



Research Article

# Design, synthesis and biological evaluation of heterocyclic methyl substituted pyridine Schiff base transition metal complexes

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## Abstract

In recent years heterocyclic Schiff base metal complexes attract more attention in biological application and also showing interesting co-ordination chemistry. In this research article a novel heterocyclic methyl-substituted pyridine Schiff base transition metal complexes of Fe(III), Co(III), Cu(II), and Ni(II) have been design and synthesized by reacting metal acetate or metal salts (FeCl<sub>3</sub>, CoOAc, CuOAc, NiOAc), with substituted heterocyclic ligand. All newly synthesized metal complexes were characterized by spectroscopic data and screened for elemental analysis, FT-IR, ESR, Magnetic susceptibility and TGA. The Electronic spectra and magnetic susceptibility measurements indicates that square planer and octahedral geometry of these complexes also suggest their structure in which (N, O) group acts as bidentate ligand. The thermal stability, decomposition rate and thermodynamic parameters of synthesized metal complexes were calculated by Freeman Carroll method. Also the biostatistical data of antimicrobial and anti-oxidant activities of synthesized metal complexes indicates moderate to good results.

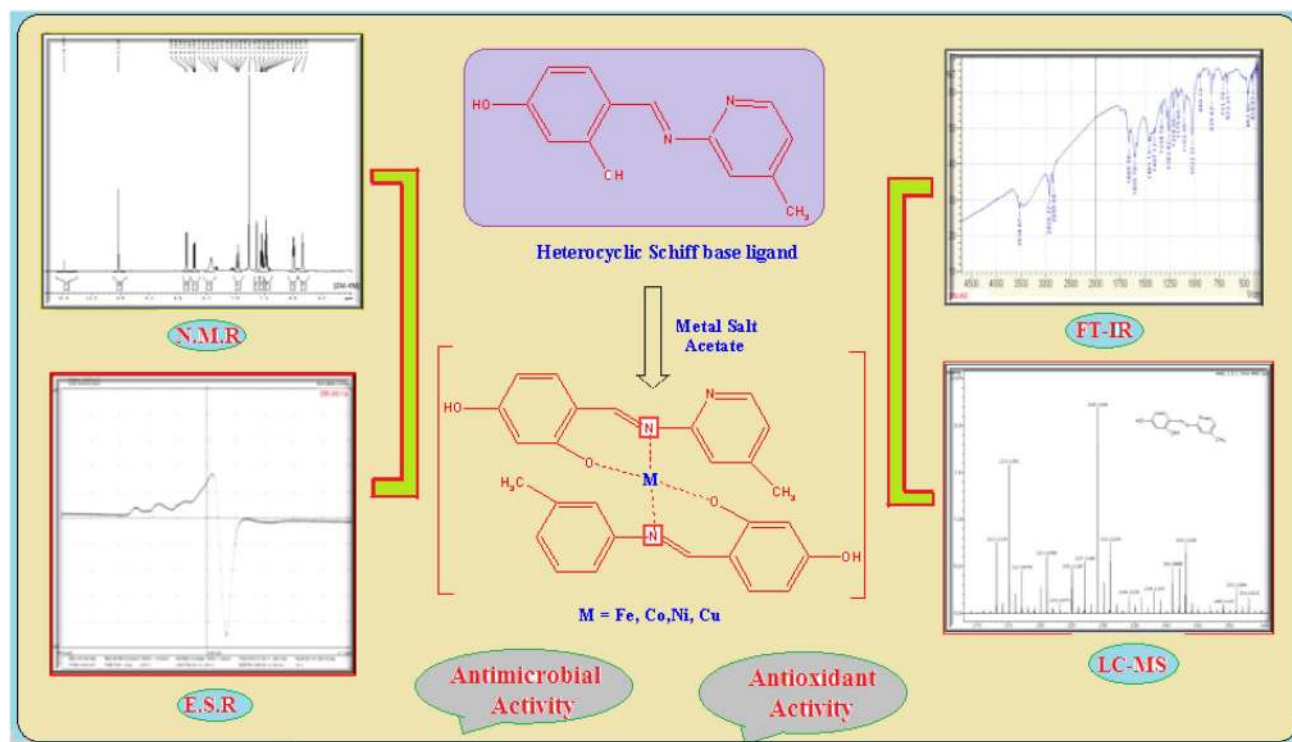
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## Graphic abstract



**Keywords** Heterocyclic ligand · Metal complexes · TGA · Antimicrobial · ESR · Magnetic susceptibility

## 1 Introduction

A large number of heterocyclic Schiff base ligand and their transition metal complexes have been dynamically investigated not only for their biological application, thermal analysis, spectral analysis but also for their interesting coordination chemistry such as Cu(II), Co(II), Ni(II), Zn(II) and Ru(II) complexes with the Schiff base ligand derived from 5-amino-4H-1,2,4-triazole-3-thiol and 3-hydroxy-4-methoxybenzaldehyde, benzothiazoleimino-benzoic acid ligands and their Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) complexes. Again synthesis of bidentate triazole ligand and its monomeric metal complexes in the company relating to Cd(II), Co(II), Fe(III), Cu(II), and Ni(II) ions is demonstrated and their antibacterial study relating to Ni(II), Cu(II), Fe(III), Cd(II), and Co(II) complexes of 4-amino-5-stearyl-1,2,4-triazole-3-thiol [1–4]. Mostly Schiff base with multiple and different coordination sites their metal complexes and different oxidation property. In general aromatic aldehyde reacts faster than ketones in condensation reaction leading to the formation of ligand. Schiff base ligand of aliphatic aldehyde and ketone are relatively unstable compared to that of aromatic aldehyde because

the presence of effective conjugation present in ring system. The presence of donating substituent at ortho position helpful for coordination also presence of lone pair of electron in the  $sp^2$  hybridized orbital of nitrogen atom of the azomethine group is playing significant role in coordination and offer good chelating ability. Schiff base ligands are easily synthesized from condensation of aliphatic or aromatic aldehyde with primary aliphatic or aromatic amine in ethanolic solvent the reaction is accelerated by adding the catalytic amount of acid [5]. The common structural feature of these compounds is the azomethine group with a general formula ( $R-CH=N-R$ ), where R is any alkyl group which may be variously substituted. These compounds are also known as anils, imines, azomethine [6]. Schiff base ligands are well known for their wide application and are useful intermediates in organic synthesis [7]. These compounds have intrinsic biological activities, including anticancer [8], antitumor [9], antitubercular [10], antibacterial [11], antifungal and antifertility [12], herbicidal [13], antioxidant [14], antiproliferative [15], activities. Moreover Schiff bases also exhibit fluorescence [16], photoluminescence [17] and potentiometric titration [18], aggregation [19] and anthelmintic activities [20].

