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Synthesis, physicochemical investigation and antimicrobial efficacy of Co(II) and Ni(II) chelates with bidentate azomethine ligand

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Abstract

The azomethine ligand was afforded by condensation reaction of 2-aminobenzoic acid and 4-(N,N-dimethylamino) benzaldehyde in equimolar ratio in an ethanolic medium. Refluxing the Schiff base ligand with $CoCl_2.6H_2O$ and $NiCl_2.6H_2O$ yielded the corresponding chelates. The synthesized compounds were investigated by melting point/decomposition temperature determination, solubility test, estimation of water of crystallization, elemental analysis, infrared spectral analysis, magnetic susceptibility and molar conductance measurements. The azomethine ligand and the metal chelates were differently coloured, air stable, non-hygroscopic solids which were found soluble in nearly all of the organic solvents used. The presence of water of hydration was established by heating the complexes to constant weight in an oven. From the high decomposition temperatures, the complexes are suggested to have high thermal stability. The elemental analysis data showed their formation in 1:2 metal - ligand ratio. The obtained molar conductance values of 6.08 and 9.12 $ohm^{-1}cm^2mol^{-1}$ entailed that the chelates are non-electrolytes. The infrared data implied that the azomethine ligand has denticity of 2 with the imine nitrogen atom (C=N) and the deprotonated carboxyl oxygen atom as the coordination sites. The magnetic moment values of 5.44 and 2.93 B.M for the Co(II) and Ni(II) chelates respectively, suggest a paramagnetic phenomenon around a six-coordinate octahedral geometry. The in vitro antibacterial and antifungal sensitivity studies revealed that the metal chelates are more potent against the tested microbes than the uncomplexed ligand.

Keywords: Infrared, magnetic moment, octahedral, molar conductance, antimicrobial potency, denticity.

Introduction

During the past decades, the synthesis and characterization of Schiff base complexes has received great attention because of their catalytic importance in various biological systems, polymers and dyes; medicinal and pharmaceutical field. Their uses in birth control, allergic inhibition activity, analgesic and anti – oxidant have been reported[1]. Many Schiff bases of biological importance have been reported for anticonvulsant, anti-tumour and anti-HIV activities[2]. Applications of Schiff base metal complexes as antifungal, antibacterial, anticancer, antiviral and herbicidal agents have been widely studied[3]. Because of their fascinating properties, the study of metal complexation is not only specialized by inorganic chemists but also by organic and physical chemists, biochemists, pharmacologists, molecular and environmental biologists[4].

Patel and Patel[5] synthesized Co(II), Ni(II) and Cu(II) complexes from Schiff base, N-[4-dimethylamino]benzylidene benzene-1,2-diamine derived from *p*- dimethylaminobenzaldehyde and o-phenylenediamine. The structures of the compounds were confirmed by FT-IR, thermogravimetric analysis (TGA), elemental and electronic spectral analyses. The free ligand and its metal complexes were tested against several bacteria viz; *Escherichia coli*, *Bacillus megaterium* and *Pseudomonas aeruginosa*. The ligand and metal complexes showed different effect on the bacteria in the different solvents.

Several chelates with Schiff base obtained from 2-aminophenol and 4-(N,N-dimethylamino) benzaldehyde have been synthesized and investigated by, electrical conductivity, decomposition temperature, solubility, FT-IR, microanalysis and magnetic susceptibility measurement. The Schiff base acted as bidentate ligand coordinated via the nitrogen of the azomethine and phenolic oxygen[6].

We report herein the synthetic route, physicochemical and antimicrobial potency of the azomethine derived from 4-(N,N-dimethylamino) benzaldehyde and 2-aminobenzoic acid and its Co(II) and Ni(II) complexes.

