

Synthesis, Spectroscopic Study and Biological Activity of new Bidentate Schiff Base (4-(Dimethylamino) Benzylidene)-5-(3,4,5-Trimethoxybenzyl)-5 Pyrimidine-2,4-Diamine) and Transition Metal Mn(II), Ni(II) and Cu(II) Complexes

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ABSTRACT

The Schiff bases ligand (L₁) was synthesized by condensing (2,4-diamine (Trimethoxybenzyl 3,4,5)-5 pyrimidine) and (4-dimethylamino benzaldehyde). The transition metal complexes of [Mn(L₁)₂Cl₂], [Ni(L₁)₂Cl₂], and [Cu (L₁)₂Cl₂] were then produced. The ligand and its metal complexes Mn(II), Ni(II), and Cu(II) were examined by analyzing the elemental composition, the metal content, the chloride content, and the molar conductance, FT-IR, ¹H-NMR, UV-Vis spectra, magnetic susceptibility, mass spectra, and thermal analysis (TGA). The results indicated that the ligand behaves as a bidentate ligand in all of the complexes produced. The [Cu (L₁)₂Cl₂] complex is more poisonous to microorganisms.

Keywords: Ligand field, Schiff bases, Mass spectra, Charge transfer (C.T).

INTRODUCTION

Trimethoprim, chemical formula (C₁₄H₁₉N₄O₃), systematically named as (2,4-diamine (Trimethoxybenzyl 3, 4,5)-5 pyrimidine), its white to yellowish compound with bitter taste, it contains two components: 3,4,5-trimethoxytoluene and 2,4-diamino-5-methylpyrimidine. It is a dihydrofolate reductase inhibitor, which is a class of chemotherapeutic medicines. It is useful in the treatment of prevention and urinary tract infections [1]. Aroylhydrazones can operate as N4 chelators, forming redox-efficient complexes that cause reactive oxygen species generation, inhibit metalloproteins, interact with DNA, and alter intracellular homeostasis [2]. Trimethoprim and its derivatives are antimicrobials with antiparasitic action that were discovered by Roth and coworkers [3]. Due to their anticancer, antibacterial, antiviral, and antifungal activities, due to the presence of the –C=N– group, Schiff bases are often referred to as azomethine. They serve a key function in biological systems. They have also been extensively used as ligands in coordination chemistry due to their superior donor properties as chelating agents [3-7]. Additionally, Schiff bases are widely used as catalysts and photochromic sensors in a variety of fields of life sciences [8]. Due to their stability, ease of modification, and huge biological characteristics, Schiff base-transition metal complexes have garnered considerable attention in recent years [9, 10].

In this respect, The Schiff base ligand was produced and characterized by a series of reactions (2,4-diamine (Trimethoxybenzyl 3,4,5)-5 pyrimidine) with (4-dimethylamino benzaldehyde) and their metal complexes.

Experimental

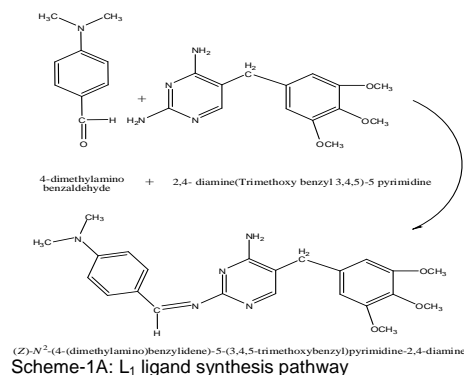
Materials and measurements: All chemicals and reagents were obtained commercially (Sigma-Aldrich, Merck, etc.) and used unpurified. The ¹H-NMR spectra were acquired using the following techniques: Bruker On Eurovector EA 3000A, Al al-Bayt University, Ultra Sheild 300 MHz NMR and elemental microanalysis (C.H.N) were done (Jordan). The metal ion content was determined gravimetrically as metal oxides. Conductometer WTW was used to measure the molar conductance of metal complexes of the ligand at a concentration of 1x10⁻³M. Magnetic measurements were made at 25 °C, England, by the Johnson mattey catalytic system division of balance. UV-Vis spectra were examined using a Shimadzu UV-1800 spectrophotometer. using a quartz cell 1.0 cm from the wavelength range (200-1100 nm). SHIMADZU FT-IR 8400S was used to acquire Fourier Transform Infrared (FT-IR) spectra. Fourier transformations in the wavenumber range 4000 to 200 cm⁻¹ using KBr and CsI discs, Department of Chemistry, College of Science, University of Baghdad. The mass spectra were acquired on the GC MS –QP 2010 VLTRA instrument at the Department of Chemistry, College of Science, AL- Mustansiriyah University. Thermo gravimetric analyses were carried out experimentally using Perkin-Elmer Pyris Diamond TG. All

