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Synthesis and characterization of novel metal complexes with new azo-schiff base ligand derived from sulfa drug and toxicological studies of its complexes as antibacterial

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***Abstract*---**The New Azo- Schiff base ligand [4-((E)-(2-hydroxyphenyl)diazenyl)-3-(((1E,2E)-2-((2-((E)-(2-hydroxyphenyl)diazenyl)-5-(N-(pyrimidin-2-yl)sulfamoyl)phenyl)imino)-1,2-diphenylethylidene)amino)-N-(pyrimidin-2-yl)benzenesulfonamide] (4HDPS) was primed. Three chelate complexes have correspondingly been equipped by reacting this ligand (4HDPS) with the metal ions Co (II), Ni (II) and Cu (II). (UV-Vis) electronic spectra of complexes showed bathchromic shift, as compared with that of free ligand .The Mass Spectrum and 1HNMR Spectrum of the free ligand has been taken and the FTIR spectrums of the Ligand and its chelating complexes have been investigated. This may specify that coordination among the metal ions and the equipped ligand takes place .The conductivity and magnetic measurements, Elemental micro analysis and the percentage of metal ions were determined. Based on these consequences, the proposed geometrical structures of the equipped complexes of Co(II),Ni(II) and Cu(II).ions are octahedral with mole ratio (M:L) was (1:1) for all prepared complexes while the conductivity measurements shows non – electrical properties. The final stage involved the study of the biological activity of prepared component to two type of pathogenic bacteria: (G+) Staph. Aureus and Escherichia coli (G-) using Well diffusion methods**.** Three different concentration were tested (100, 500, 1000) ppm in Ethanol Absolute (99%) as a

solvent. The prepared compounds showed different results (high, moderate, low, and inactive). While the new prepare Azo-Schiff (4HDPS) showed less inhibition growth against both type of bacteria in comparison with its complexes. Also, the metallic ligand complexes showed more inhibition activity against Gram positive than Gram negative.

***Keywords*---**Azo-Schiff ligand, Sulfadiazine derivatives, Elemental micro analysis, Toxicological Studies.

Introduction

Sulfonamides mainly sulfa drugs are the first possible chemotherapeutic make use of for microorganism disease in human beings. For this reason Many sulfa drugs and its derivatives have a wide range of pharmacological application, such as: Antiepileptic against hypertensive, Oral hypoglycemic, antiretroviral and antiprotozoal. Moreover many studies have been confirmed that some sulfa drugs are also read to abstract cancerous cell.[1,2] . Sulfadiazine is regarded as a parent compound sulfamide sulfate medication, a major type of drug with various classes of antithyroid pharmacologics[3], antimicrobial[4] and hypocycaemic[5]. In addition, Schiff bases ligand and complexes derived from sulfadiazine have shown effective activity in fungicides [6]. Schiff base ligand, under study, as chelate extraction reagents for divalent metal cations are currently being used as analogues such as Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, and Cd^{2+} [7, 8].

The base ligands of the Azo Schiff include Azo groups as well as Azomethine. The azo group is excellent and important for coordination chemistry [9,10]. In the last few years huge amount of (N,N')-donor ligands type azo- azomethine have synthesized [11-13].

In order to focus on designing new synthetic methods for these products, theory calculations, and applications in several industries, heterocyclic azo dye chemistry has become increasingly important. In addition to having important applications for textile dyes [14,15], certain antibacterial azo compounds were found [16-19]. This class of azo compounds has an azo- imine, active (π-acidic), which functions as a stabilizer efficient in the low valent oxidation of metals [11,12], as a result of the existence of azo-centered π*-molecular orbital. So, a quantity of these azo compounds have synthesized and their ability as chelating ligands was examined[12-14]. This is why they have been synthesized and their abilities were tested.

Materials and Method

Materials and Measurements

The employed chemicals are of the uppermost purity and are used without further purification in accordance with (Fluka,BDH or Merck). Shimadzu Agilent Technologies 5975C has been recorded with Mass Spectra. Elemental analysis was done through the C.H.N element analyser micro analyzer unit (EURO EA3000

