

**DIVALENT TRANSITION METAL COMPLEXES
OF POTENTIALLY POLYNUCLEATING
8-HYDROXYQUINOLINE-5-SULFONYL HYDRAZONE***

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The Co(II), Ni(II), Cu(II) and Zn(II) complexes with 8-hydroxyquinoline-5-sulfonylhydrazone are described. It has been found that the ligand can coordinate to metal ion as a monobasic bidentate chelating agent and it can form di- and trinuclear complexes while acting as a dibasic tetradentate one. The structure of the isolated complexes have been suggested on the basis of elemental analysis, IR, ¹H NMR spectroscopy and conductivity measurements. The complexes are all formulated as four-coordinate. Some complexes showed enhanced antimicrobial activity relative to the free ligand.

Sulfonamides and quinolinol derivatives are drugs of proven therapeutic importance and used against a wide range of bacterial ailments¹⁻³. It has been reported that drugs have increased activity when administered as metal complexes more so as metal chelates^{4,5}. Therefore and in continuation of our studies on metal complexes of biologically active ligands⁶⁻⁸ we reported in this article on the Ni(II), Cu(II), and Zn(II) complexes with the new potentially polynucleating 8-hydroxyquinoline-5-sulfonylhydrazone which is thought to be of special interest in view of the expected therapeutic applications. The present study involves synthesis of the metal complexes with the title ligand with the aim of investigation their biological activity.

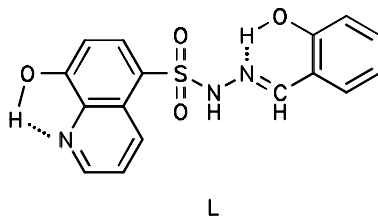
EXPERIMENTAL

Solvents used in this study were of the a.r. grade and are used without further purification. General grade metal salts, CoCl₂ · 6 H₂O, NiCl₂ · 6 H₂O, CuCl₂ · 6 H₂O and ZnCl₂ · 6 H₂O were used.

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Preparation of the Organic Ligand

The following procedure⁹ was applied for preparation of ligand L. 8-Hydroxyquinoline was treated with chlorosulfonic acid. The resulting sulfonyl chloride was allowed to react with hydrazine hydrate (98%) in dry benzene. The resulted 8-hydroxyquinoline-5-sulfonyl hydrazide was condensed with salicylaldehyde by the usual procedure. The purity of the obtained 8-hydroxyquinoline-5-sulfonylhydrazone was checked by elemental analysis and IR spectra.



Synthesis of the Solid Chelates

a) Mononuclear complexes. To a hot ethanolic solution (50 ml) of the ligand (1 mmol) a hot aqueous solution of the metal salt (1 mmol or 2 mmol) was added dropwise with stirring. The stirring was continued for about half an hour and the mixture was evaporated to about one third its original volume and left overnight whereby a crystalline solid was obtained. This was filtered, washed with a cold water-ethanol (1 : 1, v/v) mixture and dried in vacuo over P_4O_{10} .

b) Polynuclear complexes. Homo- and heterobinuclear complexes were prepared by mixing the calculated amount of the binary complex suspended in absolute ethanol with an equimolar amount of the metal salt solution in ethanol. The mixture was then refluxed on a water bath for 2 – 4 h after complete dissolution and then concentrated to a small volume and left to cool whereby a crystalline solid was obtained.

Two different procedures were used for the preparation of trinuclear complexes; (i) as described above in *b*) but using the binary complex : metal salt ratio (1 : 2), and (ii) by mixing an excess of the metal salt solution to the ligand solution and following procedures as in *a*). The solid products obtained by the two methods were found to have similar analytical data.

The obtained solid complexes were analyzed for their carbon, hydrogen, nitrogen, sulfur and chloride contents. The data are reported in Table I. The complexes are sparingly soluble in common organic solvents; soluble in DMF and DMSO except for the homotrinnuclear Ni(II) and Cu(II) complexes **10** and **11**.