Schiff base ligands are easily synthesized and form complexes with almost all metal ions [21]. However the incorporation of transition metal ions in to these compounds have enormous wide application in the fields of the food industry, dye industry, analytical chemistry, catalysis, fungicidal, agrochemicals along with biological activities and decrease in the cytotoxicity of both metal ion and Schiff base [22, 23]. The chemistry of coordination compound with heterocyclic Schiff base ligand containing Oxygen, Nitrogen, Sulfur as donor atoms [24–26]. The Schiff base ligand containing these hetero atoms Coordinates to the metal atoms in different ways [27]. These chelating properties of Schiff base ligand display application in many fields such as pharmaceutical, Industrial, and Agricultural field [28]. Schiff base complexes play a vital role in designing metal complexes related to synthetic and natural oxygen carrier [29]. Metal complexes make the compound effective as stereo specific catalyst towards oxidation, reduction, hydrolysis, biological activity and inorganic chemistry. In organic compound the presence of N=C along with other functional group form stable complexes compared to compound with only N=C coordinating moiety. Similarly pyridine derivatives have been of great interest because of their role in natural and synthetic organic chemistry. Many products which contain a pyridine sub unit exhibit biological activity such as antimicrobial [30] and antituberculosis activity [31]. Tetradentate Schiff base complexes have been shown to form stable complexes, with coordination taking place through the dinitrogen-dioxygen donor atoms [32, 33]. Ligational, density functional theory, and biological studies on some new Schiff base metal complexes such as  $N_2O_2$  Tetradentate Schiff Base Metal Complexes [34, 35]. Also recently new Schiff base metal complexes of Zr(II), Ni(II), La(III) and Th(IV) introduced which derived from Dithranol and heterocyclic ligand 8-hydroxyquinoline [36].

In present research paper heterocyclic N-substituted pyridine Schiff base ligand and their transition metal complexes were synthesized by condensing stoichiometric ratio 1:1 of substituted aromatic aldehyde and methyl derivative of heterocyclic primary amine in anhydrous ethanol along with catalytic amount of dil. HCl. Finally yellow colored precipitate of Schiff base ligand obtained. The methanolic solution of obtained ligand mixed and reflux with solution of Metal acetate or different metallic salt with constant stirring. The solvent was degassed through rotary evaporator, after cooling colored solid of metal complexes were separate out. The colored precipitate of different metal complexes washed by petroleum ether and dried under desiccators.

## 1.1 Material method

The entire reagent used for the synthesis heterocyclic Schiff bases and their transition metal complexes Such as 2, 4-Dihydroxybenzaldehyde, 2-amino 4-methyl pyridine. (Heterocyclic primary amine), Cobalt acetate tetrahydrate, Nickel acetate, Cupric acetate monohydrate, Ferric chloride, hexane, methanol, ethyl acetate, glacial acetic acid, petroleum ether, were purchase from loba chemie and sigma Aldrich A.R grade and solvent like anhydrous ethanol were purified by standard distillation method and good purity. The reaction was monitored by thin layer chromatography by using pre-coated silica gel aluminum plates and ratio of n-hexane and ethyl acetate 7:3 proportion was used as mobile phase and spot is visualizing in U.V chamber.

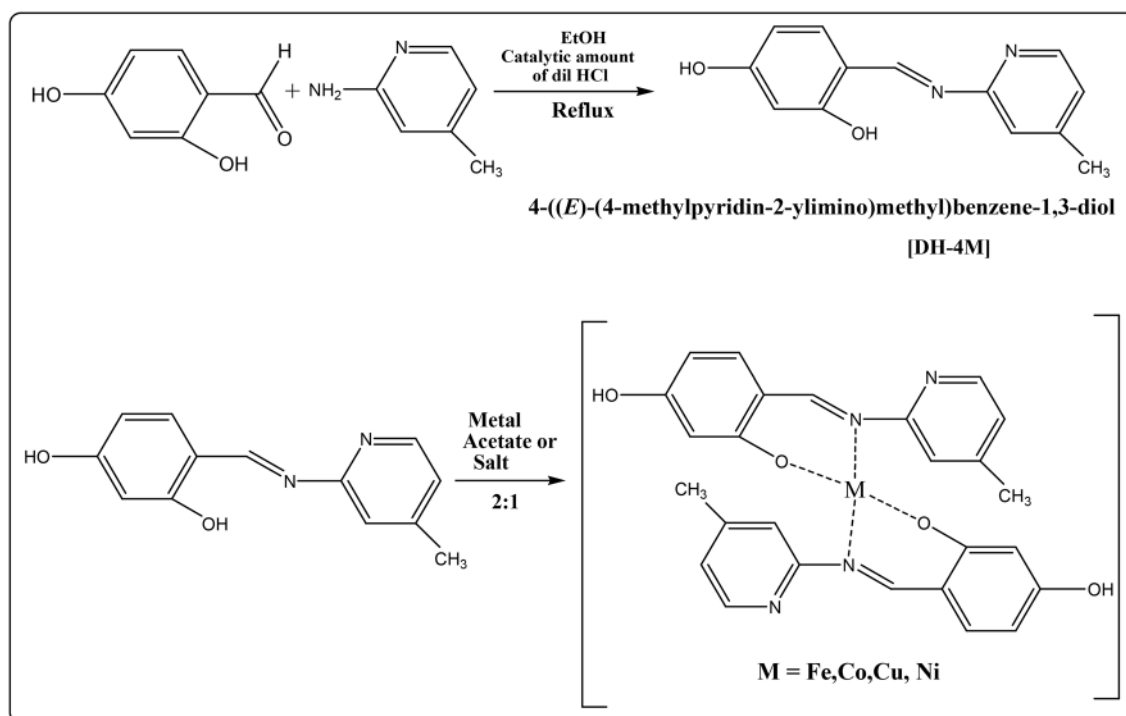
## 1.2 Physical measurement

Different kinds of physico-chemicals techniques are used to characterize the structure of organic Schiff base ligand transition metal complexes. The melting points were taken in to open capillaries and are uncorrected. The FTIR characterization was recorded on model no Shimadzu FTIR 8400 S. using KBr disc method. And  $^1H$  NMR spectra were obtained in  $CDCl_3$  a solvent and Mass spectrum was done by using Bruker Compass Data analysis 4.2 having scanning capacity 600 m/z. The X-band of ESR spectra of copper complexes was recorded in the solid state at liquid nitrogen temperature 77 K in DMF as solvents using DPPH as standard on ESR-JEOL. ESR Spectrometer with X band. The synthesized heterocyclic Schiff bases their transition metal complexes were screened for antimicrobial activity and antioxidant activity by Disc diffusion method Disc size 6 mm. TGA analyses of all metal complexes were carried out at 25 °C to 500 °C in nitrogen atmosphere having heating rate 10 °C per min using Shimadzu TGA-50.