Materials and methods

Analar grade chemicals as commercially supplied were used in this work. Clinical isolates were obtained from Aminu Kano Teaching Hospital through the Department of Microbiology, Bayero University, Kano, Nigeria for *in vitro* antimicrobial screening. Ampicilin capsule and Nyastatin tablet were used as positive controls in the antibacterial and antifungal studies respectively. Disc Diffusion method[7]was adopted for the

antimicrobial studies using dimethylsulphoxide (DMSO) as solvent.

Physical Measurements: College B154 Metler Toledo electric balance was used for weighing. Determination of water of hydration was done on Gallenkamp Hotbox Oven Size Two. Melting point/decomposition temperatures were recorded on Stuart SMP 10 melting point apparatus at the Multipurpose Laboratory of Bayero University, Kano, Nigeria.

Freshly prepared 10^{-3}M solutions in Dimethylformamide (DMF) were subjected to Conductivity measurements using Siemens WPA CM35 Conductivity meter at the Department of Biochemistry, Bayero University, Kano, Nigeria.

FTIR Nicolel IS10 Thermo scientific was used to record the IR spectra in the region 400-4000 cm^{-1} at Ahmadu Bello University, Zaria, Nigeria.

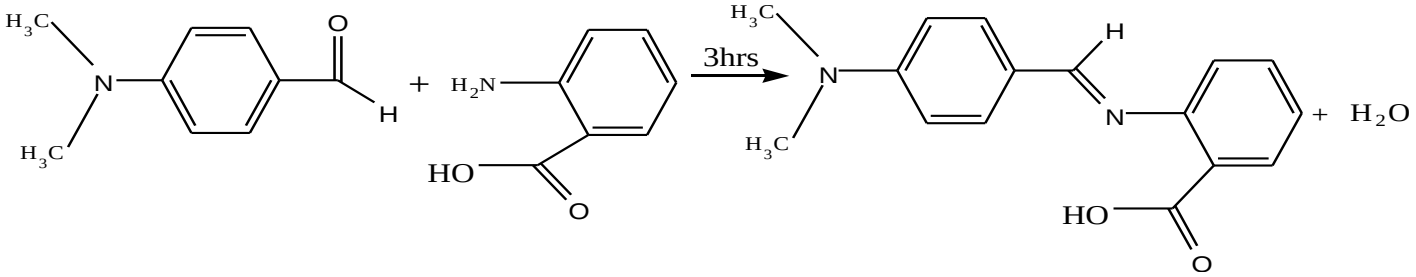
The measurements of Magnetic susceptibility were carried out at room temperature at the Instrument Laboratory of the Department of Pure and Industrial Chemistry, Bayero University, Kano, Nigeria using Sherwood MK1Magnetic susceptibility balance using $Hg[Co(SCN)_4]$ as standard, and Pascal's diamagnetic constants were applied[8].

The metal contents were estimated using 210 VGP Atomic Absorption spectrophotometer at the Department of Biochemistry, Bayero University, Kano, Nigeria and the elemental analysis of CHN was carried out at OEA labs., Callington, United Kingdom using a CE instruments (thermo) EA1110 Elemental Analyser using Xperience software. The system was single tube configured for CHN mode and was calibrated to acetanilide traceable to NIST.

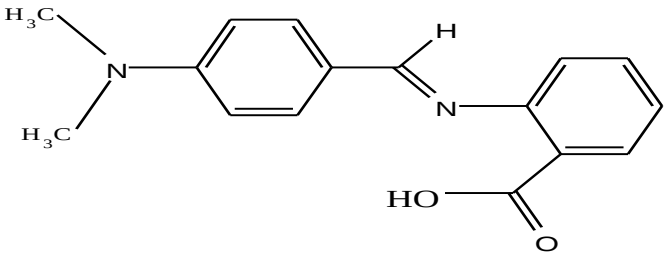
Synthesis of the Schiff base (DBAB): This was obtained by adding $75cm^3$ ethanolic solution of 2-aminobenzoic acid (4.11g, 0.03mol) to the same volume of ethanolic solution of 4-(N,N-dimethylamino) benzaldehyde (4.47g, 0.03mol). The solution was then subjected to refluxing with stirring for 3 hours. The resulted solution was evaporated to half its volume and the precipitated solid was separated, washed twice with $15cm^3$ hot ethanol and dried in a desiccator using anhydrous calcium chloride as desiccant[9]. The equation for the reaction is shown in Scheme-1.

