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Transition Metal Complexes with Tridentate Ligand: Preparation, Spectroscopic Characterization, Thermal Analysis and Structural Studies

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Abstract

New series of metal ions complexes have been prepared from the new ligand 1,5- Dimethyl-4- (5-oxohexan-2- ylideneamino) -2-phenyl- 1H-pyrazol-3 (2H)-one derived from 2,5-hexandione and 4-aminophenazone. Then, its V(IV), Ni(II), Cu(II), Pd(II), Re(V) and Pt(IV) complexes prepared. The compounds have been characterized by FT-IR, UV-Vis, mass and ^1H and ^{13}C -NMR spectra, TGA curve, magnetic moment, elemental microanalyses (C.H.N.O.), chloride containing, Atomic absorption and molar conductance. Hyper Chem-8 program has been used to predict structural geometries of compounds in gas phase, the heat of formation, (binding, total and electronic energy) and dipole moment at 298 K.

Key words: Schiff base Ligands, 2,5-Hexandione, Metal Complexes.

Introduction:

Schiff base derivatives attract a significant interest and occupy an important role in the development of coordination chemistry [1]. Moreover, Schiff base complexes containing transition metals have been studied in several research areas such as structural chemistry [2]. Metal complex with Schiff bases are important class of ligands due to their synthetic flexibility, selectivity and sensitivity towards the central metal atom, structural similarities with natural biological substances, and also, due to presence of azomethine group which imports in elucidating the mechanism of

transformation and racemisation reaction in biological system [3-4] also have been studied for their application in clinical, analytical and pharmacological areas [5]. In report herein the synthesis and spectroscopic studies as well as the thermal investigation of a novel Schiff base derivative ligand = 1, 5-Dimethyl-4-(5-oxohexan-2-ylideneamino)-2-phenyl-1H-pyrazol-3 (2H)-one with some transition metals such as Ni(II), VO(II), Cu(II), Pd(II), Re(V) and Pt(IV) complexes. (^1H , ^{13}C) NMR, FT.IR and Mass spectra were obtained to determine the structure of the ligand.

Materials and Methods:

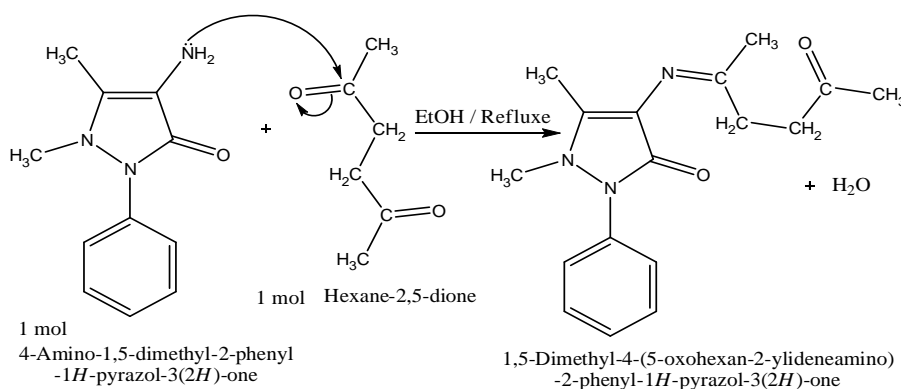
The following chemicals were commercially available products of analytical reagent grade. 2,5-hexanedione, 4-aminophenazone, DMSO, pure ethanol, methanol, CaCl_2 , $\text{VOSO}_4 \cdot \text{XH}_2\text{O}$, $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$, PdCl_2 , CuCl_2 , ReCl_5 and $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$ were obtained from Fluka, Aldrich.

(FT-IR) the spectra were recorded in the range (4000-400) cm^{-1} on a Shimadzu 3800, spectrometer. Electronic absorption spectra were recorded in the range (200-1100) nm on a Shimadzu 160 Spectrophotometer. Thermal analysis studies of the compounds were performed on Perkin-Elmer Pyris Diamond DTA/TG Thermal system under nitrogen atmosphere at a heating rate of $10^\circ\text{C}/\text{min}$. ^1H - ^{13}C NMR spectra were recorded using Bruker 400 MHz spectrometer and elemental (C.H.N.O) analyses were carried out on a Perkin-Elmer automatic equipment model 240.B. Mass spectra were obtained by LC-Mass 100P Shimadzu. Melting points were obtained on a Buchi

SMP-20 capillary melting point apparatus and are uncorrected. Metals were identified using a Shimadzu (A.A) 680 G atomic absorption Spectrometer. Conductivity measurements were made with DMSO solutions using a Jenway 4071 digital conductivity meter at room temperature, chlorine content. Magnetic properties were measured using (Balance magnetic susceptibility model MSR-MKi).

Synthesis of Ligand: 1, 5-Dimethyl-4-(5-oxohexan-2-ylideneamino)-2-phenyl-1H-pyrazol-3(2H)-one

A solution of 4-aminophenazone (1 g, 4.92 mmol) in absolute ethanol (25 ml) was mixed with a solution of 2,5 hexanedione (0.56g, 4.92mmol). The reaction was stirred and heated in water bath ($40\text{-}50^\circ\text{C}$) for four hrs. A colorless precipitated washed with diethyl ether. Recrystallization has been carried out in ethanol: water (1:1). The product was dried via anhydrous CaCl_2 in vacuum as shown in Scheme (1). The yield is (1.38g), 93.66%, mp. 179°C .



