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Synthesis, Characterization of New Metal Complexes of Co (II), Cu (II), Cd (II) and Ru (III) from azo ligand 5-((2-(1H-indol-2-yl)ethyl) diaziny)l)-2-aminophenol, Thermal and Antioxidant Studies

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Abstract:

A novel metal complexes Cu (II), Co (II), Cd (II), Ru (III) from azo ligand 5-((2-(1H-indol-2-yl)ethyl) diaziny)l)-2-aminophenol were synthesized by simple substitution of tryptamine with 2-aminophenol. Structures of all the newly synthesized compounds were characterized by FT IR, UV-Vis, Mass spectroscopy and elemental analysis. In addition measurements of magnetic moments, molar conductance and atomic absorption. Then study their thermal stability by using TGA and DSC curves. The DCS curve was used to calculate the thermodynamic parameters ΔH , ΔS and ΔG . Analytical information showed that all complexes achieve a metal:ligand ratio of [1:1]. In all complex examinations, the Ligand performs as a tridentate ligand, connecting Cu (II), Co (II), Cd (II), and Ru (III) ions through the nitrogen atom of amine, azo groups and the oxygen phenolic group. Cu (II), Co (II), and Cd (II) complexes were characterized as having tetrahedral geometry, while Ru (III) complex was found to have octahedral geometry. The antioxidant activity of the metal complexes was assessed against the DPPH radical (1,1-diphenyl-2-picrylhydrazyl) and compared to that of a common natural antioxidant Gallic acid to observe the produced compounds. The results demonstrated ligands have more antioxidant activity than metal complexes.

Keywords: Azo ligand, Antioxidant activity, Gallic acid, Thermal studies, Mass spectroscopy.

Introduction:

Coordination chemistry for transition metal complexes with azo ligands is An important and interesting area of chemistry that plays an essential function in technology, industry, and biological systems¹. Azo compounds are a significant class of chemical compounds that are being studied by scientists. They have long been used as dyes and pigments because they are intensely colored. Additionally, they have received a lot of attention because of their superior thermal and optical qualities in uses such as oil-soluble lightfast dyes, ink-jet printing, and optical recording medium toner². Azo-dyes are substances made up of at least one conjugated chromophore azo bond (-N=N-) and one or more aromatic or heterocyclic moieties. Because they are distinguished by the presence of an azo moiety (N=N) in their structure, they make up the most significant group of dispersed dyes³. During the review of literature it was noticed that, there are many common methods in preparation and as an

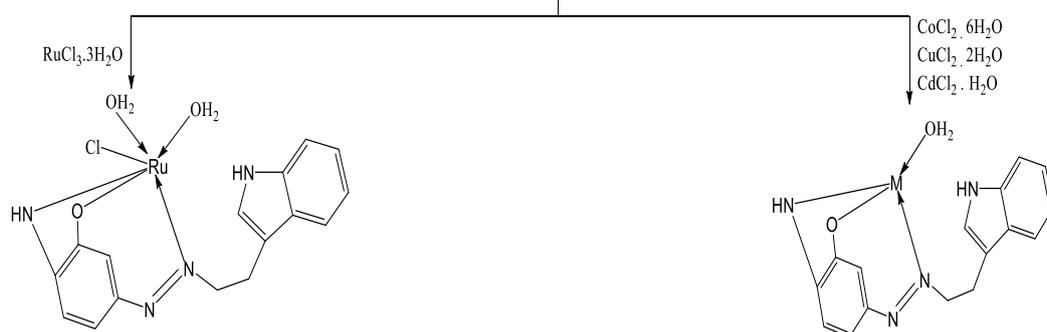
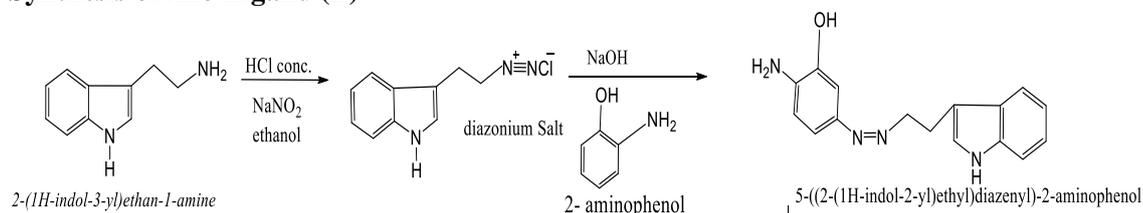
example we mentioned the classical method which uses diazonium salt which is considered one of the most important materials in preparation of a large number of pure organic compounds and according to the electrophilic features in diazonium salt^{4,5}. Azo compounds are the most common class of organic dyes produced industrially. Due to their wide range of applications in fields like dyeing textile fiber, biomedical research, advanced organic synthesis, and high technology fields like a laser, liquid crystalline displays, and electro optical devices^{6,7}. They have good thermal and optical properties, are highly colored, and demonstrate significant applications like optical data storage and nonlinear optical materials. They are participating in a number of biological processes, including bacterial and fungal defense mechanisms and carcinogenesis. Azo compounds metal complexes are also receiving a lot of interest to their applicability in optical computing, functional materials, dyes, and pigments^{8,9}. The aim

of this work is to synthesize a novel metal ions complexes Cu(II), Co(II), Cd(II) and Ru(III) from azo ligand (L) as well as characterization with spectroscopic analysis and studying of thermal decomposition and thermal stability by using TGA and DSC curve.