Synthetic Method of the Metal Chelates: The metal complexes were obtained by dissolving 0.015mol (4.02g) of the Schiff base ligand (DBAB) in $75cm^3$ hot ethanol which was added with stirring to $75cm^3$ ethanolic solution of 0.0075 mol of the metal(II) chlorides separately refluxed for 1 hour. On cooling to room temperature, the coloured crystals of the complexes formed, were filtered, washed with $15cm^3$ ethanol and dried in a desiccator using anhydrous $CaCl_2$as dessicant[9].

Determination of Water of Hydration: The water of hydration was determined by separately placing 0.2g of each of the complexes in a weighed watch glass which was then kept in an oven at 110^oC for 2 hours until constant weight was obtained. After cooling, the net weight loss was taken as weight of water of hydration[10]. The percentage of water of hydration was calculated using the following equation: % of water of hydration $= \frac{\text{weight loss}}{\text{Initial weight of sample}}$ x 100%.



Scheme-1: Preparation route of the azomethine ligand.



+ $MCl_2.nH_2O$ → Complex M= Co^{2+} or Ni^{2+}

Scheme-2: Synthetic route for the metal(II) complexes formation.

Estimation of Metal in the Complexes: Exactly 0.05g of each metal(II) complex was accurately weighed and heated with a mixture of $3cm^3$ concentrated HNO_3 of specific gravity 1.42; 69% by mass and $2cm^3$ of hydrogen peroxide to dryness. The heating process was repeated three times. After which $3cm^3$ dilute hydrochloric acid (0.1M) was added to get a clear solution. Then allowed to cool and made up to $100cm^3$ with distilled water. The working solutions were obtained by further diluting $10cm^3$ of the stock solutions with distilled water to make up $100cm^3$ in a volumetric flask. The concentrations of metal ions were then measured against the blank solution using Atomic Absorption spectrophotometer[11].

Antimicrobial Sensitivity Test: Disc diffusion method was adopted for the *in vitro* antimicrobial sensitivity test. The synthesized compounds were separately dissolved in dimethylsulfoxide (DMSO) to have three different concentrations (60µg/disc, 30µg/disc and 15µg/disc) per disc. Each of these was separately applied on the surface of the culture and subjected to incubation at 37°C for 24 hours for the antibacterial studies and for 48 hours in case of the antifungal studies. The diameter of zone of inhibitions produced by the Schiff base and metal chelates were related to the positive controls, Amoxicilin capsule and Nyastatin tablet respectively[7,12].

Results and Discussion

The prepared Schiff base was orange red, non – hygroscopic solid crystal with a yield of 54.69%. The synthesized Co(II) and Ni(II) Schiff base chelates were dark red and yellow respectively. The colours observed are due to d-d electronic transition[12]. The Schiff base has melting point of 177°C while theSchiff base complexes have decomposition temperatures of 221 and 192°C respectively. These moderately high decomposition temperatures indicate that the complexes are fairly stable[13]. This could be as a result of the effective bond that exists between the metal ions and the bidentate ligand forming chelates[14]. The molar conductivity values of the metal chelates were found to be low (6.08 and 9.12 $ohm^{-1}cm^2mol^{-1}$ respectively). These suggest their non- electrolytic nature[15]. The analytical data are in Table-1.

Table-1: Physical and Microanalytical Data of the synthesized Compounds.