Screening for Antimicrobial Activity

The antimicrobial activity of the ligand and its metal complexes was tested using the usual cup-plate diffusion technique^{10,11}. The culture media used are nutrient agar (NA) supplemented with 1 g yeast per liter. A final concentration of 1% of the tested compounds in DMF were used. The results obtained are given in Table II.

TABLE I
Analytical data, decomposition temperature and molar conductance values of the complexes

No.	Compound	Colour	Calculated/Found							$\Lambda_{m, \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}}$
			% C	% H	% Cl	% N	% S			
1	NiCl ₂ · H ₂ O [NiC ₁₆ H ₁₂ N ₃ SO ₄ Cl · H ₂ O]	greenish yellow	42.28	3.10	7.80	9.24	7.05	23.4		
			41.80	3.30	7.50	9.60	6.90			
2	CuLCl ₂ · H ₂ O [CuC ₁₆ H ₁₂ N ₃ SO ₄ Cl · H ₂ O]	green	41.83	3.07	7.73	9.15	6.98	26.6		
			41.60	3.20	8.00	9.40	7.20			
3	CoL ₂ · 2 H ₂ O [Co(C ₁₆ H ₁₂ N ₃ SO ₄) ₂ · 2 H ₂ O]	orange	49.30	3.62	—	10.78	8.22	33.2		
			49.50	3.40	—	11.20	8.50			
4	NiL ₂ [Ni(C ₁₆ H ₁₂ N ₃ SO ₄) ₂]	light green	51.68	3.25	—	11.30	8.62	18.2		
			51.40	3.50	—	11.50	9.00			
5	ZnL ₂ · 2 H ₂ O [Zn(C ₁₆ H ₁₂ N ₃ SO ₄) ₂ · 2 H ₂ O]	yellow	51.22	3.76	—	11.20	8.54	41.5		
			50.80	4.00	—	10.90	8.30			
6	Co ₂ LCl ₂ · 4 H ₂ O [Co ₂ C ₁₆ H ₁₁ N ₃ SO ₄ Cl ₂ · 4 H ₂ O]	brown	31.93	3.18	11.80	6.98	5.33	21.7		
			31.60	3.30	12.10	7.40	5.10			
7	Ni ₂ LCl ₂ · 2 H ₂ O [Ni ₂ C ₁₆ H ₁₁ N ₃ SO ₄ Cl ₂ · 2 H ₂ O]	yellow	33.97	2.67	12.55	7.42	5.66	16.7		
			34.20	2.90	12.70	7.60	5.80			
8	NiLCH ₂ O · CuCl · H ₂ O [NiC ₁₆ H ₁₁ N ₃ SO ₄ · CuCl ₂ · 2 H ₂ O]	yellow green	33.68	2.65	12.44	7.36	5.62	42.3		
			33.80	2.20	12.10	7.80	5.20			
9	NiLCl ₂ · H ₂ O · CoCl · H ₂ O [NiC ₁₆ H ₁₁ N ₃ SO ₄ · CoCl ₂ · 2 H ₂ O]	orange	33.95	2.67	12.54	7.42	5.66	44.5		
			34.30	2.82	12.60	7.11	5.80			
10	Ni ₃ LCl ₄ · H ₂ O [Ni ₃ C ₁₆ H ₁₁ N ₃ SO ₄ Cl ₄ · H ₂ O]	green	28.36	2.08	20.96	6.20	4.73	—		
			28.60	2.20	21.32	6.60	5.04			
11	Cu ₃ LCl ₄ · H ₂ O [Cu ₃ C ₁₆ H ₁₁ N ₃ SO ₄ Cl ₄ · H ₂ O]	dark green	27.80	1.89	20.52	6.07	4.63	—		
			28.20	2.10	20.60	6.36	4.80			

Physical Measurements

Electronic spectra were recorded on a CECIL 599 spectrophotometer (200 – 900 nm) using 1 cm matched silica cells. IR spectra were obtained as KBr disks a Perkin–Elmer 599B spectrophotometer, ^1H NMR spectra were run on a Varian EM-390 spectrophotometer using $(\text{CD}_3)_2\text{SO}$ solutions. Conductivity measurements were carried out using an LF Digi 55 conductance bridge. All measurements were carried out at room temperature ($\sim 25^\circ\text{C}$).