## 1.3 Synthesis of heterocyclic Schiff bases [DH-4M]

### 1.3.1 4-((E)-(4-methylpyridin-2-ylimino)methyl)benzene-1,3-diol

Schiff base were synthesized by Mahale et al. [37]. The equimolar quantity of 2, 4-Dihydroxy benzaldehyde  $C_7H_6O_3$  (0.01 M) and 2-amino 4-methyl pyridine  $C_6H_8N_2$  (0.01 M) in anhydrous ethanol solvent in catalytic amount dil. HCl Scheme 1. The reaction mixture was heated at reflux with stirring for 4–5 h and then poured in ice cold water finally colored solid were obtained by filtration and it recrystallized in ethyl alcohol.



**Scheme 1** Synthesis of heterocyclic Schiff base ligand and its metal complexes

## 1.4 Analytical and spectral data of [DH-4M]

### 1.4.1 4-((*E*)-(4-methylpyridin-2-ylimino)methyl)benzene-1,3-diol

Practical Yield (70%); M.P 68–70 °C;  $\lambda_{\max} = 278,335$  nm. FT-IR (KBr,  $\text{cm}^{-1}$ ) (OH), 3479–3394 (C=C), 1582 (CH=N) 1624.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz);  $\delta$ : 6.57–7.00 (m, 7H, Ar-H), 2.32 (s, 3H,  $\text{CH}_3$ ), 6.6 (s, Ar-OH), 7.23 (s, 1H, CH). Elem Analysis for  $\text{C}_{13}\text{H}_{12}\text{N}_2\text{O}_2$ ; C = 68.41, H = 5.30, N = 12.27, O = 14.02%. Found C = 68.02, H = 5.20, N = 12.15, O = 14.01%. LCMS (m/z): Calculated 213.20, Obs 213; color: Orange Solid.

### 1.5 Synthesis of Fe(III) complex. [DH-4M] Fe(III)

The gradually addition of (0.01 mol) hot methanolic solution of  $\text{FeCl}_3$  to (0.03 mol) methanolic solution of Schiff base ligand [DH-4M] solution with constant stirring having stoichiometric ratio (1:3). The reflux condition was maintained for 4–5 h after completion of reaction the reaction mixture was filtered and concentrated precipitate was filtered and washes with cold methanol.

### 1.6 Analytical and spectral data of [DH-4M] Fe(III)

Practical Yield = 71% Colour: Reddish Brown Solid.  $\lambda_{\max} = 345,415$  nm. FT-IR (KBr, pellet  $\text{cm}^{-1}$ )  $\nu_{\max}$ : 1570

(C=N), 1273 (C-O), 1550 (C=C), 542 (M-O), 448 (M-N). Elemental Analysis for  $\text{C}_{26}\text{H}_{22}\text{FeN}_4\text{O}_4$  (%): C = 61.19, H = 4.35, N = 10.98, Fe = 10.98, O = 12.54. Found: C = 61.15, H = 4.28, N = 10.60, Fe = 10.85, O = 12.35. The magnetic susceptibility  $\mu_{\text{eff}}$ : 1.76B.M.

### 1.7 Synthesis of Co(III) complex. [DH-4M] Co(III)

The transition metal complexes were prepared by mixing a stoichiometric ratio (1:3) by dissolving in methanol. The hot methanolic solution of  $\text{CoOAc}$  (0.01 mol) and ligand [DH-4M] (0.03 mol) are mixed in hot condition with continuous stirring. The mixture were reflux for about 4–5 h. After cooling the volume of reaction mixture is reduced to half, and then colored solid metal complex is formed. Thus obtained solid metal complexes were purified by petroleum ether. The elemental analysis, spectral data and chemical analysis of synthesized metals complexes assigned geometry of Fe(III) and Co(III) metal complexes exhibit Octahedral structure.

### 1.8 Analytical and spectral data of [DH-4M] Co(III)

Practical Yield = 64% Colour: Brown Solid.  $\lambda_{\max} = 630,412$  nm. FT-IR (KBr, pellet  $\text{cm}^{-1}$ )  $\nu_{\max}$ : 1565 (C=N), 1235 (C-O), 1450 (C=C), 542 (M-O), 418 (M-N). Elemental Analysis for  $\text{C}_{26}\text{H}_{22}\text{CoN}_4\text{O}_4$  (%): C = 60.82, H = 4.32,

N = 10.91, Co = 11.48, O = 12.47. Found: C = 60.75, H = 4.28, N = 10.85, Co = 11.40, O = 12.40. The magnetic susceptibility  $\mu_{\text{eff}}$ : 4.64 B.M.

### 1.9 Synthesis of [DH-4M] Ni(II) and [DH-4M] Cu(II)

Schiff base metal complexes of heterocyclic Schiff base ligand were synthesized by gradual addition of ethanolic solution of ligand [DH-4M] to solution of NiOAc and CuOAc in ethanol. The mixture was stirred for 2–3 h at room temperature having ligand–metal stoichiometric ratio (2:1). Then mixture was heated at reflux for about 4 to 5 h on cooling the volume of reaction mixture is reduced to half, and then colored solid metal complex is formed, washed with ethanol twice. The elemental analysis, spectral data and chemical analysis of synthesized metals complexes assigned geometry of Ni(II) and Cu(II) metal complexes exhibit square planer structure.

### 1.10 Analytical and spectral data of [DH-4M] Ni(II)

Practical Yield = 70% Colour: light Green, Solid.  $\lambda_{\text{max}} = 418, 550$  nm. FT-IR (KBr, pellet  $\text{cm}^{-1}$ )  $\nu_{\text{max}}$ : 1566 (C=N), 1295 (C–O), 1555 (C=C), 490 (M–O), 428 (M–N). Elemental Analysis for  $\text{C}_{26}\text{H}_{22}\text{NiN}_4\text{O}_4$  (%): C = 60.85, H = 4.32, N = 10.92, Ni = 11.44, O = 12.47. Found: C = 60.75, H = 4.28, N = 10.90, Ni = 11.40, O = 12.35. The magnetic susceptibility  $\mu_{\text{eff}}$ : 0.00 B.M.

### 1.11 Analytical and spectral data of [DH-4M] Cu(II)

Practical Yield 70% Colour: Shining Green, Solid.  $\lambda_{\text{max}} = 375, 595$  nm. FT-IR (KBr, pellet  $\text{cm}^{-1}$ )  $\nu_{\text{max}}$ : 1552 (C=N), 1242 (C–O), 1461 (C=C), 539 (M–O), 437 (M–N). Elemental Analysis for  $\text{C}_{26}\text{H}_{22}\text{CuN}_4\text{O}_4$  (%): C = 60.28, H = 4.28, N = 10.82, Cu = 12.27, O = 12.35. Found: C = 60.15, H = 4.25,

N = 10.72, Cu = 12.13, O = 12.25. The magnetic susceptibility  $\mu_{\text{eff}}$ : 1.83 B.M.