Compound	F. Wt (g/mol)	Colour	Yield (%)	M.P (°C)	D. Temp (°C)	Microanalysis % Found (Calculated)				Λm ($\Omega^{-1}cm^2$ mol^{-1})
						C	H	N	M	
DBAB	268	Orange red	55	177	-	71.35 (71.62)	5.91 (6.01)	10.11 (10.44)	-	-
$[Co(DBAB)_2(H_2O)_2].4H_2O$	701	Dark red	64	-	221	55.30 (54.80)	5.09 (5.98)	7.91 (7.98)	7.89 (8.40)	6.08
$[Ni(DBAB)_2(H_2O)_2].3H_2O$	683	Yellow	83	-	192	55.46 (56.26)	5.35 (5.86)	8.27 (8.20)	8.42 (8.60)	9.12

DBAB = $C_{16}H_{16}N_2O_2$, F. Wt. = Formula Weight, M.P = Melting point, D. Temp.=Decomposition Temperature, Λm=Molar conductance.

Table-2: Magnetic Properties of the Metal(II) Complexes.

Compound	Mass Susceptibility X_g (erg. G^{-2} g^{-1})	Molar Susceptibility X_m (erg. G^{-2} mol^{-1})	Paramagnetic Contribution X_p	μ_{eff} (B.M)	n	Hybridization	Geometry
$[Co(DBAB)_2(H_2O)_2].4H_2O$	1.725×10^{-5}	1.2097×10^{-2}	1.2402×10^{-2}	5.44	3	sp^3d^2 (High spin)	Octahedral
$[Ni(DBAB)_2(H_2O)_2].3H_2O$	4.741×10^{-5}	3.2383×10^{-3}	3.5107×10^{-3}	2.93	2	sp^3d^2 (High spin)	Octahedral

DBAB = $C_{16}H_{16}N_2O_2$,n=Number of unpaired electrons.

Table-3: Percentage Composition by Mass of Water of Hydration, Metal and Schiff base in the Complexes.

Complex	Weight loss (g)	Water of Hydration (%)	Metal (%)	DBAB (%)
$[Co(DBAB)_2(H_2O)_2].4H_2O$	0.0205	10.25	7.89	79.86
$[Ni(DBAB)_2(H_2O)_2].3H_2O$	0.0158	7.90	8.42	81.68

DBAB is $C_{16}H_{16}N_2O_2$.

Table-4: Solubility Test on the Synthesized Compounds.

Compounds	Solvents								
	Acetone	CCl_4	Chloroform	DMF	DMSO	Ethanol	Methanol	Nitro benzene	Water
DBAB	S	SS	S	S	S	S	S	SS	IS
$[Co(DBAB)_2(H_2O)_2].4H_2O$	SS	SS	SS	S	S	SS	SS	SS	IS
$[Ni(DBAB)_2(H_2O)_2].3H_2O$	SS	IS	SS	S	S	SS	SS	SS	IS

DBAB = $C_{16}H_{16}N_2O_2$,S=Soluble, SS= Slightly soluble, IS=Insoluble, DBAB = $C_{16}H_{16}N_2O_2$, DMF= Dimethylformamide, DMSO= Dimethylsulfoxide.

Table-5: Important IR Frequencies (cm^{-1}) of the Synthesized compounds.

Compound	*v*(OH) H_2O	*v*(C=O)	*v*(C=N)	*v*(COO^-)	Coordinated *v*(H_2O)	*v*(M-N)	*v*(M-O)
DBAB	-	1680.41	1611.17	1485.25	-	-	-
$[Co(DBAB)_2(H_2O)_2].4H_2O$	3447.49	1612.54	1587.32	1458.22	816.93	515.53	504.76
$[Ni(DBAB)_2(H_2O)_2].3H_2O$	3304.26	1614.31	1592.15	1457.77	810.20	520.30	424.86

DBAB is $C_{16}H_{16}N_2O_2$

Table-6: Antibacterial Sensitivity Test on the Azomethine Ligand and its Metal(II) Chelates.