Scheme 1: Preparation of the Ligand

Synthesis of Complexes

A solution of the ligand (0.5 mmol) in methanol (15 ml), and methanol solution (10 ml) of the metal salt (0.5 mmol) ($\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$, CuCl_2 , ReCl_5 , $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$, PdCl_2 and $\text{VOSO}_4 \cdot \text{H}_2\text{O}$) was then added drop wise. The resulting mixture was refluxed 3-4 hrs, the solid mass which was washed

several times with hot ethanol and dried under vacuum. Physical properties for the compounds are given in Table (1).

Programs used in Theoretical Calculation

Hyper Chem-8 program is a sophisticated molecular modeler, editor and powerful computational package

that are known for its quality, flexibility and ease of use, uniting 2D visualization and animation with quantum chemical calculations, molecular mechanics and dynamic. (PM3) and (AMBER) are more popular than other semi-empirical methods due to the availability of algorithms and more accurate than with other methods. It has parameterized primarily for organic molecules and selected transition metals [6, 7].

Results and Discussion:

The UV spectrum for free ligand one peak in (282 nm) attributed to ($\pi \rightarrow \pi^*$), shown the Figure (1). The LC-Mass for ligand (299.3m/z) with ($C_{17}H_{21}N_3O_2$), (244.2 m/z) with ($C_{14}H_{18}N_3O$), (243.3 m/z) with ($C_{14}H_{17}N_3O$) and (144.2 m/z) with ($C_6H_{14}N_3O$). 1H -NMR (DMSO- d_6 , ppm): δ 2.044 (s,3H, N=C-CH₃), 2.147 (s,3H, O=C-CH₃), 3.11 (s, 3H, C=C-CH₃), 3.31 (s,3H, N-CH₃), 5.88 (tri, 4H, CH₂-CH₂), 7.282-7.513 (m, 5H, Ar-H) shown the Figure (2). ^{13}C -NMR (100.622 MHz, DMSO- d_6): δ 162.22 (C_{16}), 153.25 (C_{12}), 134.67 (C_4), 129 (C_2 , 6), 127 (C_8 , 10), 124.31 (C_9), 109.83 (C_{11}), 105.95(C_7), 77.25($C_{5,15}$), 76.93

(C_3), 50.41(C_{17}), 36.09 (C_4), 12.5 (C_{13}), 10.62 (C_1), shown the Figure (3,4).

Molar conductance values were found in the range (3 - 19) S. cm² mol⁻¹ for V(IV), Ni(II) and Cu(II) complexes which indicates that they are non-electrolytes, the range (44-45) S. cm². mol⁻¹ for Pd(II) and Pt(IV) complexes which indicates that they are electrolytes (1:1) and (70) S. cm². mol⁻¹ for Re(V) complex which indicate that the is electrolyte [1:2] [8-9]. These were determined in (DMSO) solution (10⁻³M). Physical properties and elemental microanalysis are listed in Table (1).

