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Synthesis Characterization and Antimicrobial Analyses of Iron (III) Complexes of 1-(imino-4-antipyrinyl)-8-aminonaphthalene.

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ABSTRACT

The synthesis and characterization of the perchlorate, nitrate, thiocyanate, chloride and bromide complexes of iron(III) with a new Schiff base ligand 1-(imino-4-antipyrinyl)-8-aminonaphthalene (DANC) prepared from 4-formyl antipyrine and 1,8-diaminonaphthalene have been done by elemental analysis, electrical conductance in non-aqueous solvents, infrared and electronic spectra as well as thermogravimetry. The infrared spectral data suggest that DANC acts as a neutral bidentate ligand coordinating through both the carbonyl oxygen and azomethine nitrogen. The UV-VIS spectral and magnetic susceptibility data suggest a high spin octahedral geometry around the central metal ion in all the complexes. The antibacterial and antifungal screening analyses of the ligand and the complexes reveals that the Schiff base and its metal complexes show significant activity against microorganisms.

Keywords: 1-(imino-4-antipyrinyl)-8-aminonaphthalene, 4-formylantipyrine, iron(III) complexes, , octahedral, antimicrobial studies.

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INTRODUCTION

4-aminoantipyrine and its versatile Schiff base derivatives have been extensively investigated and effectively applied in biological as well as pharmacological areas [1, 2]. Also antipyrine derived complexes were found applications of enhancement of silver nano particles [3] and in textile industry, dye for polyester fabrics [4]. In the present investigation we have synthesized five complexes of iron(III) with varying counter ions with the Schiff base ligand 1-(imino-4-antipyrinyl)-8-aminonaphthalene (DANC). All the complexes were characterized and the structures were proposed by using analytical and spectral methods. The antibacterial and antifungal studies of the ligand DANC and all the complexes were carried out.

EXPERIMENTAL SECTION

REAGENTS AND EXPERIMENTAL METHODS

4-antipyrine carboxaldehyde and 1,8-diaminonaphthalene used for the synthesis of ligand were supplied by Sigma Aldrich Chemical Co. USA. The metal salts used for the synthesis of complexes were purchased from E. Merck (AR grade), India Pvt. Ltd. The bromide and perchlorate of the metal were prepared from the metal carbonates (AR) and the respective acids by the following procedure. The metal carbonates were dissolved in 50% hot acids and the undissolved carbonate is removed by filtration. The filtrate was concentrated on a water bath to get the solid form of the salt. It was then dried under vacuum over phosphorous (V) oxide.

Ferric thiocyanate was prepared by the following method. 30ml of aqueous concentrated solution of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ and 70ml of concentrated ammonium thiocyanate solutions were mixed in the ratio 1:3 by weight. The deep red ferric thiocyanate formed was extracted with diethyl ether. The ether layer containing the metal salt was separated by evaporation. The solvents used were purified by distillation.

Iron present in the complexes was estimated gravimetrically. Volhard's method [5] was used for the estimation of chloride content and perchlorate content by Kurz's method [6]. The elemental analyses of the complexes were done using a Heraeus-CHN-Rapid Analyzer. Molar conductance of 10^{-3}M solutions of the complexes was measured using a Systronics conductivity bridge with a dip conductance cell having two platinum electrodes. The infrared spectra in the range $4000\text{--}400\text{ cm}^{-1}$ were recorded in a Shimadzu FTIR 8400 S spectrophotometer using KBr pellet technique and in a Bruker IFS 66v FTIR spectrometer in the range $500\text{--}100\text{ cm}^{-1}$ using polyethylene powder. Electronic spectral studies of the Schiff base and the complexes in solid state were carried out on a Shimadzu UV-visible spectrometer UV-2450. Magnetic susceptibility measurements were done for all the complexes.

