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Synthesis, Spectral, and Antifungal Activity of Ru(II) Mixed-Ligand Complexes

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ABSTRACT

Several new hexa-coordinated ruthenium(II) complexes of the type $[Ru(CS)(Cl)(Py)(PPh_3)(L)]$, [Ru(CS)(Cl)(Bipy)(L)] and $[Ru(Cl)(Phen)-(PPh_3)(L)]$, (where Py = pyridine, Bipy = 2,2'-bipyridyl, Phen = 1,10-phenanthroline, L = monobasic bidentate Schiff base viz salicylaldehydemethylamine (HSalmet), salicylaldehydecyclohexylamine (HSalchx) and salicylaldehyde-2-aminopyridine (HSalampy)) have been synthesized. All of the new complexes have been characterised on the basis of analytical and spectral data. These new complexes showed a reasonable amount of antifungal activity.

Key Words: Schiff base ligands; Ruthenium(II) mixed-ligand complexes; Spectra; Antifungal activity.

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INTRODUCTION

There is considerable interest in the chemistry of transition metal complexes of ligands containing oxygen, nitrogen and sulfur donor atoms due to the carcinostatic, antitumour, antiviral, antifungal and antibacterial activity and their industrial uses of complexes derived from them.^[1-4] In addition, the presence of nitrogen and oxygen donor atoms in the complexes makes these compound effective and stereospecific catalysts for oxidation,^[5] reduction,^[6] hydrolysis^[7] and they also show biological activity^[8] and other transformations of organic and inorganic chemistry. It is well known that some drugs have higher activity when administered as metal complexes than as free ligands.^[9–11] Although a large number of reports are available on the chemistry of transition metal complexes with various donor sites, only very few reports have been available on Ru(II) complexes containing thiocarbonyl and nitrogen heterocycles.^[12,13] In the present work we report the synthesis, characterization and antifungal activity of such ruthenium(II) mixed ligand complexes. The Schiff base ligands used in this study are as shown in Figure 1.

EXPERIMENTAL

All reagents used were Analar grade. All the solvents were freshly distilled before use. C, H and N analyses were performed at the Regional Sophisticated Instrumentation Centre, Central Drug Research Institute, Lucknow. IR spectra were recorded in KBr pellets on a Perkin-Elmer 597 IR grating spectrophotometer in the range $4000-200 \text{ cm}^{-1}$. Electronic spectra were recorded in CHCl₃ with a Hitachi model UV 3410 UV-Visible spectrophotometer in the range 800-200 nm. The ¹H NMR spectra were



RAbbreviationCH3HsalmetC6H11HsalchxC5H4NHsalampy

Figure 1. Structure of Schiff base ligands.

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recorded in $CDCl_3$ with a Bruker 300 MHz instrument using TMS as reference. Melting points were recorded with a Boetius micro heating table and are uncorrected.

The antifungal activity studies of the ligands and their complexes have been carried out against the fungus *Aspergillus flavus* in Sabour dextrose agar medium by the diffusion method with an incubation period of 72 h at 30 °C. The test solutions are prepared in DMSO. The percentage inhibition of fungal growth is calculated by the Vincent equation.^[14]

% inhibiton = 100(C - T)/C

where C = diameter of fungal growth on the control plate T = diameter of fungal growth of the test plate.

The starting complexes, $[Ru(Cl)_2(Py)(CS)(PPh_3)_2]$, $[Ru(CS)(Cl)_2(Bi-py)(PPh_3)]$, $[Ru(Cl)_2(Phen)(PPh_3)_2]^{[15]}$ and the Schiff base ligands^[16] were prepared by literature methods.

Preparation of Complexes

 $[Ru(Cl)(CS)(Py)(PPh_3)(L)]$

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To a solution of $[Ru(Cl)_2(CS)(Py)(PPh_3)_2]$ (0.082 g, 0.100 mmol) in dry benzene (20 mL) the appropriate Schiff base ligand (0.014–0.020 g, 0.100 mmol) (1:1 mole ratio) was added. The solution was heated under reflux for 6 h. After concentrating the solution to about 2 mL, the product was separated by the addition of a small quantity of petroleum ether (60–80 °C). The complex was then filtered, washed with petroleum ether and recrystallised from a CH₂Cl₂/petroleum ether mixture in 1:3 volume ratio, respectively.