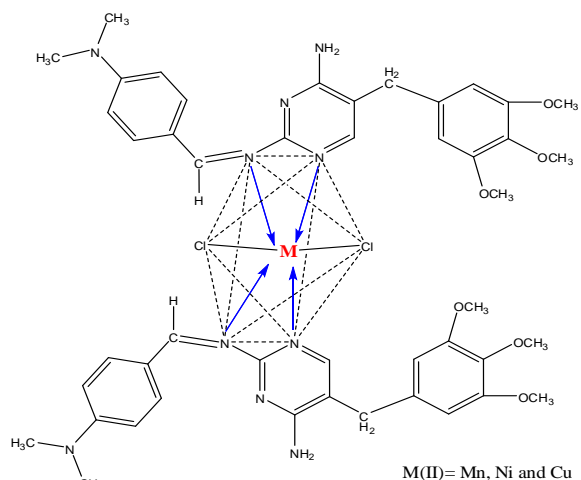
experiments were conducted in a single crucible with a flow rate of 100C/min and a temperature range of 25-700oC. Biological activities of selected samples were determined using the agar diffusion method developed by the Ministry of Science and Technology.

Synthesis of ligand (L₁): 4-(dimethylamino)benzylidene)-5-(3,4,5-trimethoxybenzyl)-5 pyrimidine-2,4-diamine: This ligand was synthesized by reacting (3.5 mmol, 1 g) (2,4-diamine (Trimethoxybenzyl 3,4,5)-5 pyrimidine) and (3.5 mmol, 0.5 g) (4-dimethylamino benzaldehyde) in a 30 ml pure alcoholic medium with the addition of 5 drops of acetic acid glacial. The mixture was then refluxed for 8 hours to precipitate the product The product was ethanol crystallized –ether (1:1), collected, and dried in vacuum over anhydrous CaCl₂. The melting point of the ligand is determined to be (228-230 oC), the molecular weight is (421.49 g mol⁻¹), and the yield is 76 percent. (Scheme-1.a) The ligand's synthesis pathway. The ¹HNMR spectrum of ligand L₁ in DMSO-d₆ is shown in (Figure -1). The spectrum displayed a peaks observed at δ (2.328-2.882) ppm was assigned to solvent DMSO, peaks observed at δ (3.235) (2H) s , (CH₂), δ (3.535-4.216) (9H) m, (OCH₃), δ (4.330-4.599) (6H) t , (N-CH₃), δ (6.646-7.412) (7H) m arom , δ(8.292) (2H) s, (NH₂), 9.195 (1H) s azomethine group (N=C-H) [3,4,5].

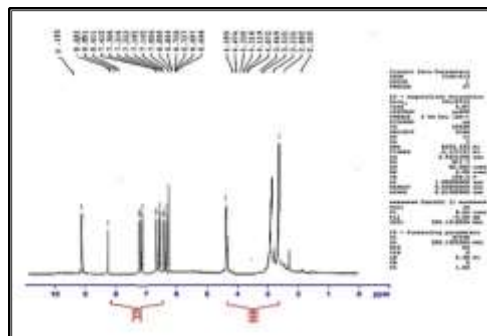
Procedures for the production of metal complexes in general:

It was prepared by dissolving Schiff base ligand L₁ an ethanolic solution (2mol) (30 ml) in around beaker, then, added (NaOH + water) with stirring after that added metal salt (1mol) that dissolve in ethanol– water (1:1) (20 ml). The combination was heated for 4 hours while stirring, the precipitate and solution were filtered, the product was ethanol was used to clean the crystals, and they were recrystallized in ethanol and diethyl ether. The product was collected and dried in vacuum over anhydrous CaCl₂. (Scheme-1.b) Metal complexes with proposed structures.