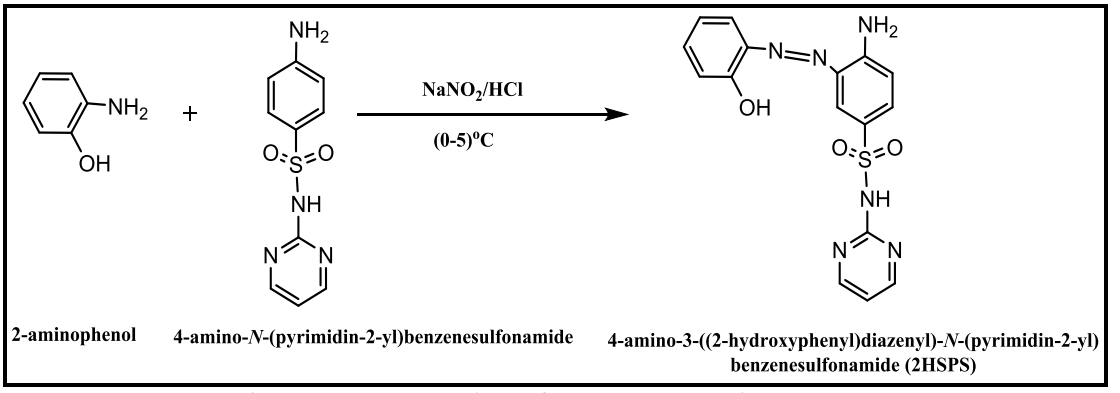
Single) using a Spectrophotometer Shimadzu UV-Vis 1700 to solve complexes in aqueous ethanol under room temperature were recorded absorption spectra and quartz cell of 1cm. In the range of (4000-400) cm^{-1} with KBr Disk IR spectra with the FT-IR-8000 Shimadzu were recorded. Electric conductivity measured in digital meter WTW,720 with solute ETOH 10^{-3} M concentration, metal percentages have been measured by means of atomic absorption techniques with a spectrophotometer of atomic absorptions -5000, perkin - Elmer.

Preparation of new Azo- Schiff base ligand (2HDPS).

The preparation of the ligand [4-((E)-(2-hydroxyphenyl)diazenyl)-3-(((1E,2E)-2-((2-((E)-(2-hydroxyphenyl)diazenyl)-5-(N-(pyrimidin-2-yl)sulfamoyl)phenyl)imino)-1,2-diphenylethylidene)amino)-N-(pyrimidin-2-yl)benzenesulfonamide] (2HSPS) included two steps the first one is synthesis of the Azo compound [4-((E)-(2-hydroxyphenyl)diazenyl)-3-(((1E,2E)-2-((2-((E)-(2-hydroxyphenyl)diazenyl)-5-(N-(pyrimidin-2-yl)sulfamoyl)phenyl)imino)-1,2-diphenylethylidene)amino)-N-(pyrimidin-2-yl)benzenesulfonamide] (4HDPS).which was resulted from Diazotization reaction between of 2-Hydroxy aniline and Sulfadiazine. The second step was preparation of the new Azo- schiff base ligand by acid catalyzed condensation of the product of step one (4HDPS) with Benzil in glacial acetic acid (GAA) as a solvent.

Synthesis of Azo compound (4HDPS)

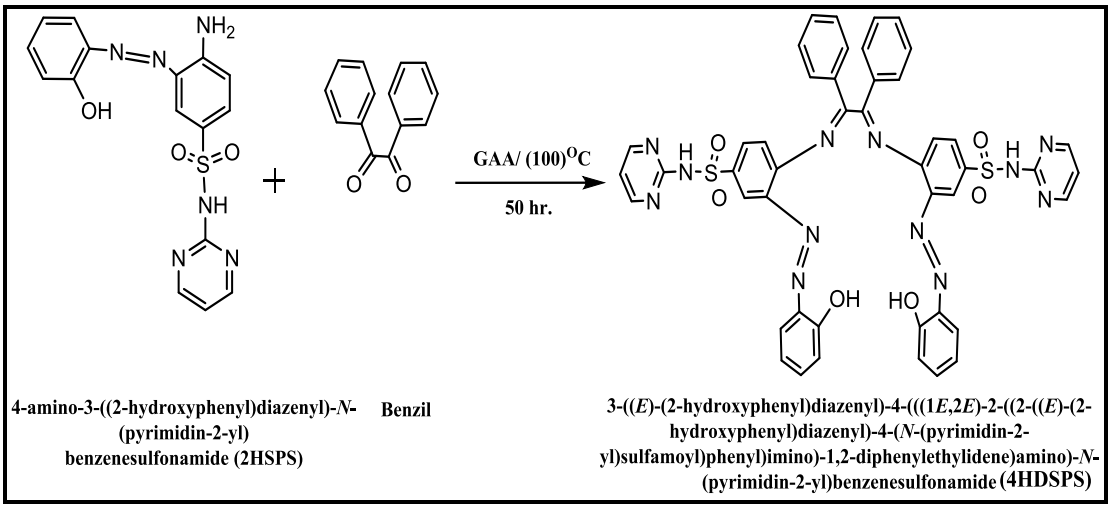
The Azo compound (4HDPS) was prepare by dissolving (1.09 g, 0.01 mol) of 2-Hydroxy aniline in 10 ml of distilled water and 5ml of concentrated hydrochloric acid, then a solution has been cooled under 5 °C. To this mixture, the solution of (0.75g, 0.01 mol) of sodium nitrate in 10 ml of distilled water has inserted drop wise at 0-5 °C. Then, after completing the addition process, a solution was left to settle for half an hour .This diazonium salt solution has inserted drop wise to a 400 ml beaker containing (2.5 g, 0.01 mol) of Sulfadiazine dissolved in 50 ml of alkaline 10 % NaOH the solution was cooled below 0 °C and acidified with dilute hydrochloric acid to pH = 7.0 .A mixture has been allowed to stand overnight. A crude dye was collected by filtration and recrystallized two times from ethanol and then dried in the oven under 50 °C for one hrs (5)[20,21]. The melting point of the Azo was (243-246)°C, (82 %), and The structural formula of its shown in Scheme 1 .



