

“Cr(III), Mn(III), Fe(III) and VO(IV) complexes of 2,4-dihydroxyacetophenone and sulphapyridine.”

¹V A Sadafale and ²P R Mandlik

¹ Department of Chemistry, Adarsha Science, J. B. Arts & Birla Commerce Mahavidyalaya, Dhamangaon Rly.

² P. G. Department of Chemistry, Shri Shivaji Science College, Amravati.

Abstract : Complexes of Cr(III), Mn(III), Fe(III) and VO(IV) with Schiff base derived from 2,4-dihydroxyacetophenone and sulphapyridine were synthesized and characterized using elemental analysis, molar conductance, magnetic susceptibility measurements, spectral studies (IR, ¹H NMR, UV- Visible) mass and TGA. Elemental analysis of the complexes suggested 1:2 metal:ligand stoichiometry in case of VO(IV) complex whereas 1:1 metal:ligand ratio for Cr(III), Mn(III) and Fe(III) complexes. The molar conductance measurements reveal the non-electrolytic nature of all the complexes. IR spectra of the compounds show monobasic bidentate (ON) nature of the ligand, coordinating mainly through hydroxyl oxygen and azomethine nitrogen. The electronic spectral data supported octahedral geometry for Cr(III), Mn(III) and Fe(III) complexes while square pyramidal for VO(IV) complex. Thermogravimetric analysis shows that the complexes are thermally more stable than that of the ligand. Kinetic parameters were calculated by using Freeman-Carroll and Sharp-Wentworth methods and results are comparable. All the compounds have been tested in vitro to evaluate their antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsella pneumoniae* using well-diffusion method.

Index Terms - 2,4-dihydroxybenzophenone, sulphapyridine, well-diffusion.

I. INTRODUCTION

Recently the research field dealing with Schiff base coordination chemistry has expanded enormously. The importance of Schiff base complexes for bioinorganic chemistry, biomedical applications, supramolecular chemistry, catalysis and material science, separation and formation of compounds with unusual properties and structures has been well recognized and reviewed [1]. In addition to important role of Schiff base complexes in catalysis and organic synthesis, they have also clinical, analytical and industrial applications [2].

Sulphur ligands are widespread among coordination compounds and are important components of biological transition metal complexes which possess many applications such as diuretic, antiglaucoma or antiepileptic drugs. [3]

The biological activity of sulphur containing ligand increases on complexation. salicylaldehyde, benzaldehyde and furfural moiety when coupled with sulfonamides yields sulfonamide-imine which may show superior biological activity.

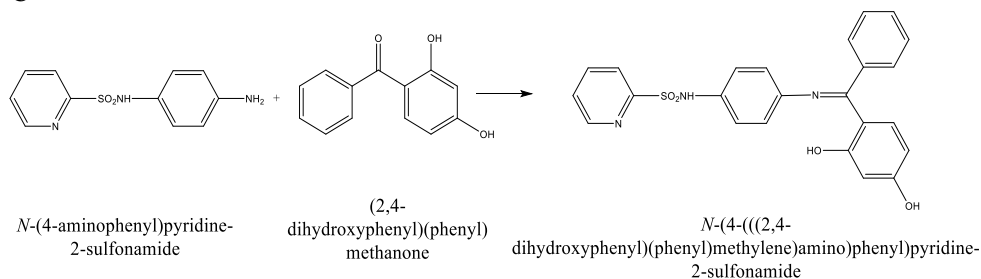
II. Material and Method

All the metal salts and solvents used were analytical reagent grade supplied by SD Fine and Merck. Pure sample of dapsone was obtained from Shah Scientific Pvt. Ltd. Mumbai. Solvents were purified and dried before use by literature method [4]. The ligands used in the present work are not commercially available, hence were synthesized in laboratory. Manganese acetate dihydrate was prepared by the oxidation of Mn(OAc)₂·4H₂O using Christensen's method [5] while all other metal salts are commercially available and used as received. The amounts of metal present in the complexes were estimated by metal oxide method [6]. The molar conductance of the complexes in dimethyl formamide (DMF) solution (10⁻³ M), was measured using Equiptronic digital conductivity meter EQ-660 with a cell constant of 1.00cm⁻¹ at room temperature. The infrared Fourier-transform infrared (IR) spectra of ligand and complexes were recorded as KBr pellets using Shimadzu spectrometer (IR Affinity-1S). The thermal analysis was performed with a Perkin Elmer (TGS-2 model) thermal analyzer at a heating rate of 10°C min⁻¹ in the temperature range 40-500°C.

