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SYNTHESIS AND CHARACTERISATION OF RUTHENIUM(III) COMPLEXES CONTAINING MONOBASIC BIDENTATE SCHIFF BASES AND THEIR BIOLOGICAL ACTIVITIES

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SYNTHESIS AND CHARACTERISATION OF RUTHENIUM(III) COMPLEXES CONTAINING MONOBASIC BIDENTATE SCHIFF BASES AND THEIR BIOLOGICAL ACTIVITIES

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ABSTRACT

New hexa-coordinated ruthenium(III) complexes of the type $[RuX_2(L)(EPh_3)_2]$ (X = Cl or Br; L = monobasic bidentate Schiff base ligand; E = P or As) have been synthesised by the reactions of $[RuCl_3(PPh_3)_3]$, $[RuCl_3(AsPh_3)_3]$, $[RuBr_3-(AsPh_3)_3]$ or $[RuBr_3(PPh_3)_2(MeOH)]$ with the appropriate ligands such as anthranilic acid cinnamaldehyde (Hanthcin), anthranilic acid *p*-tolualdehyde (Hanth-*p*-tol) and anthranilic acid *p*-anisaldehyde (Hanth-*p*-ans). All of these new complexes were characterised using various physico-chemical methods such as elemental analyses, spectral (IR, electronic and EPR), magnetic moment and cyclic voltammetric data. The antibacterial activities of ligands and their complexes have also been determined. An octahedral structure has been tentatively assigned to all of the new complexes.

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INTRODUCTION

In recent years there has been a great deal of interest in the synthesis and characterisation of transition metal complexes containing Schiff bases as ligands, due to their importance as catalysts for many reactions¹. Furthermore, tetradentate Schiff base complexes are important for designing metal complexes related to synthetic and natural oxygen carriers². Although there is a wealth of information available on transition metal complexes of Schiff bases, only very little attention has been given to their ruthenium analogues^{3–5}. Besides, some carbonyl complexes of ruthenium play an important role in homogeneous catalysis⁶. Ruthenium(III) complexes showed a positive result in antibacterial activity studies¹.

In view of growing interest in oxygenation and carbonylation with ruthenium(III) complexes as new catalysts, we describe in this paper the synthesis and characterisation of stable ruthenium(III) complexes of the type $[RuX_2(L)(EPh_3)_2]$ (X = Cl or Br; HL = monobasic bidentate Schiff base ligand; E = P or As). The ligands used in this study are of the type shown in Fig. 1.



R	Acronym
CH=CH-C ₆ H ₅	Hanthcin
$C_6H_4CH_3$	Hanth- <i>p</i> -tol
C ₆ H ₄ OCH ₃	Hanth-p-anz

Figure 1. Structure of the ligand.

EXPERIMENTAL

All reagents used were chemically pure or analytical reagent grade. Solvents were purified and dried according to standard procedures¹. RuCl₃·3H₂O was purchased from Loba Chemie Pvt. Ltd., Bombay and was used without further purification. $[RuCl_3(PPh_3)_3]^7$, $[RuCl_3(AsPh_3)_3]^8$, $[RuBr_3(AsPh_3)_3]^9$ and $[RuBr_3(PPh_3)_2(MeOH)]^{10}$ and the ligands¹¹ were prepared by reported literature methods.

The analyses of carbon, hydrogen and nitrogen were performed on Carlo Erba 1106 and Perkin-Elmer Model 240 CHN analyzers at the Central Drug Research Institute, Lucknow, India. IR spectra were recorded in KBr pelletes in the 4000–500 cm⁻¹ region using a Shimadzu FTIR-8200 spectrophotometer. Electronic spectra were recorded in dichloromethane solution with a Hitachi Perkin-Elmer 20/200 spectrophotometer in the range 800–200 nm. EPR spectra of the powdered samples were recorded with a Bruker Model ER 200-D spectrometer at X-band frequencies. Magnetic susceptibilities were recorded on an EG and G-PARC vibrating sample magnetometer. Cyclic voltammetric studies were carried out in acetonitrile using a glassy-carbon working electrode and the potentials were referenced to a saturated calomel electrode. Melting points were recorded with a Boetius micro-heating table and are uncorrected.