Material and Methods:

The following chemical ingredients were obtained from metal salts CuCl₂.H₂O, CoCl₂.6H₂O, CdCl₂. H₂O, and RuCl₃.3H₂O (Sigma-Aldrich, Merck, and others). 2-(1H-Indole-3-yl)- ethylamine, 2-aminophenol, hydrated sodium nitrate NaNO₂ hydrochloric acid HCl, pure ethanol, DMSO, NaOH. The following chemical ingredients were obtained from metal salts were employed to explore the IR spectra captured as CSI discs. 8300 FTIR spectroscopy, 4000–200 cm⁻¹ range. C, H, and N elemental analyses were utilizing Euro vector model EA/3000, single-V.3.O-single, utilized to conduct elemental analyses.. UV-1800 Shimadzu spectrophotometer was employed to study electronic spectra to the (200-1100 nm) range using 10⁻³ M solutions in DMSO at 25 °C. Using a Shimadzu (A.A) 680 G atomic clock, metals were identified. Spectrum analyzer for absorption. A conductometer WTW was used to detect conductivity while it was at room temperature with DMSO solutions. On QP50A: DI Analysis Shimadzu QP-2010-Plus (E170Ev) spectrometer, electron impact (70 eV) mass spectra were captured. Gravimetric estimation of the chloride concentration was made. The balancing magnetic susceptibility model MSR-MKI was used to measure magnetic characteristics. Perkin-Elmer Pyris Diamond DS/TGA was used for all prior sorts of thermal analysis.

Synthesis of Azo Ligand (L)



Scheme1. Synthesis of metal complexes

Tryptamine has been dissolved in (2 ml HCl, 10 ml of ethanol) at 0- 5°C during refrigeration. To minimize temperature increases of up to 5°C, gradually added (10%, 0.42 g, 0.006 mol) NaNO₂. After the reaction has been stirred for approximately 30 minutes, add the (0.671g, 0.006 mol) of 2-aminophenol dissolved in 10ml of ethanol. Then, 10 ml of a 1M NaOH solution was added, and the precipitation of a dark brown-colored azo ligand was observed. This product is collected after being filtered and dried. Its melting point was 191 ° C, and its yield was 81.5%¹⁰. ¹H NMR (DMSO-d₆, ppm): 1.61-1.94((4H)t,CH₂-CH₂), 2.51-2.61 DMSO, 6.76((1H) s, CH-NH Indole), 6.94((1H) s, CH-OH), 7.58-7.60((1H) d,CH-NH₂), 7.83-7.86((1H)d, CH-N=N), 7.96-8.04((4H) m, CH arom),9.01((2H) s,NH₂), 10.52 ((1H)s, OH),11.30 ((1H)s, N-H). ¹³C-NMR:196.1(C₁), 157.04(C₂), 134.21(C₃), 131.62(C₄), 180.52(C₅), 106.38(C₆), 24.02(C₇), 49.33(C₈), 122.41(C₉), 162.11(C₁₀), 146.11(C₁₁), 151.87(C₁₂), 145(C₁₃), 115.34(C₁₄), 166(C₁₅) and 152.16(C₁₆). Mass spectrum the molecular ion peak, at m/z=280.32The spectrum exhibits others peaks at (m/z):164.18(C₈H₁₀N₃O⁺), 116.14 (C₈H₆N⁺),84.10 (C₄H₆NO⁺),83.11 (C₄H₇N₂⁺), 67.11 (C₅H₇⁺) and 56.09 (C₃H₆N⁺).

Synthesis for complexes

The metal salt (1 mmol) was dissolved in 10 ml of ethanol. Drop by drop the addition of (15 ml) from Azo ligand (1 mmol). The resulting mixture was refluxed for 2 h. The solid complexes were separated, and any unreacted components were removed by briefly immersing them in hot ethanol. The complexes were collected, dried and weighed. Scheme1 shows the formation of the metal ions complexes.

Result and Discussion:

The concrete results of produced metal complexes' elemental analyses were in good accord with what was predicted theoretically. The metal-ligand ratios in complexes were [1:1], according to

elemental studies. The complexes of ligands, which are soluble in DMSO solvent in 10^{-3} M solution at 25°C , are described by the molar conductance of complexes are all by nature non-electrolytic. Table1 lists the physical and analytical information about the azo ligand and their metal complexes.

Table 1. The characterization information of the prepared compounds

Comp. formula	M.wt	%M (Expert) Calc	%Cl (Expert) Calc	(Expert) Calc				color	m.p $^{\circ}\text{C}$	Yield%	$\Lambda_m \text{ cm}^2 \Omega^{-1} \text{ mol}^{-1}$
				%C	%H	%N	%O				
L	280.32	-	-	(67.89)	(5.74)	(21.01)	(7.00)	reddish	192-	81	-
$\text{C}_{16}\text{H}_{16}\text{N}_4\text{O}$				67.84	6.71	19.78	5.65	brown	195		
$[\text{Co}(\text{L})(\text{H}_2\text{O})]$	354.93	(15.66)	-	(55.06)	(3.61)	(16.20)	(10.0)	green	d	66	13
$\text{C}_{16}\text{H}_{16}\text{CoN}_4\text{O}_2$		16.60		54.09	4.54	15.77	9.01		250-253		
$[\text{Cu}(\text{L})(\text{H}_2\text{O})]$	359.54	(16.86)	-	(53.01)	(4.04)	(16.09)	(9.09)	brown	d230	72	17
$\text{C}_{16}\text{H}_{16}\text{CuN}_4\text{O}_2$		17.30		53.40	4.48	15.57	8.89				
$[\text{Ru}(\text{L})(\text{H}_2\text{O})_2\text{Cl}]$	450.52	(23.64)	(6.98)	(42.97)	(4.05)	(12.82)	(9.63)	brown	d214-	68	12
$\text{C}_{16}\text{H}_{18}\text{ClN}_4\text{O}_3\text{Ru}$		22.43	7.86	42.60	3.99	12.43	10.65		216		
$[\text{Cd}(\text{L})(\text{H}_2\text{O})]$	408.41	(26.62)	-	(47.86)	(4.24)	(14.02)	(7.29)	reddish	d 238	67	9
$\text{C}_{16}\text{H}_{16}\text{CdN}_4\text{O}_2$		27.52		47.01	3.91	13.71	7.83	brown			

d= decompose

1. Mass spectrum

The mass spectra of $[\text{Cu}(\text{L})(\text{H}_2\text{O})]$ show in the Fig2. the pattern of fragmentation is summarized in Scheme2. The molecular ion peak, which corresponds to the ligand formula weight, has peaked at $m/z=359.87$. And other peaks at (m/z) (341.85, 211.69, 130.10 and 96.58) might be related to $(\text{C}_{16}\text{H}_{14}\text{CuN}_4, \text{C}_7\text{H}_6\text{CuN}_3\text{O}^+, \text{C}_9\text{H}_8\text{N}^+, \text{C}_6\text{H}_3\text{N}_2^+$ and $\text{H}_3\text{CuNO}^+)$ respectively . The mass spectrum of