[Ru(Cl)(CS)(Bipy)(L)]

To a solution of $[Ru(Cl)_2(CS)(Bipy)(PPh_3)]$ (0.063 g, 0.100 mmol) in dry benzene (20 mL) the appropriate Schiff base ligand (0.014–0.020 g, 0.100 mmol) (1:1 mole ratio) was added. The solution was heated under reflux for 6 h. After concentrating the solution to about 2 mL, the product was separated by the addition of a small quantity of petroleum ether (60–80 °C). The complex was then filtered, washed with petroleum ether and recrystallised from a CH₂Cl₂/petroleum ether mixture in 1:3 volume ratio, respectively.

 $[Ru(Cl)_2 (Phen)(PPh_3)_2 (L)]$

To a solution of $[Ru(Cl)_2(Phen)(PPh_3)_2]$ (0.088 g, 0.100 mmol) in dry benzene (20 mL) the appropriate Schiff base ligand (0.014-0.020 g, 0.100

	Tab	1. AU	arguerar uara or rult	i) ocilii uase (comprexes.		
					Ш	lemental analysi	S
	Complexes	Vield		Melting	Fou	nd (calculated)	(%)
	(empirical formula)	(%)	Color	point (°C)	С	Н	Ν
1	[Ru(CS)(CI)-	71	Green	138-140	58.72 (58.57)	4.42 (4.30)	4.06 (4.27)
	(PPh ₃)(Py)(salmet)]						
5	(C32H28CHN2OFNUS) (020.11) [Ru(CS)(CI)-	68	Green	128-131	60.92 (61.36)	4.94 (5.01)	3.68 (3.87)
	(PPh ₃)(Py)(salchx)]					, ,	
	$(C_{37}H_{36}CIN_2OPRuS)$ (724.22)						
$\widehat{\mathbf{S}}$	[Ru(CS)(Cl)-	73	Yellowish green	152 - 155	59.82 (60.12)	3.96(4.06)	5.92 (5.84)
	$(PPh_3)(Py)(salampy)]$						
	$(C_{36}H_{29}CIN_{3}OPRuS)$ (719.18)						
4	[Ru(CS)(Cl)(Bipy)(salmet)]	82	Light brown	220 - 222	48.39 (48.47)	3.46 (3.40)	8.91 (8.93)
	$(C_{19}H_{16}CIN_{3}ORuS)$ (470.92)						
(2	[Ru(CS)(Cl)(Bipy)(salchx)]	75	Light brown	185 - 187	53.79 (53.49)	4.29 (4.46)	7.91 (7.80)
	$(C_{24}H_{24}CIN_{3}ORuS)$ (529.03)						
9	[Ru(CS)(Cl)(Bipy)(salampy)]	60	Light brown	182 - 186	51.31 (51.73)	3.09 (3.21)	10.26 (10.50)
	$(C_{23}H_{17}CIN_4ORuS)$ (533.97)						
6	[Ru(Cl)(PPh ₃)(Phen)(salmet)]	58	Green	208 - 210	64.14 (64.04)	4.12 (4.38)	5.75 (5.90)
	$(C_{33}H_{31}CIN_3OPRu)$ (653.08)						
8	[Ru(Cl)(PPh ₃)(Phen)(salchx)]	59	Green	170 - 173	71.06 (71.46)	5.20 (5.37)	5.68 (5.78)
	(C ₄₃ H ₃₉ CIN ₃ OPRu) (787.25)						
6	[Ru(Cl)(PPh ₃)(Phen)(salampy)]	57	Green	168 - 170	65.22 (65.00)	4.08(4.16)	7.14 (7.22)
	$(C_{42}H_{32}CIN_4OPRu)$ (776.20)						

Table 1. Analytical data of Ru(II) Schiff base complexes.

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mmol) (1:1 mole ratio) was added. The solution was heated under reflux for 6 h. After concentrating the solution to about 2 mL, the product was separated by the addition of a small quantity of petroleum ether (60–80 °C). The complex was then filtered, washed with petroleum ether and recrystallised from CH_2Cl_2 /petroleum ether mixture in 1:3 volume ratio, respectively.

RESULTS AND DISCUSSION

All the new complexes of the type $[Ru(CS)(Cl)(Py)(PPh_3)(L)]$, [Ru(CS)(Cl)(Bipy)(L)] and $[Ru(Cl)(PPh_3)(Phen)(L)]$ have been obtained from the reaction of $[Ru(CS)(Cl)_2(Py)(PPh_3)_2]$, $[Ru(CS)(Cl)_2(Bipy)(PPh_3)]$, $[Ru(Cl)_2(Phen)(PPh_3)_2]$ with various bidentate Schiff bases (L) viz., HSalmet, Hsalchx and Hsalampy in dry benzene in the molar ratio 1:1, respectively.