Compound	Concentration (µg/disc)	Bacterial Zone of Inhibition (mm)		
		Staphylococcus aureus	*Echerichia coli*	*Salmonella typhi*
DBAB	60	12	10	11
	30	10	08	08
	15	09	-	07
$[Co(DBAB)_2(H_2O)_2].4H_2O$	60	18	-	08
	30	13	-	-
	15	11	-	-
$[Ni(DBAB)_2(H_2O)_2].3H_2O$	60	16	-	14
	30	14	-	12
	15	12	-	09
Amoxicillin (control)	60	28	31	27
	30	22	28	21
	15	15	19	17

DBAB= $C_{16}H_{16}N_2O_2$

Table-7: Antifungal Sensitivity Test on the Azomethine Ligand and its Metal(II) Chelates.

Compound	Concentration (µg/disc)	Fungal zone of inhibition (mm)		
		Aspergillus flavus	*Aspergillus Niger*	*Aspergillus Fumigatus*
DBAB	60	10	-	12
	30	09	-	10
	15	-	-	07
$[Co(DBAB)_2(H_2O)_2].4H_2O$	60	14	11	15
	30	12	08	12
	15	08	07	10
$[Ni(DBAB)_2(H_20)_2].3H_2O$	60	16	11	08
	30	14	08	-
	15	11	-	-
Nystatin (Control)	60	27	20	28
	30	18	16	23
	15	14	10	17

DBAB= $C_{16}H_{16}N_2O_2$

Microanalysis: The elemental content of the Schiff base and its complexes has been determined. The calculated and experimental values are in good agreement. This revealed the purity of the synthesized compounds. The molecular formula of the Schiff base ligand can be represented as $C_{16}H_{16}N_2O_2$ and the complexes are formed by 1:2 metal - ligand ratio. The results are presented in Table-1.

Solubility Test: The solubility of the synthesized compounds was determined in some common solvents as presented in Table-4. The synthesized compounds were soluble in dimethylsulphoxide and dimethylformamide but insoluble in water. The solubility of these compounds in these solvents could be attributed to the strong coordinating nature of the solvents. However, Co(II) complex was found to be slightly soluble in the other solvents used.

FT-IR Spectra: The infrared spectral frequencies of the azomethine ligand and its metal(II) chelates are shown in Table-5. The IR spectrum of the Schiff base exhibits a strong peak at 1611cm^{-1} assignable to the *ν*(C=N) group[6]. The shifting of this peak to lower wave numbers of 1587 and 1592cm^{-1} in the spectra of the chelates indicates the involvement of the azomethine nitrogen in complexation. The band at 1680cm^{-1} in the free ligand which is assigned to C=O has undergone bathochromic shift to 1612 and 1614cm^{-1} in the chelates indicating linkage between the metal ion and carboxylate oxygen[16]. The IR spectra of the complexes exhibit broad bands at 3447 and 3304cm^{-1} attributable to the presence of water of hydration; and at 810 and 817cm^{-1} corresponding to coordinated water[6]. Further supportive evidence of the chelation was explicitly shown by the manifestation of weak new bands in the far infrared at 516 and 520cm^{-1} due to *ν*(M-N) and at 505 and 424 cm^{-1} due to *ν*(M-O) stretching vibrations[17].

Magnetic Property Studies: The room temperature magnetic susceptibility measurements of the metal(II) Schiff base chelates were determined. The observed magnetic moment of 5.44 B.M for Co(II) complex indicative of three unpaired electrons was complimentary of octahedral geometry since magnetic moments in the range 4.7-5.3 B.M are generally observed in octahedral Co(II) compounds. Usually, square planar Ni(II) complexes exhibit diamagnetism while octahedral and tetrahedral complexes of Ni(II) show paramagnetism with magnetic moments in the range 2.8-3.4B.M. and 3.4-4.2B.M. respectively[3,18]. The Ni(II) chelate reported herein has a magnetic moment of 2.93B.M indicative of two unpaired electrons around an octahedral geometry. The results are presented in Table-2.