$[\text{Co}(\text{L})(\text{H}_2\text{O})]$ is shown in the Fig1 . The pattern of fragmentation is summarized in Scheme3. The molecular ion peak, which corresponds to the ligand formula weight, has peaked at $m/z=355.42$ and shows many peaks at (m/z) (337.24, 207.08, 130.17, 103.10 and 91.96). The pattern for these peaks may be assigned to various fragments with $(\text{C}_{16}\text{H}_{14}\text{N}_4\text{CoO}^+, \text{C}_7\text{H}_6\text{CoN}_3\text{O}^+, \text{C}_9\text{H}_8\text{N}^+, \text{C}_6\text{H}_3\text{N}_2^+$ and $\text{H}_3\text{CoNO}^+)$ respectively¹¹⁻¹⁴.

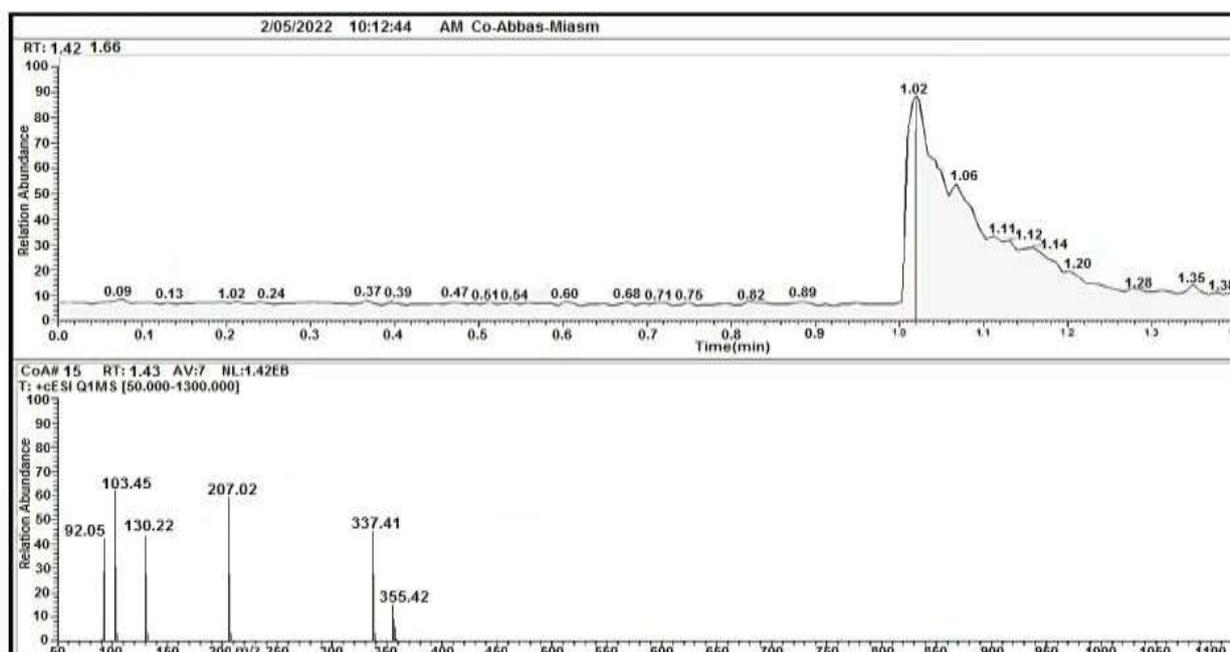


Figure1. Mass spectrum of $[\text{Co}(\text{L})(\text{H}_2\text{O})]$

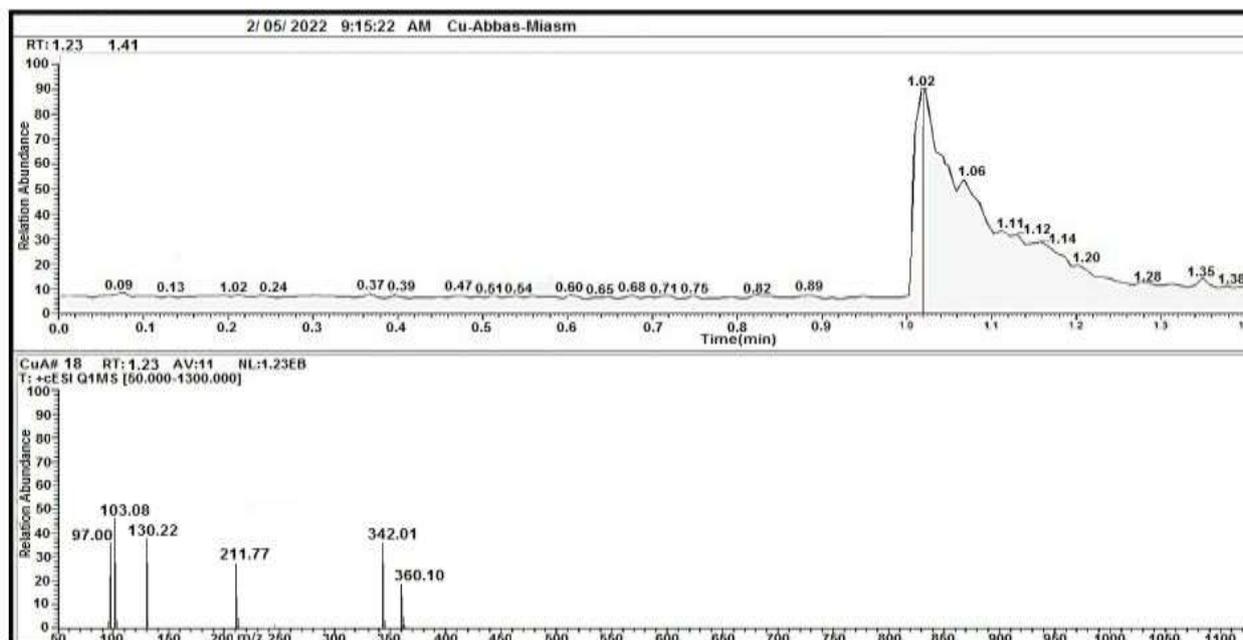
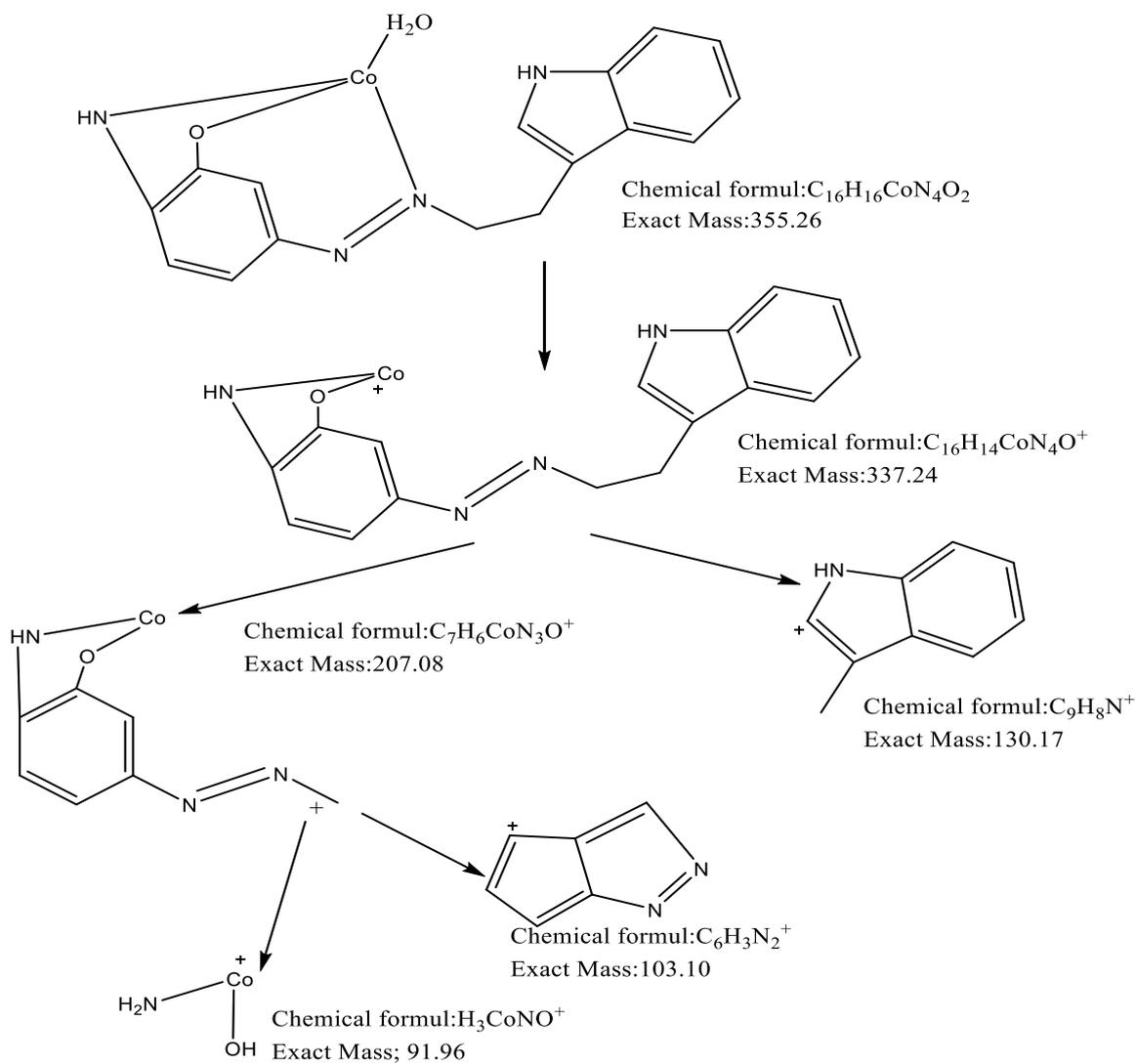
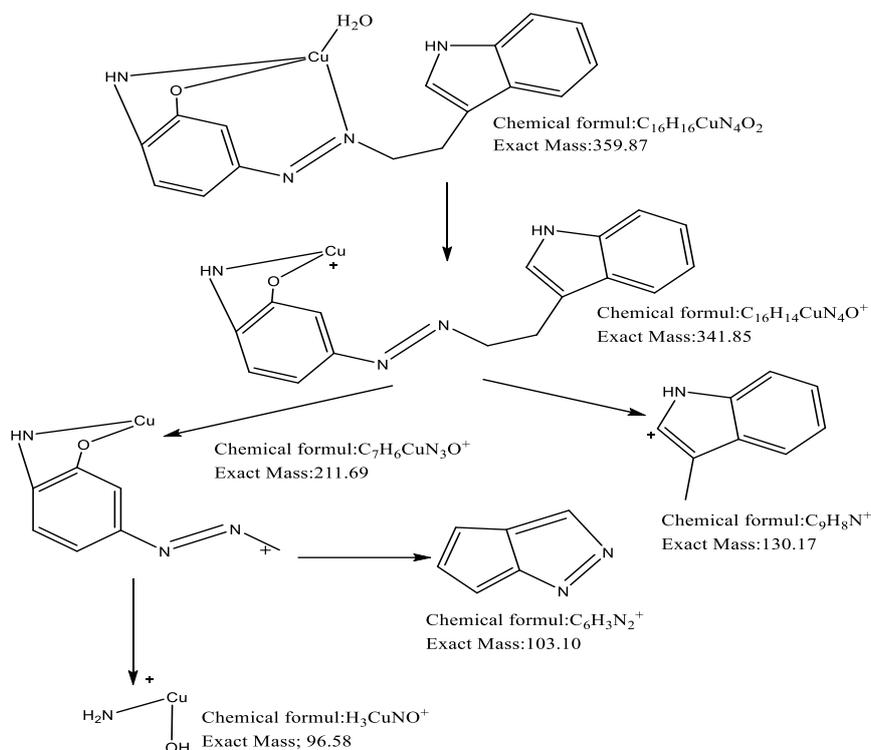