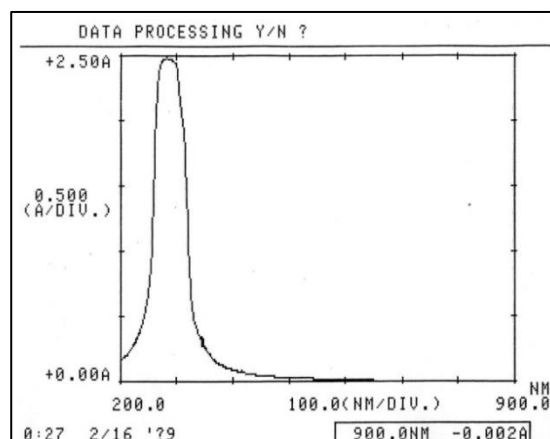


Fig. (1) UV-Vis Spectrum of Ligand

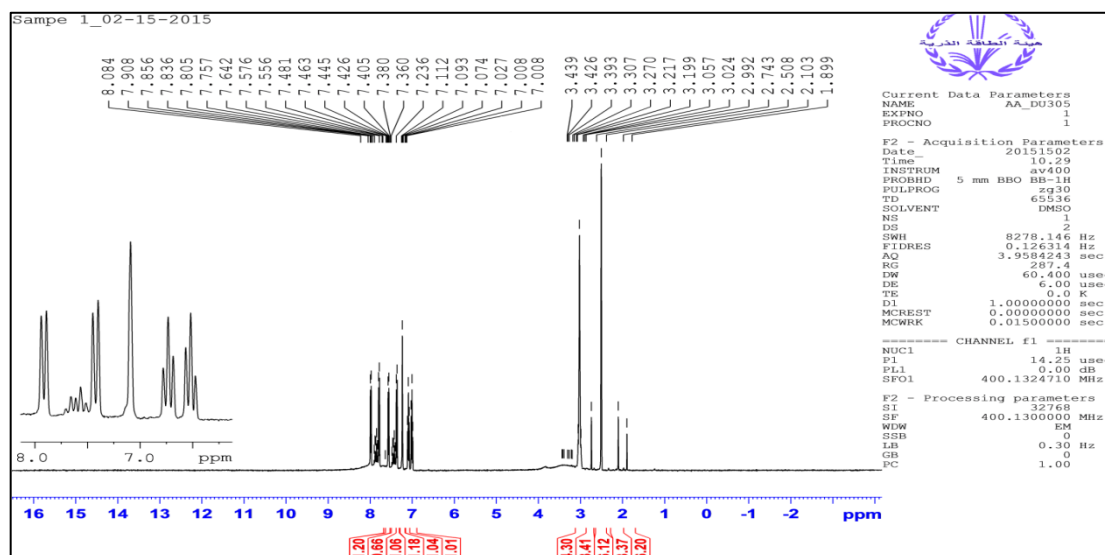


Fig. (2) 1H -NMR Spectrum of Ligand

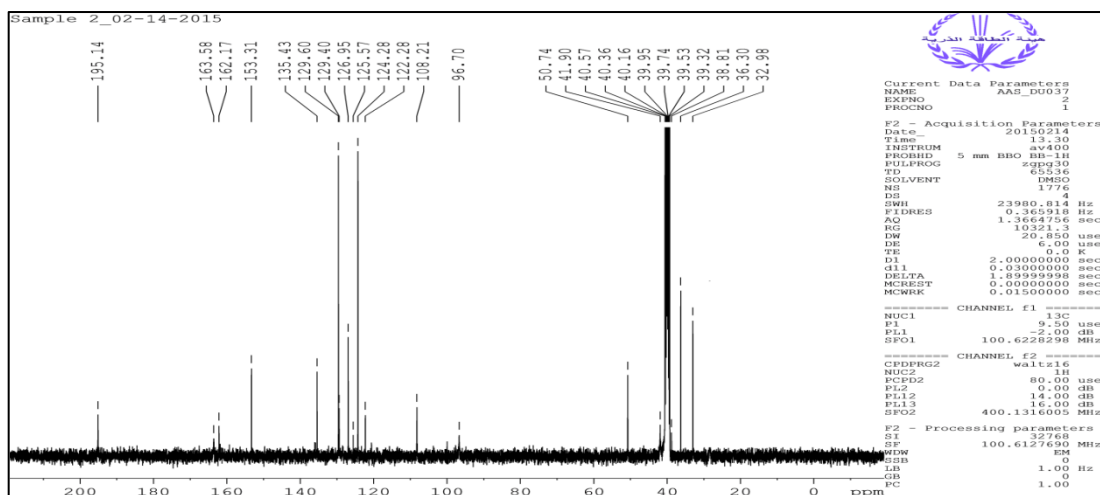


Fig. (3) ¹³C-NMR Spectrum of Ligand

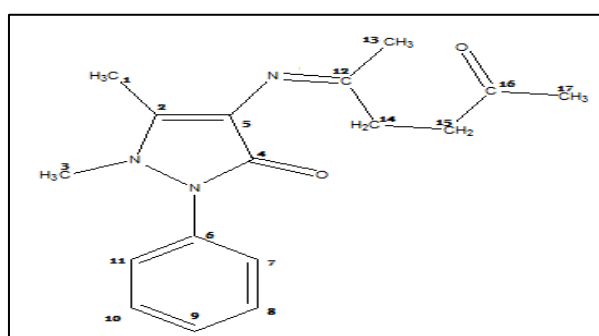


Fig. (4) Structure of Ligand

Table (1) Microanalysis results and some physical properties of the Ligand and its complexes

Sample Formula	M. wt. Yield%	Color m. p °C	Molar conductance S. cm ² . mol ⁻¹	Elemental Analysis % Calc					
				Experimental					
				C	H	N	O	M	Cl
L C ₁₇ H ₂₁ N ₃ O ₂	299.37 89	Colorless 179	-	68.20	7.07	14.04	10.69		
				67.76	6.83	15.56	11.12		
VL C ₁₇ H ₂₁ N ₃ O ₇ VS	462.37 86	Brown reddish 138-139	3	44.16	4.58	9.09	24.22	11.02	
				45.48	5.74	9.09	25.07	12.76	
NiL C ₁₇ H ₂₃ N ₃ O ₃ NiCl ₂	446.98 92	Brown reddish 285-286	13	45.68	5.19	9.40	10.74	13.13	15.86
				44.87	6.66	11.09	11.25	14.13	15.55
CuL C ₁₇ H ₂₃ N ₃ O ₃ CuCl ₂	451.83 93	Green 230-232	19	45.19	5.13	9.30	10.62	14.06	15.69
				46.09	6.87	10.09	11.23	15.35	14.43
PdL C ₁₇ H ₂₁ N ₃ O ₂ PdCl ₂	476.69 77	Dark brown 244-245	44	42.83	4.44	8.81	6.71	22.32	14.87
				40.97	5.31	10.02	7.76	22.34	14.66
ReL C ₁₇ H ₂₁ N ₃ O ₂ ReCl ₅	662.84 71	Dark brown 267- 268	70	30.80	3.19	6.34	4.83		26.74
				30.32	4.11	5.54	4.32		27.98
PtL C ₁₇ H ₂₁ N ₃ O ₂ PtCl ₄	636.26	Red brown 288-290	45	32.09	3.33	6.60	5.03	30.66	22.29
				33.12	4.03	7.09	4.65	31.22	21.54

Mass spectra for complexes

The main high resolution mass spectrometer values of the [PtL Cl₃]Cl and [ReL₁ Cl₃]Cl₂ complexes are shown in Figure (5) and Figure (6) respectively,

the molecular ion peak for the [PtL₁ Cl₃]Cl was observed at m/z = 636 (M) (relative abundance is 92%) for C₁₇H₂₁N₃O₂PtCl₄ which is in excellent agreement with the theoretical value and

the molecular ion peak for the $[\text{ReL}_1\text{Cl}_3]\text{Cl}_2$ was observed at $m/z = 663$ (M) (relative abundance is 90%) for $\text{C}_{17}\text{H}_{21}\text{N}_3\text{O}_2\text{ReCl}_5$ which is in excellent agreement with the theoretical value [10]. All these fragmentations can be shown in Table (2).