Antibacterial Assay: The synthesized compounds have been assayed against a gram-positive bacterium, *Staphylococcus aureus* and twogram negative bacteria viz.: *Escherichia coli* and *Salmonella typhi*. The results are shown in Table-6. The Schiff base showed good activity against all the tested bacteria at all concentrations except *E. coli* which showed no inhibitory action at concentration of 15µg/disc. The metal chelates exhibit higher antibacterial activities than the uncomplexed ligand. The enhancement in the biological activity of the metal chelates was as a result of the effect of metal ions on the metal chelates which could be explicated based on overtone`s concept and Tweedy`s chelation theory[19]. According to this theory, on chelation, the polarity of the metal ions reduces extensively as a result of the overlap of orbital of the Schiff base ligand and partial sharing of positive charges of metal ions with the donor groups. Moreover, the delocalization of the π electrons over the whole chelate rings increases and the lipophilicity of the chelatesenhances therebyimproving the streaming of the chelates into the lipid membranes. This may disable the enzymes of microorganisms by blocking the metal binding sites. Besides, these chelates interrupt the respiration of the cell thus impeding the protein synthesis, which restrains further growth of the microbes. The varying activity of the different chelates against the microbial isolates under assay depends either on the impermeability of the microbial cells or difference in their ribosomes[20]. The complexes showed no activity against the gram-negative bacterium *E. coli* at all concentrations. Additionally, Co(II) complex displayed lesser activity against *Salmonella typhi* as compared to the ligand.

Antifungal Assay: The result of the antifungal test is reported in Table-7. The antifungal sensitivity test of the Schiff base ligand showed that it is active against *Aspergillus flavus* and *Aspergillus fumigatus* at all concentrations for the later and at concentrations of 60 and 30µg/disc for the former, but showed no activity against *Aspergillus niger*. The metal(II) complexes showed enhanced activities against *Aspergillus flavus* and *Aspergillus niger*. Similarly good activities were observed for the Co(II) complex against *Aspergillus fumigatus* at all concentrations while Ni(II) complex showed less activity compared to the ligand at concentration of 60µg/disc and no inhibition zone was observed at concentrations of 30µg/disc and 15µg/disc. The inactivity of the chelates in this study may be attributed to their probable lipophobic nature as a result of an outer protective layer called lipopolysaccharide. The outer layer provides supplementary fortification to the cell membrane thereby restricting the concentration of test compounds from streaming through the bacterial cell wall[20]. The proposed general molecular geometry of the chelates is shown in Figure-1.

Conclusion

Successful synthesis and investigation of the azomethine ligand and its Co(II) and Ni(II) chelates have been reported. The analytical and microanalytical data showed the stoichiometric formation of the chelates in 1:2 metal – ligand ration. The complexes were found to be non- electrolytes in DMF. The Schiff base behaves as monoanionic bidentate ligand coordinated to the central metal ions via the nitrogen of ν(C=N) and carboxyl oxygen atoms. On the basis of magnetic analytical and spectroscopic data, a six – coordinate octahedral molecular

structure has been proposed for the chelates. The azomethine ligand and its chelates under investigation showed enhanced activity against the tested clinical isolates.

