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SYNTHESIS, SPECTROSCOPIC CHARACTERIZATION AND ANTI-MICROBIAL ACTIVITIES OF (Z)-4-(4-(DIMETHYLAMINO)BENZYLIDENEAMINO)-1, 5-DIMETHYL-2-PHENYL-1*H*-PYRAZOL-3(2*H*)-ONE SCHIFF BASE LIGAND AND ITS DIVALENT METAL COMPLEXES

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ABSTRACT

Five Schiff base complexes derived from Ni(II), Zn(II), Cu(II), Co(II) and Fe(II) salts were prepared and investigated using FTIR, ^{13}CNMR, ^{1}HNMR, GCMS, and UV/Visible electronic spectra. The Schiff base was derived from a reaction between 4-aminoantipyrine and 4-(N,N-dimethylamino)benzaldehyde. The ligand formed was complexed with different metals salts to study their chemical and microbial behaviours. From the results, the Infra-red data revealed the proper coordination sites of the ligand to the metal ions and displayed the different groups in the compounds. The UV/Visible electronic spectra data showed the different transfers and transitions in the ligand and metal complexes. The different absorptions in the electronic spectra also predicted the possible structures of the complexes. The ^{13}CNMR and ^{1}HNMR showed the different carbon and hydrogen environments in the ligand and complexes. The GCMS confirmed the structure of the ligand and exhibited different fragments. The antimicrobial activities of the ligand were enhanced with the metal complexes and the results were very interesting as the complexes showed good antifungal and antibacterial activities.

Key Words: 4-aminoantipyrine, antibacterial, antifungal, complexes, Schiff base

INTRODUCTION

A Schiff base is a nitrogen analog of an aldehyde or ketone in which the C=O group is replaced by a C=N-R (imine group). There are several works on Schiff bases and more researches are going on because the Schiff bases have served as synthetic intermediates and have wide applications in natural products, penicillin chemistry, pharmacology, medical practice, industries, mineralogy and other interdisciplinary sciences (Abdul, 2005). Schiff bases derived from pyridoxal (the active form of vitamin B_6) and amino acids are considered as very important ligands from a biological point of view. Transition metal complexes of such ligands are important enzyme models (Agarwal *et al*, 2006). The rapid development of these ligands has widened the field of coordination chemistry leading to very interesting conclusions and findings. Many biologically important Schiff bases have been reported in literature possessing antibacterial, antifungal, anti convulsant, anti-HIV, anti-inflammatory and anti-tumor activities (Eman *et al*, 2008).

The ligand used in this work is a reaction between 4-aminoantipyrine or 4-amino-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one and *4-(N,N-dimethylamino)benzaldehyde*. The compound which has a pyrazolone moiety is believed to be pharmaceutically active as its skeletal component (pyrazolone) has proved to be an active component in non-steroidal anti-inflammatory agents used in the treatment of arthritis and other musculo skeletal and joint disorders.

In this work, we have synthesized, characterized and screened (antibacterial and antifungal activities) for Schiff base and its metal complexes of Fe(II), Co(II), Ni(II), Cu(II) and Zn(II) salts.

MATERIALS AND METHODS

Chemicals and Reagents

All chemicals used in this work were of analytical grade from Merck and Sigma Aldrich and they include 4-dimethylaminobenzaldehyde, 4-aminoantipyrine or 4-amino-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one, $ZnCl_2$, $NiCl_2.6H_2O$, $CuCl_2.2H_2O$, $CoCl_2.6H_2O$, $FeCl_2.4H_2O$, dimethyl sulphoxide (DMSO), Ethanol.

Preparation of Schiff base: (Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one

The Schiff base was prepared by adding 25ml ethanolic solution of 4-amino-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one (2.03g, 0.01mol) to 25ml ethanolic solution of 4-(N,N-dimethylamino)benzaldehyde (1.49g, 0.01mol) (Aliyu and Mohammed, 2009; Elemike *et al*, 2011). The mixture was stirred and refluxed for two hours. It was allowed to stand for 3days after which it was recrystalized with hot ethanol. The compound formed was yellow in colour and soluble in ethanol and the melting point was 138-140°C. The resulting yield was 73.4%.