Preparation of the Ligands

The monobasic bidentate ligands have been prepared by the condensation reaction of substituted aldehydes [cinnamaldehyde (6.30 mL, 0.05 mol) or *p*-tolualdehyde (5.89 mL, 0.05 mol) or *p*-anisaldehyde (6.08 mL, 0.05 mol)] with anthranilic acid (6.85 g, 0.05 mol) in 1 : 1 molar ratio in ethyl alcohol (20 mL). The solution was heated under reflux for 7 h and then concentrated to 5 mL. On cooling the solutions the products separated out. The crude products were purified by column chromatography on silica gel using petroleum ether/ethyl acetate (95/5%) as eluant. The purity of the compounds was checked by TLC. They were dried under vacuum.

Characterisation of the Ligands

The ligands, namely Hanthcin, Hanth-*p*-tol and Hanth-*p*-anz, have been characterised on the basis of elemental analysis and IR spectra. The elemental analyses (Table I) agree very well with the molecular formulas. The IR spectra of all the ligands showed a strong band in the region

	Table I. Analytical Data o	f the Ligands	s and Their Ru	thenium(III) Co	mplexes		
	Complex				Analysis	Found (ca)	lcd.) %
S. No	(empirical formula) (formula weight)	Colour	M.p. (°C)	Yield (%)	С	Н	Z
(1)	[Hanthein]	Yellow	120	75	72.46	5.22	5.88
(2)	($\sum_{1} \frac{1}{1} \frac{1}{1} \frac{1}{2} \frac{1}{2$	Yellow	108	73	75.28	5.48	5.85
į	$(C_{15}H_{13}NO_2)$ (239.119)	;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;		Î	(74.95)	(5.50)	(5.90)
(3)	[Hanth- <i>p</i> -ans] (C1,tH1,2N0,1) (255,119)	Yellow	112	70	70.56 (70.32)	5.14 (5.20)	5.49 (5.45)
(4)	$[RuCl_2(anthcin)(PPh_3)_2]$	Brown	120	71	65.93	4.50	1.50
	$(C_{52}H_{42}O_2NP_2RuCl_2)$ (946.358)				(65.94)	(4.47)	(1.48)
(5)	[RuCl ₂ (anthcin)(AsPh ₃) ₂]	Brown	117	80	60.30	4.10	1.34
	$(C_{52}H_{42}O_2NAs_2RuCl_2)$ (1034.198)				(60.34)	(4.09)	(1.35)
(9)	$[RuBr_2(anthcin)(AsPh_3)_2]$	Black	122	67	55.70	3.88	1.30
	$(C_{52}H_{42}O_2NAs_2RuBr_2)$ (1121.298)				(55.65)	(3.78)	(1.26)
6	$[RuBr_2(anthcin)(PPh_3)_2]$	Black	119	70	60.39	4.09	1.41
	$(C_{52}H_{42}O_2NP_2RuBr_2)$ (1033.458)				(60.38)	(4.10)	(1.36)

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(8)	$[RuCl_2(anth-p-tol)(PPh_3)_2]$	Black	109	75	65.56	4.57	1.48
	$(C_{51}H_{42}O_2NP_2RuCl_2)$ (934.357)				(65.51)	(4.53)	(1.50)
(6)	$[RuCl_2(anth-p-tol)(AsPh_3)_2]$	Black	111	73	59.76	4.12	1.40
	$(C_{51}H_{42}O_2NA_{52}RuCl_2)(1023.297)$				(59.81)	(4.14)	(1.37)
(10)	$[RuBr_2(anth-p-tol)(AsPh_3)_2]$	Brown	113	74	55.30	3.87	1.22
	$(C_{51}H_{42}O_2NAs_2RuBr_2)$ (1108.497)				(55.21)	(3.82)	(1.26)
(11)	$[RuBr_2(anth-p-tol)(PPh_3)_2]$	Black	107	68	59.95	4.10	1.40
	$(C_{51}H_{42}O_2NP_2RuBr_2)$ (1021.457)				(59.91)	(4.14)	(1.37)
(12)	$[RuCl_2(anth-p-ans)(PPh_3)_2]$	Brown	114	99	64.45	4.40	1.50
	$(C_{51}H_{42}O_{3}NP_{2}RuCl_{2})$ (950.357)				(64.40)	(4.40)	(1.47)
(13)	$[RuCl_2(anth-p-ans)(AsPh_3)_2]$	Brown	131	70	58.89	4.10	1.40
	$(C_{51}H_{42}O_3NAs_2RuCl_2)$ (1039.297)				(58.76)	(4.07)	(1.35)
(14)	$[RuBr_2(anth-p-ans)(AsPh_3)_2]$	Brown	136	75	54.50	3.80	1.23
	$(C_{51}H_{42}O_3NAs_2RuBr_2)$ (1124.497)				(54.43)	(3.77)	(1.25)
(15)	$[RuBr_2(anth-p-ans)(PPh_3)_2]$	Brown	127	69	58.99	4.10	1.39
	$(C_{51}H_{42}O_3NP_2RuBr_2)$ (1037.457)				(58.99)	(4.08)	(1.35)