Scheme 1: Preparation of Azo compound (4HDPS)

Synthesis of new Azo - Schiff base ligand (4HDSP).

The new heterocyclic Azo- Schiff base ligand (4HDSP) has been equipped by condensing Azo compound (4HDPS) (3.70 g ; 0.02 mol) which has dissolved in (20 mL) hot glacial acetic acid (GAA) then added to (2.10 g ; 0.01 mol) of Isatin was dissolved in 30 ml GAA . The mixture has refluxed with the stirring at 100^{0}C for (50 hr)[13]. a clear orange solution was obtained. T.L.C. was followed by advances in this reaction. The mixture was crushed onto the ice after completion. The solid was filtered, washed out of the hot abs with 2% Sodium bicarbonate and distilled water. Ethanol [22, 23]. The azo-Schiff base Ligand was dried over anhydrous $CaCl_2$. The melting point of the New Azo - Schiff base ligand (DCPS) was (177-175)°C , (75 %), as showed in (Scheme 2).



Scheme Schem 2: Preparing ligand (2HSPS)

Transition metal complexes synthesis

The (1:1) chelate complexes were prepare by dissolving (0.914 g ; 0.001mol) Azo - Schiff base (2HSPS) in 15 ml of hot ETOH. The metal chloride salts of $CoCl_2.6H_2O$,

$NiCl_2.6H_2O$and $CuCl_2.2H_2O$ of (0.001 mol) has been dissolved in hot ethanol 15 mL and mixed with hot ETOH solution of a ligand and refluxed for (1 hr). The complexes are separated out in every case. A product has been filtered, washed with ethanol and dried under vacuum. Table.1 explains the physical features and analytical data for a ligand besides its complexes.

Table 1
Analytical data and Physical properties of the ligand (2HSPS) and its complexes**.**

NO.	Chemical formula	M.Wt	M.P.^{0}C	Color	Yalid %	Rf
1	$C_{16}H_{14}N_6O_3s$	370.385	243-246	Yellow	**82**	-
2	$C_{46}H_{34}N_{12}O_6S_2$	914.967	175-177	Orange	**7**5	0.56
3	$[Co(C_{46}H_{32}N_{12}O_6S_2)].\ H_2O$	989.900	230-232	Dark brown	79	0.67
4	$[Ni(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	989.660	253-255	brown	84	0.53
5	$[Cu(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	994.513	220-223	Greenish brown	82	0.81

Result and Discussion

HNMR spectra

Figure (1) shows The ^{1}HNMR spectrum of the New Azo-Schiff base ligand in a DMSO-d6 as a solvent shows the following signals :
a single (singlet) signal at (11.24) ppm belonging to the proton of the nitrogen atom bound to the sulfonic group (-SO_2-NH-) [23]. The phenol group proton (O-H) showed a single signal within the range (10.32) ppm . a multiplet appeared in the range (7.57-8.53) ppm, which belongs to the protons of the pyrimidine ring, and a multiplet (multiplet) appeared in the range (6.00- 7.5) ppm, which belongs to the protons of the aromatic ring ppm, and this is consistent with what was stated in the literature [20-22] and finally, the spectrum showed a single signal belonging to the protons of the solvent DMSO-d6 at the range (2.47-2.55) ppm and A single signal at the range (3.29-3.45) ppm belongs to the protons of the water molecule D_2O.

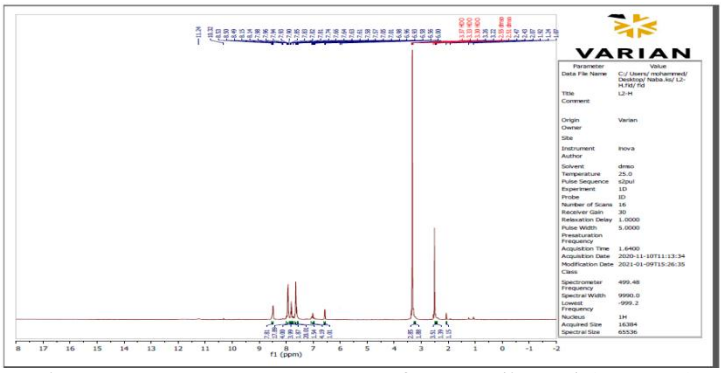


Figure1. ^{1}HNMR spectrum of a new ligand (2HSPS)

Electronic spectra

The Electronic spectra of ligand (2HSPS) (Figure.2) and its Co(II),Ni(II)and Cu(II) complexes (Figure.3-Figure.5) have been investigated and the spectral data have shown in table (2) . UV-Vis spectrum of the Azo-Schiff base ligand has categorized principally by 3 absorption peaks at (310and 338) nm assigned to(π ⟶ π *) and at (362)nm for (n ⟶ π*). These electronic transition have moved to upper frequencies in the electronic spectrums of all organized complexes, ratifying the coordinated ligand with metal ions [24].