## 2 Result and discussion

### 2.1 FT-IR spectra

In this investigation FT-IR is effective tool to detect functional group form in ligand. The observed frequency of carbonyl and primary amine was disappearing. This clearly indicate that formation of azomethine (CH=N) group in Schiff base ligand. The frequency observed at  $1600\text{ cm}^{-1}$  were shifted to lower frequency in metal complexes clearly indicates that azomethine nitrogen coordinate to metal ion. Here was an important variation in the position of these bands in case of metal complexes as compared to chelates. The new weak bands appear in the region  $415\text{--}445\text{ cm}^{-1}$  and  $510\text{--}535\text{ cm}^{-1}$  can be assigned to the metal nitrogen (M–N) and metal oxygen (M–O) vibration modes in co-ordination complexes respectively.

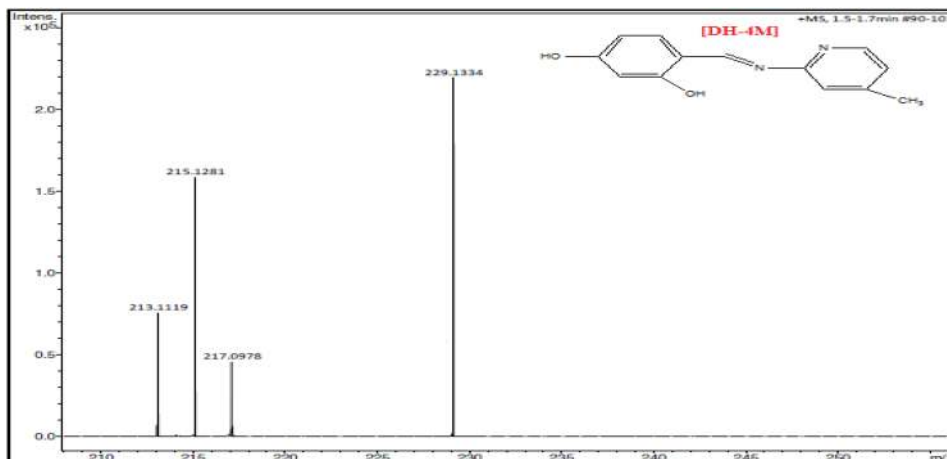
### 2.2 Mass spectra

Mass spectrometry has been successfully used to determine the molecular ion peak for heterocyclic Schiff base ligand. The peak obtained are in good agreement with proposed structure of heterocyclic Schiff base ligandas shown in Fig. 1.

### 2.3 Electronic spectra

The electronics spectra of heterocyclic Schiff base ligand and their transition metals complexes were recorded in DMSO solution between 200 and 800 nm at ambient temperature. In free ligand two band were observed at 278, 335 nm which can be assigned to  $\pi\text{--}\pi^*$  transition of

**Fig. 1** Mass Spectrum of Schiff base ligand [DH-4M]



the aromatic ring and for imines groups respectively [38]. These bands were also observed at similar position in the U.V spectra of complexes. The spectrum of [DH-4M] Cu(II) shows an absorption band having 375 nm due to the ligand to metal charge transfer and 595 nm band showing square planer geometry. [DH-4M] Ni(II) complex show 418 nm band assign ligand to metal ion charge transfer and d-d transition and 550 nm indicating square planer geometry [39–41]. A band at 630 nm in the spectrum of [DH-4M] Co(III) complex possesses Octahedral geometry. The electronic spectra [DH-4M] Fe(III) shows an absorption band 345, 415 nm assign for  $n \rightarrow \pi^*$  Transition and showing octahedral geometry respectively.

## 2.4 $^1\text{H}$ NMR spectra of ligand

In the  $^1\text{H}$  NMR Spectra of ligand  $\text{C}_{12}\text{H}_{12}\text{N}_2\text{O}_2$  [DH-4M] Fig. 2 shows signals of  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz); the aromatic proton of the compound appear as multiplet in the region  $\delta$  6.57–7.00 (m, 7H, Ar-H), and methyl proton which attach to ring appear in the region give the singlet  $\delta$  2.32 (s, 3H,  $\text{CH}_3$ ), and main signal in the region of  $\delta$  7.23–9.2 (s, 1H, CH). Out of two hydroxyl groups of [DH-4M] ligand p-OH shows  $\delta$  9.10 (s, 1H, -OH,) and m-OH 8.98 (s, 1H, -OH).

## 2.5 Magnetic measurements and ESR spectra

The data of magnetic moment value of transition metal complexes [DH-4M] Ni(II) complexes shows magnetic moment zero and diamagnetic in nature. The magnetic moment of [DH-4M] Cu(II) 1.83 B.M complex is consistent with the square planer geometry. While that of Complex of Fe(III) and Co(III) show 1.76 and 4.76 B.M. correspond

to one and four unpaired electron respectively indicates octahedral geometry.

The ESR Spectrum Fig. 3 of [DH-4M] Cu(II) Complex at liquid nitrogen temperature at 77 K was recorded in DMF Solvent. The g tensor quantity principles of [DH-4M] Cu(II) complex can be used to derived the ground state hence from ESR spectrum of [DH-4M] Cu(II) complex g value sequence and other factors  $g_{\parallel} = 2.93$ ,  $g_{\perp} = 2.073$ ,  $g_{\text{avg}} = 2.175$ ,  $G = 5.71$ ,  $f = 136.01$ , were derived. It was practical that  $g_{\parallel} > g_{\perp} > g_{\text{avg}}$  and f value are in span 105–135  $\text{cm}^{-1}$  this brand of arrangement has been reported that square planer complex [42]. Similarly fact point to that unpaired electron lies in the  $dx^2-y^2$  orbital giving  $^2\text{B}_{1g}$  as the ground state. In addition value of  $g_{\parallel} = 2.39$  is nearer to 2.3–2.4 indicating the existence of mixed copper-Nitrogen and Copper-Oxygen bands in these chelates [43–46]. The value of  $\alpha^2 = 0.5$  indicate complete covalent bonding while that of value of  $\alpha^2 = 1.0$  suggest perfectly ionic bonding. The obtained value of  $\alpha^2 = 0.65$  is less than one which indicates that the complex has some covalent character in the ligand environment [47].

## 2.6 Anti-microbial activities

The Synthesized transition metal complexes were screening for their antimicrobial activity particularly Antibacterial and Antifungal activity and this is done with the help of disc diffusion method. Microorganism like gram positive bacteria *Staphylococcus aureus*, Gram negative bacteria *Escherichia coli*. The microorganism fungi used for these activities are *Candida albicans* *Aspergillus niger* and *Fusarium moniliforme*.

