methods [14]. Nitrogen and sulfur were determined by Kjeldahl's and Messenger's method, respectively. Molecular weight determinations were carried out by the Rast camphor method. The purity of the ligand and complexes was confirmed by thin layer chromatography using silica gel- glass plates as the stationary phase and ether and ethanol (8:2) as the mobile phase. Molar conductance was measured in DMF (10^{-3} M solution) on an ELICO Digital Conductivity meter Model CM-180. The electronic spectra of the complex in DMF were recorded on UV-Systronic spectrophotometer. The IR spectra were recorded in KBr disc on a Perkin Elmer Model 1600 FTIR spectrophotometer. The ^{1}H-NMR Spectra was recorded in DMSO on a VXR-300S Varian Supercon NMR Spectrometer using TMS as the internal reference. Magnetic Susceptibility measurements were carried out by employing the Gouy method using Hg [Co (SCN) $_4$] as a calibrant.

Preparation of ligand

Ethyl 2-amino-4, 5, 6, 7tetrahydrobenzo(b)thiophene3-carboxylatewas prepared according to a reported method [15]. To a solution of this thiophene derivatives (0.01mol) in ethanol (20ml) was added a solution of (3*Z*)-4-hydroxypent-3-en-2-one (0.01mol) in ethanol (10ml) in small portion with constant stirring. The resulting solution was refluxed on a water bath for about four hours. On cooling the solution, the Schiff base crystallized. It was then filtered, washed and suck dried. Further purification was done by crystallization from ethanol (MP 142^{o}C).

Preparation of metal complexes

The metal complexes were prepared by the following a general procedure. To a magnetically

stirred and warmed ethanolic solution (20ml) of the ligand (0.01mol) was added an ethanolic solution of metal (II) salts in appropriate ratios dissolved in ethanol (10ml) in small parts. After complete additions of the metal salt solution, the pH was adjusted to 7.5 by adding ethanolic ammonia. It was then refluxed for about six hours in a water bath and the resulting solution was reduced to half the initial volume and allowed to stand overnight. The complex formed was filtered, washed successively with aqueous ethanol and ether. Finally the complex was dried in vacuum over P_4O_{10}.

Test organisms used in the study

A total of 19MDR (Multi-Drug Resistant) gram negative uropathogens were used in the study including 6 ESBL (Extended spectrum β-lactamase) and 7 MBL (Metallo-β-lactamase) producers (Table-1).

Table 1
Test organisms used in the study

ESBL Producing uropathogens	MBL Producing uropathogens	Non- ESBL and MBL Producing MDR uropathogens
E.coli strain 1	*E.coli* strain 1	*Proteus vulgaris*
Citrobacterdiversus strain 1	*E.coli* strain 2	*Proteus mirabilis*
E.coli strain 2	*Pseudomonas aeruginosa*	*E.coli*
Pseudomonas aeruginosa	*E.coli* strain 3	*Morganellamorganii*
Citrobacterdiversus strain 2	*Klebsiella pneumonia* strain 1	*C.diversus*
Proteusvulgaris	*Klebsiella pneumonia* strain 2	*Pseudomonas aeruginosa*
	Citrobacterdiversus	

Antimicrobial susceptibility of uropathogens

Antibiotic sensitivity test of the pathogens was carried out using Kirby Bauer method so as to obtain their Antibiogram pattern[16].

Antibacterial activity

Antibacterial activity of the metal complexes was determined by Agar cup method. The metal complexes were dissolved in HPLC grade ethanol to obtain final concentration of 200 µg/µl. A loopful of the test isolates were inoculated in 10 ml of Brain Heart infusion (BHI) broth and incubated at 37°C for 24 hours in order to obtain actively growing log phase isolates. Sterile 20 ml of Luria Bertani agar was melted cooled to around 40°C and 0.4 ml test strain (0.1 O.D. at530nm) was seeded and poured into a 9cmdiameter Aneubra Petri plates. Using a sterile cork borer (8 mm in diameter), wells was punched in each plate after solidification of the medium. 50 µl of the test sample (metal complex) was then added to the wells and incubated at 37°C for 24 hours to observe the zones of inhibition against each metal complex. Control wells were also set up using 50 µl of ethanol (solvent) for each isolate. The mean value obtained for three individual replicates was used to calculate the zone of inhibition for each isolate[17].