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1620–1600 cm⁻¹ characteristic of the azomethine v(C=N) group. The ligands showed the v(OH) stretching frequency in the region $3500-3300 \text{ cm}^{-1}$ and a strong band around 1670 cm^{-1} due to v(C=O).

Preparation of the Complexes

All the preparations were carried out under strictly anhydrous conditions. The Schiff bases (0.21–0.28 g, 0.01 mmol) were added to a solution of [RuX₃(EPh₃)₃] (0.99–1.13 g, 0.01 mmol) (E = P, X = Cl; E = As, X = Cl, Br) or [RuBr₃(PPh₃)₂(MeOH)] (0.90 g, 0.01 mmol) in 1:1 molar ratio in benzene (25 mL) and the mixtures were refluxed for 7 h. The resulting dark coloured solutions were concentrated to about 3 mL. The complexes were precipitated by the addition of a small quantity of petroleum ether (b.p. 60–80 °C). The complexes were then filtered, washed with petroleum ether and recrystallised from CH₂Cl₂/petroleum ether (1:4 v/v) and dried under vacuum. All of the complexes were prepared using the above procedure.

RESULTS AND DISCUSSION

The ligands used in this work were synthesised by the condensation of anthranilic acid with the appropriate substituted aldehydes in 1:1 molar ratio. These ligands react with $[RuCl_3(PPh_3)_3]$, $[RuCl_3(AsPh_3)_3]$, $[RuBr_3(AsPh_3)_3]$ or $[RuBr_3(PPh_3)_2(MeOH)]$ in 1:1 molar ratio to give hexa-coordinated ruthenium(III) complexes of the type $[RuX_2(L)(EPh_3)_2]$ (X = Cl or Br; L = monobasic bidentate Schiff base ligand; E = P or As). All of the complexes are dark coloured and quite stable in the air and light. The analytical data given in Table I for the complexes are in good agreement with the formulae proposed.

IR Spectra

The characteristic infrared frequencies for all the complexes listed in Table II. The spectra of the free Schiff base ligands have been compared with those of the complexes formed by the corresponding Schiff bases in order to confirm the coordination of the ligands to the metal atom. The v(OH) absorption observed around $3500-3300 \text{ cm}^{-1}$ in the free Schiff bases is absent in the complexes, indicating that deprotonation occurs prior to the coordination through the oxygen atom. The v(C=O) (carboxyl group) showed a band around 1670 cm^{-1} in the free Schiff bases. In the complexes,