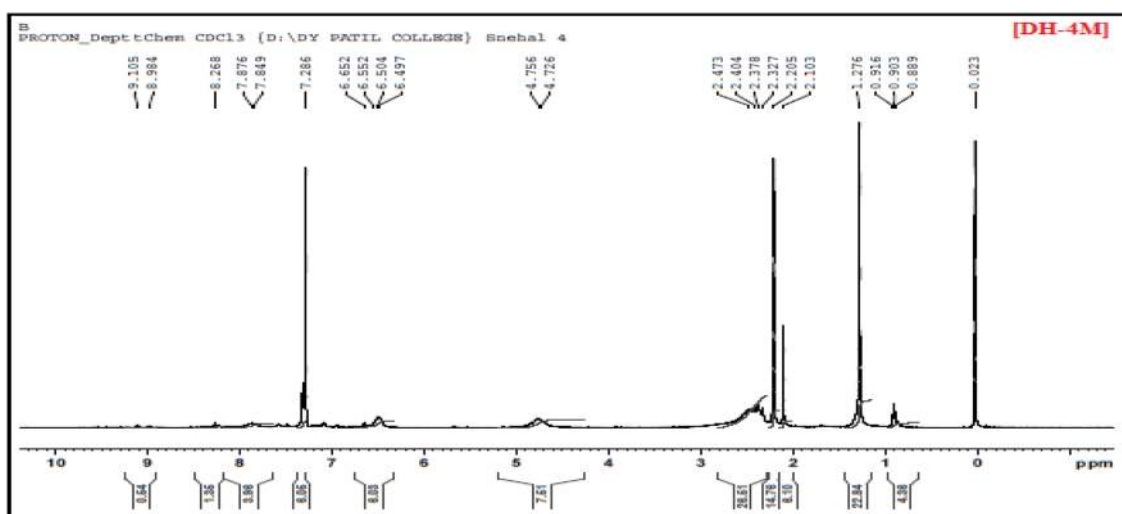
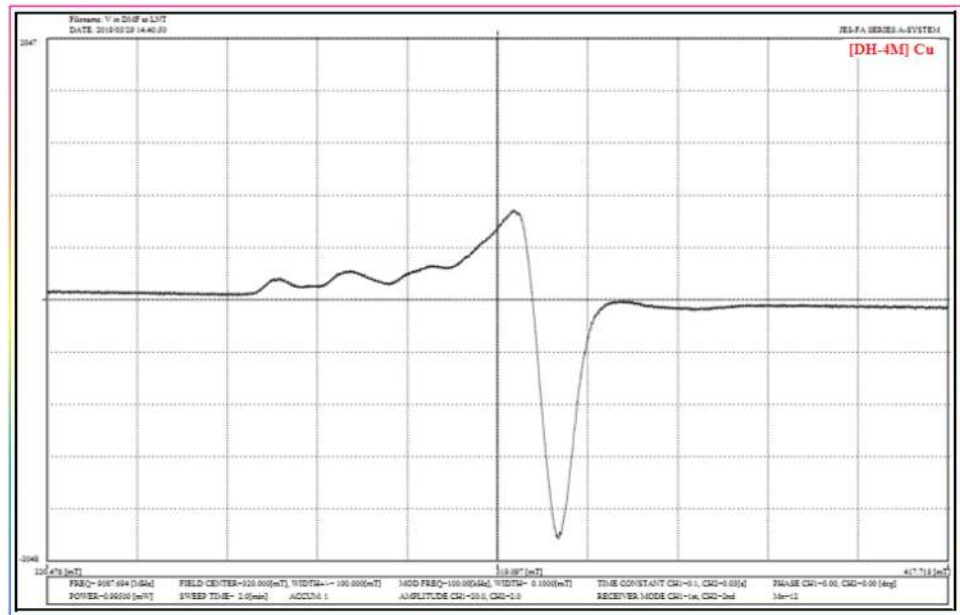


Fig. 2 NMR Spectrum of Schiff base ligand [DH-4M]

**Fig. 3** X-Band ESR spectrum of [DM-4M] Cu(II)



## 2.7 Method use for concentration of compound

Agar diffusion assay (disc diffusion method, Disc size 6 mm) is used. The stock solution is prepared of 1000 µg per ml of each compound. The assay is carried out by taking 100 µg per disk. *Chloramphenicol* (10 microgram/disc, *Amphotericin-B* (100 units/disc) moistened with water are used as standard. The synthesized complex [DH-4M] Fe(III) exhibits the potent antifungal activity for the fungi of *Aspergillus niger* and show moderate activity for the fungi of *Candida albicans* against its standard *Amphotericin-B*. The synthesized complex [DH-4M] Cu exhibit moderate antibacterial activity for the gram positive bacteria of *Staphylococcus aureus* and gram negative bacteria of bacterium *Escherichia coli*. While that of fungi of *Candida albicans* exhibits moderate antifungal activity against its standard *Amphotericin-B* and complexes of [DH-4M] Co(III) and [DH-4M] Ni(II) which growth does not affected for selected microorganism like *Staphylococcus aureus* and *Escherichia coli* and the fungi *Aspergillus niger*, *Candida albicans* and *Fusarium moniliforme* does not show the any antifungal activity its zone of inhibition is nil.

The judgment of this anti-microbial data it is clear that synthesized compound [DH-4M] Fe(III) show potent antifungal activity for the fungi of *Aspergillus niger* its zone of inhibition is 15.80 mm compared to its standard 15.78 mm also show moderate activity toward *Candida albicans* and *Staphylococcus aureus*. The complex of [DH-4M] Cu(II) exhibits moderate antibacterial activity toward gram positive and gram negative bacteria. Its inhibition zone 9.44 and 10.44 mm respectively compared to its standard is 15.11 mm also fungi of *Candida Albicans* show moderate

activity against standard *Amphotericin-B*. The biostatistical data of antimicrobial activity shown in Fig. 4 and Table 1

## 2.8 Antioxidant activity

The free radical scavenging activity of the Schiff bases and their transition metal complexes. Its test sample was determined using 2, 2 diphenyl-1 picrylhydrazyl radical (DPPH) method. Different concentration of test compound 50, 100, 200, 300, 400 mg/ml and its standard is Ascorbic acid as well as Gallic acid. The antioxidant activity of the sample was done by using DPPH radical scavenging method. The assay was carried out in a 96 well microlitre plate to 200 µl of DPPH solution, 10 µl of each of the test sample or standard solution was added separately in wells of the microlitre plates. The plates were incubated at 37°C for 20 min and the observance of each well was at 517 nm, using ELISA reader against corresponding test and standard blanks and the remaining DPPH was calculated. The IC<sub>50</sub> (Inhibitory Concentration) is concentration of the sample required to Scavenge 50% DPPH free radicals.

$$\% \text{Inhibition} = \frac{\text{Controll} - \text{Sample}}{\text{Controll}} * 100$$

The IC<sub>50</sub> calculated based on regression equation generated by plotting the graph of Conc. Vs % inhibition.