Synthesis of N-(4-(((2,4dihydroxy)(phenyl)methylene)amino)phenyl)pyridine-2-sulfonamide (L⁴H₂)

Equimolar (0.01m) solutions of 2,4dihydroxybenzophenone (2.14g) and sulphapyridine (2.49g) were separately dissolved in ethanol and refluxed for three hours. The volume of reaction mixture was reduced to one third and cooled at 0°C. The solid residue was filtered off and recrystallized by ethanol. The purity of the compound was checked by thin layer chromatography (TLC).

Yield- 80%, M. P.- 145⁰C



Synthesis of Metal complex

The complexes were synthesized by adding ligand and respective metal salt, i.e., CrCl₃·6H₂O, Mn(OAc)₃·2H₂O, FeCl₃·6H₂O, VOSO₄·5H₂O in 1:1 ratio to the ethanol. Few drops of 1N KOH were added to the reaction mixture and the reaction mixture was refluxed in water bath for about 10-12 h. The coloured solids obtained were filtered off, washed several times with small amount of ethanol followed by petroleum ether and finally dried over fused calcium chloride.

III. Results & Discussion

In the present study, all the complexes are found to be coloured solids, air stable and non- hygroscopic. The analytical data indicate 1:1 metal to ligand stoichiometry. The complexes are insoluble in water and common organic solvents but soluble in coordinating solvents like DMF and DMSO. Lower values of molar conductance indicate that complexes are nonelectrolytes. The analytical and physical data of ligand and its complexes are given in Table 1.

Table 1: Elemental analysis and kinetic data for ligand and metal complexes

| S. N. | Compounds | Formula weight g mol ⁻¹ | Colour | Time of Reflux | Elemental Analysis | | |
|-------|-------------------------------|---------------------------------------|--------------|-------------------|--------------------|----------------|----------------|
| | | | | | C% | H% | N% |
| 1 | L ⁴ H ₂ | 445.11 | Yellow | 3 h | 64.71 (64.69) | 4.30 (4.28) | 9.43 (9.36) |
| 2 | Cr- L ⁴ Hcomplex | 621.43 | Brown | 10 h | 46.39 (46.47) | 3.89 (3.98) | 6.76 (6.83) |
| 3 | Mn- L ⁴ Hcomplex | 671.56 | Black Cherry | 11 h | 50.08 (50.17) | 4.50 (4.81) | 6.26 (6.06) |
| 4 | Fe- L ⁴ Hcomplex | 625.28 | Black | 12 h | 46.10 (46.31) | 3.87 (3.94) | 6.72 (6.87) |
| 5 | VO- L ⁴ Hcomplex | 955.21 | Brown | 11 h | 60.31 (60.45) | 3.80 (3.95) | 8.79 (8.91) |

¹H NMR spectra of ligand

The ¹H nuclear magnetic resonance (NMR) spectra of Schiff base ligand was recorded in dimethyl sulfoxide (DMSO) using TMS as an internal standard. The spectrum shows following peaks.

¹H NMR (DMSO) δ ppm: 12.5 (s, 2H, phenolic OH), 5.90-7.69 (m, 16H, aromatic), 2.61 (s, 3H, -CH₃) [7-9].

IR Spectra

To study the binding modes of ligand toward metal ion IR spectral data of Schiff base ligand was compared with the complexes (Table 2). The broad band that appeared in the spectra of the ligand and their metal complexes in the range 3309-3402 cm⁻¹ is assigned to the stretching vibration of ν(N-H) [10-11]. The IR spectral bands in the spectra of the ligand and its metal complexes indicates that the band at 3232 cm⁻¹ due to intramolecular hydrogen bonded ν(OH) group in the free ligand spectrum disappeared in spectra of all the complexes suggesting the coordination of ligand through phenolic oxygen via deprotonation [12]. Further the bands at 1620 cm⁻¹ (azomethine C=N) shifted its position to lower frequency on complexation [13]. The bands at 1350 cm⁻¹ and 1122 cm⁻¹ in the ligand are assigned to ν_{as}(SO₂) and ν_s(SO₂) [14-15]. These bands remain almost at the same position in the complexes suggesting non-involvement of sulfonyl oxygen in coordination with the metal. The spectra of VO(IV) complex show new band at around 994 cm⁻¹ due to ν(V=O) vibration. The ν(M-N) and ν(M-O) bands have been assigned in the region 505-559 cm⁻¹ and 445-459 cm⁻¹ respectively [16]. The coordination of water in Cr(III), Mn(III) and Fe(III) complexes is indicated by appearance of bands at 3410- 3460 cm⁻¹, 1536-1546 cm⁻¹, 820-840 cm⁻¹, 756-771 cm⁻¹ assignable to ν(OH), δ(OH), ρ_i(H₂O), ρ_w(H₂O) mode respectively [17-18].