Figure 2. Mass spectrum of [Cu(L)(H₂O)]



Scheme 2. Fragmentation pattern for [Co(L)(H₂O)]



Scheme 3. Fragmentation Pattern for [Cu(L)(H₂O)]

2. IR spectra

The complexes were diagnosed by infrared spectra and then the spectra were compared with the spectra of the ligands in the free state¹⁵. The shift of some bands towards longer or shorter wavelengths, changes in their shapes and intensity, the disappearance of bands and the emergence of new bands, and the following is a careful study of the infrared spectra of the prepared complexes, and the spectra data are shown in table 2. The FTIR spectrum ligand (L) shows bands at $(3408) \text{ cm}^{-1}$ were assigned to the stretching vibration $\nu(\text{NH}_2)$, $\nu(\text{NH}_2)$, and $\delta(\text{NH}_2)$, $(3759, 3286) \text{ cm}^{-1}$ that, when compared to the free raw materials, assign to the (O-H), (NH) indole ring, and at 1485 cm^{-1} , the novel azo group (N=N) is attributed, indicating the creation of the ligand¹⁶⁻¹⁸. On the other hand, the FT-IR spectra of the complexes of Co(II), Cd(II) and Ru(III) showed the O-H phenolic group's stretching characteristic had

eliminated, proving that coordination through phenolic oxygen had taken place. Additionally, they demonstrated that the N=N mode has altered in size, strength, and location when compared to the mode of ligand. And new bands are appeared that belong to (M-N) at $(541, 526, \text{ and } 561) \text{ cm}^{-1}$ for the Co(II), Cd(II) and Ru(III) complexes, respectively, (M-O) at $(442, 431, \text{ and } 411) \text{ cm}^{-1}$ for the Co(II), Cd(II) and Ru(III) complexes, respectively which supports coordination occurrence through the nitrogen and oxygen atoms. Furthermore, it was discovered that the water molecule was coupled to displayed stretching vibrational activity at $3689, 1618 \text{ and } 746 \text{ cm}^{-1}$, as well as at $3566, 1635 \text{ cm}^{-1}$, and 749 cm^{-1} , $3532, 1611, 713 \text{ cm}^{-1}$ assigned to the (H₂O) aqua of the Co(II), Cd(II) and Ru(III) complexes, respectively. This suggests that the metal ion and ligand were coordinated by the H₂O atom^{19,20}. A list of all is provided in Table 2 below.

Table 2. Infrared data of metal complexes (cm^{-1})

Comp.	ν (NH)	ν (C-H) arom.	ν (C-H) aliph.	ν (N=N)	ν (M-N)	ν (M-O)	ν (H ₂ O) aqua	Additional bands
L	-	3016	2918	1485	-	-	-	ν (NH ₂) 3408 ν (NH) _{indole} 3286 ν (OH) _{phenolic} 3759
[Co(L)(H ₂ O)]	3391	3173	2928	1458	541	442	3689 749	-
[Cd(L)(H ₂ O)]	3411	3215	2966	1489	526	431	3531 749	-
[Ru(L)(H ₂ O) ₂ Cl]	3423	3245	2947	1476	561	411	3532 713	ν (M-Cl) 321

3.3 Electronic spectral, magnetic moments

The electronic transition of Co(II) complex shown in Fig3.depicts a peak at 276,633 and 986nm assigned to $\pi \rightarrow \pi^*$, ${}^4A_2 \rightarrow {}^4T_{1(P)}B$ and ${}^4A_2 \rightarrow {}^4T_{1(F)}$ respectively which is indicative of a tetrahedral geometry²¹⁻²³.The Ru (III) complex exhibited peaks at 288,327 and 583nm ascribed to the $\pi \rightarrow \pi^*$, C.T,M \rightarrow L, ${}^2T_{2g} \rightarrow {}^2A_{2g}$ respectively is in good agreement with prior work on octahedral geometry.

The electronic absorption of Cd (II) complex displayed peaks at (362)nm is assigned to the $\pi \rightarrow \pi^*$, and (489)nm, (568) nm belongs to the ${}^1A_{1g} \rightarrow {}^1B_{1g}$, ${}^1A_{1g} \rightarrow {}^1A_{2g}$ respectively, which area good evidence for square planer geometry²⁴⁻²⁷. Table 3 displays the electronic assignment, magnetic measurements, and proposed formula for metal complexes.