Regression equation.

$$y = MX + C$$

where Y = intercept i.e., 50; C = Concentration required to inhibit the oxidative radical to 50%; M and C are the

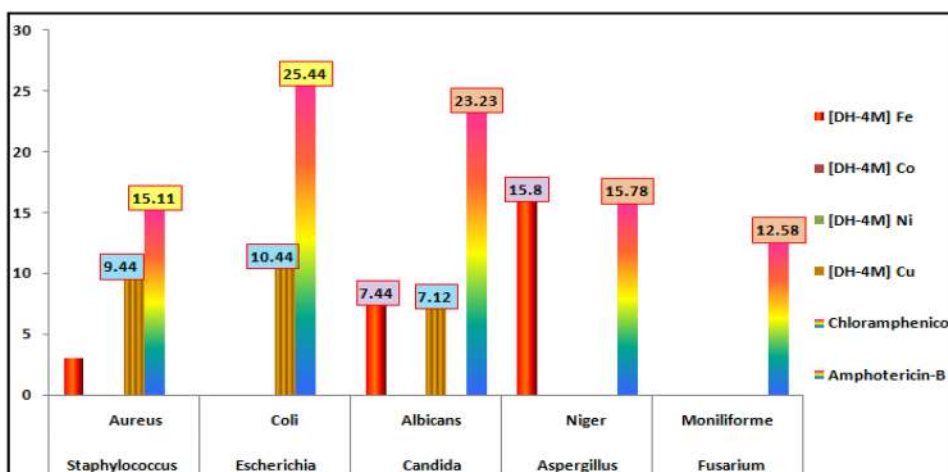
component of regression generated on the graph in MX excel.

The antioxidant activity of synthesized transition metal complexes such as [DH-4M] Fe(III), Co(III), Ni(II), and Cu(II) is tested against different concentration. The IC<sub>50</sub> value is inversely proportional to the free radical scavenging activity of sample that means lower the value IC<sub>50</sub> higher is the rate of antioxidant activity. The synthesized Complex [DH-4M] Fe(III) shows different percent inhibition at different concentration but at concentration 50 mg/ml having IC<sub>50</sub> value 2.96 % and standard deviation 0.50. Similarly at different concentration 100, 200 shows moderate antioxidant activity. While

that of synthesized complex [DH-4M] Co(III) has 4.04% lower IC<sub>50</sub> at concentration 50 mg/ml having standard deviation 0.30. Similarly the complexes of [DH-4M] Cu(II) and [DH-4M] Ni(II) exhibits lower percent inhibition at concentration 50 mg/ml its IC<sub>50</sub> value 2.3 and 6.84 and standard deviation 0.17 and 0.19 respectively shown in Table 2.

From the conclusion of a biostatistical data shows synthesized transition metal complex Fig. 5 of [DH-4M] Cu(II) show excellent antioxidant activity at concentration 50 mg/ml its IC<sub>50</sub> value 2.39 and standard deviation was 0.17 compared to the rest of metal complexes such as [DH-4M] Fe(III), Co(III), Ni(II).

**Fig. 4** Graphical representation of antimicrobial activity



**Table 1** Antimicrobial data of metal complexes

Sr. no	Sample code	<i>Staphylococcus Aureus</i>	<i>Escherichia Coli</i>	<i>Candida Albicans</i>	<i>Aspergillus Niger</i>	<i>Fusarium Moniliforme</i>
1	[DH-4M] Fe	3.02	-	7.44	15.80	-
2	[DH-4M] Co	-	-	-	-	-
3	[DH-4M] Ni	-	-	-	-	-
4	[DH-4M] Cu	9.44	10.44	7.12	-	-
	Chloramphenicol	15.11	25.44	NA	NA	NA
	Amphotericin-B	NA	NA	23.23	15.78	12.58

**Table 2** Antioxidant data of metal complexes

Conc [µg/ml]	[DH-4M] Fe		[DH-4M] Co		[DH-4M] Cu		[DH-4M] Ni	
	% Inhibition	±SD	% Inhibition	±SD	% Inhibition	±SD	% Inhibition	±SD
50	2.96	0.50	4.04	0.30	2.39	0.17	6.84	0.19
100	7.21	0.24	7.13	0.33	2.39	0.29	11.27	0.29
200	9.44	0.70	8.33	0.15	4.58	0.17	15.80	0.17
300	11.65	0.84	9.25	0.42	6.00	0.29	15.90	0.29
400	14.13	0.40	9.55	0.32	6.00	0.50	69.65	0.50
IC50	1615.22		3110.51		3988.43		387.03	



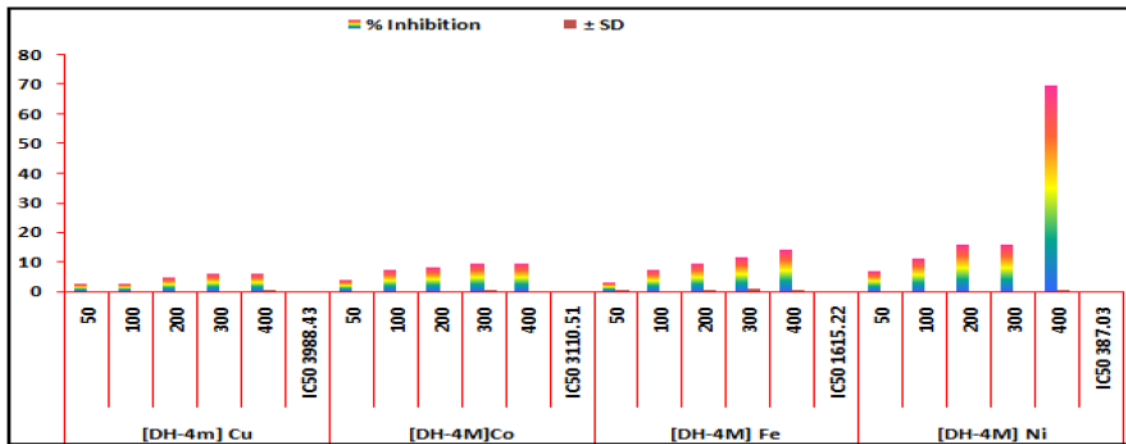


Fig. 5 Graphical representation of Antioxidant activity

## 2.9 Thermogravimetric analysis

TGA study find out 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. In TGA technique several kinetics parameter such as energy of activation ( $E_a$ ), free energy change ( $\Delta G$ ), Entropy change ( $\Delta S$ ), Order of reaction ( $n$ ). Thermogravimetric analysis measure weight loss curve gives information on change in sample composition, thermal stability, and kinetic parameters for chemical reaction in the samples.