Table (2) The Fragmentation Pattern data for Complexes

complexes	Assignment	Peak m/z	Relative abundance%
$[\text{PtL}_1\text{Cl}_3]\text{Cl}$	$\text{M}=(\text{C}_{17}\text{H}_{21}\text{N}_3\text{O}_2\text{PtCl}_4)$	636	92
	$\text{M}-\text{PtCH}_2\text{Cl}_2=\text{M}_1$	355	73
	$\text{M}_1-\text{C}_{10}\text{H}_9\text{N}$	212	34
$[\text{ReL}_1\text{Cl}_3]\text{Cl}_2$	$\text{M}=\text{C}_{17}\text{H}_{21}\text{N}_3\text{O}_2\text{ReCl}_5$	663	90
	$\text{M}=\text{CH}_2\text{ReO}_2\text{Cl}_2=\text{M}_1$	355	71
	$\text{M}_1-\text{C}_9\text{H}_7\text{N}_2$	212	33

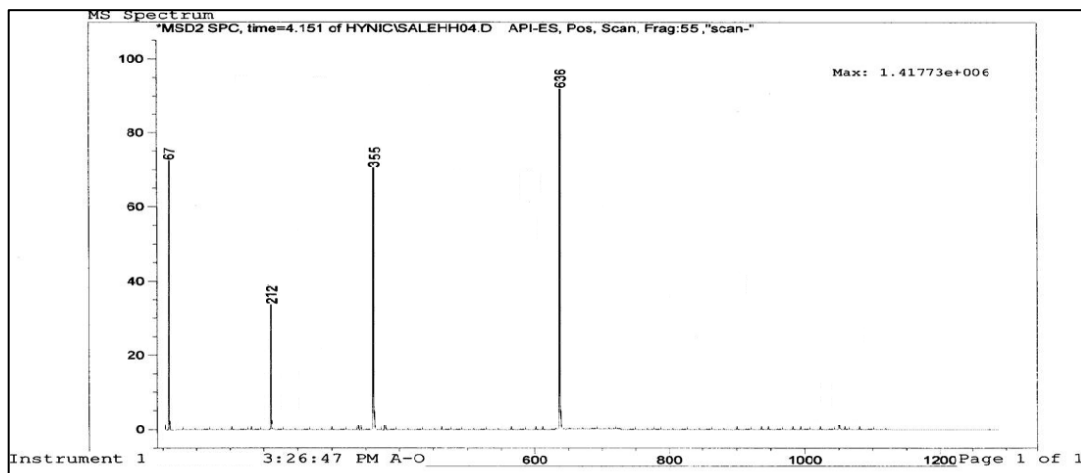


Fig. (5) LC-Mass Spectrum of $[\text{PtL}_1\text{Cl}_3]\text{Cl}$

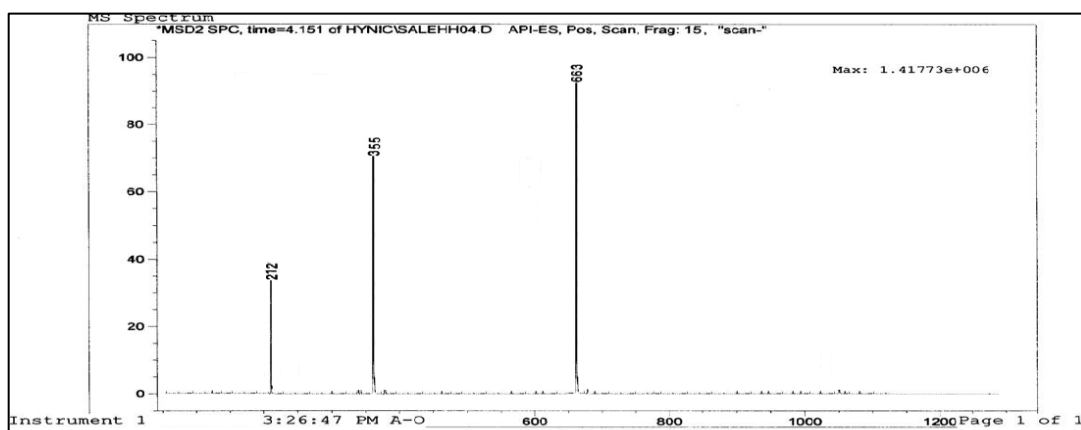


Fig. (6) LC-Mass Spectrum of $[\text{ReL}_1\text{Cl}_3]\text{Cl}_2$

IR spectra:

The bands IR of spectra of the ligand and its complexes were observed at 1740 , 1696 and 1640 cm^{-1} due to the $\nu(\text{C}=\text{O})$ ring pyrazol, $\nu(\text{C}=\text{O})$ and $\nu(\text{C}=\text{N})$ functional groups, respectively, [11]. The IR spectra of the complexes exhibited bands for the ligand bands with the appropriate shifts due complexes formation [12]. Moreover, the $\nu(\text{carbonyl})$ ring, $\nu(\text{carbonyl})$ and $\nu(\text{azomethine})$, bands of the ligand were observed at 1740 , 1696 and 1640 cm^{-1} and these bands were shifted to the lower frequencies by $(76-62)$, $(62-54)$

and $(20-16)\text{ cm}^{-1}$ respectively in the spectra of all complexes. This indicates that the ligand was coordinated with the metal ions through O, O carbonyl groups and N azomethine group atoms, but these shifts confirm the coordination of the ligand via the nitrogen of azomethine and the oxygen of carbonyl ring group to Vanadium ions. At lower frequency the complexes exhibited new bands around $(470-447)$, and $(432-413)\text{ cm}^{-1}$ assigned to the $\nu(\text{M}-\text{N})$ and $\nu(\text{M}-\text{O})$, respectively [13-15]. All these data are shown in Table (3).

Table (3) The Infrared Spectra Data of the free Ligand and its Metal Complexes in (cm⁻¹)

Comp.	$\nu\text{C}=\text{O}$ ring	$\nu\text{C}=\text{O}$	$\nu\text{C}=\text{N}$	$\nu\text{H}_2\text{O}$	$\nu\text{M}-\text{N}$	$\nu\text{M}-\text{O}$	Others bands
L	1740	1696	1640				
CuL	1664	1636	1622	3418 891	447	413	
NiL	1678	1642	1620	3410 883	451	424	
PdL	1678	1637	1624		467	420	
PtL	1675	1634	1624		465	424	
ReL	1673	1636	1624		467	420	
VOL	1678	1642	1624		470	432	999= $\nu(\text{V}=\text{O})$ 1103, 1084, 1022= $\nu(\text{SO}_4)$

UV-Vis Spectra, Magnetic Moments

The electronic spectrum of the ligand exhibit intense absorption at 282 nm attributed to $\pi \rightarrow \pi^*$. The electronic spectrum of Ni(II) complex showed three broad peaks at 434, 486 and 786 nm assigned to ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{1g}(\text{P})$, ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{1g}(\text{F})$ and ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{2g}(\text{F})$ [16] and the electronic spectrum of Re(V) complex showed three broad peaks at 489, 637 and other at 715 nm assigned to ${}^3\text{T}_{1g} \rightarrow {}^3\text{A}_{2g}$, ${}^3\text{T}_{1g} \rightarrow {}^3\text{T}_{1g}(\text{P})$ and ${}^3\text{T}_{1g} \rightarrow {}^3\text{T}_{2g}(\text{F})$ respectively [17, 18]. The spectrum of VO(II) complex gave two band at 496 and 763 nm assigned to ${}^2\text{B}_2 \rightarrow {}^2\text{B}_1$ and ${}^2\text{B}_2 \rightarrow {}^2\text{E}$ transition, respectively suggesting a square pyramidal geometry [18,19], Furthermore, the magnetic moment of

the VO(II) (d1) complex was found to be 1.77 B.M. The electronic spectrum of Pd(II) complex showed two broad peaks at 493 and 765 nm assigned to ${}^1\text{A}_{1g} \rightarrow {}^1\text{B}_{1g}$ and ${}^1\text{A}_{1g} \rightarrow {}^1\text{A}_{2g}$, the electronic spectrum of Pt(IV) complex showed two broad peaks at 485 and 520 nm assigned to ${}^1\text{A}_{1g} \rightarrow {}^1\text{T}_{2g}$ and ${}^1\text{A}_{1g} \rightarrow {}^1\text{T}_{1g}$ respectively, suggesting an octahedral geometry. The electronic spectrum of Cu(II) complex showed one broad peaks at 494 nm assigned to ${}^2\text{B}_{1g} \rightarrow {}^2\text{A}_{1g}$, suggesting an octahedral geometry. The magnetic moment value 2.84, 1.86 and 2.95 B.M. of Ni(II) (d⁸), Cu(II) (d⁹) and Re(V) (d²) complexes respectively are typical for octahedral geometry [18-20]. All these electronic spectra data can be shown in Table (4).

Table (4) Electronic Spectral Data of the Metal Complexes with Ligand and Magnetic Moments