All of the new Schiff base ruthenium(II) complexes are highly coloured, stable to air and light and soluble in chloroform, methylene dichloride, benzene, DMF and DMSO. The analytical data (Table 1) are in good agreement with the general molecular formula proposed Figure 2.

IR Spectra

In order to study the binding mode of the Schiff bases to ruthenium in the new complexes, IR spectra of the free Schiff bases were compared with the spectra of known ruthenium(II) complexes. A strong band is observed in the free ligand at around $1604-1629 \text{ cm}^{-1}$, characteristic of the azomethine (>C=N) group.^[17] Coordination of the Schiff bases to the ruthenium ion through the azomethine nitrogen atom is expected to reduce the electron density in the azomethine link and, thus, lower the v(C=N) absorption frequency. Hence, this band undergoes a shift to lower frequency to $1596-1606 \text{ cm}^{-1}$ after complexation indicating coordination of the azomethine nitrogen^[18,19] to ruthenium (Table 2).

A medium intensity band around $3313-3417 \text{ cm}^{-1}$ in the spectra of the free ligands due to v(OH) was absent in the spectra of all the complexes, indicating the deprotonation of Schiff bases prior to coordination^[17] through its oxygen atom. This is further supported by an increase in the absorption frequency of the phenolic C–O band from $1249-1280 \text{ cm}^{-1}$ in the spectra of the free ligands to $1282-1361 \text{ cm}^{-1}$ in the spectra of the complexes, indicating that the other coordination site of the Schiff base is the phenolic oxygen.^[18–20] A strong band observed around $1260-1280 \text{ cm}^{-1}$ due to v(C=S) in the starting complexes containing a thiocarbonyl group is merged with the v(C–O) absorptions in the complexes.

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	Table	2. IR and ele	ectronic specti	ral data of Ru	ı(II) complexe	es.	
	Compound	v(Ru-Cl)	v(Ru-P)	v(O-H)	v(C=N)	v(C-O)	λ_{\max} (E)
(1)	HSalmet	I	I	3113 s	1604 vs	1249 s	1
5	HSalchx	I	I	3417 s	1629 vs	1280 s	1
3	HSalampy	I	Ι	3390 s	1614 vs	1280 s	I
(4)	$[Ru(Cl)_2(CS)(Py)(PPh_3)_2]$	325 m	1434 s	I	I	Ι	Ι
(S)	[Ru(Cl) ₂ (CS)(Bipy)(PPh ₃)]	322 m	1434 s	I	I	Ι	I
9	$[Ru(Cl)_2(CS)(Phen)(PPh_3)_2]$	335 m	1436 s	I	I	I	Ι
6	$[Ru(CS)(CI)(PPh_3)-$	328 m	1430 s	I	1600 vs	1288 s	585 (8530), 439 (7218),
	(Py)(salmet)]						273 (32808)
8	$[Ru(CS)(CI)(PPh_3)-$	330 m	1432 s	I	1598 vs	1290 s	602 (1231), 441 (2246),
	(Py)(salchx)]						325 (17246)
6	$[Ru(CS)(CI)(PPh_3)-$	325 m	1434 s	I	1606 vs	1282 s	479 (2734), 308 (22518)
	(Py)(salampy)]						
(10)	[Ru(CS)(Cl)(Bipy)(salmet)]	324 m	1436 s	I	1598 vs	1286 s	589 (1046), 458 (4550),
							300 (10464)
(11)	[Ru(CS)(Cl)(Bipy)(salchx)]	320 m	1435 s	I	1598 vs	1286 s	447 (4005), 300 (10027)
(12)	[Ru(CS)(Cl)(Bipy)(salampy)]	320 m	1435 s	I	1598 vs	1286 s	592 (5666), 444 (6777),
							299 (13888)
(13)	[Ru(Cl)(PPh ₃)(Phen)(salmet)]	328 m	1436 s	Ι	1596 vs	1359 s	443 (941), 226 (15429)
(14)	[Ru(Cl)(PPh ₃)(Phen)(salchx)]	335 m	1434 s	I	1596 vs	1361 s	451 (6898), 265 (19072)
(15)	[Ru(Cl)(PPh ₃)(Phen)(salampy)]	332 s	1434 s	I	1600 vs	1361 s	589 (2128), 477 (3571),
							292 (17175)
							Í

v in cm⁻¹, λ_{max} in nm; ϵ in dm³ mol⁻¹ cm⁻¹; vs = very strong, s = strong, m = medium

