Synthesis, Characterization and Antibacterial Activity of Some Metal Complexes of Azo Guanosine and Adenosine Derivatives

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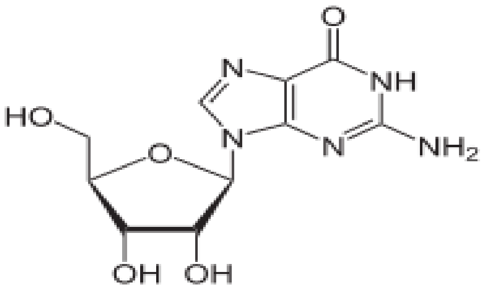
Abstract: A series of new coordination complexes of Cu(II), Co(II), Ni(II) with the azo nucleosides derived from the coupling reaction of guanosine and adenosine with substituted phenyl diazonium salts have been prepared .These metal complexes were characterized by elemental analysis, IR, UV-Visible, Conductivity measurement and magnetic susceptibility. It was found that the azo compounds behaves as N,N'-Bidentate donor ligand forming chelates with 1:1 (metal: ligand) stoichiometry. The ligands and their metal complexes have been screened for their antibacterial activity against five species of pathogenic bacteria: Staphylococcus aureus, Streptococcus viridans, Proteus vulgaris, Pseudomonas aeruginosa and Escherichia coli using Disc diffusion method. The activity data had shown that the metal complexes to be more potent antibacterial than the parent azo ligands against one or more bacterial species suggesting that metalation increase the antibacterial activity of those compounds.

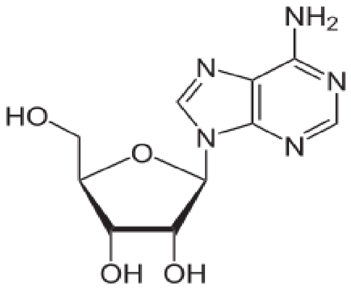
Keywords: Azo Compounds, Metal Complex, Antibacterial

1. Introduction

Azo compounds and its complexes are a very important class of chemical compounds receiving attention in scientific research; these compounds are explored for their applications in different field (Khalid et al, 2016); (Hao et al, 2008). Their biological importance is well known and they are used as antineoplastics (Garget & Praksh, 1971), anti-diabetic (Garg & Praksh, 1972), antiseptics (Parekh et al, 2011). On the other hand, Nucleosides belong to a class of organic compounds with their structures being composed of a nitrogen-containing heterocyclic nucleobase and a 5-carbon sugar as shown in fig (1) (Ri-Ming et al, 2014). In this respect, Synthesis of azo complexes of Co (II), Ni (II) and Cu (II) containing guanosine and adenosine moiety have been achieved in this work.



Guanosine



Adenosine

Figure (1)

2. Methodology

All the chemicals are of analytical reagent grade. Solvents were dried and distilled before use. According to guanosine, adenosine, p-bromoaniline and p-aminobenzoic acid were purchased from BDH. Melting points were measured on BIO COTE Model SMP10 melting apparatus. Elemental composition was estimated on Thermo Scientific Flash 2000 organic elemental analyzer. FTIR was recorded on Thermo Scientific Nicolet-6700 FTIR spectrophotometer, UV-visible spectrum was recorded on UV-visible spectrophotometer Shimadzu 1800. IR spectra in the range 4000-200 cm^{-1}were recorded on a "Shimadzu F.T.I.R 8400S"Spectrophotometer. Magnetic susceptibilities were determined by Faraday method at room temperature using Balance Magnetic (MSB -MKI) apparatus, and diamagnetic corrections for the ligand were calculated using Pascal's constant [11]. Molar conductance of the prepared metal complexes were determined in Ethanol using conductivity meter Alpha-511 at 282C, A concentration of the solutions was (10 $^{-3}$ mol. L1).