SYNTHESIS OF LIGAND

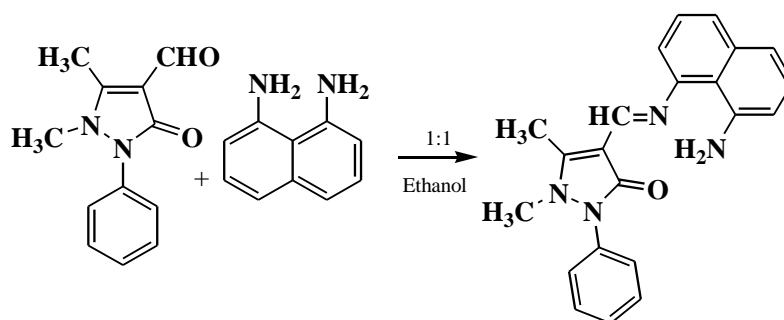


Figure 1. Scheme of Synthesis of DANC

The Schiff base ligand, 1-(imino-4-antipyrinyl)-8-aminonaphthalene was prepared by the condensation between 4-antipyrine carboxaldehyde and 1,8-diaminonaphthalene in ethanol medium for about 3 hours in 1:1 molar ratio (Scheme 1). The precipitate thus obtained was filtered and washed with hot

acetone to remove the excess reagents. It was then recrystallized from methanol and dried over phosphorous(V)oxide under vacuum. The yield was about 72%.

The purity of the ligand was checked by TLC, Infrared, mass, NMR spectra and by elemental analysis. The melting point of the compound was found to be 215°C. The molecular formula and molecular weight of the ligand were $C_{22}H_{20}N_4O_2$ and 356.42 respectively. The elemental analysis data is shown below; Found: C = 75.04 H = 5.68 N = 15.97; Theoretical: C = 74.13 H = 5.65 N = 15.74. The Schiff base ligand 8-(imino-4-antipyrinyl)-1-aminonaphthalene (DANC) contains one carbonyl, one azomethine and one amino groups in such a way that two six membered rings can be formed by the incorporation of metal ion. Thus a tridentate behavior is expected for the ligand. But the possibility of non-participation of either of the groups cannot be ruled out.

PREPARATION OF COMPLEXES

The complexes 1-5 were prepared by the following procedure. A quantity of one mmol of $Fe(ClO_4)_3 \cdot 6H_2O$, $Fe(NO_3)_3 \cdot 6H_2O$, $FeBr_3 \cdot 6H_2O$ or $Fe(SCN)_3 \cdot 6H_2O$, in methanol (10mL) or $FeCl_3 \cdot 6H_2O$ in acetone (10mL) was added to a boiling suspension of 1.2mmol of in ethyl acetate (100mL). The mixture was refluxed for about 3 hours on a steam bath. The precipitated complexes formed were filtered and washed repeatedly with hot ethyl acetate to remove the excess ligand and were recrystallized from ethanol. It was then dried over phosphorous(V) oxide under vacuum.

$[Fe(DANC)_2(ClO_4)](ClO_4)_2$ (1) dark brown solid, Yield: 76%, M.p.: 184°C, anal(%): Calcd(%) for $C_{44}Cl_3FeH_{40}N_8O_{14}$, C 49.06, H 3.74, N 10.49, Fe 5.23, ClO_4 9.96. Found, C 49.94, H 4.02, N 10.59, Fe 5.28, ClO_4 9.50. IR spectral data (KBr cm^{-1}); 1630 (s), 1566 (m), 1143(s), 1116(m), 1080(s), 1018(m), 624(m), 280(w), 554(m), 452(w). Electronic spectral data (DMF cm^{-1}); 29411, 46512, 32680, 21459. μ_{eff} (BM) 5.08.

$[Fe(DANC)_2(NO_3)_2]NO_3$ (2) dark brown solid, Yield: 71%, M.p.: 175°C, anal(%): Calcd(%) for $C_{44}FeH_{40}N_{11}O_{11}$, C 55.30, H 4.18, N 16.13, Fe 5.84. Found C 55.26, H 4.06, N 16.02, Fe 5.62. IR spectral data (KBr cm^{-1}) 1629 (s), 1574 (m), 1477(s), 1382(s), 1312(s), 825(m), 553(m), 454(w). Electronic spectral data (DMF cm^{-1}), 28375, 45872, 30875, 22371. μ_{eff} (BM) 5.43.

$[Fe(DANC)_2(SCN)_2]SCN$ (3) reddish brown solid, Yield: 68%, M.p.: 160°C, anal(%): Calcd(%) for $C_{47}FeH_{40}N_{11}O_2S_3$, C 59.82, H 4.24, N 16.33, Fe 5.92. Found C 59.36, H 4.12, N 16.22, Fe 5.88. IR spectral data (KBr cm^{-1}) 3365(m), 3260(m), 2054(s), 1629(s), 1572 (m), 853(m), 480(w), 553(m), 452(w). Electronic spectral data (DMF cm^{-1}), 25240, 46082, 31645, 21739, 21881. μ_{eff} (BM) 5.25.