Preparation of the complexes

The Schiff base prepared (0.01mol) in ethanol (25ml) was mixed with 25ml ethanolic solution of the different metal salts $NiCl_2.6H_2O$ (2.37g, 0.01mol), $CoCl_2.6H_2O$ (2.38g, 0.01mol), $ZnCl_2$ (1.36g, 0.01mol), $CuCl_2.2H_2O$ (1.72g, 0.01mol) and $FeCl_2.4H_2O$ (1.98g, 0.01mol) (Aliyu and Nwabueze, 2009).

Each of the mixtures was refluxed for 2 hours and filtered. The mixtures were left for 3 days after which the different crystals formed were recrystallised with hot ethanol. The resulting crystals were dried in a desiccator using $CaCl_2$ under vaccum (Isaa *et al*, 2008; Hossain *et al*, 2012).

Instrumental measurements

The melting points were determined using the melting point apparatus. ^1H and $^{13}CNMR$ were recorded in d_6DMSO on an FT-NMR spectrophotometer in City University, London, United Kingdom. The electronic spectra were determined using UV/Visible Spectrophotometer in Central Laboratory University of Ibadan, Ibadan.

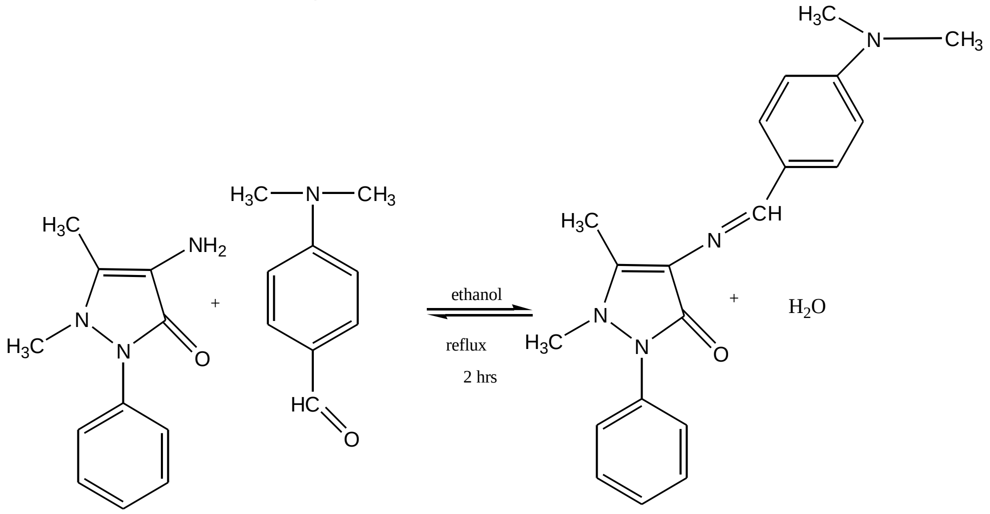
The IR absorptions were determined using FTIR-8400S spectrophotometer and the mass spectra of the compounds observed using GCMSQP2010 plus Schimadzu instrument in NARICT Zaria.

Sensitivity test

The ligand and complexes were screened against some bacteria which include *Klebsiella pneumoniae, Staphylococcus aureus, Escherichia coli, Enterococcus feacalis,* and fungi *Candida albicans and Microsporum audonii.* The test organisms were supplied by Department of Pharmaceutical Microbiology, University of Benin, Benin City. The nutrient agar were prepared and poured into petri dishes. They were then inoculated with the micro-organisms after which the dishes were impregnated with the solutions of the ligand and the complexes. They were incubated at 37°C for 18 hours after which the different zones of inhibitions were measured [Ikotun et al, 2012; Obasi et al, 2009].