2.1 Preparation of 8-(4-Bromo phenyl azo) Guanosine (GB)

p- Bromoaniline 0.344 g(0.002mol) was dissolved in in a solution containing of 0.8 ml of concentrated HCl and 6 ml of distilled water. The mixture was cooled to 0 C^{o} . A solution of Sodium nitrite 0.156 g (0.002 mol) in 8 ml distil water was added drop wise with continuous stirring, so that the temperature never goes above 5°C. When the addition was completed, the mixture was stirred for another 2 - 3 minutes. A Solution of 0.534 g (0.002) mole guanosine in 10 ml (10%) sodium hydroxide was added to the diazonium salt in an ice bath, with vigorously stirring for a few minutes. The mixture was acidified with 1 M hydrochloric acid and the orange product was filtered and washed with distilled water and recrystallized from a solution of ethanol: water (1:1).8-(4-Bromo phenyl azo) Adenosine (AB) were prepared by following the same procedures above.

2.2 Preparation of 8-(4-carboxylic phenyl azo) Guanosine (GC)

Amino benzoic acid (0.274 g ,0.002mol) was dissolved in a mixture of (1ml) HCl, and (6ml) distilled water, and diazotized at 5°C with aqueous solution of sodium ntrite 0.156 g (0.002mol) in 8ml distilled water. The resulting diazonium chloride solution was added dropwise with stirring to guanosine(0.534 g,0.002 mol) dissolved in 10ml sodium hydroxide(10) solution below5°C . The mixture was neutralized and the yellow precipitate was filtered off and washed with distilled water and recrystallized from (1:1) ethanol: water, solution then left to dry. Abbreviation and Chemical formula of the prepared ligands are shown in table (1)

Table 1**:** Abbreviation and Chemical formula of the prepared ligands

abbreviation	Name of the ligand	Chemical formula
AB	8-(Bromophenyl azo)adenosine	$C_{10}H_{12}N_5O_4(4\text{-}Br\text{-}C_6H_4N_2)$
GB	8-(Bromophenyl azo)guansine	$C_{10}H_{12}N_5O_5(4\text{-}Br\text{-}C_6H_4N_2)$
GC	8-(Carboxylic phenyl azo)guanosine	$C_{10}H_{12}N_5O_5(4\text{-}CO_2H\text{ -}C_6H_4N_2)$

2.3 Preparation of Ligand−Metal Complexes.

The complexes of cobalt (II), nickel (II) and copper (II) (10 mmol) were prepared in by refluxing the metal (II) chlorides with the organic ligand (1:1 molar ratio) in 100mL of ethanol in alkaline medium (PH=9-9.5). The crystalline products were filtered and recrystallized from ethanol. The elemental analysis, some of the physical properties and the Percentage yield for the ligands and their complexes are shown in Table (2).

Table 2: The elemental analysis for the ligands and their complexes

Compound	C %	H %	N %	M.P^{0}C	Yield %	Color
AB	41.52(42.66)	3.43(3.55)	20.53(21.77)	143-141 $_{\text{Dec}}$	72	Red
GB	42.17(41.20)	4.26(3.43)	20.47(21.73)	261-259 $_{\text{Dec}}$	73	Orange
GC	46.49(47.33)	3.25(3.94)	21.92(22.73)	293-291 $_{\text{Dec}}$	75	Yellow
$[Co(GB)(H2O)_2]Cl_2$	31.10(30.38)	3.62(3.16)	15.72(15.51)	213 -211 $_{\text{Dec}}$	60	Brown
$[Co(GC)(H2O)_4]Cl_2$	32.87(32.23)	3.85(3.63)	15.89(15.48)	195-193 $_{\text{Dec}}$	72	Light brown
$[Ni(GB)Cl_2]$	32.86(32.23)	2.93(2.68)	16.76(16.45)	219-217$_{\text{Dec}}$	54	Brown
$[Ni(GC)Cl_2]$	36.75(36.38)	2.87(3.03)	17.90(17.48)	350< $_{\text{Dec}}$	74	Light brown
$[Ni(AB)Cl_2]$	32.89(33.12)	3.15(2.76)	17.23(16.90)	180-177 $_{\text{Dec}}$	85	Light brown
$[Cu(AB)Cl_2]$	33.13(32.8	3.11(2.73)	17.00(16.76)	173-171 $_{\text{Dec}}$	71	Red