Scheme -1B: Structures of metal complexes that have been proposed


 Figure 1: ¹H-NMR spectrum of ligand L₁

RESULTS AND DISCUSSIONS

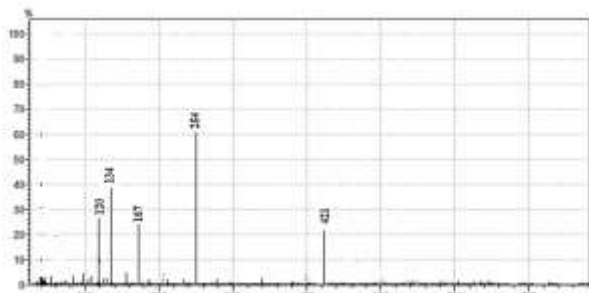
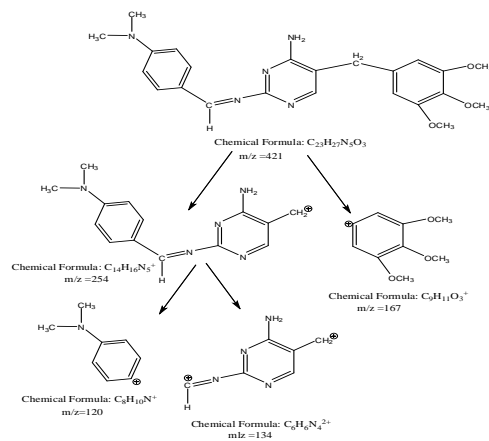
The bi-identical complexes were synthesized by reacting metal ions in a 1:2 molar ratio with a Schiff base (metal:ligand). The stiff composite base Schiff ligands and complexes are extremely stable at room temperature. Additionally, there are physicochemical data given in (Table 1).

 Table 1: The elements' results of rigorous research and certain physical features of the L₁ bond and their metal complexes

Compound	Formula	M.wt	Elemental Analysis Cal (Found)%				
			C	H	N	M	Cl
L ₁	C ₂₃ H ₂₇ N ₅ O ₃	421.49	(65.12) 65.54	(6.33) 6.46	(17.30) 16.62	-	-
[Mn (L ₁) ₂ Cl ₂]	C ₄₆ H ₅₄ N ₁₀ O ₆ MnCl ₂	967.13	(56.48) 57.07	(5.10) 5.58	(13.94) 14.47	(5.60) 5.67	(7.11) 7.32
[Ni (L ₁) ₂ Cl ₂]	C ₄₆ H ₅₄ N ₁₀ O ₆ NiCl ₂	970.89	(57.44) 56.85	(5.28) 5.56	(14.10) 14.41	(5.83) 6.04	(7.20) 7.29
[Cu (L ₁) ₂ Cl ₂]	C ₄₆ H ₅₄ N ₁₀ O ₆ CuCl ₂	975.74	(54.93) 56.57	(5.21) 5.53	(14.45) 14.34	(6.33) 6.51	(7.03) 7.25

Mass spectrum: Mass spectra of the new ligand were obtained using electron impact of fragmentation [11, 12].