		v(C=	O) ^a				
S. No	Complex	V _{asy}	V _{sym}	v(C=N) ^a	$\lambda_{\max}{}^{b}$	$(\epsilon)^{c}$	Assignment
(4)	[RuCl ₂ (anthcin)(PPh ₃) ₂]	1630 s	1420 s	1595 vs	350	(2535)	charge transfer
					505	(756)	$^{2}\mathrm{T}_{\mathrm{2g}} \rightarrow ^{2}\mathrm{A}_{\mathrm{2g}}$
(2)	[RuCl ₂ (anthcin)(AsPh ₃) ₂]	1620 s	1400 s	1590 vs	380	(3218)	charge transfer
9	$[RuBr_2(anthcin)(AsPh_3)_2]$	1640 s	1430 s	1580 vs	305	(4012)	charge transfer
					480	(954)	$^{2}\mathrm{T}_{2\mathrm{g}}{\rightarrow}^{2}\mathrm{A}_{2\mathrm{g}}$
E	$[RuBr_2(anthcin)(PPh_3)_2]$	1630 s	1410 s	1585 vs	360	(3214)	charge transfer
					505	(1021)	$^{2}\mathrm{T}_{2\mathrm{g}}{ ightarrow}^{2}\mathrm{A}_{2\mathrm{g}}$
(8)	$[RuCl_2(anth-p-tol)(PPh_3)_2]$	1620 s	1400 s	1580 vs	350	(4120)	charge transfer
					490	(987)	$^{2}\mathrm{T}_{2\mathrm{g}}$
(6)	$[RuCl_2(anth-p-tol)(AsPh_3)_2]$	1625 s	1420 s	1590 vs	380	(2987)	charge transfer
					520	(668)	$^{2}\mathrm{T}_{2\mathrm{g}}{ ightarrow}^{2}\mathrm{A}_{2\mathrm{g}}$
(10)	$[RuBr_2(anth-p-tol)(AsPh_3)_2]$	1650 s	1440 s	1580 vs	350	(3987)	charge transfer
					510	(1011)	$^{2}\mathrm{T}_{2\mathrm{g}}$
(11)	$[RuBr_2(anth-p-tol)(PPh_3)_2]$	1630 s	1410 s	1580 vs	310	(3257)	charge tranfer
					495	(1121)	$^{2}\mathrm{T}_{2\mathrm{g}}{ ightarrow}^{2}\mathrm{A}_{2\mathrm{g}}$
(12)	$[RuCl_2(anth-p-ans)(PPh_3)_2]$	1640 s	1430 s	1575 vs	400	(2998)	charge transfer
(13)	$[RuCl_2(anth-p-ans)(AsPh_3)_2]$	1630 s	1410 s	1590 vs	350	(4011)	charge transfer
(14)	$[RuBr_2(anth-p-ans)(AsPh_3)_2]$	1620 s	1400 s	1595 vs	385	(3885)	charge transfer
					480	(395)	$^{2}\mathrm{T}_{2\mathrm{g}}{\rightarrow}^{2}\mathrm{A}_{2\mathrm{g}}$
(15)	$[RuBr_2(anth-p-ans)(PPh_3)_2]$	1625 s	1420 s	1575 vs	360	(3657)	charge transfer

Table II. IR and Electronic Spectral Data of Ruthenium(III) Complexes

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 acm^{-1} ; bmm; $cin dm^3 mol^{-1} cm^{-1}$; s = strong, vs = very strong.

the absorptions due to carbonyl group were observed at around $1650-1620 \text{ cm}^{-1}$ and around $1430-1410 \text{ cm}^{-1}$ arising from asymmetric and symmetric stretchings, respectively. The difference between v_{asym} and v_{sym} vibrations of the carbonyl group has been found to be around 210 cm^{-1} . This is a clear indication of the monodentate coordination of the carboxyl group with the free carbonyl group¹². A strong band was observed at 1620-1600 in the free ligand which is characteristic of the azomethine (HC=N) group. It is expected that coordination of the nitrogen to the metal atom would reduce the electron density in the azomethine link and thus lower the v(C=N) stretching frequency. In the complexes this frequency was observed in the region $1595-1575 \text{ cm}^{-1}$ indicating coordination of the Schiff bases through the azomethine nitrogen¹³. In addition to the above, the other characteristic bands due to triphenylphosphine and triphenylarsine were also present in the expected region.

Electronic Spectra

Electronic spectra of all the complexes in CH₂Cl₂ showed one or two bands in the region 520–305 nm (Table II). The ground state of ruthenium(III) (t_{2g}^{5} configuration) is ${}^{2}T_{2g}$ and the first excited doublet levels in the order of increasing energy are ${}^{2}A_{2g}$ and ${}^{2}T_{1g}$ which arise from the $t_{2g}^{4} e_{g}^{1}$ configuration. In most of the ruthenium(III) complexes the electronic spectra show only charge transfer bands¹⁵. It has been observed that the charge transfer bands of the type $L\pi^* \rightarrow t_{2g}$ are prominent in the low energy region which obscure the weaker d-d transition. Hence, it is difficult to assign conclusively the bands of ruthenium(III) complexes in the visible region. However, the bands around 520–480 nm have been assigned to the ${}^{2}T_{2g} \rightarrow {}^{2}A_{2g}$ transition based on the low extinction coefficient value (ϵ) as compared to charge transfer bands. This is in conformity with assignments made for similar other octahedral ruthenium(III) complexes^{14,15}. The other bands in the region 400–305 nm have been assigned to charge transfer bands.