	5)					
[Cu(GB)Cl_2]	32.31(31.97)	2.98(2.66)	16.74(16.32)	123-120 $_{Dec}$	60	Brown

2.4. Evaluation of Antibacterial Activity

The ligands and their metal complexes have been screened for their antibacterial activity against five species of pathogenic bacteria: *Staphylococcus aureus*, *Streptococcus viridans*, *Proteus vulgaris*, *Pseudomonas aeruginosa and Escherichia coli* .Qualitative determination of antimicrobial activity was done using the disc diffusion method (*Bonev* et al, 2008). Where a series of concentrations in DMSO were prepared (100,50,25,10,1,0.5,0.2 mg/ml)for each ligand and complex .

3. Results and Discussion

The elemental analysis shows that the suggested molecular composition is in a good agreement with the experimental results as shown in Table (1).The metal-ligand ratios of complexes were determined by molar ratio method (at fixed concentration of metal ion ($1x10^{-4}$ M) and increasing concentration of ligand(0.25-4.0 $x10^{-4}$M) at optimum pH and λmax. The mole ratio of complexes (Metal:Ligand) was (1:1). The molar conductance in DMF (10^{-3} M), revealed that complexes behave as 1:1 electrolyte. These results along with the other analytical and spectral data support the molecular formulas of the synthesized complexes

3.1. IR Spectra of the Prepared Compounds

Infra-red spectra of the ligands have shown absorption bands between 1518-1420cm-1 with in the range of vibrational frequencies for υ (C=C) and υ (N=N) .These bands represents a characteristic feature of the azo compounds (Saha et al, 2006). Where The position of azo group υ (N=N) absorption band depends on groups attached to it (Silverstein & Webster, 1999).The infrared spectra show a distinctive Band in the range (1623-1600 cm^{-1}) due to υ(C=N) stretching frequency while the bands at 1696- 1710 cm^{-1} in the ligands GB and GC spectra refers to the ν(C=O), (Murtaza et al, 2012); (Banyay et al, 2003). The bands observed at 563-615 cm^{-1} is assigned to (C-Br). υstretching vibration (Kemp, 1975). The infrared spectra of the complexes show Considerable changes at the region 1530-1400cm^{-1} corresponding to $\upsilon(N=N),\upsilon(C=C)$. These findings are supports the coordination of azo nitrogen to metal ion. It has been noticed that The υ(C=N) bands at (1629-1609 cm^{-1}) of some complexes show red shift while the others have blue shift when compared with that of the ligands. This is attributed to the sort of the metal ion binding to the ligand. Charcteristic bands have been found near 970 cm^{-1} in$[Co(GB)(H_2O)_2]Cl_2$ and $[Co(GC)(H_2O)_4]Cl_2$ due to the coordinated water molecules (Nakamoto,1978). The infra-red spectra of $[Co(GB)(H_2O)_2]Cl_2$ and $[Co(GC)(H_2O)_4]Cl_2$ have shown bands in the region (565-520 cm^{-1}) are attributed to υ(M-Cl) stretching frequency(Addison,1960). The appearance of bands in the complexes in the (429-422 cm^{-1}) regions which may be assigned to the ν(M-N) stretching vibrations of the coordinated N atoms of the ligands (Nakamoto, 1978). The Characteristic IR absorption bands of the ligands and their complexes complexes are shown in table (3).

Table 3: The Characteristic IR absorption bands of the prepared ligands and their complexes