The electronic spectrum of Co(II) complex(Fig.5) depicted new absorption peak (640)nm which may be attributed to (d-d) electronic transition of **$^4T_1g(F) \longrightarrow {}^4T_1g(P)$** and at (374) nm assigned to Charge Transfer , signifying octahedral geometry around Co(II) ion [25]. An electronic spectrum of Ni (II) complex depicted new absorption peak , at (460)nm may be assigned to charge transfer spectrum which shielded (d-d) electronic transition type **$^3A_2g(F) \longrightarrow {}^3T_1g(P)$** and at (504) nm assigned to **$^3A_2g(F) \longrightarrow {}^3T_1g(F)$**. This peak was a worthy conformity of octahedral geometry for Ni(II) complex [18].An electronic spectrum of Cu(II) complex showed a new absorption peak at (508) nm refers to charge transfer spectrum type**$^2B_1g \longrightarrow {}^2Eg$**, suggesting distorted octahedral geometry around Cu(II) ion [26].

Table 2
The electronic spectrums of the ligand (4DCPS) besides its chelate complexes

Compounds	λmax (nm)	Absorption bands(cm^{-1})	Transitions	Geometry	Hybridization
H_2L = $C_{46}H_{34}N_{12}O_6S_2$	310	32258	π →π*	----	----
	338	29585	π →π*		
	362	27624	n →π*		
[Co H_2L].H_2O	374	26737	MLCT	Octahedral	Sp^3d^2
	640	15625	$^4T_1g(F) \longrightarrow {}^4T_1g(P)$		
[Ni H_2L].H_2O	460	21739	$^3A_2g \rightarrow {}^3T_1g(P)$	Octahedral	Sp^3d^2
	504	19841	$^3A_2g \rightarrow {}^3T_1g(F)$		
[Cu H_2L].H_2O	508	19685	$^2B_1g \rightarrow {}^2Eg$	Octahedral	Sp^3d^2

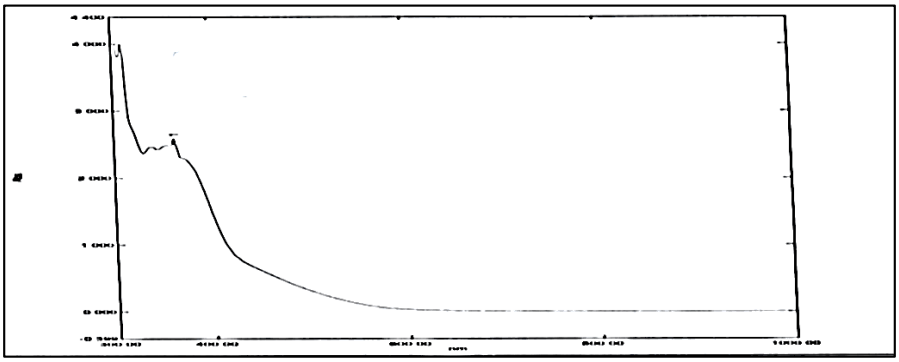


Figure 2. Absorbance spectrum for ligand (2HSPS)