RESULTS AND DISCUSSION

The molar conductance values of $1 \cdot 10^{-3}$ M DMF solutions of the different complexes are in the range $16.7 - 51.2 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$. These values indicate a nonelectrolytic nature of the prepared complexes since the reported range for 1 : 1 electrolytes in DMF solutions is $65 - 90 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$ (ref.¹²).

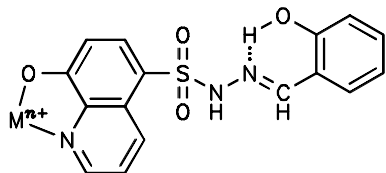
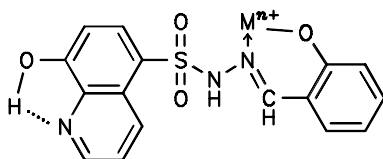
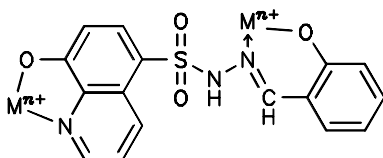
The results of elemental analysis, reported in Table I, indicate the formation of 1 : 1, 1 : 2, 2 : 1, 3 : 1 (metal ion : ligand) complexes. The quinolinol sulfonylhydrazone ligand used in this study is flexidentate where it can act as monobasic bidentate chelating agent through two different sites (cf. structures *I* and *II*). It is capable also to act as dibasic tetradentate ligand utilizing the two sites in binuclear complexes (structure *III*).

However, spectroscopic data provide ample evidence in favour of the coordination of the ligand as in (*I*) in both 1 : 1 and 1 : 2 (metal ion : ligand) complexes **1** – **5**. This is evidenced from the ^1H NMR spectra where signals due to both NH and azomethine CH protons appearing at 10.98 and 8.9 ppm, respectively^{13,14} are almost unaltered on complexation. On the other hand the multiplet resonance appearing in the region 7.20 – 7.74 ppm in the ^1H NMR of the free ligand due to quinoline protons is downfield shifted in the ^1H NMR spectra of these complexes. Therefore, in the mononuclear complexes, the ligand coordinate to the metal ions as a monobasic bidentate one with the bonding sites

TABLE II
Antimicrobial activity of selected metal complexes

Complex	Mean inhibition zone, mm					
	<i>S. aureus</i>	<i>M. luteus</i>	<i>Sterr. Sp.</i>	<i>Asp. fumigates</i>	<i>M. pusillus</i>	<i>C. indicium</i>
L	–	–	–	–	–	–
1	–	–	16	–	14	–
2	16	12	18	–	–	–
5	20	16	25	20	18	20
8	18	14	20	–	10	12

are the quinoline ring nitrogen and the adjacent phenolic oxygen atom. Further evidence for the existence of the mononuclear complexes as in structure *I* is attained from the IR spectra where $\nu_{as}(S=O)$, $\nu_s(S=O)$ and $\nu(C=N)$ (azomethine) appear, in the spectra of these complexes, at more or less the same frequencies as in the spectra of the free ligand (cf. Table III). Unambiguous evidence for the mode of coordination of the present ligand from the shift in $\nu(OH)$ can not be achieved since the ligand has two phenolic hydroxyl group having similar features where both are involved in a hydrogen bonding and their frequencies appear in the range of NH stretching vibration (Table III).