RESULTS AND DISCUSSION

Analytical data indicated that ethyl 2-amino-4,5,6,7-tetrahydro-1-benzothiophene-3-carboxylate condensed with (3*Z*)-4-hydroxypent-3-en-2-one in 1:1 molar ratio and the product formed well defined complexes with the metal salts. Formation of the complexes can be symbolized as follows:

$2VOSO_4 + 2HL \rightarrow [(VOL)_2 SO_4] + H_2SO_4$

$ZrOCl_2 + 2HL \rightarrow [ZrL_2] Cl_2 + H_2O$

HL = ethyl 2-{[(2*E*,3*Z*)-4-hydroxypent-3-en-2-ylidene]amino}-4,5,6,7-tetrahydro-1-benzothiophene-3-carboxylate.

Formulation of the complexes has been based on their elemental analytical data, molar conductance values and magnetic susceptibility data. The stoichiometry of the complex 1:1 (Metal: ligand) of vanadyl complex whereas 1:2 (metal: ligand) of zirconium complexes. Complexes are brightly coloured, non hygroscopic and decomposed above 166^{o}C.The molar conductance values support the non-electrolyte nature of the oxovanadium

complexes. On the other hand conductivity values measured under same conditions for the Zr (IV) complex is 69.68 $\Omega^{-1}cm^2mol^{-1}$indicate its electrolytic behavior (Table-2). This suggests that the anion (Cl^-) is ionically bonded in the outer sphere of coordination[18].

Table 2
Physico-chemical characteristic of Schiff base ligand and its metal complexes

Compound	Colour	F.Wt	Elemental analysis(%) Found(calcd)					Molar Cond. ($\Omega^{-1}cm^2mol^{-1}$)
			C	N	S	Cl	M	
HL	Yellow	307.41	62.51 (63.02)	4.56 (3.86)	10.43 (9.56)	-	-	------
$[(VOL)_2SO_4]$	Teak Brown	842.7	44.21 (45.61)	4.12 (3.32)	12.51 (11.4)		11.12 (12.0)	12.54
$[ZrL_2]\ Cl_2$	Sand stone	774.93	47.87 (49.60)	4.17 (3.61)	8.55 (8.28)	10.46 (9.15)	10.1 (11.7)	69.68

The most important IR bands presented and assigned in Table 3show the following characteristics: The three bands appearing at 3200, 1700 and 1658 cm^{-1} in the ligand spectra, were assigned to stretching vibration modes v(O-H), v(C=O) and v(C=N) respectively. In the cases of the complexes the band appearing at 1658 cm^{-1} in the free ligand, assignable to the vibration mode undergoes shift to lower wave numbers in the complexes spectra, thus indicating the participation of azomethine nitrogen atom in coordination. The band at 1700 cm^{-1} in spectrum of the free ligand, assignable to the ester υ(C=O) has been shifted to lower frequency in the metal complexes indicating coordination by ester function[19]. A broad band at 3200cm^{-1} which is assigned to the enolic OH group of the (3Z)-4-hydroxypent-3-en-2-one moiety .The broadness of this band indicates the presence of hydrogen bond, the disappearance of this band in the complexes indicate deprotonation of enolic group, which leads to a six-membered ring structure around metal ions. A strong band around 2930 cm^{-1} due to υ(C-H) of cyclohexane did not show any appreciable change in metal complexes. Infra spectra of the complexes also showed non-ligand band in the region 510-520cm^{-1}and430-460cm^{-1}, which could be assigned to υ(M-O) and υ(M-N) modes respectively[20]. Absence of υ(M-S) band in the far infrared spectra of the metal complexes gives direct evidence to non-involvement of ring sulphur in bond formation. By comparing the infrared spectra of the vanadyl complexes with that of the corresponding free Schiff base ligands, in the 800−1100 cm^{-1} region, it was possible to identify the V=O stretching frequencies which was at 945cm^{-1} [21]. The presence of chelating bidentate coordination of the SO_4^{2-} group in oxovanadiun (IV) complex is supported by the presence of triply degenerate v_3 and single $v_1$bands (Table 3) in the IR spectra[20].