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In the spectra of the complexes containing coordinated pyridine, a weak band is observed^[21,22] around 1027 cm⁻¹. The v(Ru-Cl) absorption lies around 320–335 cm⁻¹ in the spectra of the complexes. In addition to the above absorption, other characteristic bands due to coordinated triphenylphosphine were also present around 1432–1436 cm⁻¹ in the spectra of ruthenium(II) Schiff base complexes.

Electronic Spectra

Electronic spectra of all the complexes in chloroform showed two to three bands in the region 266–609 nm. The ground state of ruthenium(II) in an octahedral environment is ¹A1g arising from the $t_{2g}^{\ 6}$ configuration. The excited states corresponding to the $t_{2g}^{\ 5} e_g^{\ 1}$ configuration are ${}^3T_{1g}$, ${}^3T_{2g}$, ${}^1T_{1g}$, and ${}^1T_{2g}$. Hence, four bands corresponding to the transition ${}^1A_{1g} \rightarrow {}^3T_{1g}$, ${}^1A_{1g} \rightarrow {}^5T_{2g}$, ${}^1A_{1g} \rightarrow {}^1T_{1g}$. and ${}^1A_{1g} \rightarrow {}^1T_{2g}$ are possible in order of increasing energy. The bands around 585–609 nm are assigned to ${}^1A_{1g} \rightarrow {}^1T_{1g}$ and the bands around 443–479 nm to the transition ${}^1A_{1g} \rightarrow {}^1T_{2g}$ which confirms the assignment made for similar octahedral complexes.^[23–25] The other high-intensity band observed around 273–325 nm has been assigned to charge transfer transition arising from the excitation of electrons from the metal t_{2g} level to the unfilled molecular orbitals derived from the π level of the ligands.

¹H NMR Spectra

Further evidence for the coordinating mode of the ligands is obtained from ¹H NMR spectra of the complexes (Figure 3). In the spectra of the complexes [Ru(CS)(Cl)(Bipy)(salmet)] and [Ru(CS)(Cl)(Bipy)(salchx)] a sharp singlet appeared at δ 9.1 and has been assigned to the azomethine proton (>C=N). The positions of azomethine signal in the complexes are downfield in comparison with that of the free ligands, suggesting deshielding of the azomethine proton due to its coordination to ruthenium through the azomethine nitrogen.^[25] The aromatic protons of the Schiff base and 2,2'-bipyridyl appeared as a multiplet in the region δ 7.16–8.57. The methyl protons showed a singlet in the region δ 1.65. The cyclohexyl CH2 protons showed a singlet at δ 1.56. The absence of a resonance in the region δ 12.50–12.92 in the complexes indicates deprotonation of the phenolic group of the Schiff bases on complexation and coordination to ruthenium through the phenolic oxygen^[17] (Table 3).

It is difficult to assign conclusively the relative position of CS and Cl in the bipyridyl complex in the absence of a crystal structure. However, the starting bipyridyl compound, $[Ru(CS)(Cl)_2(Bipy)(PPh_3)]$ was prepared from the dimer $[Ru(CS)(Cl_2)(PPh_3)_2]_2$ where the CS and Cl are oriented *cis* to



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Figure 3. ¹H NMR spectrum of [Ru(CS)(CI)(Bipy)(salmet)] (4).

each other^[15] Therefore, it is reasonable to assume the same geometrical disposition of CS and Cl in the resulting Schiff base complexes.

On the basis of the elemental analyses, IR, electronic and ¹H NMR spectral data an octahedral structure has been tentatively proposed for all the complexes.

Antifungal Activity

These Schiff base ligands and their ruthenium chelates were screened in vitro in order to evaluate their antifungal activity against *Aspergillus flavus* at four different concentrations. The results showed that the ruthenium chelates are more toxic compared to their parent ligands against the same microorganisms under identical experimental conditions. The toxicity of ruthenium chelates increases on increasing the concentration. The

Table 3. ¹H NMr data of Ru(II) Schiff base complexes (δ , ppm).