Table 2: IR spectral data for Schiff base ligand and its metal complexes

| S. N. | Compound | ν(O-H) hydrogen bonded | ν(NH) | ν(C=N) | ν(SO ₂) | | ν(M-O) | ν(M-N) |
|-------|-------------------------------|------------------------------|-------|--------|---------------------|------|--------|--------|
| | | | | | asym | sym | | |
| 1 | L ⁴ H ₂ | 3232 | 3402 | 1620 | 1350 | 1122 | -- | -- |
| 2 | [Cr(L ⁴ H)] | -- | 3335 | 1598 | 1338 | 1135 | 540 | 446 |
| 3 | [Mn(L ⁴ H)] | -- | 3393 | 1596 | 1340 | 1122 | 542 | 458 |
| 4 | [Fe(L ⁴ H)] | -- | 3321 | 1607 | 1369 | 1145 | 559 | 458 |
| 5 | [VO(L ⁴ H)] | -- | 3358 | 1600 | 1332 | 1128 | 536 | 454 |

Mass Spectra

Mass spectrometry has been successfully used to determine the molecular ion peak for Schiff base ligand. The various fragmentation peaks obtained for ligand, Cr(III), Fe(III), Mn(III) and VO(IV) complexes are in good agreement with proposed structure. Mass spectrum of ligand was shown in Figure.

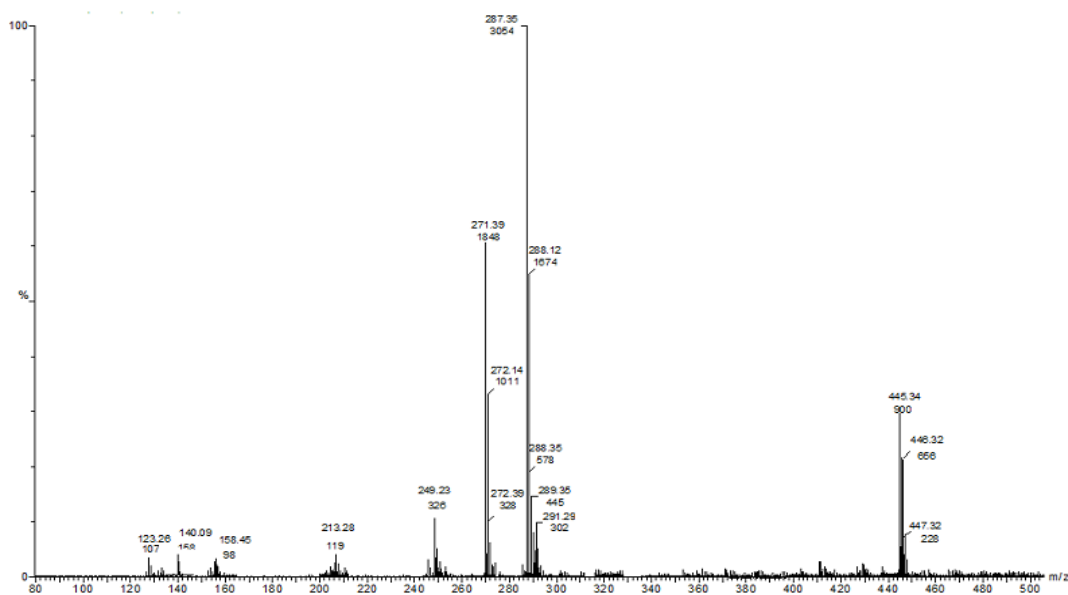


Fig.: Mass spectrum of Ligand L⁴H₂.