$[Fe(DANC)_2Cl_2]Cl$ (4) dark brown solid, Yield: 79%, M.p.: 172°C, anal(%): Calcd(%) for $C_{44}Cl_3FeH_{40}N_8O_2$, C 60.33, H 4.57, N 12.79, Fe 6.38, Cl 12.79. Found C 59.99, H 4.47, N 11.99, Fe 6.26, Cl 12.78. IR spectral data (KBr cm^{-1}) 3366(m), 3261(m), 1631 (s), 1574 (m), 278(w), 554(m), 454(w). Electronic spectral data (DMF cm^{-1}), 28985, 46948, 31847, 22371. μ_{eff} (BM) 5.59.

$[Fe(DANC)_2Br_2]Br$ (5) dark brown solid, Yield: 70%, M.p.: 176°C, anal(%): Calcd(%) for $Br_3C_{44}FeH_{40}N_8O_2$, C 52.35, H 3.96, N 11.06, Fe 5.53, Br 11.06. Found C 52.34, H 3.79, N 11.04, Fe 5.25, Br 11.04. IR spectral data (KBr cm^{-1}) 1614 (s), 1566 (m), 552(m), 453(w). Electronic spectral data (DMF cm^{-1}), 29240, 45872, 31645, 22371. μ_{eff} (BM) 5.94.

ANTIMICROBIAL STUDIES

The in vitro antimicrobial screening of the complexes 1-5 were tested for their effect on certain pathogenic bacteria and fungus by well diffusion method [7,8]. $10^{-3}M$ (MIC) solutions of all the complexes were prepared in DMSO. Both the Gram positive (*Escherichia coli* and *Bacillus subtilis*) and Gram negative (*Vibrio parahaemolyticus*, *Salmonella typhi*, *Salmonella weltevreden*, *Aeromonas hydrophila*) bacteria were grown in nutrient agar medium and incubated at 37°C for 48h followed by frequent subculture to Muller Hinton agar medium and were used as test bacteria. The fungi, *Trichophyton tonsurans* grown into the Sabouraud dextrose agar medium, incubated at 27°C for 72h followed by periodic sub culturing to fresh medium and were used as

test fungus. Then the Petri dishes were inoculated with bacterial or fungal culture and spread throughout the Petri dishes uniformly with a sterile glass spreader. The test samples (10 mg/mL) and reference streptomycin (1 mg/mL for bacteria) or chlorothalonil (10 mg/mL for fungus) were added with a sterile micropipette in the wells of each plate. The plates were then incubated at $35 \pm 2^\circ\text{C}$ and $27 \pm 1^\circ\text{C}$ for 24–48h for bacteria and fungus respectively. Plates with well containing respective solvents served as control. The growth of inhibition was recorded by measuring the diameter of the inhibitory zone after the period of incubation. All the experiments were repeated twice and average values are presented here.

RESULTS AND DISCUSSION

The iron(III) complexes are dark brown non-hygroscopic solids except the thiocyanate complex which is reddish brown in colour. These are soluble in acetonitrile, benzene, DMF, DMSO, ethanol and methanol and are insoluble in acetone, ethyl acetate and nitrobenzene. The metal, bromide, chloride, perchlorate, carbon, nitrogen and hydrogen content in the complexes were determined and presented earlier. The data suggests that the complexes may be formulated as $\text{Fe}(\text{DANC})_2\text{X}_3$; where $\text{X} = \text{ClO}_4, \text{NO}_3, \text{SCN}, \text{Cl}$ or Br .