Compounds	N=N cm^{-1}	C=O cm^{-1}	C=N cm^{-1}	C-O-C cm^{-1}	C-N cm^{-1}	C-Br cm^{-1}	M-N cm^{-1}	M-X cm^{-1}
AB	1432_{m} 1499_{s}		1600_{s}	1230_{w}	813_{s}	563_{m}		
GB	1420_{m} 1488_{b} 1518_{s}	1710_{s}	1618_{m}	1238_{m}	812_{s}	615_{w}		
GC	1428_{m} 1497_{m} 1506_{m}	1696_{s}	1623_{s}	1263_{m}	815_{m}			
$[Co(GB)(H2O)_{2}]Cl_{2}$	1396b 1473b 1516b	1685b	1609s	1277b 1037b	781m	629m	426s	520m
$[Co(GC)(H2O)_{4}]Cl_{2}$	1452s 1484m	1701m	1618s	1021b	782b	667b	427m	565m
$[Ni(GB)Cl_{2}]$	1456b 1472b	1688b	1611b	1278m 1039m	783w	660b	427b	-
$[Ni(GC)Cl_{2}]$	1468b 1490b	1695b	1629s	1041b	780b	670m	426b	-
$[Ni(AB)Cl_{2}]$	1458s 1473s	1647s	1618s	1226b	827m	668m	427w	-
$[Cu(AB)Cl_{2}]$	1400b 1420b 1453s	1680s	1613s	1233b	826m	669s	429m	-

$[Cu(GB)Cl_2]$	1398s 1451s	1684s	1618s	1272b	833b	670m	422b	-

3.2. UV-vis Spectra of Ligands

The electronic absorption spectra of the azo compounds under study were recorded in ethanol as 10^{-4}M, The electronic spectra data of the azo ligand and its complexes re shown in table (4) and(5). The ligand is characterized by bands appearing at 333-290 nm which can be assigned to π-π* transition of intermolecular charge-transfer taken place through the azo group while the band at λ max =240-280 nm due to the absorption of the aromatic rings (. Pavia et al, 2001).

Table 4: The molecular absorbance coefficient of the prepared ligands in absolute ethanol solvent at a concentration of 10-4 M

Ligands	(λ_{max}) nm	$(Є_{max})$ mol^{-1}.cm^{-1}
AB	251.2,333.9,366.9	8240,30000,26280
GB	249.6,290.9,365.6	6100,11090,10640
GC	25101,301.1,322.4	8340,25810,26170

3.3. UV-vis Spectra of the Complexes

The positions of ligand bands are shifted which is due to chelation between metal ions and azo ligand that were assigned to d-d transition (weak in intensity) and ligand field. The absorption spectra of$[Co(GC)(H_2O)_4]Cl_2$ complexes showed two weak peak at 15873 cm^{-1},630 nm and 22272 cm^{-1},449nm due to (4T1g(f) → 4A2g (f) (υ2) and ${}^4T_{1g}$(f) → ${}^4T_{2g}$ (p) (υ$_3$)) transitions respectively. These transitions are responsible for the octahedral six-coordinate high-spin geometry and this is confirmed by the measured magnetic moment values 5.01 B.M. For the complex **$[Co(GB)(H_2O)_2]Cl_2$** , a bathochromic shift in comparison with free ligands arises from the energy change of the intense π→π* transition of the conjugated chromophore due to the chelation between metal (II) ions and azo ligands .this is belong to the transition (${}^4A_2$(f) → ${}^4T_1$(p)(υ$_3$)) at 592.5 nm (16708 cm^{-1}) . While the transitions ^{4}A2 (f) → ${}^4T_1$ (f) (υ$_2$) and ${}^4A_2$(f) → ${}^4T_2$ (f) (υ$_1$) do not appear in the measuring device because they occur in the nearby infrared region at 7800-4600 cm^{-1} or 4000-3000 cm^{-1}(.Bailar and Uraban,1973) However, the measured magnetic moment Value 4.31 B.M confirmed these transitions which is attributed to the tetrahedral high-spin geometry for cobalt (II) complex.Nickel (II) complex with the ligands AB,GC,GB, showed the shift of the peaks of the ligand spectrum to the higher wavelength and the emergence of a new peak pointed out for the chelation between metal (II) ions and azo. The spectrum of**$[Ni(GB)Cl_2]$** gave the peak at 627 nm **(**15949 cm^{-1},) while**$[Ni(GC)Cl_2]$** and **$[Ni(AB)Cl_2]$** showed peaks at 632 nm (15823 cm^{-1}) and630 nm (15873 cm^{-1}) respectively .All these bands were assigned to the transition $^3T_1(f) \longrightarrow {}^3T_1(p)(\upsilon_3)$. This is consistent with the tetrahedral geometry (Buffagni et al, 1964) as demonstrated by their magnetic moment values 4.02, 3.96, 3.89, B.M respectively. For the complex **[Cu(GB)Cl$_2$]** there was a red shift for the spectra of the ligand and appearance of anew peak at 430.3 nm (23240 cm^{-1}) indicated the occurrence of bonding between the ligand and the metal .A broad integrated peak at 532 nm (18797cm^{-1}) belongs to the transitions $^2B_1g \longrightarrow {}^2E_1g$ (υ_1) and $^2B_1g \longrightarrow {}^2A_1g$ (υ_2) , where the value of these two transitions ranges from 16000 to 20000-cm^{-1} for the square planar geometry Therefore, it is easy to use the electronic spectrum to distinguish between the octahedral copper complexes (II) that shows bands below (15000 cm^{-1}) and those that have the structure of square planar from the bands locations(Purohit & Vramana, 1980) .As for the copper complex (II) with the liqand AB, the displacement of the peaks from its position and the appearance of a new top in 292.8 nm (34153 cm-1) is associated with the ligand –metal bond and the absence of a band in the range 10000-20000 $^{cm-1}$ It excludes the occurrence of a square arrangement of copper (II) and confirms the tetrahedral arrangement. But it is necessary to have a broad beam in the nearby infrared zone confirming this arrangement (Hughes & Rutt, 1972).