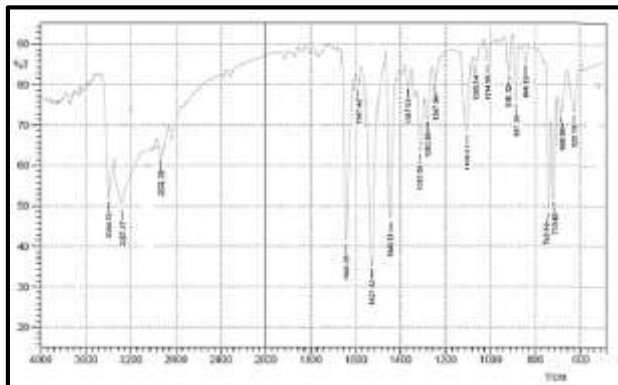
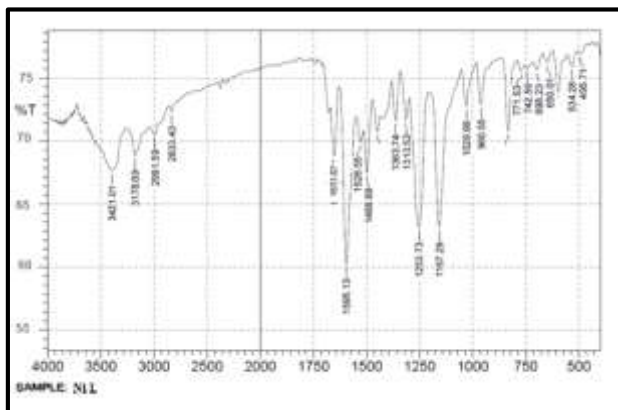
In Figure 1, The effect of the electron effect on the mass spectrometry of the L₁ ligand is depicted (Figure -2). This ligand has an estimated molecular weight of (421.49) g/mol. The spectrum revealed a peak at (421) m/z corresponding to the Schiff base moiety [C₂₃H₂₇N₅O₃], which was attributed to [M]⁺. Other distinctive peaks at (254, 167, 134, and 120) m/z may correspond to other pieces. Their intensity conveys information about the shards' stability. The proposed paths for fragmentation and the structural assignments of fragments are outlined in (Scheme -2).


 Figure 2: The mass spectrum of the L₁ ligand as determined by LC.

 Scheme 2: L₁ ligand fragmentation pattern

Infrared analysis: The FT-IR spectra of the ligand L₁ and the complex Ni(II)L₁ is shown in (Figures -3,4). The linker (L₁) and its mineral complexes absorbance bands are summarized in (Table-2). All compounds' infrared spectra revealed associative bands with proper transitions according to their complex architecture. These findings suggest that ligand L₁ couples with the metal ion via the azomethine nitrogen groups and the nitrogen pyrimidine ring, which functions as a double bond [11, 13-18].

 Table 2: The ligand (L₁) and its metal complexes infrared spectral data

Sym.	v(NH ₂)	v(C-H) Arom.	v(C-H) aliph.	v(C=N) azomethine	v(C=C) Arom.	v(C=N) Pyrimidine	v (M-N)	v (M-Cl)
L ₁	3394.72	3257.17	2932.09	1634.35	1446.61	1527.62	-	-
Mn L ₁	3452.17	3045.22	2954.56	1649.33	1459.81	1577.32	546.12	478.64
Ni L ₁	3421.01	3178.68	2991.59	1651.07	1498.68	1595.13	534.28	495.71
Cu L ₁	3413.47	3073.43	2973.46	1653.51	1477.65	1568.41	525.01	453.63

Figure 3: FT-IR Spectrum of ligand L₁Figure 4: FT-IR Spectrum of [Ni(L₁)₂Cl₂] complex

Electronic spectra and magnetic moments studies: The UV-V spectra of ligand L₁ and its compounds provide insight into the (Table-3) Demonstrate a tape with a high density for optimal absorption at λ 270 nm (ν_{\max} 37037.0 cm⁻¹, ϵ_{\max} 2355 L.mol⁻¹.cm⁻¹) attributed to the $\pi \rightarrow \pi^*$ transition, and peak at λ 355 nm (ν_{\max} 28169.0 cm⁻¹, ϵ_{\max} 1735 L.mol⁻¹.cm⁻¹) attributed to the $n \rightarrow \pi^*$ transition, in this case, the azomethine group may be assigned to the $n \rightarrow \pi^*$ transition. The shift of this band in the complexes' spectra revealed that the nitrogen was coordinated to the metal atom.