ELECTRICAL CONDUCTANCE

The molar conductance values of the Iron(III) complexes of DANC (10^{-3}M solution) were measured in non-aqueous solvents such as acetonitrile, , DMF, methanol and ethanol. The values are given in table 1. The molar conductance values fall in the range suggests 1:2 electrolytes for perchlorate complex and 1:1 for nitrate, thiocyanate, chloride and bromide complexes [9]. Thus the complexes may be formulated as $[\text{Fe}(\text{DANC})_2\text{X}]_2$ ($\text{X} = \text{ClO}_4$) and $[\text{Fe}(\text{DANC})_2\text{X}_2]$ ($\text{X} = \text{NO}_3, \text{SCN}, \text{Cl}$ or Br)

Table 1 Molar Conductance^a data of the Iron(III) Complexes^b of DANC

Complex	Molar conductance				
	Acetonitrile	DMF	Methanol	Ethanol	Type of electrolyte
$[\text{Fe}(\text{DANC})_2(\text{ClO}_4)]_2(\text{ClO}_4)_2$	283.2	155.64	168.59	73.40	1:2
$[\text{Fe}(\text{DANC})_2(\text{NO}_3)_2]\text{NO}_3$	147.55	84.49	98.57	61.72	1:1
$[\text{Fe}(\text{DANC})_2(\text{SCN})_2]\text{SCN}$	132.52	76.28	85.2	53.65	1:1
$[\text{Fe}(\text{DANC})_2\text{Cl}_2]\text{Cl}$	142.67	88.04	98.87	59.97	1:1
$[\text{Fe}(\text{DANC})_2\text{Br}_2]\text{Br}$	121.40	73.54	105.15	55.35	1:1

^a $\text{ohm}^{-1}\text{cm}^2\text{mol}^{-1}$ ^b 10^{-3}M solution

INFRARED SPECTRA

The infrared spectrum of the ligand DANC shows strong bands at 1647 and 1589cm^{-1} , characteristic of both carbonyl [10] and azomethine groups respectively [11]. On complexation the infrared band at 1647cm^{-1} , characteristic of carbonyl groups in DANC is found to be shifted to the region $1631\text{--}1629\text{cm}^{-1}$ in all the complexes showing that the carbonyl oxygen is coordinated in these complexes [12]. An intense band due to azomethine nitrogen is shifted to the region $1566\text{--}1574\text{cm}^{-1}$ all the complexes indicating the coordination of the azomethine nitrogen [13]. Also two medium bands observed at 3367 and 3259cm^{-1} , characteristics of $-\text{NH}$ group in DANC is found to be unchanged in all the indicating the non-coordination of the NH_2 group [14].

From the infrared spectral data it is concluded that the Schiff base DANC acts as a bidentate ligand in all the complexes coordinating through the carbonyl oxygen and the azomethine nitrogen resulting in the formation of one six membered ring, there by imparting considerable stability to the complexes.

In the perchlorate complex, the triply split band maxima observed at 1143 , 1116 and 1018cm^{-1} are due to ν_8 , ν_6 and ν_1 vibrations respectively of the perchlorate ion of C_{2v} symmetry indicating the coordination of perchlorate ion in a bidentate fashion [15]. But the band observed at 1080cm^{-1} is assigned to the ν_3 vibration of uncoordinated perchlorate ion of T_d symmetry [16]. Thus indicate the presence of both the uncoordinated and bidentately coordinated perchlorate ion. The vibrational frequencies corresponding to ν_2 and ν_3 vibrations of the perchlorate (C_{2v}) ion is observed at 932 and 636cm^{-1} respectively and ν_4 vibration of the perchlorate (T_d) ion is observed at 624cm^{-1} , also support the coexistence of both uncoordinated and bidentately coordinated perchlorate ion in the complex [15].

In the nitrate complex, two medium bands at 1477 and 1312 cm^{-1} are observed which are attributable to the ν_4 and ν_1 stretching vibrations respectively of the nitrate ion of C_{2v} symmetry [17]. Since the difference between ν_4 and ν_1 is 165 cm^{-1} , the nitrate ion is monodentately coordinated [18]. A very strong band observed at 1382 cm^{-1} indicates the presence of uncoordinated nitrate ion in this complex which is due to ν_3 vibration of the nitrate ion of D_{3h} symmetry [19]. This is supported by another medium intensity band observed at 825 cm^{-1} which is attributed to the ν_2 vibration of the uncoordinated nitrate ion of D_{3h} symmetry.

In the thiocyanate complex a sharp band observed at 2054 cm^{-1} is attributed to N coordinated thiocyanate ion [20]. Further the presence of bands at 853 and 480 cm^{-1} stands as an additional evidence for the presence of N coordinated thiocyanate ion in the complex.