	Complexes	$-C_6H_5$	-HC=N-	-CH ₃	-CH ₂
(1)	[Ru(CS)(Cl)(Bipy)(salmet)]	7.16–8.57	9.14	1.65	_
(2)	[Ru(CS)(Cl)(Bipy)(salchx)]	7.20–7.49	8.63	-	1.56
(3)	[Ru(CS)(Cl)(Bipy)(salampy)]	7.18–8.6	8.91	-	_

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			% Inhibition				
S. No.	Compound	$\frac{50}{\mu g L^{-1}}$	$\frac{100}{\mu g L^{-1}}$	$\begin{array}{c} 200 \\ \mu g L^{-1} \end{array}$	$\begin{array}{c} 400 \\ \mu g L^{-1} \end{array}$		
(1)	HSalmet	12	21	32	44		
(2)	[Ru(CS)(Cl)(PPh ₃)- (Py)(salmet)]	25	38	50	58		
(3)	Hsalchx	17	23	33	42		
(4)	[Ru(CS)(Cl)- (Bipy)(salchx)]	29	40	53	63		
(5)	HSalampy	11	23	37	48		
(6)	[Ru(Cl)(PPh ₃)- (Phen)(salampy)	30	46	63	73		
(7)	Bavistin	_	92	100	_		

Table 4. Antifungal activity data of Ru(II) complexes and ligands.

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increase in the angifungal activity of metal chelates may be due to the effect of the metal ion on the normal cell process. A possible mode of the toxicity increase may be considered in light of Tweedy's chelation theory.^[26] Chelation considerably reduces the polarity of the metal ion because of partial sharing of its positive charge with the donor groups and possible π electron delocalisation over the whole chelate ring. Such chelation could enhance the lipophilic character of the central metal atom, which subsequently favours its permeation through the lipid layers of cell membrane. Furthermore, the mode of action of the compounds may involve formation of a hydrogen bond through the azomethine (>C=N) group with the active centers of cell constituents, resulting in interference with the normal cell processes.^[27] Although there is a significant increase in the fungicidal activity of the ruthenium complexes as compared to the free ligands, this does not reach the effectiveness of the conventional fungicide Bavistin. But these compounds show higher activity than other ruthenium(II) complexes containing similar bidentate Schiff base ligands against Aspergillus flavus^[28] Table 4.

REFERENCES

 Sengupta, P.; Ghosh, S.; T.C.W., Mak. A new route for the synthesis of bis(pyridinedicarboxylato)bis(triphenylphosphine) complexes of ruthenium(II) and x-ray structural characterization of the biologically active trans-[Ru(PPh₃)₂(L'(H)₂]. Polyhedron 2001, 20, 975–980.

Ru(II) Mixed-Ligand Complexes

- 2. Imaiy, H.; Nishiquchi, T.; Fukuzumi, K. Transfer hydrogenation of aldehydes catalysed by dihydridotetrakis (triphenylphoshine) ruthenium(II). Chem. Lett. **1975**, *9*, 807–808.
- Boghaei, D.M.; Mohebi, S. Non symmetrical tetradentate vanadyl Schiff base complexes derived from 1,2-phenacyldiamine and 1,3-naphthalenediamine as catalysis for the oxidation of cyclohexene. Tetrahedron 2000, 58, 5357–5366.
- Laplaca, S.J.; Ibers, J.A. Five-coordinated d⁶ complexes: structure of dichlorotris(triphenylphosphine)ruthenium(II). Inorg. Chem. 1965, 4, 778–783.
- Kureshy, R.K.; Khan, N.H.; Abdi, S.H.R.; Patel, S.T.; Iyer, P. Chiral Ru(II) Schiff base complex catalysed enantioselective epoxidation of styrene derivatives using iodosylbenzene as oxidant II. J. Mol. Catal. 1999, 150, 175–183.
- Aoyama, Y.; Kuyisawa, J.T.; Walanawe, T.; Toi, A.; Ogashi, H. Catalytic modification of borane reduction of ketone with rhodium(II)porphyrin as catalyst. J. Am. Chem. Soc. **1986**, *108*, 943–947.
- Sdrawn, R.S.; Zamakani, M.; Coho, J.L. A rationally designed, chiral Lewis acid for the asymmetric induction of some diels-alder reaction. J. Am. Chem. Soc. **1986**, *108*, 3510–3512.
- Viswanathamurthi, P.; Natarajan, K. Synthesis, characterisation and biocidal activity studies of ruthenium(II) carbonyl complexes containing tetradentate Schiff bases. Transit. Met. Chem. 1999, 24, 638–641.
- Campbell, M.J.M. Transition metal complexes of thiosemicarbazide and thiosemicarbazones. Coord. Chem. Rev. 1975, 15, 279–319.
- Williams, D.R. Metals, ligands and cancer. Chem. Rev. 1972, 72, 203– 213.
- Furst, A.; Haro, R.T. Survey of metal carcinogenesis. Prog. Exp. Tumor Res. 1969, 12, 102–133.
- 12. Sheldrick, W.S.; Exner, R. Reaction of $[RuC_{12}(PPh_3)_3]$ with α -amino acids. Synthesis and X-ray structural characterization of the Schiff's base complexes. Inorg. Chim. Acta **1990**, *175*, 261–268.
- Kimura, E.; Machinda, R.; Kochalma, M. Macrocyclic dioxopentaammines: novel ligands for 1:1 nickel(II)-oxygen (Ni(II)-O₂) adduct formation. J. Am. Chem. Soc. **1984**, *106*, 5497–5505.
- 14. Vincent, J.M. Distortion of fungal hyphae in the presence of certain inhibitors. Nature **1947**, *159*, 850–854.
- Gilbert, J.D.; Baird, M.C.; Wilkinson, G. Thiocarbonyl and carbon disulphide complexes of ruthenium. J. Chem. Soc., A 1968, 2198–2201.
- 16. Platzer, N.; Goasdoue, N.; Bonnaire, R. Synthese et etude par resonance magnetique nucleaire de complexes olifiniques de l'iridium et du