Table 3
Important IR spectral bands of Schiff base and its metal complexes

Tentative assignment	υ(O-H)	υ(C=O)	υ(C=N)	υ(M-O)	υ(M←O)	υ(M←N)	υ(SO_4^{2-})
HL	3200br	1700s	1658s	----	----	-----	-----
$[(VOL)_2SO_4]$	_____	1670s	1636s	555m	510m	460m	υ_3=1155,1138,1065 υ_1=845
$[ZrL_2]\ Cl_2$	_____	1668s	1640s	546m	519m	449m	-----

The absence of NH_2 proton signal in the NMR spectrum of ligand in DMSO-d^6 indicates successful Schiff base formation by replacement of the C=O group of (3*Z*)-4-hydroxypent-3-en-2-one .A signal at 12.8 δ indicates the enolic proton and therefore the weakest shielded proton in the molecule. The disappearance of the signal at 12.8δ was confirmed to the fact that the ligand underwent deprotonation of the enolic OH group during complexation with the metal ions. The signal at 1.50 δ (d) and 4.30 δ (m) can be assigned for methyl and methylene proton respectively of the ester group. Two multiplets centered at 2.6-2.7 δ and doublet at 1.2 δ in the ligand and metal complexes are due to different hydrogen atom of the tetrahydrobenzothiophene ring. A signal at 5.8 δ and 2.0 δ is due to methine and two methyl group proton respectively. The electronic absorption spectrum of the ligand in alcohol showed three band at 285,340 and 360nm.the first one may be assigned to intraligand π→π* transition which is nearly unchanged on complexation, whereas the second and third band may be assigned to the n→π* and charge transfer transition of the azomethine and ester C=O group[22,23].It is found that these bands were shifted to lower energy on complexation, indicating participation of these groups in coordination with the metal ions.

The electronic spectra of oxovanadium (IV) complex show bands at840nm, 635nm, and 453nm.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 for distorted five coordinate square pyramidal oxovanadium(IV) complexes[24]. Accordingly, the observed bands can be assigned to $^2B_2 \rightarrow {}^2E$, $^2B_2 \rightarrow {}^2B_1$, and $^2B_2 \rightarrow {}^2A_2$ transitions, respectively. The electronic spectra of Zr(IV) exhibit only highly intensive additional band at405nm, which may be due to charge transfer besides ligand bands. However, the electronic spectra of Zr (IV) could not provide structural details of the complex. The room temperature magnetic moment (μeff) value of the five oxovanadium (IV) complex is 1.62 BM. This value is less than the spin-only moment for a d^1 system. The subnormal magnetic moments can be considered as due to an exchange interaction between vanadium(IV) ions[25]. The values are in good agreement with the molecular formulae obtained from elemental analysis and the proposed binuclear structures. There are several reports on such binuclear structures proposed for a number of oxovanadium(IV) complexes with subnormal magnetic moments[26,27]. Zr(IV) complex is diamagnetic as it is in d^o configuration.

Antimicrobial susceptibility testing using Kirby Bauer method of gram negative uropathogenswas carried out and it was found that these uropathogens were resistant to most of the antibiotics as shown in Table-4. All isolates used in the study were Multiple Drug Resistant (Resistant to more than 3 antibiotics) including resistance to 3rd generation Cephalosporins (Ceftazidime, Cefotaxime and Ceftriaxone). The effect of metal complexes on these test isolates are shown in table-5 below. Ethanol (solvent) did not show any zone of inhibition against the test organisms. However zirconium and vanadium showed considerable zones of inhibition in its complex form as compared to ligand. The antibacterial activity of these complexes can be attributed to its lipophilic nature which may allow easy binding and penetration of the complex in the cellular structure of the pathogens. It can also be explained with the help of the concept of chelation, which reduces the polarity of the metal ion. As the positive charges of the metal are partially shared with the donor atoms present in the ligands and there is possible π-electron delocalization over the metal complex formed, the lipophilic character of the metal chelate increases and favors its permeation more efficiently through the lipid layer of the microorganism, thus destroying them more forcefully[28].