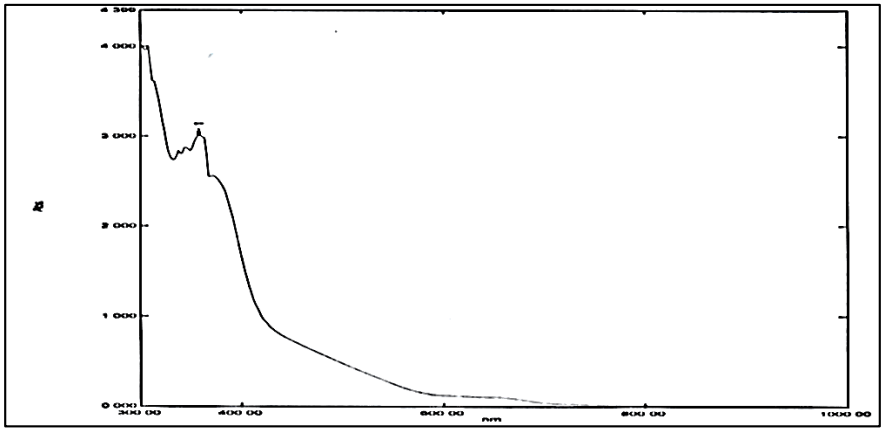


Figure 3. Absorbance spectrum of ligand (2HSPS) with Co(II) ion complex

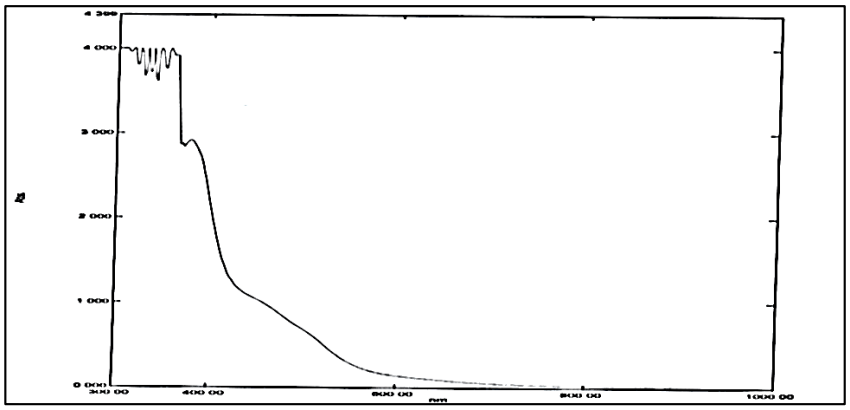


Figure 4. Absorbance spectrum of ligand (2HSPS) with Ni(II) ion complex

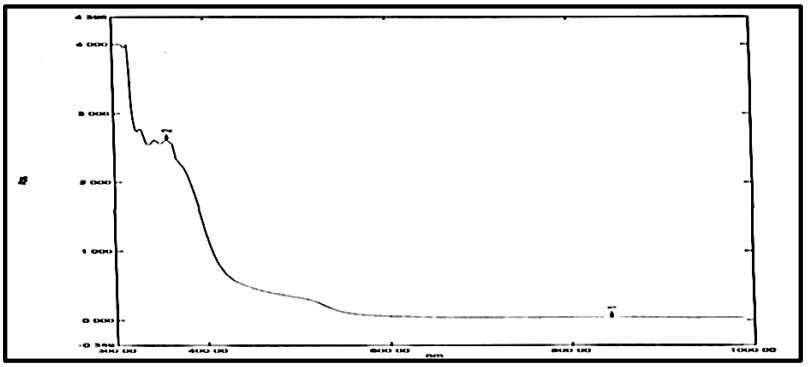


Figure 5. Absorbance spectrum of ligand (2HSPS) with Cu(II) ion complex

Elemental analysis data

The elemental analysis data of 1:1 [M:L] ratio complexes have specified that the theoretic magnitudes agreed well with the existing data, as illustrated in table(5).A pureness of azo-Schiff base ligand has verified through TLC method and C.H.N analysis.

Table 3
The elemental analysis data of the ligand (2HSPS) and its chelate complexes

NO	Chemical formula	C Found % (cal.)	H Found % (cal.)	N Found % (cal.)	S Found % (cal.)	M Found % (cal.)
1.	$C_{46}H_{34}N_{12}O_6S_2$	60.33 59.60)(	3.71 3.68)(	18.36 18.30)(	6.99 6.94)(	— —
2.	$[Co(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	55.76 55.66)(	3.23 3.52)(	16.97 16.68)(	6.42 (5.74)	5.95)5.50(
3.	$[Ni(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	55.77 55.98) (	3.23 2.99)(	16.97 16.87)(	6.46 (6.80)	5.93)5.45(
4.	$[Cu(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	55.50 55.24)(	3.21 3.56)(	16.89 16.77)(	6.43 6.84)(	6.38)5.98(

Magnetic measurements

- Co (II) complex explains magnetic moment μeff. (4.59 B.M) based on 3 unpaired electrons. This magnitude proposes an octahedral environment nearby the Co (II) ion [22].
- Ni (II) complex explains magnetic moment μeff. (3.31 B.M) under room temperature based on dual unpaired electrons. This magnitude refers to the octahedral geometry nearby the Ni (II) ion [24].
- The magnetic moment value μeff. of Cu (II)[25] complex (1.81 B.M) that may indicates the octahedral geometry. The magnetic moment μeff. were showed in table (4)

Conductivity measurements

All soluble complexes have given molar conductivity magnitudes at range (13.8 – 17.5) $S.cm^2.\ mol^{-1}$in ETOH solvent in $10^{-3}M$ under room temperature, These magnitudes specify lower conductivity .and Non-ionic structure (1:1) of these complexes [1,2].The conductivity magnitudes have been given in table 4.