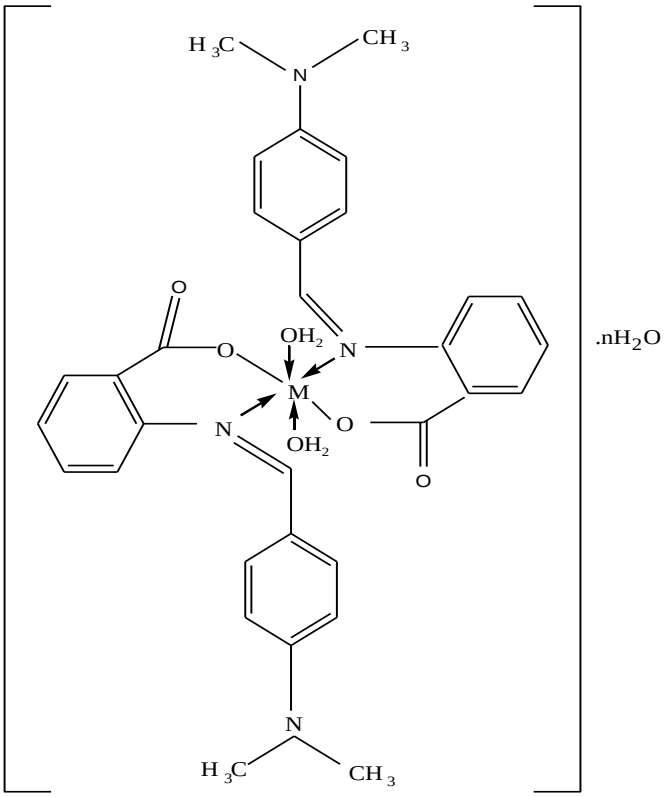


Figure-1: Proposed General Molecular Geometry of the Chelates. M= Co(II) or Ni(II), n= 4 for Co(II) and n=3 for Ni(II) Complex

References

1. Anant, P. and Devjani, A. (2011). Application of Schiff bases and their Metal Complexes - A Review. *International Journal of Chem Tech Research*, 3(4), 1891-1896. www.sphinxsai.com

2. Kelly, J. L., Linn, J. A., Bankston, D. D., Burchall, C. J., Soroko, F. E. and Cooper, B. R. (1995). 8-Amino-3-benzyl-1,2,4-triazolo[4,3-œ]pyrazines: Synthesis and Anticonvulsant activity. *Journal of Medicinal Chemistry*, 38(18), 3676-3679. http://doi.org/10.1021/jm00018a029

3. Nejo, A. A. (2009). Metal (II) Schiff base Complexes and the Insulin Mimetic Studies on the oxovanadium(IV) Complexes. *An Unpublished PhD Thesis Submitted to the Department of Chemistry, Faculty of Science and Agriculture, University of Zululand, South Africa.*

4. Rehman, M., Imran, M., Arif, M. and Farooq, M. (2014). Synthesis, Characterization and Metal Picrate Extraction Studies of Salicylaldehyde Derived Macrocyclic Schiff bases. *International Research Journal of Pure and Applied Chemistry*, 4(2), 243–250. https://doi.org/10.9734/IRJPAC/2014/8147

5. Patel, D. D., and Patel, A. (2011). Synthesis and Antimicrobial activity of Metal(II) N-[4-dimethylamino] benzylidenebenzene-1.2-diamine Complex. *Journal of Pharmaceutical Science and Technology*, 4(4), 25-38

6. Ahmed, A. A. and Yunusa, Y. (2018). Synthesis and Spectroscopic Characterization of Mn(II) and Fe(II) Complexes with a Schiff Base derived from 4-(N,N-Dimethylamino) benzaldehyde and 2-aminophenol. *International Journal of Chem Tech Research,*11(1), 308-313. www.sphinxsai.com

7. Yusha'u, M. and Sadisu, F. U. (2011). Inhibitory Activity of *Detarium Microcarpum* Extracts on Some Clinical Isolates. *Biological and Environmental Sciences Journal for the Tropics*, 8(4), 113-117.