In the far IR spectrum of the chloro and bromo complexes the Fe-Br and Fe-Cl bands are observed at 276 and 278 cm^{-1} respectively which are not present in the spectrum of the ligand.

The above IR spectral results are in conformity with the conductance data that one of the perchlorates as well as two of the nitrates, thiocyanates, chlorides and bromides are coordinated to the metal ion in these complexes. Further the $\nu_{\text{Fe-O}}$ and $\nu_{\text{Fe-N}}$ stretching vibrations are observed at about 554 and 452-454 cm^{-1} respectively in all the complexes.

ELECTRONIC SPECTRAL STUDIES

The electronic spectra of the ligand DANC shows two absorption maxima at 30675 and 45662 cm^{-1} corresponding to $n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$ transitions respectively [21]. In the complexes, compared to DANC $n \rightarrow \pi^*$ transitions are found to be red shifted to the regions 28735-29411 cm^{-1} and the $\pi \rightarrow \pi^*$ transitions are found to be blue shifted to 45872-46948 cm^{-1} [22]. The absorption band observed in the region 21459- 22371 cm^{-1} of the complexes may be assigned to ${}^6A_{1g} \rightarrow {}^4T_{1g}$ transition which is in agreement with octahedral geometry around the iron(III) ion [23]. Also an intense band observed in the region 30875-34680 cm^{-1} in all the complexes may be due to charge transfer transition.

The observed magnetic moment values of the complexes of DANC are in the range 5.08- 5.94 BM suggest a high spin octahedral geometry around Fe(III) in all these complexes [24]. In high spin octahedral iron(III) complexes the expected value is 5.9BM. The lower values observed for perchlorate, nitrate, thiocyanate and chloride complexes indicate metal-metal interaction [25].

THERMOGRAVIMETRIC ANALYSES

The phenomenological aspect of thermal decomposition of the iron(III) complexes of is discussed here and the data are presented in table 2. All the complexes undergo two stage decomposition.

Table 2 Phenomenological data for the thermal decomposition of the Iron(III) complexes of DANC

Complex	Stages of Decomposition	Temp. (°C)	DTG peak (°C)	Residual species	Decomposition species	Total Mass Loss(%)	
						Found	Calculated
[Fe(DANC) ₂ (ClO ₄) ₂](ClO ₄) ₂	I	182-275	221	FeO	three perchlorate ion	27.72	27.95
	II	275-488	389		Two molecules of DANC	66.28	66.80
[Fe(DANC) ₂ (NO ₃) ₂ NO ₃	I	201-348	341	FeO	three nitrate ion	19.24	19.48
	II	342-652	529		Two molecules of DANC	74.26	74.66
[Fe(DANC) ₂ (SCN) ₂ SCN	I	198-406	320	FeO	One thiocyanate ion and one molecule of DANC	43.44	43.96
	II	406-	445		two thiocyanate	49.66	50.11

		572			ions and one molecule of DANC		
[[Fe(DANC) ₂ Cl ₂]Cl]	I	185-262	238	FeO	three chloride ion	12.02	12.15
	II	262-672	462		Two molecules of DANC	81.65	81.46
[Fe(DANC) ₂ Br ₂]Br]	I	186-458	374	FeO	three bromide ion	23.68	23.77
	II	458-730	632		Two molecules of DANC	70.32	70.68

In perchlorate complex there is no mass loss up to 182°C indicating the absence of water or any solvent molecules. The first stage starts at 182°C and ends at 275°C. The corresponding mass loss (27.72%) is due to the decomposition of three perchlorate ions. The maximum rate of mass loss occurs at 221°C as indicated by DTG peak. The second stage starts at 275°C and ends at 488°C with a DTG peak at 389°C. The corresponding mass loss (65.46%) is due to the decomposition of two molecules of DANC molecule. The decomposition gets completed at 490°C and the final residue is qualitatively proved to be anhydrous FeO.

In nitrate complex there is no mass loss up to 201°C indicating the absence of water or any solvent molecules. The first stage starts at 201°C and ends at 348°C. The corresponding mass loss (19.24%) is due to the decomposition of three nitrate ions. The maximum rate of mass loss occurs at 341°C as indicated by DTG peak. The second stage starts at 348°C and ends at 652°C with a DTG peak at 529°C. The corresponding mass loss (74.26%) is due to the decomposition of the two DANC molecules. The decomposition gets completed at 660°C and the final residue is qualitatively proved to be anhydrous FeO.