Table 4
Antibiotic resistance profiie of the uropathogens

Isolates	Antibiotic resistance profile		
ESBL Producing uropathogens			
	Sensitive	Intermediate	Resistant
E.coli strain 1	AS, AK, GF		BA, CF, PC, CH,RC, CI, TE, ZN, GM, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
Citrobacterdiversus strain 1	AS, BA, CH		CF, PC,RC, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
E.coli strain 2	AS, CH, AK, GF	ZN	BA, CF, PC, RC, CI, TE, GM, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
Pseudomonas aeruginosa	CH, AK, GF		AS, BA, CF, PC, RC, CI, TE, ZN, GM, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
Citrobacterdiversus strain 2	ZN, AK, GF	NX, CU, CP, PB, AS, CF, RC, GM	BA, PC, CH, CI, TE, TT, OX, RP, ZX, CB, NA, AG, FG
Proteusvulgaris	NX, AS, GM, AK	TT, RP, PC, RC, GF	BA, CF, CH, CI, TE, ZN, OX, ZX, CB, NA, AG, CU, CP, FG, PB
Non- ESBL and MBL Producing uropathogens			
Proteus vulgaris	AK, LOM, SPX, NET, CAZ, CIP, CPX, GEN, A/S, CZX, OF, PF, NX, CTR, CPZ, CTR, CFM, CPO, CPM		NA
Proteus mirabilis	CI, CF, BA, PB, CU, NA, NX, OX	TT, AG, CP, TE, AK	GF,GM, ZN, RC, CH, PC, AS, FG, CB, ZX, RP
E.coli	AG, CU, PB, PC	CB, CI	GF, AK, GM, ZN, TE, RC, CH, CF, BA, AS, FG, CP, CU, NX, NA, ZX, RP, OX, TT
Morganellamorganii	RC, CI, TE, PC, PB, AG, CU, OX	AK, GM, CH, CP	TT, RP, ZX, CB, NA, NX, FG, AS, BA, CF, ZN, GF
C.diversus	AS, BA, CF, PC, CH,RC, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB		
Pseudomonas aeruginosa	TT, RP, AG, CU, FG, AS, CF, CH, CI, TE,	OX, CB, PB, ZN, PC	BA, RC, GM, AK, GF, ZX, NA, NX, CP
MBL Producing uropathogens			
E.coli strain 1	CH	PC	AS, BA, CF, RC, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
E.coli strain 2	CH	AK	AS, BA, CF, PC, RC, CI, TE, ZN, GM, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
Pseudomonas aeruginosa			AS, BA, CF, PC, CH, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
E.coli strain 3	RC		AS, BA, CF, PC, CH, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
Klebsiella pneumonia strain 1			AS, BA, CF, PC, CH,RC, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
Klebsiella pneumonia strain 2	CH	AK	AS, BA, CF, PC, CH,RC, CI, TE, ZN, GM, AK, GF, TT, OX, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB
C.diversus	OX, BA, CH, GM	TE, AK, GF	AS, CF, PC, CH,RC, CI, ZN, GM, TT, RP, ZX, CB, NA, NX, AG, CU, CP, FG, PB