8. Bain, G. A. and Berry, J. F. (2008). Diamagnetic Corrections and Pascal's Constant. *Journal of Chemical Education*, 85(4), 532-536. http://dx.doi.org/10.1021/ed085p532

9. Hadi, M. A. (2009). Preparation and Characterization of Some Transition Metal Complexes with Schiff base ligand. *Journal of Kerbala University*, 7(4), 52–57. https//www.iasj.net

10. Ibrahim, A. K., Yusuf, B. A. and Hamisu, A. (2017). Synthesis, Characterization and Antimicrobial Studies of Cu(II) and Zn(II) Complexes with Schiff base N-Salicylidene-4-chloroanilinie. *Chem Search Journal*, 8(2), 68-74. https://www.ajol.info/index.php/csj/article/view/166253

11. Anu, M., Prabha, L., Banukarthi, G., Kanjana, P. R. and Rajeswari, K. (2013). UV-visible, IR and NMR spectra on Copper(II) Schiff base Complex. *International Journal of Institutional Pharmacy and Life Sciences*, 3(6), 23-32 www.ijipls.com

12. Khalifa, H. A. (2014). Synthesis, Characterization and Antimicrobial Studies of Some Divalent Metal Complexes with Schiff base derived from *p*- aminophenol and benzaldehyde. *An Unpublished M. Sc. dissertation Submitted to the Department of Pure and Industrial Chemistry, Bayero University, Kano, Nigeria*.

13. Ogunira, K. O., Tella, A. C., Alensela, M. and Yakubu, M. T. (2007). Synthesis, Physical Properties, Antimicrobial Potential of Some Antibiotic Complexes with Transition Metals and their Effects on Alkaline Phosphates Activities of Selected Rat Tissues. *African Journal of Biotechnology*, 6(10), 1202 – 1208. http://www.academicjournals.org/AJB

14. Badamasi, A. (2011). Synthesis, Characterization, Antibacterial and Antifungal Evaluation of Ampicilin Divalent Metal Complexes. *An Unpublished M.Sc. Thesis*

Submitted to the Department of Chemistry, Faculty of Science, Bayero University, kano, Nigeria.

15. Shamkhy, E. T. (2015). Synthesis, Characterization and Spectroscopic Studies of 2 – {{E} – hydroxyphenyl) imino) methyl} phenol Schiff base with Some Metal Complexes. *Journal of AL-Nahrain University*, 18(1), 39–45. https://anjs.edu.iq

16. Suresh, M. S. and Prakash, V. (2010). Preparation, Characterization and Microbiological Studies of Cr^{3+}, Mn^{+2}, Co^{+2}, Ni^{+2}, Cu^{+2} and Cd^{+2} Chelates of Schiff base derived from Vanillin and Anthranilic acid. *International Journal of the Physical Sciences*, 5(9), 1443–1449. https://academicjournals.org/IJPS

17. Chohan, Z. H.; Munawar, A and Supuran, C. T. (2001). Transition Metal ion Complexes of Schiff bases: Synthesis, Characterization and Anti-bacterial Properties. *Metal based drugs*, 8(3), 137–143. doi:10.1155/MBD.2001.137.

18. Osowole, A. A., Wakil, S. M. and Alao, O. K. (2015). Synthesis, Characterization and Antimicrobial Activity of Some Mixed trimethoprim – sulfamethoxazole metal drug Complexes. *World Applied Sciences Journal*, 33(2), 336 – 342. DOI: 10.5829/idosi.wasj.2015.33.02.22206

19. Mounika, K., Anupama, B., Pragathi, J. and Gyanakumari, C. (2010). Synthesis, Characterization and Biological Activity of a Schiff base derived from 3-ethoxy salicyladehyde and 2-amino benzoic acid and its Transition Metal Complexes. *Journal of Scientific Research*, 2(3), 513 – 524. DOI: https://doi.org/10.3329/jsr.v2i3.4899

20. Sobola, A. O. and Watkins, G. M. (2013). Antimicrobial activity and Cu(II) complexes of Schiff bases derived from Orthoaminophenol and Salicylaldehyde Derivatives. *Journal of Chemical and Pharmaceutical Research*, 5(10), 147 – 154. www.jocpr.com