*I**II**III*

In the IR spectra of di- and trinuclear complexes both azomethine and quinoline ring C=N stretching vibrations appearing at 1 625 and 1 575 cm^{-1} , respectively, in the spectrum of the free ligand are shifted to lower frequencies. This behaviour indicates that both ring and azomethine nitrogens are involved in coordination in these complexes. Furthermore signals due to both NH and azomethine CH protons are shifted downfield in the spectra of the polynuclear complexes relative to their position in the ^1H NMR spectrum of the free ligand. This shift is due to deshielding caused by the coordination of the azomethine nitrogen to the metal ions^{15,16}. Also, the multiplet resonances due to phenyl and quinolinylnyl protons appearing at 6.72 – 6.95 and 7.2 – 7.74, respectively, in the ^1H NMR spectrum of the free ligand are altered in position on complexation and appear as multiplets in the ^1H NMR spectra of these complexes. It is to be noted that the appearance of $\nu_{as,s}(S=O)$ in the spectra of the polynuclear complexes at almost the same frequencies as in the free ligand rules out the possibility of an additional coordination from the sulfonyl oxygen to the metal ion. The above spectral features indicate that the two bonding centers of the ligand involved in coordination in the di- and trinuclear complexes are according to structure *III*. Careful comparison of the IR spectra of the complexes with that of the free ligand revealed the presence of $\nu(M-Cl)$ in the

TABLE III
Some IR frequencies of the free ligand L and its complexes

Compound	$\nu(\text{OH})^d$	$\nu(\text{NH})^b$	$\nu(\text{C}=\text{N})^c$	$\nu(\text{C}=\text{N})^d$	$\nu_{\text{as}}(\text{S}=\text{O})$	$\nu_s(\text{S}=\text{O})$	$\nu(\text{M}-\text{Cl})$
L	—	3 300	1 625	1 590	1 390	1 150	—
1	3 380	3 310	1 625	1 575	1 390	1 150	340
2	3 400	3 200	1 620	1 580	1 390	1 150	350
3	3 390	3 150	1 625	1 575	1 385	1 150	330
4	—	3 200	1 625	1 575	1 390	1 155	340
5	3 450 ^e	3 300	1 620	1 575	1 390	1 150	335
6	3 400	3 200	1 605	1 580	1 390	1 150	335
7	3 380	3 200	1 605	1 580	1 385	1 150	330
8	3 380	3 300	1 595	1 575	1 390	1 155	345
9	3 380	3 300	1 600	1 580	1 390	1 150	340
10	3 400	3 150	1 600	1 575	1 385	1 150	295
11	3 400	3 310	1 605	1 575	1 390	1 155	305

^a Coordinated water; ^b broad band including H-bonded OH stretching; ^c azomethine; ^d ring; ^e crystallization water.

range 350 – 330 cm^{-1} for mono- and binuclear complexes and around 300 cm^{-1} for the trinuclear ones. The occurrence of $\nu(\text{M}-\text{Cl})$ band lower frequencies in the latter complexes is suggestive of the presence of chlorine bridging¹⁷.

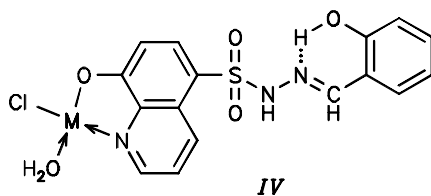
Electronic Spectra

The reflectance, as Nujol mulls, and/or DMF solution spectra were recorded in the wavelength range 300 – 800 nm. λ_{max} and ϵ_{max} values of the bands observed are listed in Table IV. The strong band appeared in the range 28 000 – 26 000 cm^{-1} are due to

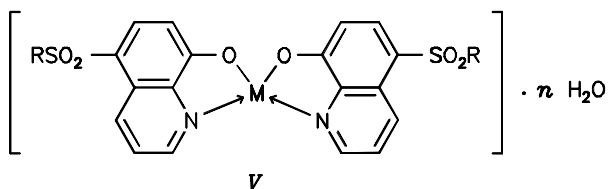
TABLE IV
Electronic spectral data of the complexes