Key: TT -Ticarcillin/clavulanic acid, OX- Oxytetracycline, RP – Ceftriaxone, ZX – Cefepime, CB – Cefuroxime, NA - Naladixic acid, NX- Norfloxacin, AG - Amoxycillin/clavulanic acid, CU – Cefadroxil,CP - Cefoperazone, FG- Ceftazidime, PB - Polymixin B, AS – Ampicillin, BA - Co-trimaxazole, CF – Cefotaxime, PC- Pipperacillin, CH – Chloramphenicol, RC – Ciprofloxacin, CI – Ceftizoxime, TE – Tetracycline, ZN – Ofloxacin, GM – Gentamicin, AK –Amikacin, GF – Gatifoxacin

Table 5

Antibacterial activity of schiff base metal complexes against drug resistant uropathogens

Isolates	Metal complexes (200µg/µl)	
	$[ZrL_2]\ Cl_2$	$[(VOL)_2SO_4]$
ESBL Producing uropathogens showing zones of inhibition in mm		
E.coli strain 1	-	13
Citrobacterdiversus strain 1	-	-
E.coli strain 2	12	-
Pseudomonas aeruginosa	12	-
Citrobacterdiversus strain 2	12	14
Proteusvulgaris	16	16
Non- ESBL Producing uropathogens showing zones of inhibition in mm		
Proteus vulgaris	19	14
Proteus mirabilis	-	-
E.coli	-	-
Morganellamorganii	-	19
C.diversus	15	13
Pseudomonas aeruginosa	20	20
MBL Producing uropathogens showing zones of inhibition in mm		
E.coli strain 1	12	15
E.coli strain 2	13	-
Pseudomonas aeruginosa	-	12
E.coli strain 3	12	-
Klebsiella pneumonia strain 1	14	12
Klebsiella pneumonia strain 2	-	-
C.diversus	-	13