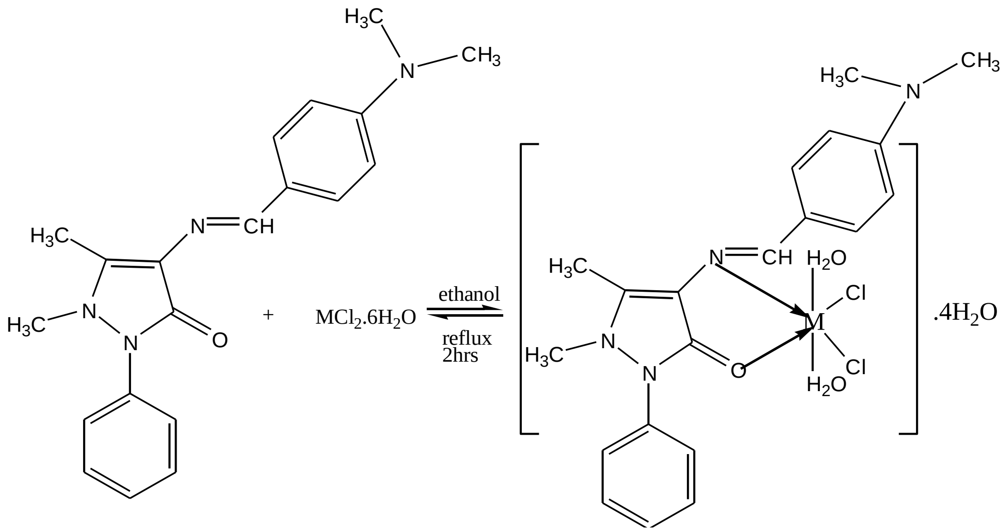
RESULTS

The proposed structures of the ligand and complexes are as follows:



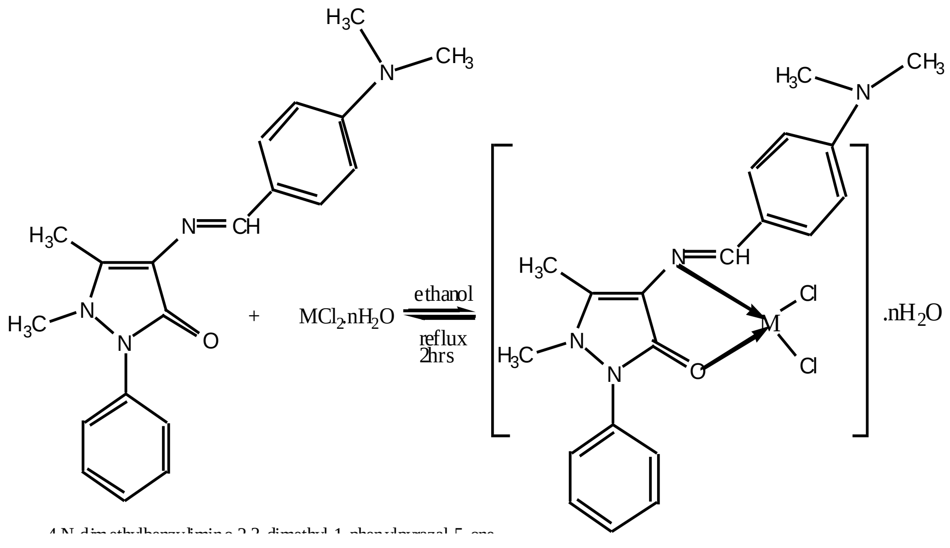
(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one

The reactions of the different metal chlorides with the Schiff base ligand in a 1:1 molar ratio is represented thus:



diaquodichloro(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one(M)(II) tetrahydrate

Where M=Co,Ni



Where M= Fe,Cu,Zn and n=4,2,0 respectively

Ligand(L)= (Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one

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FeL=dichloro(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one iron(II) tetrahydrate.

CoL=diaquodichloro-(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one cobalt(II) tetrahydrate.

NiL=diaquodichloro-(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one nickel(II) tetrahydrate.

CuL=dichloro-(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one copper(II) dihydrate.

ZnL=dichloro-(Z)-4-(4-(dimethylamino)benzylideneamino)-1,5-dimethyl-2-phenyl-1*H*-pyrazol-3(2*H*)-one zinc(II) ion.

The physical properties of the synthesized compounds were determined and recorded in Table 1 below.

Table 1: Some physical properties of the ligand and complexes

Compound	Mol. Wt	Colour	Yield	Formula	M.pt
L	334	yellow	70.4	$C_{20}H_{22}N_4O$	176-178^{o}C
FeL	533	black	41.3	$C_{20}H_{30}N_4O_5FeCl_2$	199-200^{o}C
CoL	572	Dark red	72.6	$C_{20}H_{34}N_4O_7CoCl_2$	142-144^{O}C
NiL	572	Yellowish green	93.5	$C_{20}H_{34}N_4O_7NiCl_2$	190-192^{O}C
CuL	505	black	65.3	$C_{20}H_{26}N_4O_3CuCl_2$	82-84^{O}C
ZnL	470	yellow	67.9	$C_{20}H_{22}N_4OZnCl_2$	197-198^{O}C

Table 2 shows the important functional groups present in the ligand and complexes as determined by FTIR Spectrophotometer.