Complex	$\lambda_{\text{max}}, \text{cm}^{-1}$		ϵ_{max} $\text{mol}^{-1} \text{cm}^2$	Assignment
	A^a	R^b		
1	26 200	–	2 800	<i>c</i>
	25 200	–	1 080	CT
	16 100	15 850	800 ^a	<i>d-d</i>
2	28 100	–	3 200	<i>c</i>
	24 400	–	1 300	CT
	17 100	17 200	880 ^a	<i>d-d</i>
3	24 600	–	2 100	CT
	16 400	16 800	500 ^a	<i>d-d</i>
4	25 100	–	1 800	CT
	15 600	15 400	400	<i>d-d</i>
5	27 300	–	3 000	<i>c</i>
	25 000	–	1 200	CT
6	25 000	–	2 200	CT
	14 800	14 200	300 ^a	<i>d-d</i>
7	28 500	–	3 800	<i>c</i>
	24 600	–	1 400	CT
	16 000	–	600 ^a	<i>d-d</i>
8	26 000	–	1 800	<i>c</i>
	24 200	–	1 200	CT
9	15 800	15 200	350 ^a	<i>d-d</i>
	24 600	–	1 500	CT
	16 300	16 200	280	<i>d-d</i>
10	<i>d</i>	15 200	–	<i>d-d</i>
11	<i>d</i>	18 600	–	<i>d-d</i>

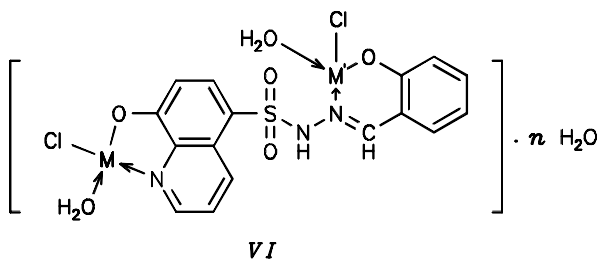
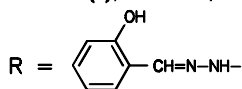
^a Absorption. ^b Reflectance. ^c Intraligand. ^d Insoluble.



M = Ni(II), Cu(II)

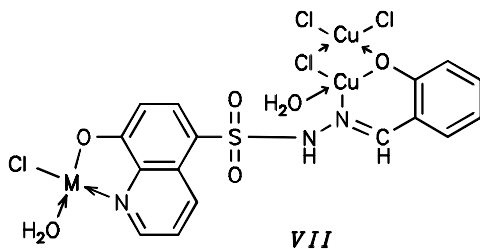


M = Ni(II), $n = 0$; M = Co(II) or Zn(II), $n = 2$



M = M' = Co(II), $n = 2$; M = M' = Ni(II), $n = 0$;

M = Ni, M' = Cu, $n = 0$; M = Ni(II), M' = Co(II), $n = 0$



M = Ni(II) or Cu(II)

intraligand electronic transition. The band of medium intensity with ν_{\max} in the range 25 200 – 24 200 cm^{-1} is assignable to a charge transfer from ligand to metal (LMCT). The absorption and reflectance spectra of the complexes displayed a $d-d$ band near 16 500 cm^{-1} for mononuclear Co(II) complex and near 14 500 for the binuclear Co(II) complex. These bands are suggestive of tetrahedral stereochemical configuration around Co(II) ion¹⁸. Therefore the two additional water molecules existing in the Co(II) complexes (**3** and **6**) are not coordinatively bonded to the metal ion. This is confirmed by a simple weight loss measurement where these two complexes possessed a loss of weight corresponding to two water molecules at a temperature 110 °C.

Ni(II) complex comprised $d-d$ bands in the range 15 200 – 16 100 cm^{-1} indicative of tetrahedral Ni(II) complexes. Copper(II) complexes showed $d-d$ band with ν_{\max} in the range 18 600 – 17 100 cm^{-1} which is usually found in the spectra of four coordinate Cu(II) ion.

Based on the foregoing discussion, the structures *IV* – *VII* are proposed for the prepared complexes.

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