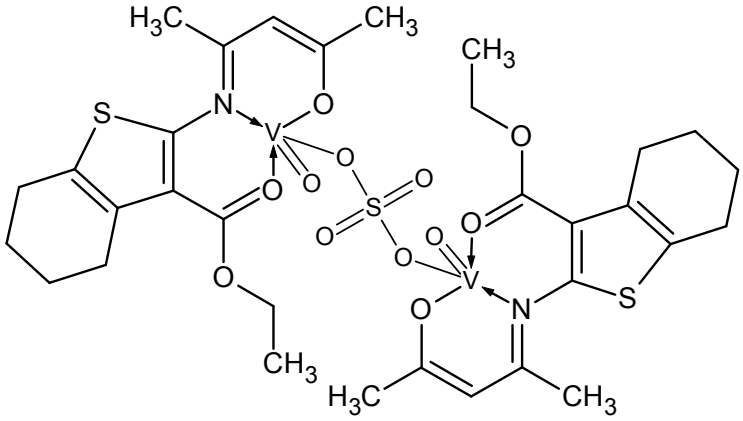

Figure 1

The proposed structure of $[(VOL)_2SO_4]$

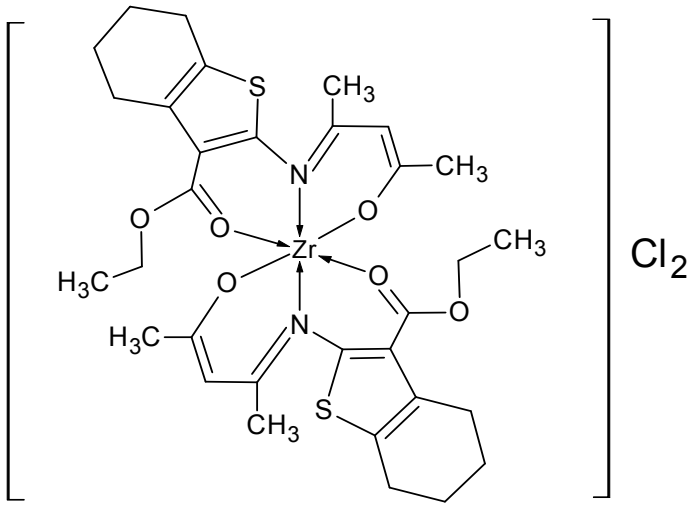

Figure 2
The proposed structure of [ZrL_2] Cl_2

CONCLUSION

From the present investigation it has been observed that a ligand ethyl 2-{[(1E,2E)-2-(hydroxyimino)-1-phenyl ethylidene]amino}-4,5,6,7 tetrahydro-1-benzothiophene-3-carboxylate form a complex with VO(IV) in 1:1 ratio whereasZr(IV) in 1:2 ratio. The data explain its square pyramidal geometry the VO (IV) complex and octahedral geometry for Zr(IV)complex. The vanadium complex has a binuclear structure as suggested by elemental analysis and molar conductance measurements. The proposed structures of metal complexes are presented in Figure 1 and 2 below. [$(VOL)_2SO_4$] and [ZrL_2] Cl_2 complexes exhibited antimicrobial activity against multi-drug resistant uropathogens.

REFERENCES

1. Strauch J., WarrenT.H., Erker G., Fröhlich R., and Saarenketo P., Formation and structural properties of salicylaldiminato complexes of zirconium and titanium, Inorganica Chimica Acta, 300 (2); 810–821, (2000).
2. Cozzi P.G., Metal-Salen Schiff base complexes in catalysis: practical aspects, Chemical Society Reviews, 33 (7); 410–421, (2004).
3. Modi K., Patel S.H., and Patel M.N., Transition metal complexes with uninegative bidentate Schiff base: synthetic, thermal, spectroscopic and coordination aspects, Journal of Thermal Analysis and Calorimetry, 87 (2); 441–448,(2007).
4. Reddy K.H., Reddy P.S. and Babu P.R.,Nuclease activity of 2-substituted heteroaromatic thiosemicarbazone and semicarbazone copper(II) complexes,Transition Metal chem,25;154-160, (2000).
5. Tarasconi P., Capacchi S., Pelosi G., Cornia M., Albertini.R., Bonati A., Dall'Aglio P.P., Lunghi P. and Pinelli S.,Synthesis, spectroscopic characterization and biological properties of new natural aldehydes thiosemicarbazones, Bioorg.Med.Chem, 8; 157-162, (2000).
6. Singh H., Yadav L.D.,and Mishra S.B.,Monomeric and dimeric products of protonation of dioxotetracyanometalates(IV)—III. The Oxo-aquo-tetracyanocomplexes of