Table 4
Molar Conductivity and Magnetic moment μeff. of Chelate complexes

Complexes	Molar Conductivity ($S.cm^2.mol^{-1}$)	μeff. (B.M)
$[Co(C_{46}H_{32}N_{12}O_6S_2)].\ H_2O$	13.8	4.59
$[Ni(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	16.1	3.31
$[Cu(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	17.5	1.81

FTIR spectral data

The FTIR spectral data of Azo-Schiff base ligand and its complexes (Figure 6,7) have been in Table 5. The FTIR spectrums of the complexes have compared with a free ligand for determining the coordination sites that are possibly involved in chelation. When a comparison was made between the spectrum of the new Azo-Schiff base ligand and its metallic complexes under study, it was found that the spectrum of the new Azo-Schiff base ligand showed a medium-strength stretching band appeared at the 3550 Cm^{-1} due to the vibration frequency of the hydroxyl group v (O-H) belonging to the aminophenol ring of the prepared ligand (121). The spectrums of the metal complexes also have indicated a disappearance of the (OH) v elastic band in the complex spectra due to the bonding of the hydroxyl group with the metallic ions after losing their proton. The of ligand and its metallic complexes showed a weak-intensity stretch band at frequencies between (3037-3099cm^{-1}), which was attributed to the stretching vibrations of the aromatic v (C = H) pinch (126). Its metallic complexes have a variable intensity stretch beam starting at the frequency of 1600 cm^{-1} and ending at 1667 cm^{-1} as related to the stretching vibrations of v (C = N) of pyrimidine ring. A strong to medium intensity stretch band appeared at the frequency 1641cm^{-1}, which was attributed to the stretching vibrations of the imine v (C = N). This band suffered a change in the shape, intensity and position in the spectra of the metallic complexes, indicating the occurrence of the coordination process between the pair of the electron atom of the nitrogen in a group of azomethine with the metal ions, which will reduce the electronic density on the nitrogen atom and thus lead to a reduction of the bond order between the carbon and nitrogen atoms of the azomethine group[20-24].

The azo-imine ligand spectrum and its metallic complexes showed a variable stretch band from acute to weak at times at the frequencies (1492-1593) cm^{-1} belonging to the v (C = C) aromatic spectrum (128) The spectrum of the new ligand showed a stretching band at the frequency 1438 cm^{-1}, which was attributed to the stretching vibrations of the v (N = N) of an azo group that suffered a change in the shape, intensity, or location of the spectra of the metallic

complexes towards lower frequencies (1440-1446) cm^{-1}, which clearly indicates the participation of the nitrogen atom in this group. In the coordination process. Likewise, the spectra of the metallic complexes showed new absorbance of weak intensity, and at low frequencies (551-486) cm^{-1} and (468-426)cm^{-1} without the spectrum of ligand, these bands were attributed to the vibration frequencies of the bonds v (M – N) and v (M – O), respectively[24]. A ligand acts as a tridentate ligand based on the metal ions via nitrogen atom of azo group and nitrogen atom of imine group .as showed in Figer2 and 3.

Table 5
Characteristic FTIR absorption bands of the ligand (2HDPS) besides its complexes in cm^{-1} units

Compound	υ(NH) Sulfone. cm^{-1}	υ(C-H) Aro.. cm^{-1}	υ(N=N). cm^{-1}	υ(C=N) cm	υ(M—N) cm^{-1}	υ(M—O) cm^{-1}
$C_{16}H_{14}N_6O_3S$	3255	3099-3037	1438	-------	-------	-------
$H_2L = C_{46}H_{34}N_{12}O_6S_2$	3381	3064-3034	1446	1641	……	…….
$[Co(L)].H_2O$	3381	3066-3041	1442	1627	522-486	426
$[Ni(L)].H_2O$	3383		1442	1587-1525	551-516	457
$[Cu(L)].H_2O$	3377	3099-3066	1440	1589	520	462

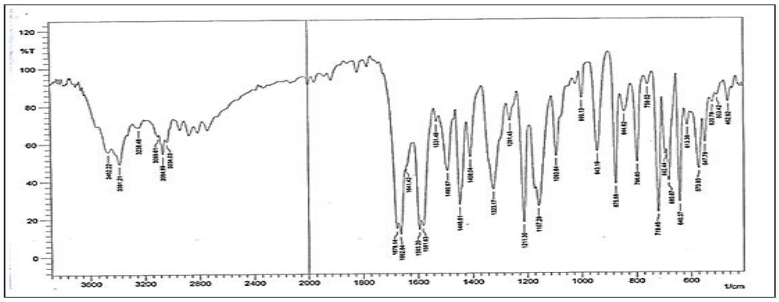


Figure 6. IR spectrum for ligand (2HDPS)

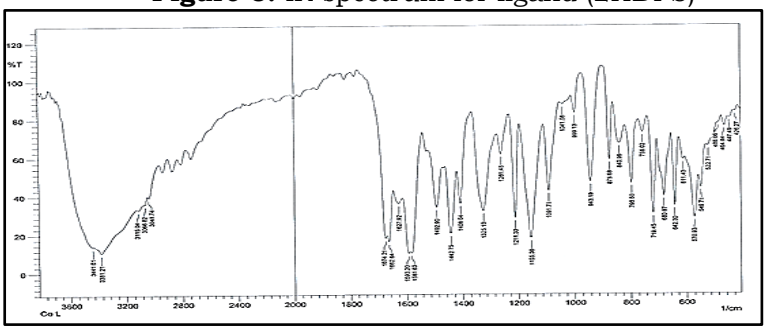


Figure 7. IR spectrum for ion complex of Co(II) with the ligand (2HDPS)

Suggested Structure

According to Mass spectrum,[1]HNMR ,FTIR and UV-Vis. spectra as well as elemental microanalysis , molar Conductivity , magnetic moment for the ligand (4ADSP), Co(II) ,Ni(II) and Cu(II) complexes , we propose that a ligand acts as Hexadentate on Complexation with metal ions via the nitrogen atom of two azo groups and nitrogen atoms of two imine groups and oxygen atom of two hydroxyl groups with Molar ratio M:L was 1:1 for each complexes . According to these results, all complexes had octahedral geometry as given in Figure (7).