Electronic Spectra

The electronic absorption spectra of metal complexes were recorded in DMSO in the range 200-800 nm. The electronic spectrum of Cr(III) complex shows bands at 302, 462 and 607 nm corresponding to transition ${}^4A_{2g} \rightarrow {}^4T_{1g}(P)$, ${}^4A_{2g} \rightarrow {}^4T_{1g}(F)$, ${}^4A_{2g} \rightarrow {}^4T_{2g}(F)$ respectively, indicating octahedral geometry around Cr(III) ion [19]. For Mn(III) complex band appears at 288, 550 and 800 nm for transition ${}^5B_{1g} \rightarrow {}^5E_g$, ${}^5B_{1g} \rightarrow {}^5B_{2g}$ and ${}^5B_{1g} \rightarrow {}^5A_{1g}$. All these transitions indicate octahedral geometry for Mn(III) complex [20]. The electronic spectrum of Fe(III) complex shows bands at 780, 539 and 332 nm corresponding to transition ${}^6A_{1g} \rightarrow {}^4T_{1g}(D)$, ${}^6A_{1g} \rightarrow {}^4T_{1g}$ and LMCT transition respectively, indicating octahedral geometry around Fe(III) ion [21]. The electronic spectrum of VO(IV) complex shows bands at 809, 463, 247 and 208 nm corresponding to transition ${}^2B_2 \rightarrow {}^1A_1$, ${}^2B_2 \rightarrow {}^1E$, CT respectively, suggesting square pyramidal geometry for complexes [22]. The absorption region, band assignment and proposed geometry of the complexes are given in Table 3.

Table 3: Electronic absorption spectral data of the complexes.

| Compounds | μ_{eff} B. M. | Δ_M $\Omega^{-1}\text{cm}^2\text{mol}^{-1}$ | Absorption (nm) | Band assignment | Geometry |
|-------------------------|-----------------------------|---|--------------------------|--|---------------------|
| [Cr (L ⁴ H)] | 3.64 | 10.12 | 288 482 611 | ${}^4A_{2g} \rightarrow {}^4T_{2g}(F)$ ${}^4A_{2g} \rightarrow {}^4T_{1g}(F)$ ${}^4A_{2g} \rightarrow {}^4T_{1g}(F)$ | octahedral |
| [Mn (L ⁴ H)] | 5.10 | 12.25 | 275 579 797 | ${}^5B_{1g} \rightarrow {}^5E_g$ ${}^5B_{1g} \rightarrow {}^5B_{2g}$ ${}^5B_{1g} \rightarrow {}^5A_{1g}$ | octahedral |
| [Fe (L ⁴ H)] | 5.50 | 8.24 | 762 537 343 | ${}^6A_{1g} \rightarrow {}^4T_g(D)$ ${}^6A_{1g} \rightarrow {}^4T_g$ LMCT | octahedral |
| [VO (L ⁴ H)] | 1.62 | 8.92 | 809 463 247 208 | ${}^2B_2 \rightarrow {}^1A_1$ ${}^2B_2 \rightarrow {}^1E$ LMCT LMCT | square pyramidal |

Thermal Analysis

Thermal analysis is performed to determine the thermal stability of complexes and its degradation pattern in which the change in the weight of the substance is recorded as function of temperature or time. Thermogravimetric analysis (TGA) was performed in nitrogen atmosphere with heating rate $10^{\circ}\text{C min}^{-1}$ and thermograms were recorded in temperature range $40\text{-}500^{\circ}\text{C}$. Using this technique several kinetic parameters such as activation energy (E_a), order of reaction (n), entropy change (ΔS), free energy change (ΔF), apparent entropy change (S^*) were calculated. The thermal data have been analyzed using Freeman- Carroll and Sharp-Wentworth methods [23-24].

An analysis of TG curves of L^4H_2 and its complexes reveals a four stage decomposition pattern for Cr(III), Fe(III) and Mn(III) complexes and one stage decomposition pattern for ligand and VO(IV) complex. All the complexes except VO(IV) are stable upto $60\text{-}70^{\circ}\text{C}$. There is no weight loss upto 220°C in the VO(IV) complex indicating the absence of any water molecules (lattice or coordinated). The TG curve of Cr(III), Fe(III) and Mn(III) complexes are stable upto 60°C . Decomposition of one lattice water was observed for Cr(III), Fe(III) and Mn(III) complexes at 120°C with % weight loss obs/calcd: Cr(III): 2.97/2.90, Mn(III): 2.73/2.68, Fe(III): 2.95/ 2.88. The further weight loss was observed for Cr(III), Fe(III) and Mn(III) complexes from $120\text{-}220^{\circ}\text{C}$ indicates the presence of two coordinate water molecules in Cr(III), Fe(III) and Mn(III) complexes [% weight loss obs/calcd: Cr(III): 5.85/5.80, Mn(III): 5.43/5.36), Fe(III): 5.81/5.76]. In all the complexes continuous and rapid weight loss has been observed above 220°C corresponding to thermal degradation of free part of the coordinated ligand along with the other groups present there in. A gradual weight loss above 340°C corresponds to the degradation of actual coordination part of the ligand. Finally the horizontal level beyond 440°C suggests the formation of final decomposition products corresponding to respective metal Cr_2O_3 , Mn_3O_4 , Fe_2O_3 and V_2O_5 . Kinetic parameters are assigned in Table 4. The relative thermal stability on the basis of half decomposition temperature is found to be $\text{Fe(III)} > \text{VO(IV)} > \text{Cr(III)} > \text{Mn(III)} > L^4H_2$.