Manganese(II) complex: At ambient temperature, the Mn(II) complex has a magnetic moment of 5.02 BM, which corresponds to the five unpaired electrons. Four absorption peaks were seen in the electronic spectra of the Mn L₁ complex. The two peaks at (282, 345) and (C. T), respectively, are attributed to the ligand field and (C. T), respectively. The final two peaks at (520, 710) nm are attributed to (d-d)electronic transitions, which provide strong support for Octahedral geometry.

Nickel (II) complex: Five absorption peaks are visible in the absorption spectrum of Ni(II) complexes, The two peaks at (275, 332) nm attributed to the ligand field and (C. T), the three d-d transition bands at (36383.6, 30120.4, 21276.5, 16949.1 and 15037.5 cm⁻¹ which correspond to ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(P)$, ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$ and ${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)$. Magnetic moments of Ni (II) complexes were determined to be 2.85 BM, consistent with a deformed octahedral structure with d8 high spin.

Copper (II) complex: The absorption spectra of Cu(II) complex display three absorption peaks, The two peaks at (285, 340) nm attributed to the ligand field and (C. T), the last peak attributed to d-d transition ${}^2E_g \rightarrow {}^2T_{2g}$. Cu(II) complexes were discovered to have magnetic moments of 1.82 BM, indicating an octahedral shape. While the low conductivity values indicated that the complexes were not electrolytes, they also indicated that the chloride ion remained coordinated to the metal ion [19-24].

Table 3: Electronic Spectral Data on Metal Complexes including (L₁) Ligand, Molar Conductivity in (DMSO 10-3M), and Magnetic Moments

Complex Geometry	λ_{\max} (nm)	ν cm ⁻¹	ABS	ϵ_{\max} L mol ⁻¹ cm ⁻¹	Assignment	Δ_m cm ² Ω ⁻¹ mol ⁻¹	μ_{eff} B.M
L ₁	270 355	37037.0 28169.0	2.355 1.735	2355 1735	$\pi \rightarrow \pi^*$ $n \rightarrow \pi^*$	-	-
[Mn(L ₁) ₂ Cl ₂] Oh	282 345 520 710	35460.9 28985.5 19230.7 14084.5	1.853 2.435 0.875 0.533	1853 2435 875 533	L.F C.T ${}^6A_{1g} \rightarrow {}^4T_{2g}(G)$ ${}^6A_{1g} \rightarrow {}^4T_{2g}(F)$	12.08	5.02
[Ni (L ₁) ₂ Cl ₂] Oh	275 332 470 590 665	36383.6 30120.4 21276.5 16949.1 15037.5	1.805 2.107 0.932 0.455 0.123	1805 2107 932 455 123	L.F C.T ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(P)$ ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$ ${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)$	10.50	2.85
[Cu(L ₁) ₂ Cl ₂] Oh	285 340 495	35087.7 29411.7 20232.2	1.745 2.082 0.627	1745 2082 627	L.F C.T ${}^2E_g \rightarrow {}^2T_{2g}$	19.10	1.82

Oh= Octahedral

Table 4: Thermal decomposition of ligand L₁ and their [Cu(L₁)₂Cl₂] complex

Comp.	Thermogra-vimetric range (°C)	DTG max(°C)	% Estimated (calculated)		Assignment
			Mass loss	Total Mass loss	
ligand L ₁	40-110	100.265	6.1081 (7.3548)	83.7426	OCH ₃
	110-430	392.662	31.7361 (32.2664)	(85.6483)	2OCH ₃ + C ₆ H ₂
	430-600	594.884	45.8984 (46.0271) 16.2580 (15.2352)		C ₉ H ₁₆ N ₅ Residue C ₅
[Cu(L ₁) ₂ Cl ₂]	75-230 230-600	215.666 594.549	15.541 (15.8853) 73.8985 (73.4826) 10.5605 (10.6073)	89.4395 (89.3679)	5OCH ₃ C ₃₉ H ₃₈ N ₁₀ Cl ₂ Residue CuO + C ₂

Thermal Analysis Data: The thermal decomposition of ligand L₁ and its complex [Cu(L₁)₂Cl₂] using TG and DTG is discussed in

depth in (Table-4) (Figs-5-6). To gain a better understanding of the thermal decomposition process, the Schiff ligand L₁ base and its

mineral complex were investigated using thermogravimetric analysis at temperatures ranging from 35 to 700 degrees Celsius at a heating rate of 10 degrees Celsius per minute in a nitrogen atmosphere. The thermograms were used to compute the complexes' breakdown phases, they demonstrated agreement in weight loss between the amounts received via heat. [25,26].