Also in TGA Pre-exponential factor decide the pathway of reaction mechanism. The Several methods have been reported for calculating the kinetics parameter of solid state reaction [48–50]. Such as Freeman and Carroll method [51] Sharp-Wentworth [52] Coats-Redfern [53] Broido [54] and Horowitz-Metzger method [55]. The thermal decomposition kinetics was proposed by Flynn Freeman and Carroll published their method of kinetics analysis of thermo analytical data. TGA of the transition metal complexes were carried out from ambient temperature to 500 °C in Nitrogen atmosphere having heating rate 10 °C per minute. The kinetic parameters of all the transition metal complexes by Freeman and Carroll methods have been determined and computerized software is essential for processing the enormous amount of data involved in this analysis and represented graphically by Microsoft Excel. Procedure suggested by Nair et al. [56].

## 2.10 Freeman and Carroll method

$$\frac{\Delta \log \left( \frac{dw}{dt} \right)}{\Delta \log W_r} = \left( -\frac{E_a}{2.303R} \right) \cdot \frac{\Delta \left( \frac{1}{T} \right)}{\Delta \log W_r} + n$$

where  $dw/dt$  = rate of change of weight with time;  $W_r = W_c - W$ ;  $W_c$  = Weight loss at the completion of reaction;  $W$  = Total weight loss up to time  $t$ ;  $E_a$  = Energy of activation;  $n$  = order of reaction.

In the thermogram of [DH-4M] Fe(III) metal complex Fig. 6 shows that there is no degradation pattern was observed and there is no significant change of mass was observed over the entire range of temperature so the complex was thermally stable. In the thermogram of [DH-4M] Co(III) metal complex its mass loss pattern exhibit in single step. The first phase of decomposition temperature range 70–130 °C with a mass loss 5.16% (Calculated 5.12%) indicate the loss of two crystal lattice water molecule. The thermogram of [DH-4M] Ni(II) complex Fig. 7 shows a two step decomposition the first step was observed in the range 58–123 °C with a mass loss 5.36% (Calculated 5.14%) indicate loss of two crystal lattice water molecule and no significant mass loss was observed in the range 160–325 °C. In the second phase of decomposition was shown in the range 330–375 °C with a mass loss 3.19% (Calculated 35.32%) indicate the loss of one acetate molecule after mass loss remain constant over the entire range of temperature. The TGA curve of [DH-4M] Cu(II) complex was studied from ambient temperature to 500 °C under Nitrogen atmosphere. Mass loss was not observed over the entire range of temperature so the copper complex thermally stable. The kinetic parameters of degradation of the metal complexes calculated by Freeman–Carroll (FC) method.

A negative change in entropy indicate that the disorder of an isolated system has decreases negative ( $\Delta S$ ) value as shown in Table 3 indicates more ordered activated state that may be possible through chemisorptions

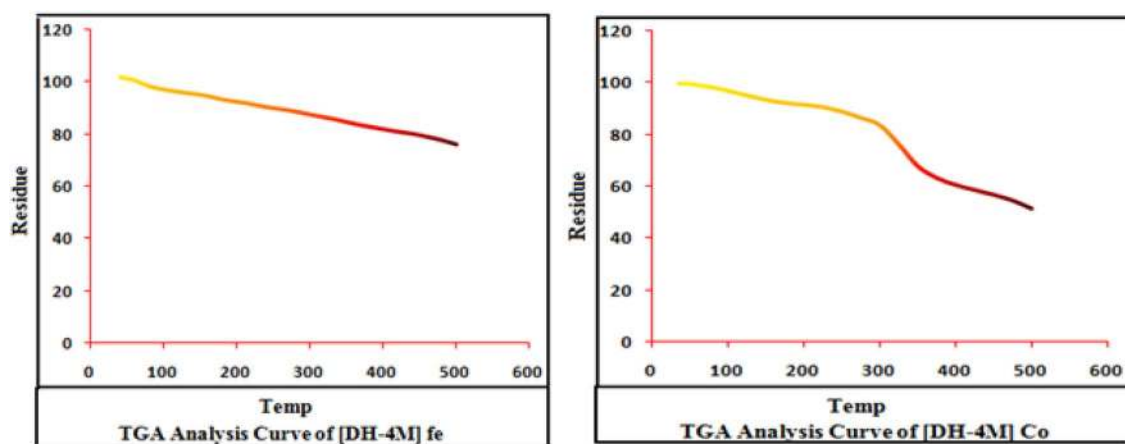


Fig. 6 TGA Analysis curve of [DH-4M] Fe and Co

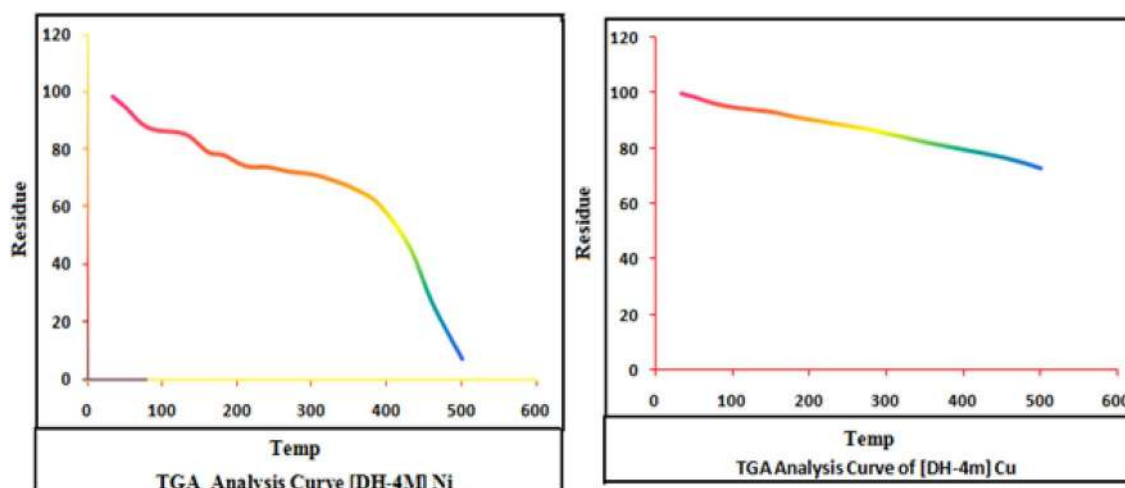


Fig. 7 TGA Analysis Curve of Ni and Cu

Table 3 Table of kinetic parameters by Freeman carroll method

Sample Code	Method	Order of Reaction (n)	Energy of Activation Ea (kJ/mole)	Entropy change ( $\Delta S$ )	Free energy change ( $\Delta G$ )	$\mu$ effective B.M
[DH-4M] Fe	FC	0.98	11,430.84	-140.18	15,840 J	1.76
[DH-4M] Co	FC	0.99	8482.18	-143.45	91,396.28 J	4.64
[DH-4M] Ni	FC	1.07	9114.04	-142.02	96,882.4 J	2.88
[DH-4M] Cu	FC	0.99	10,913.87	-140.84	94,431.99 J	1.83

of oxygen and other decomposition product. The more order nature may be due to the polarization of bond in activated state and the order of reaction is consistently one as shown in Figs. 8 and 9.