Table 2: IR Spectra data for the compounds

	υ_{OH}	υ_{N-CH3}	$\upsilon_{C=0}$	$\upsilon_{C=N}$	$\upsilon_{C=C}$
L	-	2803	-	1563	931
FeL	-	2913	1630	1596	949
CoL	3426	2958	1599	1599	947
NiL	-	2923	1596	1596	949
CuL	3420	2927	1599	1599	949
ZnL	-	2914	1649	1600	950

The UV/visible electronic spectra of the ligand and its complexes were recorded and their assignments given in Table 3.

Table 3: UV/Visible electronic data for the ligand and complexes

Compounds	Frequency υ_1(cm^{-1})	υ_2	υ_3	υ_4
L	18903 (529nm)	21692 (461nm)	24330(411nm)	
FeL	21645 (462nm)	23866 (419nm)	-	
CoL	15337 (652nm)	19455 (514nm)	21929(456nm)	
NiL	16077 (622nm)	19011 (526nm)	22883(437nm)	24509(408nm)
CuL	20618 (485nm)	25641 (390nm)	-	
ZnL	21413 (467nm)	24154 (414nm)	-	

The ^{1}HNMR spectra of the compounds were obtained in d$_6$-DMSO at room temperature using TMS as an internal standard. The ^{1}HNMR data and assignments of the compounds are presented in Table 4.

Table 4: ^{1}HNMR chemical shifts for the ligand and the metal complexes (ppm)

	CH_3-C	CH_3-N	HC=N	Aromatic protons
L	1.89	2.33	4.18,4.23	7.08-7.38
FeL	2.21	2.53	3.67,3.73	7.78-8.09
CoL	2.37	2.63	3.88,3.93	6.58-6.91
NiL	1.99	2.83	3.48,3.53	6.02-6.28
CuL	1.98	2.93	3.58,3.63	6.12-6.38
ZnL	1.58	2.53	3.58,3.63	6.42-6.68

Table 5 below shows the different carbon environments in the synthesized compounds as confirmed by the spectra peaks in the ^{13}CNMR.

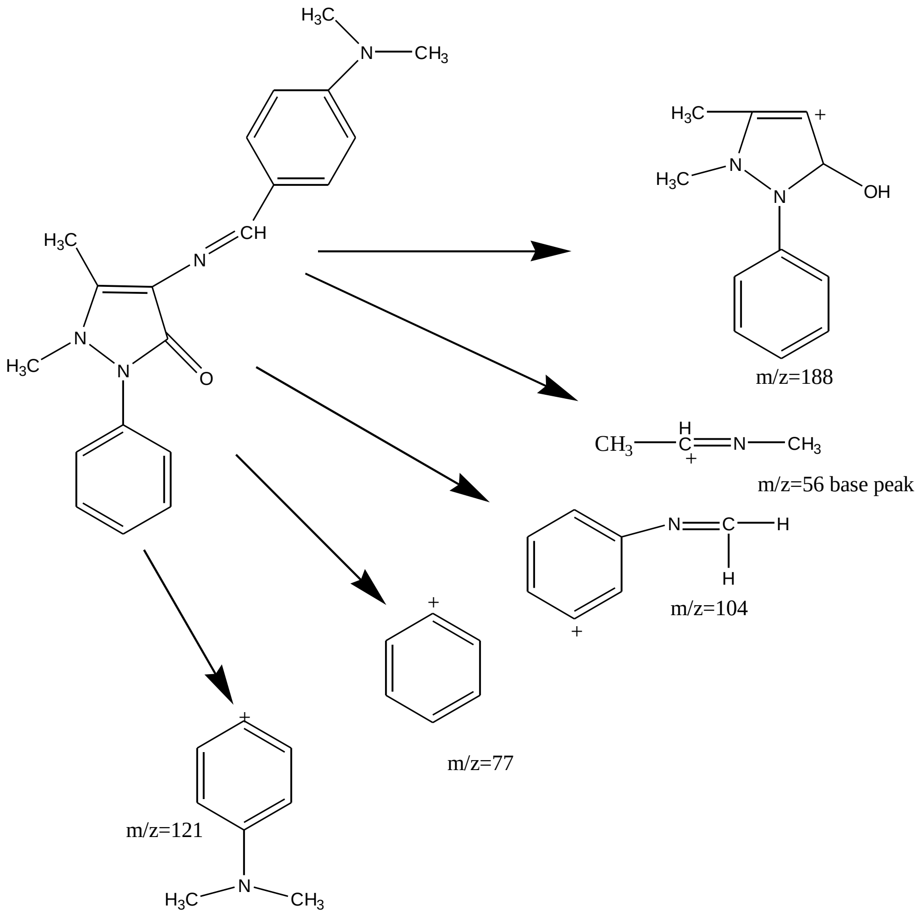
Table 5: ^{13}CNMR spectra data of the ligand and complexes (ppm)