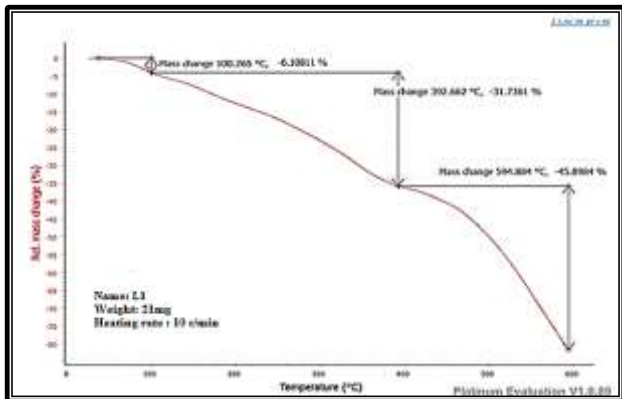


Figure 5: TG ligand thermogravimetric analysis (L₁)

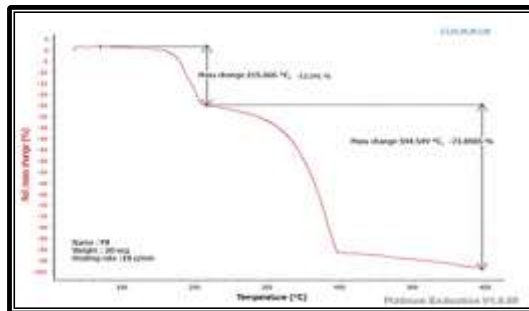


Figure 6: TG thermo gravimetric of [Cu(L₁)₂Cl₂]

Antibacterial Activates: The nutrient agar plates were prepared and incubated overnight at 37 °C to check for bacterial contamination. The bacterial suspension was grown in nutrient agar at 37°C. Then each compound spotted on the nutrient media followed by incubation for 18h at 37°C. Then inhibition zone diameters (mm) were measured for each product relate to the blank solvent DDW. The results indicate that the complexes are more hazardous to bacteria than the free ligand. This is consistent with the tweeds chelation idea. Compounds' mode of action may entail the interaction of their (C=N), (CH₃), (OCH₃), and (NH₂) groups with the active centers of cell constituents, thereby interfering with normal cell processes [27-30]. Antibacterial activities of the ligand (L₁) and their metal complexes are explained in the (Table -5).

Table 5: The ligand (L₁) and its mineral complexes has antibacterial properties.

No.	Comp.	Inhibition Diameter (mm)			
		Escherichia coli	Streptococcus pneumonia	Pseudomonas aeruginosa	Staphylococcus aureus
1.	TRM	20 mm	25 mm	10 mm	18mm
2.	L ₁	32mm	30mm	8mm	37mm
3.	MnL ₁	35mm	30mm	9mm	35mm
4.	NiL ₁	32mm	28mm	8mm	33mm
5.	CuL ₁	36mm	40mm	14mm	38mm

CONCLUSION

This paper, new Mn(II), Ni(II) and Schiff base ligand (L₁) Cu(II) complexes (4-(dimethylamino)benzylidene)-5-(3,4,5-trimethoxybenzyl)-5 pyrimidine-2,4-diamine). Physicochemical and spectroscopic approaches were used to determine the bonding mode and The complexes' general structure. The spectroscopic investigation of In all complexes, the ligand L₁ is bidentate ligand and The azomethine nitrogen groups and the nitrogen pyrimidine ring coordinate metal ions. Based on UV-vis and FT-IR spectra, it was proposed that the geometry of all metal complexes is octahedral. The CuL₁ complex have more toxicity against the bacterial species than the free ligand. (Figure -7) The 3D chemical structures of the ligand L₁.