molybdenum and tungsten, J.Inorg.Nucl. Chem, 42; 1701-1704, (1981).
7. Charo J., Charo J., Lindencrona J.A., Carlson L.M., Hinkula J., and Kiessling R., Protective efficacy of a DNA influenza virus vaccine is markedly increased by the co-administration of a Schiff base-forming drug, J Virol 78; 11321-11326, (2004).
8. West D.X., Dietrich S.L., Thientananvanich I., Brown C.A. and Liberta A.E., Copper(II) complexes of 6-methyl-2-formylpyridine ^{4}N-substituted thiosemicarbazones, Transition metal Chem, 19 (2); 195-200, (1994).
9. Kumar S., Dhar D.N., Saxena P.N.., Applications of metal complexes of Schiffs bases- A review, Journal of scientific and industrial research, 68; 181-187, (2009).
10. Mahind L.H., Waghmode S.A., Nawale A., Mane V.B. and Dagade S.P., Evaluation of Antimicrobial Activities of Zirconium (IV) Complex, IOSR Journal of Pharmacy and Biological Sciences, 5 (4); 102-105, (2013).
11. Chohan Z.H., Sumrra S.H. , Youssoufi M.H., Hadda., Metal based biologically active compounds: Design, synthesis, and antibacterial/antifungal/cytotoxic properties of triazole-derived Schiff bases and their oxovanadium(IV) complexes, 45 (7); 2739-2747, (2010).
12. Joshi S., and Pawar P., Synthesis and biological studies of Mn (II), Co (II), Zn (II) an Ni (II) complexes derived from O, N donor Schiff base of sulphamethoxazole, International Journal of Pharma and Bio Sciences, 2 (1); 170-178, (2011).
13. Subhasish S., Dharumadurai D.,Sarvanan C., Annamalai P., Synthesis, characterization and antimicrobialactivity of cobalt metal complex against multidrug resistant bacterial and fungal pathogens, facta universitatis Series: Physics, Chemistry and Technology, 7(1);73-80, (2009).
14. Vogel A.I.Textbook of Quantitative Inorganic Analysis 4th ed., Longman ELBS, 483, 487, 488, 490, (1978).
15. Gouda T.S., Jagadish, Md.Salahuddin and Shantakumar S.M.,Synthesis and Anti-inflammatory Activity of Some Novel Benzo(b)thiophene Substituted Thiazolidinones, Asian J. Chem, 21; 5171-5178, (2009).
16. Aruna K., Mobashshera T., Prevalence of extended spectrum beta-lactamase production among uropathogens in south Mumbai and its antibiogram pattern, EXCLI Journal 11:363-372, (2012).
17. Ahmad I., Beg A.J., Antimicrobial and phytochemical studies on 45 Indian medicinal plants against multi-drug resistant human pathogens, J. Ethnopharmacol. 74 (2); 113-123, (2001).
18. Geary W.J., The use of conductivity measurements in organic solvents for the characterisation of coordination compounds Coord.Chem.Rev, 7; 81-122, (1971).
19. Angoso A., Martin J.M., Manzano J.L., Martin M., Martin R., Rodriquez E. and Sona J., Preparation and study of amino acid (DL-leucine, L-isoleucine, L-histidine) Schiff bases with ethyl-α-ketocyclopentylcarboxylate and the corresponding copper(II) complexes Inorg.Chim.Acta, 195; 45-49, (1992).
20. Nakamoto N. Infrared Spectra and Raman Spectra of Inorganic and Coordination Compounds, John Wiley & Sons, New York, 155-167, (1970).
21. Ginsberg A.P., Koubek E., Williams H.J., Magnetic Exchange in Transition Metal Complexes. III. Vanadyl Complexes with Tridentate Schiff Bases, Inorganic Chemistry, 5 (10); 1656-1662, (1966).
22. Bao S.Q., Lin L.Z., Li W.X., and Xiang M.Y., *N*-Ferrocenylcarbonyl-*N*′-benzoylhydrazine and its transition metal(II) complexes, Transit Met Chem., 19; 503-505, (1994).
23. Sreeja P.B., Kurup M.R., Kishore A. and Jasmine C., Spectral characterization, X-ray structure and biological investigations of copper(II) ternary complexes of 2-hydroxyacetophenone 4-hydroxybenzoic acid hydrazone and heterocyclic bases, Polyhedron, 23 (4); 575-581 (2004).
24. Tsuchimoto M., Hoshina G., Yoshioka N., Mechano-chemical reaction of polymeric oxovanadium(IV) complexes with Schiff base ligands derived from 5-nitrosalicylaldehyde and diamines, Journal

of Solid State Chemistry, 153 (1); 9–15, (2000).
25. Rao S.N., Mishra D.D., Maurya R.C., Rao N.N.,Oxovanadium binuclear (IV) Schiff base complexes derived from aroyl hydrazones having subnormal magnetic moments Polydedron, 16 (11);1825-1829, (1997).
26. El-Dissouky., Shehata A.K., El-Mahdey G., Synthesis and characterization of oxovanadium (IV) and dichlorovanadium (IV) complexes of biologically active 4-aminoantipyrine derivative, Polyhedron, 16 (7); 1247-1253, (1997).
27. M. Tumer, H. Koksal, M.K. Sener, S. Serin.Antimicrobial activity studies of the binuclear metal complexes derived from tridentate Schiff base ligands, Transition Metal Chemistry, 24 (4); 414-420, (1999).
28. G. D. Bajju, P. Sharma, A. Kapahi, M. Bhagat, S. Kundan and D. Gupta., Oxovanadium(IV) Complexes with Nitrogen Donors: Synthesis, Characterisation, and Biological Activities, Journal of Inorganic Chemistry, Vol. 2013, Article ID 982965, 11 pages, (2013).