	C=O	C=N	C=C	aromatic carbons	CH_3-N	CH_3
L	191	152	146,149	114-144	12-26	8
FeL	203	154	143,146	111-142	12-28	8
CoL	208	148	144,146	110-142	18-28	14
NiL	216	144	136,139	107-134	22-28	18
CuL	218	150	144,146	107-132	22-29	12
ZnL	221	149	141,146	111-136	12-22	9

GCMS spectra

The molecular ion peak at ($^m/_z$) 334 corresponds to the molecular weight of the Schiff base under investigation while the base peak appeared at ($^m/_z$) 56 with several other peaks (77, 104, 121, 145, 159, 188, 217, 244).

Some of the fragments could be represented thus:



The synthesized compounds were screened against some microbes and the results are presented in Table 6.

Table 6: Antibacterial and antifungal test results (zones of inhibition in mm) of the ligand and complexes.

	Escherichia coli	*Enterococcus feacalis*	*Klebsiella pneumoniae*	*Staphylococcus auerus*	*Candida albicans*	*Miscrosporum audonii*
L	18	15	16	-	22	19
FeL	21	11	17	9	17	18
CoL	20	17	18	15	27	31
NiL	18	11	11	21	21	34
CuL	18	18	19	22	25	26
ZnL	20	12	-	9	17	12
Control	16	11	17	-	15	10

All the values are in mm (zones of inhibition measured with a metre rule)

The control drugs used were ciprofloxacin and fluconazole. The ligand was active against some of the microbes especially the fungi but activities were increased upon chelation with metal ions. The Co, Ni and Cu complexes exhibited great antifungal than antibacterial activities. Though the Zn and Fe complexes were active, they inhibited the growth of *Escherichia coli* more than other complexes but their activity were generally low compared to the other metal complexes.

DISCUSSION

From the FTIR spectra results, there appeared a C=O band in the ligand as an overtone at 3537cm^{-1}due to mechanical coupling (Fermi resonance) resulting from the C=O and C=N vibrations (Silverstein, 1974; Nwabueze and Salawu, 2007).

Bands at 3426 and 3420cm^{-1} in the cobalt and copper complexes have been assigned to υ(OH) due to water molecule (Dudley and Fleming, 1980). In both the ligand and the complexes, there appeared bands between 2803-2914cm^{-1}. These bands have been assigned to the N-CH_3 vibrations and shown in Table 2.

The azomethine bands (C=N) appeared between 1563cm^{-1} – 1600cm^{-1}. There were shifts to higher frequencies in the stretching vibrations from the ligand to the complexes indicating that the C=N was involved in coordination (Dudley and Fleming, 1980; Neelakantan *et al*, 2010). The bands due to C=O stretching vibrations appeared for iron and zinc complexes at 1630cm^{-1} and 1649cm^{-1} respectively. In some cases the C=O stretching vibrations occurred together with the C=N stretching vibrations and they were represented in the bands by double absorptions. The bands that occurred between 931-950 in the ligand and complexes were due to C=C bonds conjugated to C=O bonds (El-Ajaily *et al*, 2006; Olagboye *et al*, 2013).

Sharp bands that appeared between 441-445cm^{-1} in the complexes but absent in the ligand were assigned to metal-chlorine (M-Cl) bond (Sharma et al, 2011). Also bands that appeared between 605-607cm^{-1} and 513-516cm^{-1} were assigned to υ(M-N) and υ(M-O) vibrations respectively(Sharma *et al*, 2011; Jian-ning *et al*, 2006) .

According to the UV-vis results shown in Table 3, the ligand spectra displayed three absorption bands at 411nm (24330cm^{-1}), 461nm (21692cm^{-1}) and 529nm (18903cm^{-1}) which resulted from intra ligand charge transfer or n→π transitions and π→π transitions due to phenyl bonds and C=N bonds. There appeared four absorptions bands in the Ni(II) complex and they are 24509cm^{-1} (408nm), 22883cm^{-1} (437nm), 19011cm^{-1} (526nm) and 16077cm^{-1} (622nm).