Cyclic Voltammetry

Cyclic voltammetric studies have been carried out for the complexes in acetonitrile solution at a glassy-carbon working electrode. The oxidations and reductions of some complexes are achieved by well defined waves with E_f values in the range from 0.62 V to 0.76 V (oxidation) and from -0.36 V to -0.76 V (reduction) against saturated calomel electrode (Table III). The

			Ru(IV) -	– Ru(III)			Ru(III)	– Ru(II)	
S. No	Complex	$E_{pc}(V)$	$E_{pa}(V)$	$E_{f}(V)$	$\Delta E_p(mV)$	$E_{pa}(V)$	$E_{pc}(V)$	$E_{f}(V)$	$\Delta E_p(mV)$
(4)	$[RuCl_2(anthcin)(PPh_3)_2]$	0.70	0.61	0.66	90	-0.67	-0.75	-0.71	80
(2)	[RuCl ₂ (anthcin)(AsPh ₃) ₂]	0.65	0.59	0.62	60	-0.71	-0.80	-0.76	90
9	$[RuBr_2(anthcin)(AsPh_3)_2]$	0.77	0.69	0.73	80	-0.55	-0.49	-0.52	60
8	$[RuCl_2(anth-p-tol)(PPh_3)_2]$	0.80	0.72	0.76	80	-0.48	-0.57	-0.53	90
(10)	$[RuBr_2(anth-p-tol)(AsPh_3)_2]$	Ι	Ι	Ι	I	-0.58	-0.65	-0.62	70
(11)	$[RuBr_2(anth-p-tol)(PPh_3)_2]$	Ι	I	Ι	I	-0.48	-0.58	-0.53	100
(13)	$[RuCl_2(anth-p-ans)(AsPh_3)_2]$	0.69	0.61	0.65	80	-0.32	-0.40	-0.36	80
(14)	$[RuBr_2(anth-p-ans)(AsPh_3)_2]$	0.70	0.78	0.74	80	-0.59	-0.52	-0.56	70
(15)	$[RuBr_2(anth-p-ans)(PPh_3)_2]$	0.77	0.69	0.73	80	I	I	I	Ι
^a Cunno	ting aloot school states (NID), 1010 (0.0)	5 MD. Cono	antrotion o	f the com		L. Constants	50 V.c-1		stantiale and

Supporting electrolyte: [NBu4]CO4 (0.02 M); Concentiation of the complexes: 0.01 M; Scan rate: 2011VS $\frac{1}{2}$ and the potentials are referred to silver-silver chloride electrode; $E_{r}=0.5$ ($E_{pa}+E_{pc}$) where, E_{pa} and E_{pc} are the aniodic and cathodic potentials, respectively.

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Table III. Cyclic Voltammetric Data of Ruthenium(III) Complexes^a

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redox process observed from these complexes are metal-centered only. Most of the complexes showed reversible redox couples with peak-to-peak separation values (ΔE_p) ranging from 60 to 100 mV, indicating a single step, one-electron transfer process^{16,17}. The complexes (10) and (11) showed only a reduction potential and the complex (15) showed only an oxidation process. The reason for the irreversibility for these complexes may be due to the short-lived oxidation state of the metal ion¹⁸ or due to oxidative degradation of the ligands¹⁹.

Magnetic Moment Studies

The magnetic moments for some of the complexes have been measured at room temperature using a vibrating sample magnetometer and diamagnetic corrections have been applied. The values obtained were from 1.82 to 1.95 BM indicating the presence of one unpaired electron, suggesting a lowspin t_{2g}^{5} configuration for the ruthenium(III) ion in an octahedral environment in all of these complexes.

EPR Spectra

EPR spectra of powdered samples were recorded at room temperature. The spectra of the complexes (4), (8) and (12) exhibit an axially symmetric system with $g_{\perp}r$ around 2.20–2.34 and g_{11} el around 2.05–2.29 (Table IV). For an octahedral field with tetragonal distortion $g_x = g_y \neq g_z$ and hence, two 'g' values indicate tetragonal distortion in these complexes. The other

 $\langle g \rangle^*$ S. No Complex g_z g_x g_y 2.34 2.27 2.24 [RuCl₂(anthcin)(PPh₃)₂] 2.34 (4) 2.12 (5) [RuCl₂(anthcin)(AsPh₃)₂] _ _ (7) [RuBr₂(anthcin)(PPh₃)₂] 2.11 _ _ _ 2.34 2.34 2.29 2.32 (8) [RuCl₂(anth-*p*-tol)(PPh₃)₂] (9) [RuBr₂(anth-*p*-tol)(AsPh₃)₂] 2.13 _ _ _ _ (11)[RuBr₂(anth-*p*-tol)(PPh₃)₂] _ 2.14 2.20 2.20 2.05 2.15 (12) $[RuCl_2(anth-p-ans)(PPh_3)_2]$ (14) $[RuBr_2(anth-p-ans)(AsPh_3)_2]$ 2.07_ _ _ (15) $[RuBr_2(anth-p-ans)(PPh_3)_2]$ 2.13 _