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Rhodium avec quelques bases de Schiff desires de l'aldehyde salicylique. J. Organomet. Chem. **1978**, *160*, 456–466.

- Khera, B.; Sharma, A.K.; Kausik, N.K. Bis(indenyl)titanium(IV) and zirconium(IV) complexes of monofunctional bidentate salicylidimines. Polyhedron 1983, 2, 1177–1180.
- Ramesh, R.; Venkatachalam, G. Synthesis, spectra and redox properties of Ru(II) Schiff base carbonyl complexes. Indian J. Chem. 2002, 41 (A), 2285–2287.
- Boucher, L.J. Manganese Schiff base complexes II. Synthesis and spectroscopy of chloro-complexes of some derivatives of (salicylaldehyde ethylenediimato)manganese (III). J. Inorg. Nucl. Chem. 1974, 36, 531–536.
- Ramesh, R.; Dharmaraj, N.; Karvembu, R.; Natarajan, K. Monofunctional bidentate Schiff base complexes of ruthenium (III) containing triphenylphosphine or triphenylarsine. Indian J. Chem. 2000, 39 (A), 1079–1082.
- 21. Muthusamy, G.; Natarajan, K. Mixed-ligand complexes of ruthenium(II) with α , β -unsaturated β -ketoamines. Indian J. Chem. **1991**, *30* (A), 626–628.
- 22. Plytzanopoubs, M.; Pnematikakis, E.; Hajiliedies, N.; Katakis, D. First row transition metal complexes with 2-benzoylpyridine. J. Inorg. Nucl. Chem. **1977**, *39*, 965–972.
- Lever, A.B.P. Inorganic Electronic Spectroscopy, 2nd Ed.; Elsiever: New York, 1984; 457–473.
- Muthusamy, G.; Ramesh, R.; Natarajan, K. β-diketonate and α,βunsaturated-β-ketoaminate complexes of ruthenium(II) containing carbonyl, thiocaronyl and pyridine ligands. Synth. React. Inorg. Met.-Org. Chem. **1994**, 24 (A), 545–560.
- Muthusamy, G.; Natarajan, K. Chlorobridged binuclear ruthenium(II) β-diketaonato complexes containing triphenylphosphine and triphenylarsine. Indian J. Chem. **1995**, *34* (A), 490–492.
- 26. Tweedy, B.G. Phytopathology 1964, 55, 910–917.
- Singh Jadon, S.C.; Gupta, N.; Singh, R.V. Synthetic and biochemical studies of some hydrazine carbodithoic acid derivatives of dioxomolybdenum(VI). Indian J. Chem. **1995**, *34* (A), 733–736.
- Dharmaraj, N.; Viswanathamurthi, P.; Natarajan, K. Ruthenium(II) complexes containing bidentate Schiff bases and their antifungal activity. Transit. Met. Chem. 2001, 26, 105–106.

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