In Co(II), there appeared three absorption bands at 21929cm^{-1} (456nm), 19455cm^{-1} (514nm) and 15337cm^{-1} (652nm). The nature and intensities of the bands in the two complexes of Co(II) and Ni(II) suggest an octahedral geometry. These bands were as a result of metal ligand charge transfer (MLCT) or LMCT, d→d transfer, π→π* and n→π* transfer and the following assignments could be suggested for the Co(II) complex $^4T_{1g}\rightarrow{}^4T_{2g}$,$^4T_{1g}\rightarrow{}^4T_{1g}(F)$,and $^4T_{1g}\rightarrow{}^4A_{2g}$ and for the Ni(II) complex $3A_{2g}\rightarrow 3T_{2g}$,$3A_{2g}\rightarrow 3T_{1g}(F)$ and $3A_{2g}\rightarrow 3T_{1g}(P)$ (Gulnur *et al*, 2007; Ikotun et al, 2012). Cu(II), Fe(II) and Zn(II) have two absorption bands each and the intensities of their bands suggest a tetrahedral structure. Cu(II) gave bands at 390nm (25641cm^{-1}) and 485nm (20618cm^{-1}) and was assigned $^2T_2\rightarrow{}^2E$ transition. Fe(II) gave bands at 419nm (23866cm^{-1}) and 462nm (21645cm^{-1}) and was assigned $^5E\rightarrow{}^5T_2$.

There was no d→d transition in Zn(II) complex ,only ILCT at 414nm (24154cm^{-1}) and 467nm (21413cm^{-1}) due to n→ π and π→ π ∗ transitions.

From the ^{1}HNMR data, there appeared four proton environments for both the ligand and complexes. The aromatic protons appeared within the range of 6.02 – 8.09 ppm and were not affected by chelation (Neelakantan *et al*, 2010; El-Ajaily *et al*, 2006; Olagboye *et al*, 2013). The aromatic protons attached to nitrogen were shifted down field compared to the ones attached to –CH bond. The N-CH_3 bands appeared between 2.33-2.83 ppm. This occurred at downfield compared to the other CH_3 chemical shifts. The HC=N peaks were observed between 3.33-4.23 in both the ligand and complexes, but in the complexes, the peaks moved upfield indicating chelation.

In ^{13}CNMR, there were a total of 18 peaks in both the ligand and complexes. Two peaks were for the TMS and d_6-DMSO which appeared at 0 and 40 ppm respectively. However, there appeared 16 peaks in the ^{13}CNMR of the compounds which indicates 16 chemically unequivalent carbons.

The C=O peak appeared at 191ppm for the ligand but shifted downfield between 203-221 ppm for the complexes due to chelation. In all the compounds the C=O peak has the lowest intensity, indicating a fully substituted carbon in the molecule. Other low intensity peaks occured at 146ppm and 26ppm for the complexes and were assigned to C=C and N-C respectively. There appeared a concentration of peaks between 107 – 146 ppm indicating sp^2 hybridized carbons of aromatic and heteroaromatic rings.

According to the experimental results, the metal ions were ligated to the ligand through the azomethine nitrogen and oxygen bonds. While the Cu (II), Fe (II) and Zn(II) were suggested to have tetrahedral structures; Co(II) and Ni(II) complexes behaved like octahedral complexes. The antimicrobial test showed that the synthesized ligand and complexes are active chemotherapeutic agents and have shown great antibacterial and antifungal activites. A further study is therefore encouraged as these types of complexes are promising.

REFERENCES

Abdul, R. (2005).Synthesis and biological studies of some Schiff base compounds and their transition metal complexes. (Ph.D Thesis). Babauddin Zakariya University, Pakistan. pp 45-55

Agarwal, R.K., Singh, L. Sharma, K.D. (2006). Synthesis, Spectral and Biological properties of copper (II) complexes of thiosemicarbazones of Schiff bases derived from 4-aminoantipyrine and aromatic aldehydes. Journal of Bioinorganic Chemistry and Applications. pp 1-10

Aliyu, H.D., Nwabueze, J.N. (2009). Complexes of Valerohydroxamic acid and Isovalerohydroxamic acid with Co(II), Ni(II), Cu(II) and Vo(IV). Journal of Chemical Society of Nigeria. 32(2): 275-281.