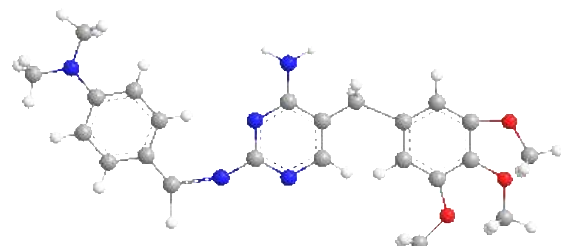


Figure 7: The 3D chemical structures of the ligand L₁

REFERENCES

- Al-Sahib SA. Preparation and identification of some a new derivative for Trimethoprim drug. Journal of university of Anbar for Pure science. 2009; 3(3).
- Zaidan BA, Majeed NM, Al-Shemary RK, Numan AT. Synthesis of some Schiff base metal complexes involving trimethoprim and 2'-amino-4-chlorobenzophenone: Spectral, thermal, DNA Cleavage antimicrobial, antifungal and Cytotoxic activity studies. Journal of Pharmaceutical Sciences and Research. 2019 Feb 1;11(2):618-26.
- Deepak KV, Gar GS. Synthesis, Spectral and Biological Studies of Some Salicylidene-Trimethoprim Schiff Base Complexes of Aryltellurium (IV). Chemical Science. 2017;6(3):437-47.
- Elgellal AA, Alshady AM. Preparation Characterization and Biological Evaluation of Schiff-Base of Some Drug Substances. Journal of Medical and Bioengineering Vol. 2014 Sep;3(3).
- Attia AM, Abdallah EK, Alzahawy HM. Synthesis and identification Of Four Membered Rings Heterocyclic Compounds Derived From Trimethoprim. kirkuk university journal for scientific studies. 2016;11(3).
- Al-Masoudi WA, Mohmmed AL, Abass WH, Al-Masoudi NA. Synthesis, antimicrobial activity and molecular modeling study of some new pyrimidine derivatives. European Journal of Chemistry. 2015 Jun 30;6(2):127-30.
- Somwanshi JL. Synthesis and characterization of Biologically Active Schiff Bases Derived from Trimethoprim. Journal of Global Biosciences. 2020;9(4):6963-73.
- Warad I, Ali O, Al Ali A, Jaradat NA, Hussein F, Abdallah L, Al-Zaqri N, Alsahme A, Alharthi FA. Synthesis and spectral Identification of three Schiff bases with a 2-(piperazin-1-yl)-N-(thiophen-2-yl methylene) ethanamine moiety acting as novel pancreatic lipase inhibitors: Thermal, DFT, antioxidant, antibacterial, and molecular docking investigations. Molecules. 2020 Jan;25(9):2253.
- Shalini AS, Amaladasan M, Prasannabalaji N, Revathi J, Muralitharan G. Synthesis, characterization and antimicrobial studies on 13-membered-N6-macrocyclic transition metal complexes containing trimethoprim. Arabian Journal of Chemistry. 2019 Nov 1;12(7):1176-85.
- Ndahi NP, Garba H, Waziri I, Osunlaja AA, Putaya HA. Complexes of Mn (II) and Fe (III) with Schiff bases Derived from Trimethoprim with Salicylaldehyde and Benzaldehyde as Potential Antimicrobial Agents.