Complex geometry	μ_{eff} B.M	ν (cm ⁻¹)	ABS	λ_{max} (nm)	$\epsilon_{\text{max}}^{\text{L}}$ mol ⁻¹ cm ⁻¹	Assignments
L	-	35460.99	2.48	282	24800	$\pi \rightarrow \pi^*$
[VOL ₁ (SO ₄)] Square pyramidal	1.77	36101.08 20161.29 13106.15	2.377 0.916 0.024	277 496 763	23770 9160 240	$\pi \rightarrow \pi^*$ ${}^2\text{B}_2 \rightarrow {}^2\text{B}_1$ ${}^2\text{B}_2 \rightarrow {}^2\text{E}$
[NiL ₁ Cl ₂ (H ₂ O)] Octahedral	2.84	36363.63 23041.47 20576.13 12722.64	2.401 0.203 0.232 0.084	275 434 486 786	24010 2030 2320 840	$\pi \rightarrow \pi^*$ ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{1g}(\text{P})\nu_3$ ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{1g}(\text{F})\nu_2$ ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{2g}(\text{F})\nu_1$
[CuL ₁ Cl ₂ (H ₂ O)] Octahedral	1.86	36363.63 20242.91	2.082 0.604	275 494	20820 6040	$\pi \rightarrow \pi^*$ ${}^2\text{B}_{1g} \rightarrow {}^2\text{A}_{1g}$ ($dx^2-y^2 \rightarrow dz^2$)
[PdL ₁ Cl] ₂ Square planar	dia	35971.22 20283.97 13071.89	2.414 0.605 0.101	278 493 765	24140 6050 1010	$\pi \rightarrow \pi^*$ ${}^1\text{A}_{1g} \rightarrow {}^1\text{B}_1 \nu_2$ ${}^1\text{A}_{1g} \rightarrow {}^1\text{A}_2 \nu_1$
[PtL ₁ Cl ₂] Octahedral	dia	37174.72 32786.88 20618.55 19230.76	1.688 2.109 0.627 0.588	269 305 485 520	16880 21090 6270 5880	$\pi \rightarrow \pi^*$ C.T ${}^1\text{A}_{1g} \rightarrow {}^1\text{T}_2g \nu_2$ ${}^1\text{A}_{1g} \rightarrow {}^1\text{T}_1g \nu_1$
[ReL ₁ Cl ₂] ₂ Octahedral	2.95	36363.63 20449.89 15698.58 13986.01	2.459 0.983 0.546 0.208	275 489 637 715	24590 9830 5460 208	$\pi \rightarrow \pi^*$ ${}^3\text{T}_{1g} \rightarrow {}^3\text{A}_{2g}$ ${}^3\text{T}_{1g} \rightarrow {}^3\text{T}_{1g}(\text{P})$ ${}^3\text{T}_{1g} \rightarrow {}^3\text{T}_{2g}(\text{F})$

dia= diamagnetic

Thermal Gravimetric Analyses TGA

To understand the thermal decomposition processes of the studied

compounds, the Schiff base ligand and its metal complexes were examined by thermo gravimetric analysis in the

temperature range of 30–700 °C. The obtained results from the TG curves for all these compounds are given in Table

(5). The final decomposition products were metal oxide CuO in the 696 °C, NiO 698 °C and PdO 698 °C) [21, 22].

Table (5) Thermal Analysis Data of the Metal Complexes Derived from Ligand.

Com	TG range (°C)	DTG _{max} (°C)	% Found (calculated)		Assignment
			Mass Loss	Total mass Loss	
L	34.6-123.7	69.5	(5.27) 4.94	98.2 (97.000)	-CH ₃ -C ₆ H ₄ -C ₉ H ₁₄ N ₂ O ₂ C
	125-431	370	(22.82)22.724		
	462-694	650	(70.09) 69.34		
NiL	99-151	140	(4.053)4.031	83.293 (83.29)	-H ₂ O -Cl ₂ -C ₇ H ₁₀ N ₂ -C ₁₀ H ₁₁ NONiO
	180-300	253	(15.581)15.862		
	300-480	380	(27.743)27.336		
	480-698	575	(35.916)36.068		
CuL	97-180	140	(4.053)3.988	82.39 (82.402)	-H ₂ O -Cl ₂ + CO -C ₆ H ₉ N ₂ -C ₁₀ H ₁₂ NCuO
	180-297	235	(21.581)21.89		
	297-433	388	(23.743)24.161		
	433-696	587	(31.906)32.363		
PdL	100-183	138	(7.593)7.436	74.324 (74.324)	-Cl -Cl -C ₈ H ₉ N ₂ -C ₉ H ₁₂ NOPdO
	183-297	237	(7.581)7.436		
	297-436	391	(27.043)27.94		
	436-698	590	(32.107)31.512		

Electrostatic Potentials:

Electron distribution governs the electrostatic potential of the molecules. The electrostatic potential (E.P) describes the interaction of energy of the molecular system with a positive point charge. (E.P) is useful for finding sites of reaction in a molecule; positively charged species tend to attack a molecule where the electrostatic potential is strongly negative (electrophonic attack) [6, 7]. The (E.P) of the free ligand was calculated and plotted as 2D contour to investigate the reactive sites of the molecules, Figure (7). Also one can interpret the stereochemistry and rates of many reactions involving “soft” electrophiles and nucleophiles in terms of the properties of frontier orbital HOMO and LUMO. The results of calculations show that the LUMO of transition metal ions prefer to react with the HOMO of three-

donor atoms of two oxygen of carbonyl and nitrogen of azomethen group for free ligand, Figure (7).

All theoretically probable structures of free ligand and their complexes have been calculated by (PM3) and (ZINDO/1) methods in gas phase to search for the most probable model building stable structure, Table (6).