Table 3. Electronic data and magnetic moments for the metal complexes

Comp.	λ_{\max} (nm)	$\nu_{cm^{-1}}$	$\epsilon_{\max}L$ $mol^{-1}cm^{-1}$	Assignment	μ_{eff} (B.M)	Suggested Structure
L	284	35211.2	1600	$\pi \rightarrow \pi^*$	-	-
[Co(L) (H ₂ O)]	421	23752.9	300	$n \rightarrow \pi^* C.T L \rightarrow L$	3.81	tetrahedral
	276	36231.8	3430	$\pi \rightarrow \pi^*$		
	633	15751.6	240	${}^4A_2 \rightarrow {}^4T_{1(P)}$		
	986	10141.9	220	${}^4A_{2(F)} \rightarrow {}^4T_{1(F)}$		
[Ru(L)(H ₂ O) ₂ Cl]	288	34722.2	950	$\pi \rightarrow \pi^*$	1.74	octahedral
	327	30581.0	910	$n \rightarrow \pi^* C.TM \rightarrow L$		
	583	17152.6	230	${}^2T_{2g} \rightarrow {}^2A_{2g}$		
[Cd(L)(H ₂ O)]	220	45454.5	0.482	$\pi \rightarrow \pi^*$	Diamagnetic	tetrahedral
	269	37174.7	0.491	$n \rightarrow \pi^*$		
	418	23923.4	0.312	C.T,M \rightarrow L		

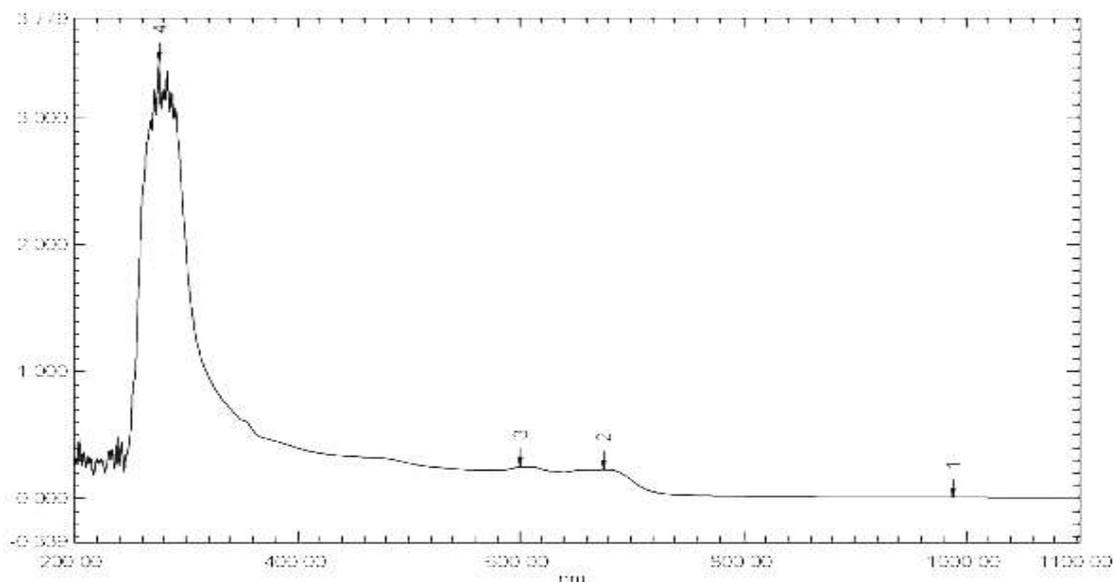


Figure 3. UV-Vis Spectrum of [Co(L) (H₂O)]

Thermal studies

The thermal analysis curves were obtained to determine each of the following thermal parameters' typical values from the TGA curves produced for the stages in the decomposition process of metal complexes²⁸⁻³¹.The decomposition's starting point temperature (Ti), is this point at which the TG curve departs from its origin. In conclusion (Tf) the temperature and where the TG curve begins to decompose. Back to its starting point The highest

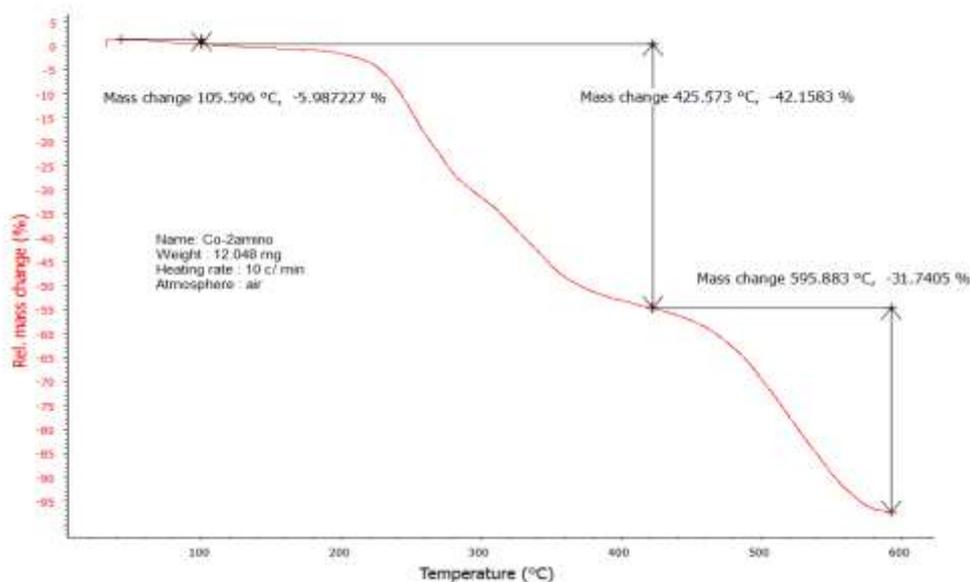
temperature, or the temperature of the maximum rate of weight loss. Furthermore, the DSC curve can be used to determine whether a heat source is exothermic or endothermic as well as its amount and calculated the thermodynamic parameters ΔH , ΔS and ΔG ³²⁻³⁴. The findings of the thermogravimetric analysis of the metal complexes are presented in tables 4,5 and Fig 4,5. Tentative decomposition reaction of metal complexes f is summarized in Scheme4.