### 3 Conclusion

All the complexes are colored solid and physical and analytical data of ligand and their metal complexes are reported with the expected values. The heterocyclic Schiff ligand prepared in this way are formed nearly high

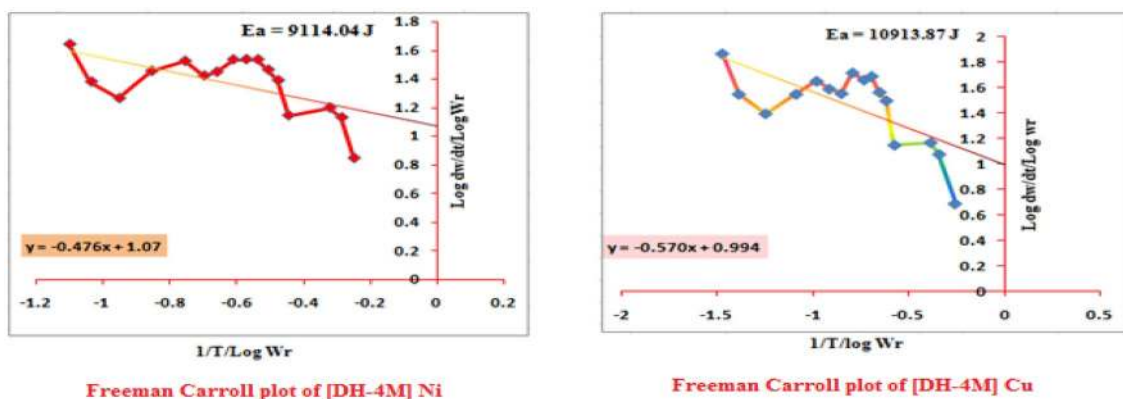


Fig. 8 Plot of Freeman Carroll equation of [DH-4M] Ni and Cu

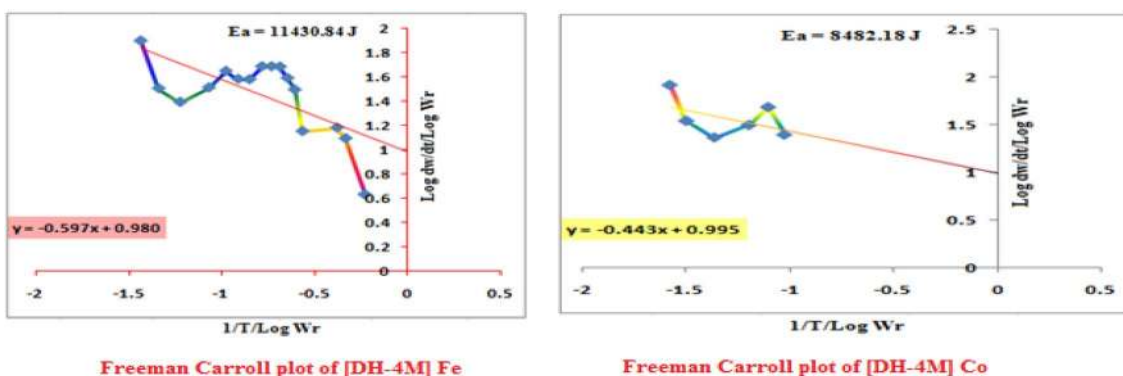


Fig. 9 Plot of Freeman Carroll equation of [DH-4M] Fe and Co

purity and percentage yield of metal complexes relatively lower than that of ligand due to steric hindrance around the coordination center. All newly synthesized metal complexes are stable at room temperature and soluble in common organic solvents such as methanol, ethanol chloroform. The ESR data and magnetic measurement indicating square planer and octahedral geometry of complexes. The novelty of this research article is screening results of biological activity complex of [DH-4M] Fe(III) shows potent antifungal activity for the fungi *Aspergillus niger* against its standard *Amphotericin-B*. and the complexes [DH-4M] Fe(III) and [DH-4M] Cu(II) exhibits moderate antibacterial activity. Also the antioxidant assay indicates that  $IC_{50}$  value is inversely proportional to the free radicals scavenging activity. The synthesized metal complex [DH-4M] Cu(II) shows good antioxidant activity at conc. 50 mg/ml having percentage inhibition 2.39 and standard deviation was 0.17 and the metal complexes [DH-4M] Fe(III), [DH-4M] Co(III), [DH-4M] Ni(II) shows moderate free radical scavenging activity.

The ESR data [DH-4M] Cu(II) provide the information about the geometry of complexes. The sequence of  $g_{\perp} > g_{\parallel} > g_{avg}$  indicates the complex is square planer geometry and the unpaired electron lies in the  $dx^2-y^2$  orbital. The  $10Dq$  or  $\Delta_o$  value for  $Fe^{+3}$  is  $-2.0\Delta_o + 2P$ , for  $Co^{+3}$  is  $-0.4\Delta_o + P$ , for  $Ni^{+2}$  is  $-2.44\Delta_o + 4P$ , for  $Cu^{+2}$  is  $1.21 + 4P$ . Also the geometry of [DH-4M] Cu confirmed by additional supporting evidences of magnetic susceptibility and FT-IR data. TGA analysis results of [DH-4M] Fe(III) and [DH-4M] Cu(II) indicates there is degradation pattern was observe over the entire range of temperature and the complex [DH-4M] Co(III) mass loss pattern exhibits in single step, complex [DH-4M] Ni(II) shows two step decomposition. In TGA several kinetics parameter such as energy of activation ( $E_a$ ), free energy change ( $\Delta G$ ), Entropy change ( $\Delta S$ ), Order of reaction ( $n$ ) by Freeman Carroll Method. The Order of reaction is consistently one and negative value of entropy indicates that more ordered activated state possible through chemisorptions of oxygen, decomposition product and polarization of bond in activated state.

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## Compliance with ethical standards

**Conflict of interest** The authors declare no conflict of interest.

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