Table 5: The electronic spectra data of metal complexes

Complexes	(λ_{max}) nm	(λ_{max}) cm^{-1}	Є mol^{-1}.cm^{-1}	Type of transition
[Co(GC)(H$_2$O)$_4$]Cl$_2$	252.1 303.2 327.6 330.5 388.0 449.0 630.0	39667 32982 30525 30257 25773 22272 15873	2940 4325 4357 4362 5150 3995 2870 →	}ligand C.T $^4T_1g(f)$ $^4T_2g(p)(v3)$ $^4T_1g(f)$ $^4A_2g(v2)$
[Co(GB)(H$_2$O)$_2$]Cl$_2$	250.0 294.3 366.2 408.3 598.5	40000 33979 27307 24492 16708	6250 → 10720 8100 8970 4215 →	}ligand C.T $^4A_2g(f)$ $^4T_1$ (p)(v3)
[Ni(GB)Cl$_2$]	252.0 292.3 366.0 384.8 627.0	39683 34211 27322 25988 15949	6630 11450 9000 9010 3500 →	}ligand C.T $^3T_1$ (f) $^3T_1$ (p)(v3)
[Ni(GC)Cl$_2$]	251.8 294.4 333.6 388.4 632.0	39714 33967 29976 25747 15823	3820 5850 5570 5910 3123 →	}ligand C.T $^3T_1$ (f) $^3T_1$ (p)(v3)
[Ni(AB)Cl$_2$]	252.2 290.4 370.2 408.5 630.0	39651 34432 27012 24480 15873	4680 6680 8973 10200 2000 →	}ligand C.T $^3T_1$ (f) $^3T_1$ (p)(v3)

[Cu(GB)Cl2]	251.5 294.4 372.5 430.3 532.0	39767 33967 23240 23240 18797	5500 8910 6470 5320 3870 →	}ligand C.T 2B1g 2E1g(ν1) 2B1g 2A1g(ν1)
[Cu(AB)Cl2]	251.4 292.8 400.0 415.8	39777 34153 25000 24225	4270 → 8500 9390 8000	Ligand C.T }ligand

3.4. Suggested Geometry for the Complexes

The transition metals (II) were coordinated to the prepared azo ligands in a ratio of 1:1.The metal is bonded to the nitrogen atom in the heterogeneous ring of guanosine or adenosine, which occupies the ortho position relative to the azo group. While the second coordinate center is the nitrogen atom of the azo group which is attached to the phenyl ring as shown in figure (2).