The vibrational spectra of the free ligand has been calculated, Table (7). The theoretically calculated wave numbers for this ligand showed that some deviations from the experimental values, these deviations are generally acceptable in theoretical calculations. Calculation of parameters has been optimized bond lengths of the free ligand and their metal complexes which to give excellent agreement with the experimental data as shown in Figure (8)

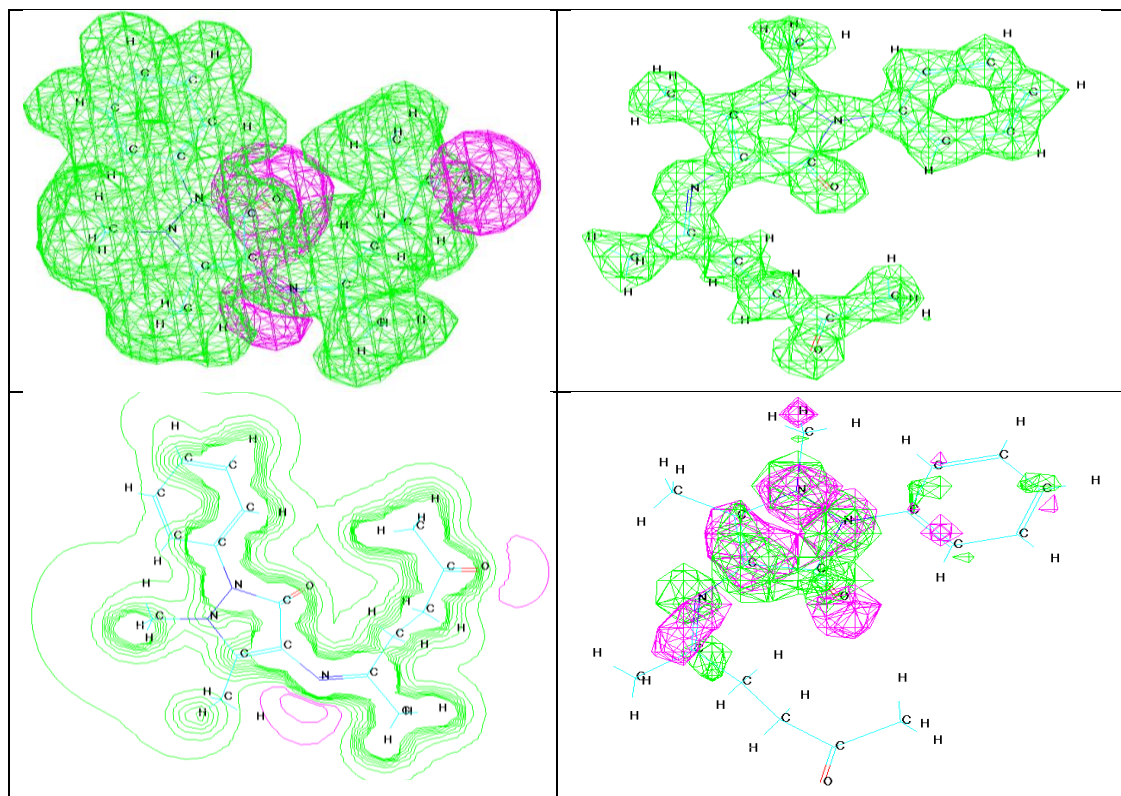


Fig. 7: Electrostatic Potential (HOMO and LUMO) Contours for Ligand

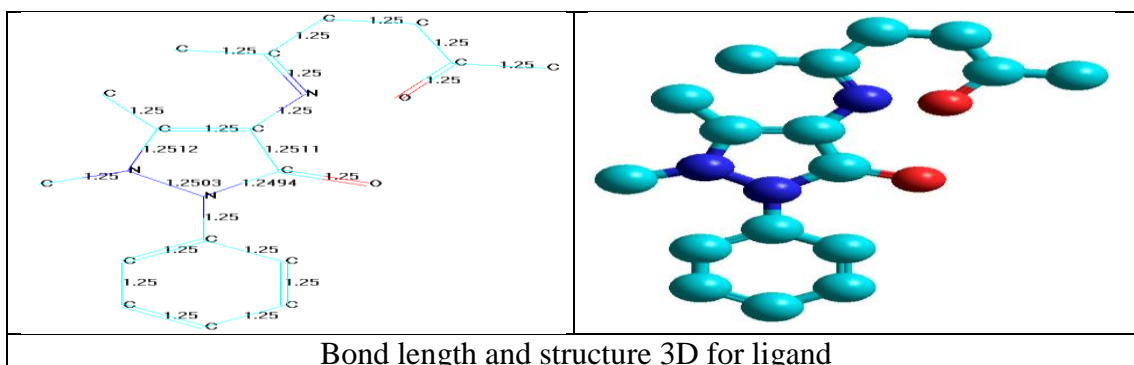
Table (6) Conformation Energetic in (K J.Mol⁻¹) for the Ligand and Complexes

Compounds	Binding Energy	Heat of Formation	Electronic Energy	Dipole moment (debyes)	Total Energy
L	-4473.7665926	-16.3765926	-603103.5158746	5.0380	-78660.2887016
NiL	-4326.4163316	2015.4616684	-1169716.1185115	19.648	-142058.723112
CuL	-4157.8280108	2249.3499892	-1235762.7660891	6.152	-12846.9020078
PdL	-2326.163316	2115.4616684	-1369716.1185115	9.648	-122058.723112
ReL	-3157.8280108	2349.3499892	-135762.7660891	11.152	-112846.9020078
PtL	-1126.463316	2515.4616684	-1149716.1185115	11.648	-112058.723112
VOL	-2257.280108	3049.3499892	-1225762.7660891	8.152	-172846.9020078