Table 4: Thermal decomposition data of ligand and its complexes

| Compound | Half decomposition temperature ($^{\circ}\text{C}$) | Activation energy (kJ/mol) | | Order of reaction (n) | Entropy change ΔS (J/mol/K) | Free energy change ΔF (kJ/mol) | Apparent entropy change S^* (kJ) |
|----------------|---|----------------------------|-------|-----------------------|-------------------------------------|--|------------------------------------|
| | | FC | SW | | | | |
| L^4H_2 | 220 | 24.38 | 24.55 | 0.95 | -278.96 | 111.69 | -38.76 |
| [Cr(L^4H)] | 280 | 12.25 | 12.44 | 0.99 | -274.588 | 98.20 | -37.62 |
| [Mn(L^4H)] | 270 | 15.56 | 15.72 | 0.97 | -320.643 | 115.92 | -37.91 |
| [Fe(L^4H)] | 350 | 22.45 | 22.63 | 0.98 | -313.261 | 120.50 | -38.71 |
| [VO(L^4H)] | 310 | 29.82 | 29.88 | 0.99 | -278.315 | 116.93 | -38.90 |

Antimicrobial activity

Antibacterial screening of Ligand (L^4H_2) and its complexes against *E. coli*, *S. aureus*, *P. aeruginosa* and *K. pneumoniae* strains were carried out. Ligand L^4H_2 found to be active against all bacterial species where it showed high activity towards *K. pneumoniae* and moderate activity towards *S. aureus*, *E. coli* and *P. aeruginosa*. Ligand and all metal complexes were bactericidal towards *E. coli*. All metal complexes showed good to moderate activity against *S. aureus* except Fe(III) and VO(IV). Bacteriocidal activity of ligand decreased on complexation with metal ions for bacteria *K. pneumoniae*. Results of studies of antibacterial effect of ligand (L^4H_2) and its complexes are summarized in Table 5.

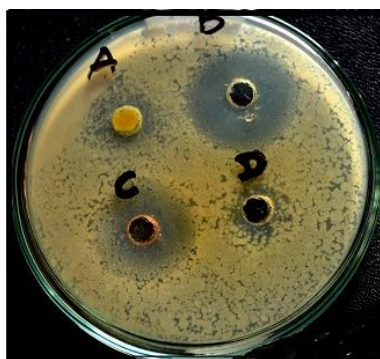


Figure : Photographic plate 1 showing zones of inhibition in *S. aureus*



Figure :Photographic plate showing zones of inhibition in *P. aeruginosa*.

Table 5: Results of antibacterial effect of ligand and its metal complexes

| Sr. No. | Ligand and its complexes | <i>E. coli</i> (mm) | <i>S. aureus</i> (mm) | <i>P. aeruginosa</i> (mm) | <i>K. pneumoniae</i> (mm) |
|---------|-----------------------------------|---------------------|-----------------------|---------------------------|---------------------------|
| 1 | L ⁴ H ₂ | S ₁₈ | S ₂₀ | S ₁₆ | S ₂₇ |
| 2 | Cr- L ⁴ H ₂ | S ₁₇ | S ₁₁ | S ₁₂ | S ₁₈ |
| 3 | Mn- L ⁴ H ₂ | S ₁₁ | S ₁₅ | S ₁₆ | S ₁₇ |
| 4 | Fe- L ⁴ H ₂ | S ₁₁ | R | R | R |
| 5 | VO- L ⁴ H ₂ | S ₁₂ | S ₁₁ | R | R |

Conclusion

The present article includes the synthesis and characterization of new Schiff base ligand and its Cr(III), Mn(III), Fe(III) and VO(IV) complexes. Characterization of compounds includes IR, mass, ¹H NMR, and TGA. Electronic spectrum suggests octahedral geometry for Cr(III), Mn(III) and Fe(III) complexes and square pyramidal geometry for VO(IV) complex. The thermal study revealed that complexes are thermally stable. The relative thermal stabilities of the complexes was in the order Fe(III) > VO(IV) > Cr(III) > Mn(III) > L⁴H₂. The Schiff base ligand and its complexes have been tested in vitro to evaluate their antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* using well-diffusion method. It has been found that the Schiff base ligand and its complexes show significant antimicrobial activity.

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