- Nigerian Journal of Pharmaceutical and Biomedical Research. 2018 Apr;3(1).
- 11 Silverstein R. M , Webster E. X, Kiley D. J . Spectrometric identification of organic compounds 7th ed , John Wilye and SonsS. INC. 2005, 1-550.
- 12 Chen BH, Liu JT, Chen HM, Chen WX, Lin CH. Comparison of the characteristic mass fragmentations of phenethylamines and tryptamines by electron ionization gas chromatography mass spectrometry, electrospray and matrix-assisted laser desorption ionization mass spectrometry. Applied Sciences. 2018 Jul;8(7):1022
- 13 Prakash A , Adhikari D. Application of Schiff bases and their metal complexes-A Review. Int.J. ChemTech Res . 2011, 3(4)1891-1896.
- 14 Figgis BN. Ligand field theory. Comprehensive Coordination Chemistry. 1987;1:213-79.
- 15 Abu-Dief AM, Mohamed IM. A review on versatile applications of transition metal complexes incorporating Schiff bases. Beni-suef university journal of basic and applied sciences. 2015 Jun 1;4(2):119-33.
- 16 Aliyu H, Ado I. Studies of Mn (II) and Ni (II) complexes with Schiff base derived from 2-amino benzoic acid and salicylaldehyde. Bayero Journal of Pure and Applied Sciences. 2010;3(1).
- 17 Singh K, Thakur R, Kumar V .Co(II), Ni(II), Cu(II), and Zn(II) complexes derive from 4-[(3-(4-bromophenyl)-1-phenyl-1Hpyrazol- 4-ylmethylene)-amino]-3-mercapto-6-methyl-5-oxo-1,2,4-triazine. Journal of basic and applied sciences.2016;5:21–30.
- 18 Yousif E, Majeed A, Al-Sammarae K, Salih N, Salimon J, Abdullah B. Metal complexes of Schiff base: preparation, characterization and antibacterial activity. Arabian Journal of Chemistry. 2017 May 1;10:S1639-44.
- 19 Lever AB. Inorganic Electronic Spectroscopy .Elsevier Publishing Company, Amsterdam, Londen. 1968.
- 20 Lever AB. Electronic spectra of some transition metal complexes. Journal of Chemical Education. 1968 Nov;45(11):711.
- 21 Figgis BN. Introduction to ligand fields. Inter science publishers; 1966.
- 22 Jisha MJ, Sobana Raj C. Isac. Synthesis and characterization of Schiff base complexes of Cu (II), Ni (II), Co (II) complexes of Schiff base derived from furan 3-carboxaldehyde and 3-amino pyridine. International Journal of Scientific and Research Publications. 2017;7(10):10-19.
- 23 Gaikwad VK, Yadav UM. Metal Complexes of Schiff Bases. SRJIS.2016; 3: 2225-34.
- 24 Sani S, Hussain S.Y.A Convenient Method to Synthesis and Characterization of Ni(II) and Zn(II) Schiff Base Complexes. International Journal of Innovative Research & Development. 2017;6(12):1-6.
- 25 M. M. El-ajaily, A. M. Hamil, M. Abdalkarem and M.Himmet. Isolation and Spectroscopic Characterization of some Schiff Base Complexes. J. Biol. Chem. Chron. , 2016, 2(2), 01-07.
- 26 A. A. Alomari and M. M. Ibrahim. Synthesis and Thermogravimetric Behavior of Ni(II), Cu(II) and Zn(II) Complexes of Triazine-Salicyldamine Schiff Bases . Asian J. Adv. Basic Sci. 2015, 3(2), 20-25.
- 27 Yu H, Zhang W, Yu Q, Huang FP, Bian HD, Liang H. Ni (II) Complexes with Schiff base ligands: preparation, characterization, DNA/Protein Interaction and cytotoxicity studies. Molecules. 2017 Oct;22(10):1772.
- 28 Saranya J, Kirubavathy SJ, Chitra S, Zarrouk A, Kalpana K, Lavanya K, Ravikiran B. Tetradentate Schiff Base Complexes of Transition Metals for Antimicrobial Activity. Arabian Journal for Science and Engineering. 2020 Jun;45(6): 4683-95.
- 29 Tajudeen SS, Kannappan G. Schiff Base–Copper (II) Complexes: Synthesis, Spectral Studies and Anti-tubercular and Antimicrobial Activity. Indian Journal of Advances in Chemical Science. 2016;4(1):40-8.
- 30 Ismail AH, Al-Zaidi BH, Hasson MM. New Bidentate Schiff Base Complexes of Some Transition Ions: Preparation, Identification, With Studying the Antibacterial Behaviour. Biochem. Cell. Arch. 2019; 19(1):1629-35.