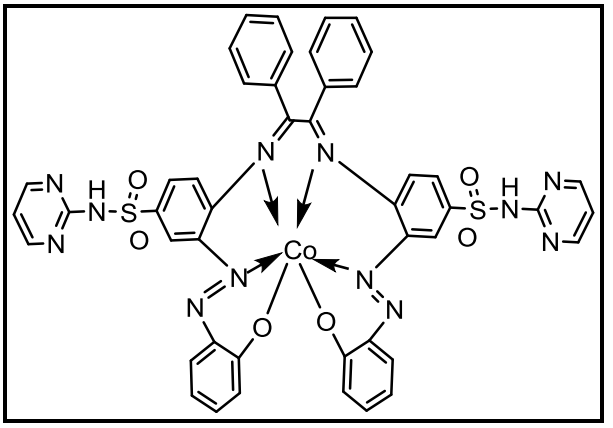


Figure 8. The proposed structure of Co (II) with Azo-Schiff base ligand (4HDPS)

Toxicological Studies

Heterocyclic compounds (Azo-Shiff) are pharmacologically active compounds that have proven their great importance in recent years, so they have been used in the field of pharmacy and agriculture (27). In its chemical structure, the sulfadiazine compound, which contains active groups as well as the azo bridge group (N=N) and azomethine =N-)CH) (28), then compared the results obtained with Hamazin in inhibiting selected organisms (bacteria) when conducting Laboratory experiments of two different types of bacteria, one of which is gram-positive (G+) it is Staph.aureus, while the other is gram-negative (Escherichia coli) (G-). By studying the bacterial activity using the diffusion hole method (29), using the following concentrations (100, 500 and 1000) ppm in a solvent (99%) Ethanol Absolute under the same conditions, most of the prepared compounds showed high or medium to weak positive results while The other is ineffective.

Depending on the results of comparing the average diameter of the inhibition bands of the new Lycand Azo-Shif (4HDPS) and complexes with absolute ethanol at a concentration of 99% and 1gm of the medicinal drug (Hamazin), the results showed that the effect of Gram-positive bacteria at a concentration of ppm (1000) for each of the complexes of copper(II), cobalt (II)and cadmium(II) The inhibition values were lower than the ligand, while the remaining complexes (nickel(II), zinc(II) and mercury(II)) recorded lower inhibition values, while at the concentration of ppm (500) the cadmium (II)complex recorded a higher rate of

inhibition beam diameter than the ligand. While the zinc(II) complex recorded a similar value to it, the complexes (copper(II), cobalt(II), nickel(II) and mercury(II)) remained lower inhibition values. In the concentration of ppm (100), the copper(II) complex recorded an average diameter of the inhibition bands higher than the ligand, while the two complexes (nickel and zinc) recorded a similar value, and the complexes (cobalt, cadmium and mercury) recorded values of inhibition less than the ligand, and accordingly the results were higher than the negative bacteria For the gram stain that recorded a higher mean diameter of inhibition bands for all complexes than the ligand for all groups (30).

The reason for this is due to the presence of a double membrane surrounding each bacterial cell. Gram-negative bacteria are characterized by having an outer membrane as well as an inner membrane that consists of two layers, one of protein lipids and the other of lipids combined with polysaccharides, and this makes the cell of negative bacteria possess a unique cell wall Of its kind, it excludes the antibiotic or chemotherapeutic substance from penetrating the bacterial cell. As for gram-positive bacteria, their cell wall consists of a thick mucopeptides layer composed of amino acids with monosaccharides, so they are less resistant to drugs and to antibiotics. (31). The explanation of the behavior of metal complexes is attributed to the lipophilic nature of those metal complexes, and chelation will facilitate the process of crossing the cell membrane of complexes (32). It also shows that the complexes possess anti-microbial activity that can inhibit these organisms and stop their growth by impeding their active sites (33), and the increase in the inhibitory ability of metal complexes compared to the free ligand can be explained according to Tweedy's theory of chelation (Tweedy, s theaory of chelation and Overtone,s concept) (34).