Aliyu, H.N., Mohammed, A.S. (2009): Synthesis and Characterization of iron(II) and nickel(II) Schiff base complexes. Bayero Journal of Pure and Applied sciences. 2(1): 132-134.

Dudley, H.W., Fleming, I. (1980): Spectroscopic methods in organic Chemistry. 3rd Edn. Mc-Graw Hill publishers UK. pp 56-60.

El-Ajaily, M.M., Maihub, A.A., Hudere , S.S., Ben-Saber, S.M. (2006). Nickel (II) Chelate of Schiff base derived from 4-dimethyl-amino-benzaldehyde with cysteine. Asian Journal of Chemical Society 18 (4): 2427-2430.

Elemike, E.E., Oviawe, A.P., Otuokere I.E. (2011). Potentiation of the antimicrobial activity of 4-benzylimino-2,3-dimethyl-1-phenylpyrazal-5-one by metal chelation. Research Journal of Chemical Sciences 1(8): 6-11

Eman, A.E., Khaled, H.H., Safaa, K.H., Nabil, S.Y. (2008): Synthesis, Characterization and Biological activity of some transition metal complexes with Schiff bases derived from 2-formylindole, salicylaldehyde, N-amino rhodamine. Australian Journal of Basic and Applied Sciences. 2 (2): 210-220.

Gulnur, K.K., Ulvi, A., Ahmet, G. (2007):Synthesis and Characterization of a new Schiff base and its metal complexes. Indian Journal of Chemistry. 46A: 1273-1276.

Hossain, B.M., Islam,S.M., Islam, M.R., Salam, A.M., Yousuf, A.M. (2012). Synthesis and characterization of mixed ligand complexes of Co(II) and Fe(III) ions with maleic acid and heterocyclic amines. Journal of Bangledesh Chemical Society 25(2): 139-145

Ikotun, A.A., Egharevba, G.O., Obafemi, C.A., Owoseni, A.O. (2012). Ring deactivating effect on antimicrobial activities of metal complexes of the schiff base of p-nitoaniline and isatin. Journal of Chemical and Pharmaceutical Research 4(1): 416-422

Isaa, R.M., Khedr, A.M., Risk, H. (2008). ^{1}H NMR, IR and UV/Vis spectroscopic studies of some Schiff bases derived from 2-aminobenzothiazole and 2-amino-3-hydroxypyridine. Journal of the Chinese Chemical Society 55: 875-884

Jian-ning, L., Bo-wan, W., Bing, Z., Yongchun, L. (2006): Synthesis and Characterization of Metal Complexes of Cu(II), Ni(II), Zn(II), Co(II), Mn(II) and Cd(II) with tetradentate Schiff bases. Turkey Journal of Chemistry 30: 41-48.

Neelakantan,M.A., Esakkiammal, M., Mariappan, S.S., Dharmaraja, J., Jeyakumar, T. (2010). Synthesis, Characterization and Biocidal activities of some Schiff base metal complexes. Indian Journal of Pharmaceutical Sciences.72: 216-222

Nwabueze, J.N., Salawu, O.W. (2007). Complexes of Ni(II) and Cu(II) sulphates with hydrazone derived from nicotinic and isonicotinic acids. Journal of Chemical Society of Nigeria. 32(2): 254-259

Scientia Africana, Vol. 14 (No.1), June 2015. Pp 178-188
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Obasi, L.N., Ukoha P.O., Omeje E.O., Esimone O.C.(2009). Synthesis and Antimicrobial Spectrum of some N-(thiazol-2-yl)sulphonamide and their uranyl acetate complexes. Journal of Chemical Society of Nigeria. 34(2): 162-167

Olagboye, S.A., Okoronkwo, A.E., Lajide, L. (2013).Synthesis,characterization and antimicrobial evaluation of mixed ligand complexes of Ni(II) and Co(II) 1,2,3-Triazole with Thiocyanate. Research and Reviews: Journal of Chemistry 2(1): 25-31

Sharma S., Ramani, J., Bhalodia, J., Patel, N., Thakkar, K., Patel, R. (2011). Synthesis, characterization and antimicrobial activity of some transition metal complexes (Mn, Co, Zn, Ni) with L-proline and Kojic acid. Advances in applied science research 2(4): 374-382

Silverstein, M. R., Bassler, G.C., Morrill, C.T. (1974). Spectrometric Identification of Organic compounds. 3rd Edn. John Wiley and sons New York. pp 92-100.