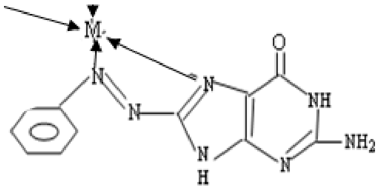


Figure (2)

Therefore the suggested geometry for the prepared complexes as shown in figure(4) were octahedral complexes of type$[M(NN)(L)_4]^{+2}$,where M =Co+2 , NN =ligand, L=water molecule, Tetrahydral complexes of type $[M(NN) X_2]$ where M= Cu^{+2},Ni^{+2},X=Cl, Tetra hedral complexes of type $[M(NN)(L)_2]^{+2}$ where ,M=Co^{+2},NN=ligand, L=water molecule and Square planar complexes of type$[M(NN)X_2]$ where M= Cu^{+2}, NN=ligand, X=Cl

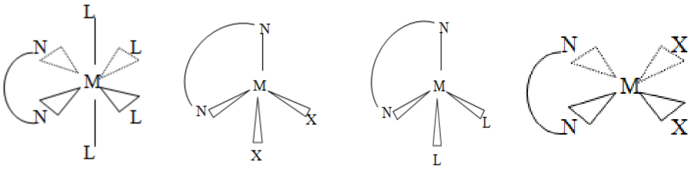


Figure (3)

3.5. Antibacterial Activity

Most of the prepared compounds used in this study showed moderate to weak positive results as chemical agents that could inhibit the growth of the bacteria. The ligand GB exhibited high activity at minimum inhibitory concentration of 1 mg /ml and the range of inhibition was (1.3 mm).As for E. coli, the minimum inhibitory concentration of 0.5 mg / ml, the ligand GB had the highest activity of

(1.2 mm) inhibition zone. Ligand GB towards Proteus vulgaris had the highest activity at the minimum inhibitory concentration of 0.2 mg / ml where it reached 1.4 mm. As for the bacteria Str. Viridans, the highest effect at the lower concentration (0.5 mg / ml) is attributable to ligand GB where it reached (1.4 mm).For the bacteria St. aureus the ligand AB showed the highest effect at the lowest concentration (0.5 mg / ml) where it reached (2.6 mm). Complexes, $[Co(GB)(H_2O)_2]Cl_2$ showed the highest activity towards bacteria Ps aeruginosa high activity at the minimum inhibitory concentration of 1 mg / ml was reached 1.2 mm. As for E. coli, the highest effect at the lowest concentration (0.5 mg / ml) was shown by $[Ni(AB)Cl_2]$، and $[Ni(GB)Cl_2]$where it reached 1.2 mm. With Proteus vulgaris, the highest effect at the lowest concentration (0.2 mg / ml) is due to complex $[Co(GB)(H_2O)_2]Cl_2$ where it reached 3.1 mm. As for bacteria Str. viridans, the complex [Ni (GC) Cl2] showed the highest effect at the lowest concentration (0.5 mg / ml) with the inhibition zone 2.1 mm. As for the bacteria St. aureus, the complex $[Cu(AB)Cl_2]$ showed the highest effect at the lowest concentration (0.2 mg / ml) where the range of inhibition (2.4 mm).

4. Conclusion

In the light of above discussion we have proposed that the azo compounds behaves as N,N'-Bidentate donor ligand forming chelates with 1:1 (metal: ligand) stoichiometry. Co(GC)(H2O)4]Cl2 has octahedral six- coordinate high-spin geometry WhileCo(GB)(H2O)2]Cl2 has tetrahedral high-spin geometry. The complexes, [Ni(GB)Cl2] , [Ni(AB)Cl2] and[Ni(GC)Cl2] have tetrahedral geometry. As for[Cu(GB)Cl2] and [Cu(AB)Cl2] complexes ,the suggested geometry were square planar and tetrahedral arrangement respectively. Most of the prepared compounds used in this study showed moderate to weak positive results as chemical agents that could inhibit the growth of the bacteria. Moreover, the microbial data revealed that the complexes were more active than the free ligand in the inhibition of the tested bacteria so it is proposed that concentration plays a vital role in increasing the degree of inhibition, the activity increased with increasing concentration of the complexes.

References

Addison. C.C., & Gatehouse, B.N. (1960). The Infared Spactra of Analaclrous Transition Metal Nitrates. *J. Chem.Soc*., 613.