In thiocyanate complex there is no mass loss up to 198°C indicating the absence of water or any solvent molecules. The first stage starts at 198°C and ends at 406°C. The corresponding mass loss (43.44%) is due to the decomposition of one thiocyanate ion and one DANC molecule. The maximum rate of mass loss occurs at 320°C as indicated by DTG peak. The second stage starts at 406°C and ends at 572°C with a DTG peak at 445°C. The corresponding mass loss (49.66%) is due to the decomposition of the two thiocyanate ions and one DANC molecule. The decomposition gets completed at 588°C and the final residue is qualitatively proved to be anhydrous FeO.

In chloro complex there is no mass loss up to 185°C indicating the absence of water or any solvent molecules. The first stage starts at 185°C and ends at 262°C. The corresponding mass loss (12.02%) is due to the decomposition of three chloride ions. The maximum rate of mass loss occurs at 238°C as indicated by DTG peak. The second stage starts at 262°C and ends at 672°C with a DTG peak at 462°C. The corresponding mass loss (81.65%) is due to the decomposition of two DANC molecules. The decomposition gets completed at 672°C and the final residue is qualitatively proved to be anhydrous FeO.

In bromo complex there is no mass loss up to 186°C indicating the absence of water or any solvent molecules. The first stage starts at 186°C and ends at 458°C. The corresponding mass loss (23.68%) is due to the decomposition of three bromide ions. The maximum rate of mass loss occurs at 374°C as indicated by DTG peak. The second stage starts at 458°C and ends at 730°C with a DTG peak at 632°C. The corresponding mass loss (70.32%) is due to the decomposition of two molecules of DANC. The decomposition gets completed at 730°C and the final residue is qualitatively proved to be anhydrous FeO.

From the above results we can conclude that all the complexes undergoes two stage decomposition and the mass loss found is in good agreement with the calculated values with a final product FeO. Among all the complexes the perchlorate complex is the least stable and bromide complex is the most stable. The thermal stability of the complexes is in the order bromide > chloride > nitrate > thiocyanate > perchlorate.

ANTIMICROBIAL ANALYSES

The antibacterial and antifungal analysis results of Fe(III) complexes are summarized in Table 3 and 4. All the complexes were showing a very good antibacterial activity against five out of six gram positive and

gram negative bacteria and the fungus compared to the standard. Generally, the complexes have higher activity than the Schiff base ligand. A possible explanation for the observed increased activity upon chelation is that the positive charge of the metal in chelated complex is partially shared with the ligand's donor atoms so that there is an electron delocalization over the whole chelate ring. This, in turn, will increase the lipophilic character of the metal [26]. The graphical representation of their activity against bacteria and fungus is shown in figure 2 and 3. From the figure we can see that the antibacterial and the antifungal activity of the perchlorate complex of Fe(III) is higher than other complexes.

Table 3 Antibacterial activity of DANC and its Iron(III) Complexes (Zone diameter in mm)

Compound	V.parahaemol yticus	S.typh i	A. hydrophila	B. subt ilis	E.coli	S.Weltevred en
DANC	17	23	20	0	16	21
[Fe(DANC) ₂ (ClO ₄)](Cl O ₄) ₂	20	24	22	0	19	20
[Fe(DANC) ₂ (NO ₃) ₂]N O ₃	20	20	23	0	20	22
[Fe(DANC) ₂ (SCN) ₂]SC N	23	0	24	0	21	22
[Fe(DANC) ₂ Cl ₂]Cl	20	24	20	0	19	19
[Fe(DANC) ₂ Br ₂]Br	22	19	22	0	20	23
Standard (Streptomycin)	4	15	16	13	12	15

Table 4 Antifungal activity of DANC and its Iron(III) Complexes (Zone diameter in mm)

Compound	Trichophyton Tonsurans
DANC	15
[Fe(DANC) ₂ (ClO ₄)](ClO ₄) ₂	18
[Fe(DANC) ₂ (NO ₃) ₂]NO ₃	17
[Fe(DANC) ₂ (SCN) ₂]SCN	16
[Fe(DANC) ₂ Cl ₂]Cl	16
[Fe(DANC) ₂ Br ₂]Br	16
Chlorothalonil	34
DMSO	0