Table (7) Comparison of Experimental and Theoretical Vibrational Frequencies for Ligand

Ligand	$\nu(\text{CH})_{\text{aromatic}}$	$\nu(\text{CH})_{\text{aliphatic}}$	$\nu(\text{C}=\text{O})_{\text{ring}}$	$\nu(\text{C}=\text{O})$	$\nu(\text{C}=\text{N})$
L	3035*	2920*	1740*	1696*	1640*
	3060**	2998**	1668**	1644**	1637**
	-0.82***	-2.67***	4.13***	3.06***	0.18***

*Experimental frequency. ** Theoretical frequency. *** Error% due to main difference in the experimental measurements and theoretical treatments of vibration spectrum.



Bond length and structure 3D for ligand

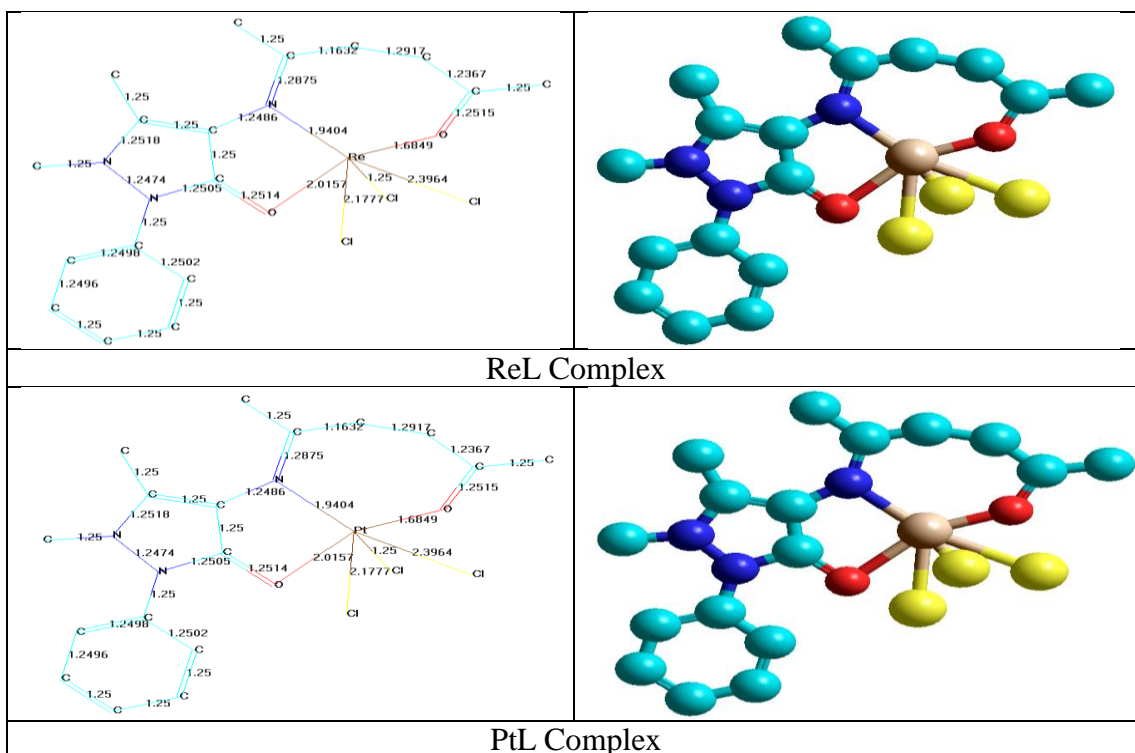


Fig. 8. Conformational Structure of (L) and their metal complexes

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معقدات العناصر الانتقالية مع ليكاند ثلاثي السن جديد: تحضير، تشخيص طيفي، تحلل حراري ودراسة تراكيبها

رحاب غالب حمودة

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الخلاصة:

تحضير سلسلة جديدة من معقدات المعادن مع الليكاند الجديد 5، 1-ثنائي مثيل -4- (5-او كسو هكسان-2-يل ثنائي ايمينو)-2-فنيل -1-بايروزول-3-اون الجديد المشتق من 2،5-هكسان ثنائي اون مع 4-امينو فينازون. وحضرت معقدات كل من الفناديوم الرباعي، النيكل الثنائي، النحاس الثنائي، البلاديوم الثنائي، الرينيوم الخماسي والبلاتين الرباعي. شخّصت المركبات المحضرة بوساطة أطياف الأشعة تحت الحمراء، فوق البنفسجية – المرئية، الكتلة والرنين النووي المغناطيسي لنظيري البروتون والكربون، ومنحنى التحلل الحراري الوزني والعزم المغناطيسي والتحليل الدقيق للعناصر ومحتوى الكلور الامتصاص الذري والتوصيلية المولارية. باستخدام برنامج الهايبر كيم -8 حددت تراكيب المركبات بالطور الغازي لاجاد حرارة التكوين وطاقة الترابط والحرارة الكلية وطاقة الالكترونات وعزم ثنائي القطب بدرجة 298 كلفن.

الكلمات المفتاحية : ليكاندات قواعد شف ، 5,2 هكسان ثنائي اون ، معقدات العناصر.