Table 4. Ligand (L) and their complexes TGA data

Compound	T _i °C	T _f °C	Max TDTG	% calculated (Estimated)		Assignment
				Mass loss	Total Mass loss	
L	54.326	596.678	368.78	95.6050 (96.556)	95.6050 (96.556)	-C ₁₅ H ₁₆ N ₄ O
[Co(L)(H ₂ O)]	28.51	105.59	51.3	5.3689	79.1176	-H ₂ O
	105.59	425.59	235,1	(5.9872)	(79.886)	-C ₈ H ₈ N ₃
	425.57	595.88	479.7	41.0966 (42.1583)	32.65214 (31.7405)	-C ₈ H ₆ N
[Cu(L) (H ₂ O)]	91.4	213.23	143.2	5.0018	77.8058	-H ₂ O
	213.23	373.07	290.2	(4.8495)	(78.0201)	-C ₉ H ₈ N ₂
	373.07	575.89	476.2	40.0144 (40/6922)	32.7896 (32.7896)	-C ₇ H ₆ N ₂
				(32.4784)		

Table 5. Ligand (L) and their complexes. DSC data

Compound	T _i °C	T _f °C	DSC max °C	ΔH J/g	ΔS J	ΔG J	Type
L	33.78	92.45	78.17	-12.90	-0.21	3.5157	endothermic
	105.93	127.97	114.91	-1.39	-0.062	5.734	endothermic
[Co(L) (H ₂ O)]	143.78	263.32	257.72	-30.45	-1.558	371.077	endothermic
	263.32	276.00	270.71	-36.90	-2.910	750.866	endothermic
	278.01	287.47	281.09	-11.55	-1.220	331.379	endothermic
[Cu(L) (H ₂ O)]	66.27	126.07	98.92	-90.28	-1.511	59.1781	endothermic