Table IV. EPR Spectral Data^a Ruthenium(III) Complexes

 $^{a}\langle g \rangle^{*} = (1/3 g_{x}^{2} + 1/3 g_{y}^{2} = 1/3 g_{z}^{2})^{1/2}.$

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complexes (5), (7), (9), (11), (14) and (15) showed single isotropic resonances with 'g' values in the range 2.07-2.14. Such isotropic lines are usually observed either due to intermolecular spin exchange which can broaden the lines or due to occupancy of the unpaired electron in a degenerate orbital. The position of the lines and the nature of the EPR spectra for all of the complexes suggest an almost perfect octahedral environment around ruthenium ion in the complexes²⁰⁻²².

Antibacterial Activity Studies

Antibacterial activity studies of the complexes and the ligands have been carried out against *Enterobacteria feacalis* and *Aeromonas hydrophilla* using nutrient agar (NA) medium by the agar-well diffusion method²³ with an incubation period of 24–48 h at 35 °C. The test solutions were prepared in DMF. Among the complexes and ligands tested, the ligand Hanth-*p*-ans and the appropriate complexes have been found to be more toxic against both species of bacteria than the other ligands and complexes under similar conditions. It has also been observed from these studies that the ruthenium chelates have a higher activity than the respective free ligands against the same microorganism under identical experimental conditions (Table V) which is consistent with the earlier reports²⁴. The mode of action of the

		Diamet	ter of Inhib	ition Zone	(mm) ^a
		E. fe	acalis	A. hydi	rophilla
S. No	Compound	1%	2%	1%	2%
	Colistin (standard bacteriocide)	7	11	8	10
	Hanthcin	+3	+1	0	+1
(5)	[RuCl ₂ (anthcin)(AsPh ₃) ₂]	+5	+8	+7	+9
(7)	[RuBr ₂ (anthcin)PPh ₃) ₂]	+6	+8	+8	+9
	Hanth- <i>p</i> -tol	+5	+7	+8	+10
(8)	[RuCl ₂ (anth- <i>p</i> -tol)PPh ₃) ₂]	+7	+9	+10	+12
(10)	[RuBr ₂ (anth- <i>p</i> -tol)(AsPh ₃) ₂]	+10	+12	+14	+15
	Hanth- <i>p</i> -anz	+8	+11	+12	+14
(13)	[RuCl ₂ (anth- <i>p</i> -ans)(AsPh ₃) ₂]	+11	+13	+15	+18
(15)	[RuBr ₂ (anth- <i>p</i> -ans)(PPh ₃) ₂]	+13	+17	+21	+24

^a1% and 2% indicate 1 g and 27 g of the compound in 100 mL of test solution.



Complex No.	Х	Е	R
(4)	Cl	Р	CH=CHC ₆ H ₅
(5)	Cl	As	CH=CHC ₆ H ₅
(6)	Br	As	CH=CHC ₆ H ₅
(7)	Br	Р	CH=CHC ₆ H ₅
(8)	Cl	Р	$C_6H_4CH_3$
(9)	Cl	As	$C_6H_4CH_3$
(10)	Br	As	C ₆ H ₄ CH ₃
(11)	Br	Р	$C_6H_4CH_3$
(12)	Cl	Р	C ₆ H ₄ OCH ₃
(13)	Cl	As	C ₆ H ₄ OCH ₃
(14)	Br	As	C ₆ H ₄ OCH ₃
(15)	Br	Р	C ₆ H ₄ OCH ₃

Figure 2. Suggested structure of the ruthenium(III) complexes.

compounds may involve the formation of hydrogen bonds through the azomethine (>C=N) group with the active centres of cell constituents resulting in the interference with normal cell processes²⁵. The complexes containing an electron donating group (-OCH₃) showed more activity than the other complexes²⁶. On comparision with the standard antibiotic Colistin, the ruthenium(III) complexes showed higher biological activity. Normally, the inhibitive action of the complexes increases with increase in the concentration of the solution.

Based on the analytical, spectral (IR, UV-visible and EPR) and electrochemical data, the following octahedral structure (Fig. 2) has been tentatively proposed for all the ruthenium(III) complexes.

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