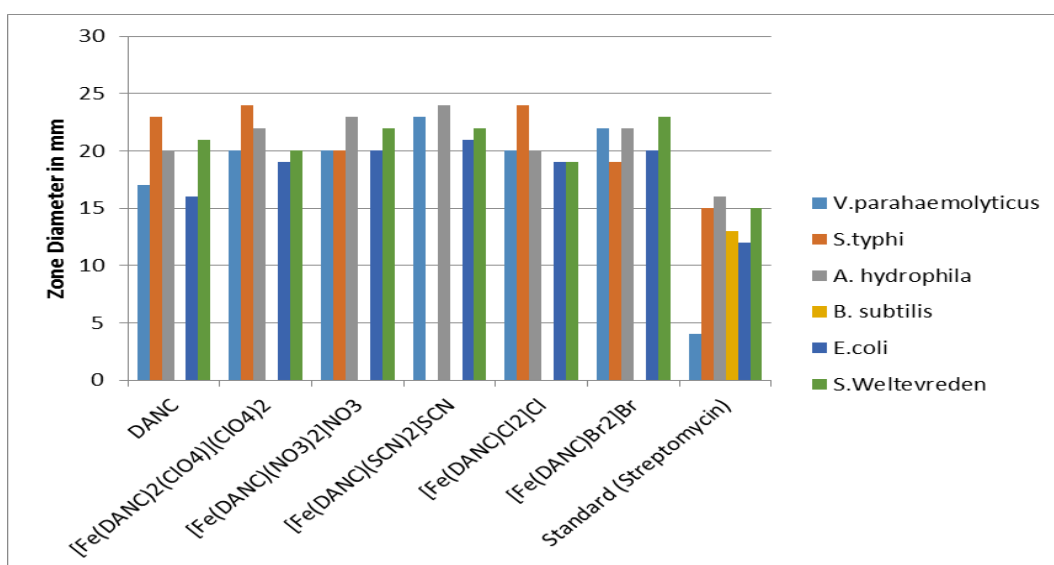


Figure 2 Graphical representation of antibacterial Activity of DANC and its iron(III) Complexes

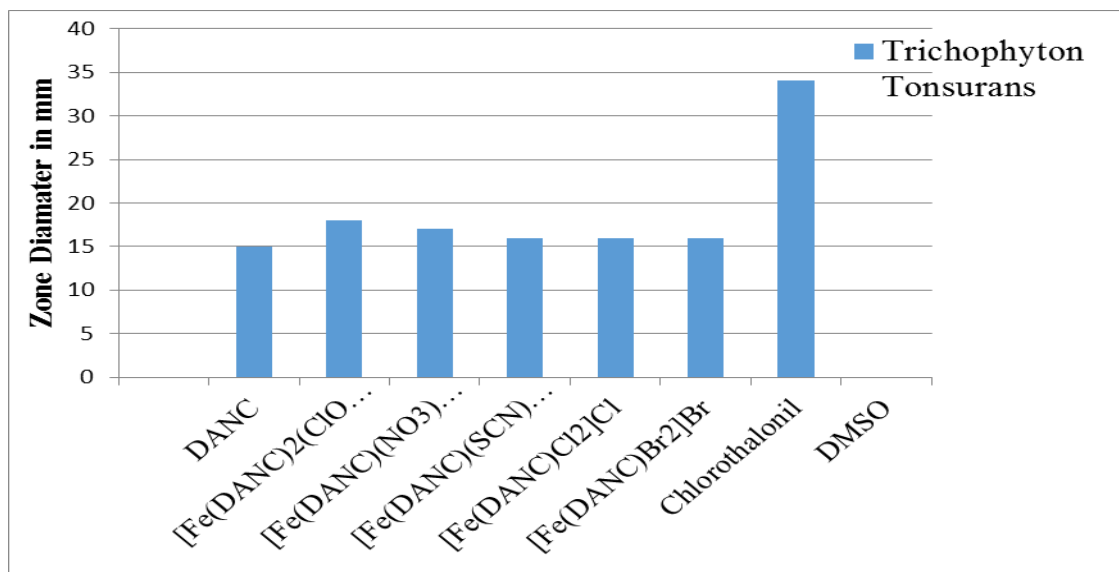


Figure. 3. Graphical representation of antifungal Activity of DANC and its Iron(III) Complexes