As a result of the delocalization of the charge, it will enhance the lipophilic nature of these complexes, and then increase the ease of passage of these complexes to the lipid membranes of the cell, which hinders the connection of the metal to the active site of the microbes. Only in fats that make them fat soluble, and this is an important factor in controlling antimicrobial agents, Therefore, the processes that occur will lead to making these compounds lipophilic and thus will increase their permeability to the fatty membranes, which will hinder the binding of the compound to the active sites in the enzymes of the microbes, which will affect the compound itself, which in turn will affect the process of cellular respiration and thus will hinder the process of cellular respiration. Protein synthesis and thus inhibiting the growth and destruction of those microbes (35).

Table 6
The inhibition zones of the new ligand (4HDPS) and their metal complexes at a concentration of (1000, 500, 100) ppm for the bacteria under study.

Compound	**(+) G** At 1000 ppm	**(-) G** At 1000 ppm	**(+) G** At 1000 ppm	**(-) G** At 1000 ppm	**(+) G** At 1000 ppm	**(-) G** At 1000 ppm
$C_{46}H_{34}N_{12}O_6S_2$	25	12	24	11	13	10
$[Co(C_{46}H_{32}N_{12}O_6S_2)].\ H_2O$	31	14	14	13	12	12
$[Ni(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	14	13	14	12	13	12

$[Cu(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	34	14	23	14	14	13
$[Zn(C_{46}H_{32}N_{12}O_6S_2)].H_2O$	24	18	24	14	13	12
$[Cd(C_{46}H_{34}N_{12}O_6S_2)Cl_2].H_2O$	26	18	25	15	12	12
$[Hg(C_{46}H_{34}N_{12}O_6S_2)Cl_2].H_2O$	14	13	14	12	12	12

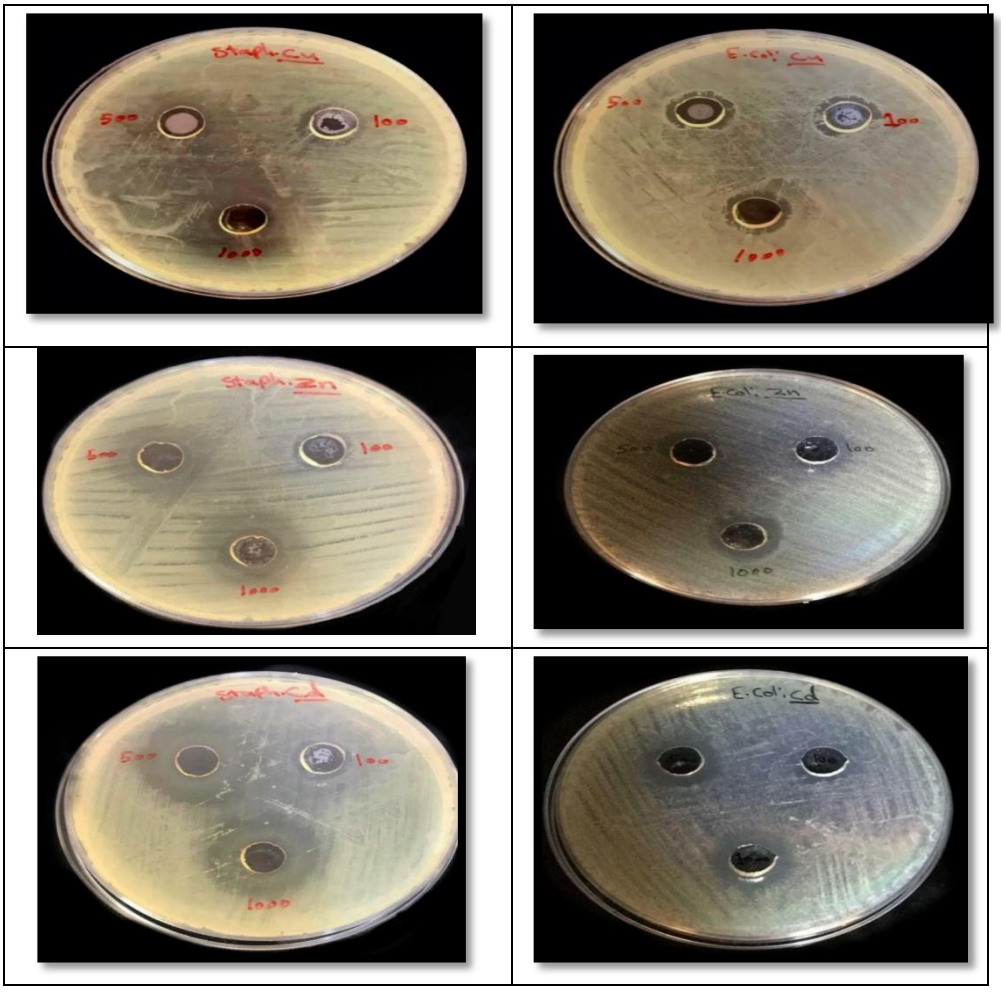


Figure 9. Biological activity of the new Azo-Schiff base ligand (4HDPS) and its metal complexes against Gram-negative and Gram-positive bacteria

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