Banyay, M., Sarkar, M., & Gräslund, A. (2003) A library of IR bands of nucleic acids in solution. *Biophys. Chem*. 104,477–488

Bonev, B., Hooper, J., Parisot, J. (2008). "Principles of assessing bacterial susceptibility to antibiotics using the agar diffusion method. *The Journal of antimicrobial chemotherapy*, 61 (6), 1295–301. doi:10.1093/jac/dkn090

Buffagni .S., Vallavino. L.M., & Quallon. J.V. (1964). *Inorg. Chem*., 3, 480

Garg, H.G., & Praksh, C. (1972). Preparation of 4-arylazo-3,5-disubstituted-(2H)-1,2,6-thiadiazine 1,1-dioxides. *J. Med. Chem*., 15, 435-436.

Garg, H.G., & Praksh, C. (1971). Potential antidiabetics. 7. *N1*-(β-hydroxybenzylmethyl)-3-methyl-4-arylhydrazono-2-pyrazolin-5-ones and *N1*-(β-hydroxybenzylmethyl)-3-methyl-4-arylazo-5-methyl- or -phenylpyrazoles. *J. Med. Chem*., 14, 175-176.

Hao, J., Han, M.J., Guo, K., Zao, Y., Qiu, L., & Shen, Y. (2008). A novel NLO azothiophene-based chromophore: Synthesis, characterization, thermal stability and optical nonlinearity, *Mater. Lett*., 62, 973-976.

Bailar, J., & Uraban, J. (1973). Comprehensive Inorganic Chemistry. 1st ed., Oxford: Perjamon Press.

Khalid, J., AL-Adilee, K., Abass, A., & Taher, M. (2016). Synthesis of some transition metal complexes with new heterocyclic thiazolyl azo dye and their uses as sensitizers in photo reactions. *Journal of Molecular Structure*,1108, 378-397

Hughes, M., & Rutt,J. (1972) Kinetic and mechanistic studies of the interaction of 2-mercapto pyridine with dichloro[1-alkyl-2-)imidazole]palladium(II) complexes Dalton Trans. Chem.Soc. 1311.

Murtaza, G., Rauf, M.K., Badshah, A., Ebihara, M., Said, M., Gielen, M., de Vos, D., Dilshad, E., & Mirza, B. (2012)Synthesis, structural characterization and in vitro biological screening of some homoleptic copper (II) complexes with substituted guanidines. *Eur. J. Med. Chem.* 48, 26–35. (doi:10.1016/j.ejmech.2011. 11.029)

Nakamoto, K. (1978). *Infrared and Raman Spectra of Inorganic and Coordiration Compounals*. 2nd edn., John Wiley and Sons.

Parekh, N., Maheria, K., Patel, P., Rathod, M. (2011). Study on antibacterial activity for multidrug resistance stain by using phenyl pyrazolones substituted 3-amino 1H-pyrazolon (3,4-b) quinolone derivative *in vitro* condition. *Int. J. Pharm Tech Res*., *3*, 540-548.

Pavia. D. L., Lampman G. M., Kirz G. S. (2001). *Introduction to Spectroscopy*", (3rd edition), NY:Thomson Learners Inc.

Purohit, K.M., & Vramana, D. (1980). Mixed Chelate Complexes of Copper (II) *J.Indian. Chem.Soc*., 57, 363

Ri-Ming, H., Yin-Ning, C., Ziyu, Z., Cheng-Hai, G. Xiangdong, S. & Yan, P. (2014). Marine Nucleosides: Structure, Bioactivity, Synthesis and Biosynthesis. *Mar. Drugs*, 12, 5817-5838; doi:10.3390/md12125817

Saha, S., Majumdar, T., & Mahapatra, A. (2006). Kinetic and mechanistic studies of the interaction of 2-mercapto pyridine with dichloro [1-alkyl-2-(arylazo) imidazole] palladium(II) *Transition Metal Chemistry*, 31(8), 1017–1023

Silverstein. R. M., & Webster, F. (1999). F. X, Spectrometric Identification of Organic Compounds, 6th Ed. John Wiley & Sons, Inc.