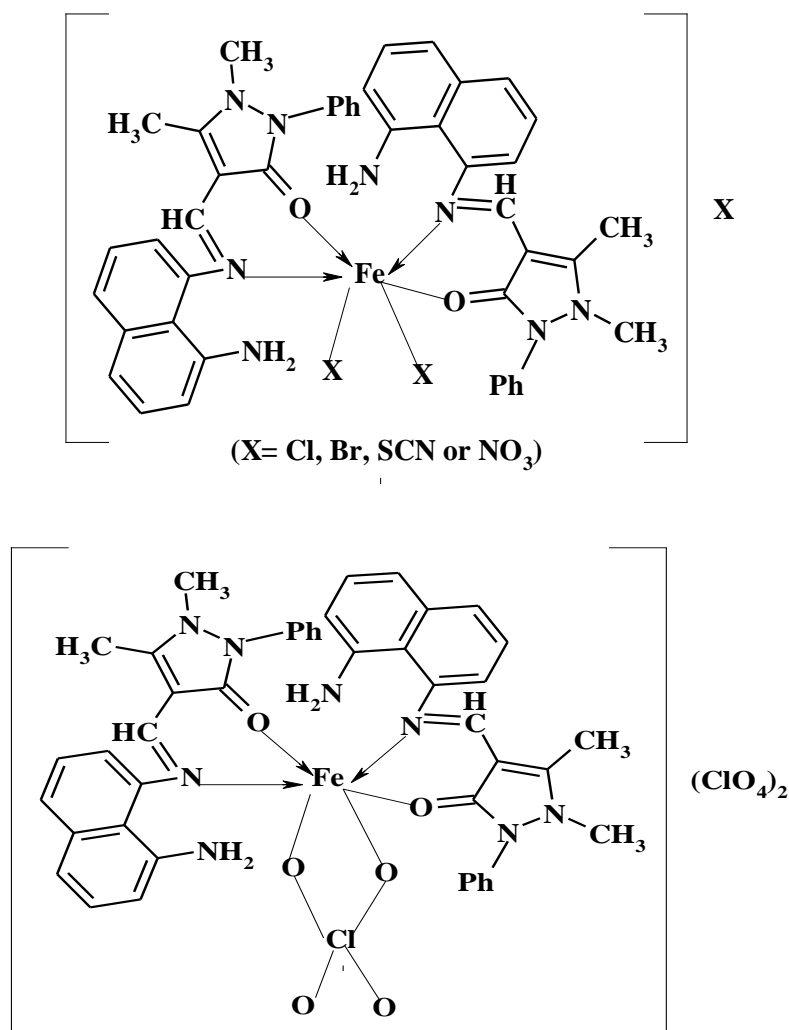


Figure 4. Tentative structures of iron(III) complexes of DANC

CONCLUSION

According to the elemental analyses and molar conductance data, the iron(III) complexes of DANC may be formulated as $[\text{Fe}(\text{DANC})_2\text{ClO}_4](\text{ClO}_4)_2$ and $[\text{Fe}(\text{DANC})_2\text{X}]\text{X}$ (where $\text{X} = \text{NO}_3^-$, SCN^- , Cl^- or Br^-). The infrared spectral data suggest that DANC acts as a neutral bidentate ligand coordinating through both the carbonyl oxygen and azomethine nitrogen. The molar conductance and the infrared spectral studies reveal that one of the perchlorate ions is coordinated bidentately, two of the nitrate ions are coordinated in a monodentate fashion and two of the thiocyanate ions are coordinated monodentately through the nitrogen atom. In the case of halide complexes, two of the chlorides and two of the bromides are coordinated. The electronic spectra and magnetic moment suggest high spin octahedral geometry around the iron(III) ion in all the complexes. Based on the results of the present study, the tentative structures of the complexes are shown in figure 4. The antibacterial and antifungal studies of the ligand DANC and the complexes shows a very good activity against the microbes. Among the complexes the perchlorate complexes were shown higher activity.

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