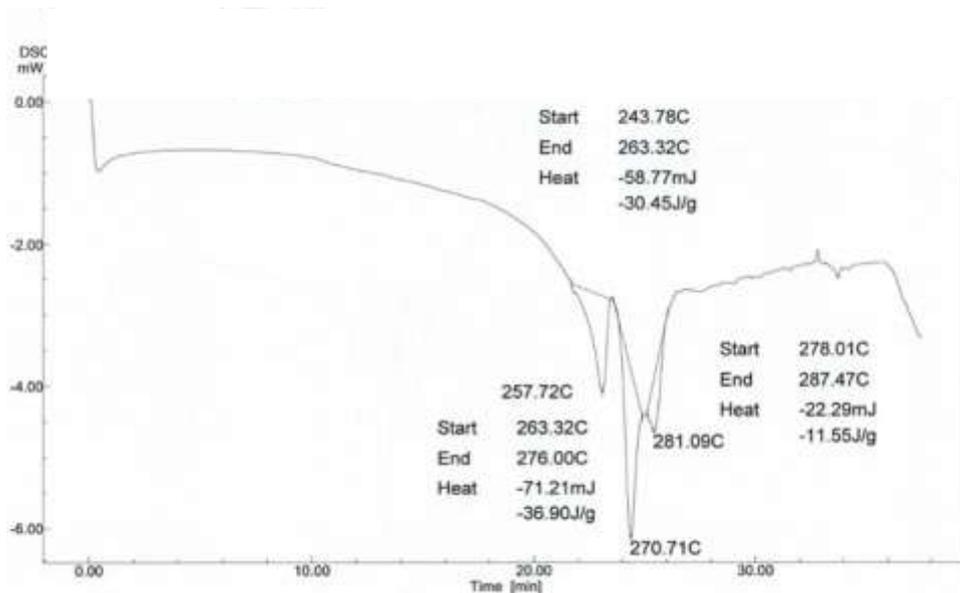


Figure 4. Thermo gravimetric Co(II) complex

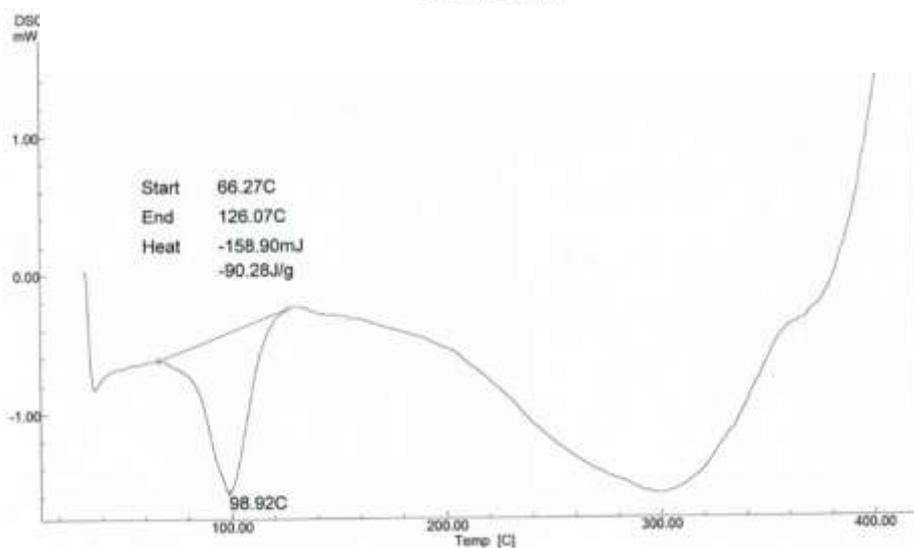
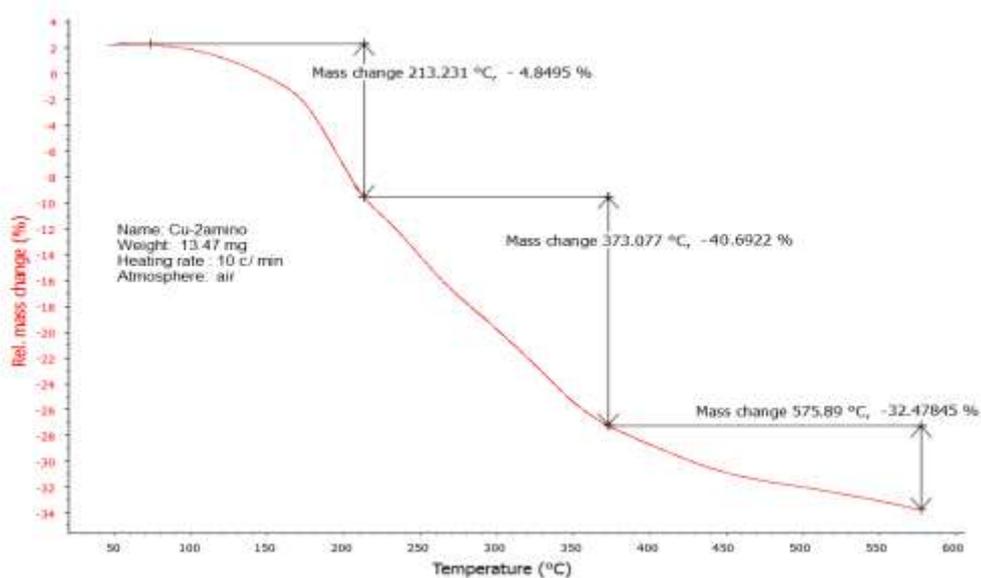
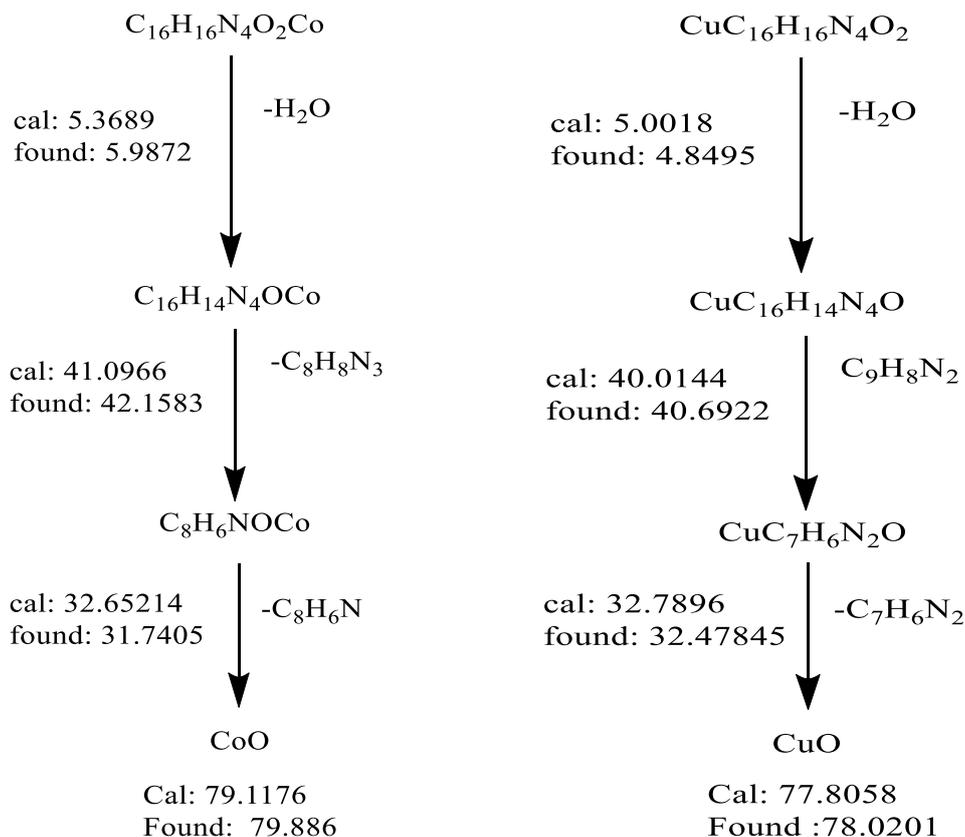


Figure 5. Thermo gravimetric Cu (II) complex



Scheme 4. Tentative decomposition reaction of metal complexes

Antioxidant assay

The assay is used to determine how well antioxidants can scavenge it. Antioxidants provide a hydrogen atom to hydrazine, which reduces the single electrons from nitrogen atoms in DPPH. When the DPPH radical solution is combined with the antioxidant, the color of the corresponding hydrazine changes from violet to yellow, which is characterized by an absorption band in an ethanol solution centered at approximately (517 nm).

electron delocalization also produces dark purple^{35,36}. The interaction of [Co(L) (H₂O)], [Cu(L) (H₂O)], [Ru(L)(H₂O)₂Cl] and [Cd(L) (H₂O)] complexes with DPPH radicals and subsequent hydrogen donation to scavenge the radicals are displayed with table 6. Effective DPPH radical scavenging is indicated by a lower IC₅₀ value. In the DPPH assay, the practically ligand has more antioxidant activity than the metal complexes³⁷.

Table 6. Means, standard deviations, coefficients of variation, Correlation coefficient and IC₅₀ of antioxidant activity in percentage (aa%) of the tested samples at 30 Minute

Tested sample	Mean	Standard deviation	Coefficient of Variation%	Correlation Coefficient	IC ₅₀
L	59.9671	2.0665	2.2221	0.9967	-6.0
[Co(L) (H ₂ O)]	32.7621	3.2261	3.7745	0.9765	-1.0051
[Cu(L)(H ₂ O)]	31.3131	4.7715	3.3096	0.9883	0.6332
[Ru(L)(H ₂ O) ₂ Cl]	27.8776	11.1212	13.2681	0.7799	0.3397
[Cd(L) (H ₂ O)]	17.0796	3.3365	13.3364	0.7654	-1.3346
Gallic acid	98.5600	2.0846	2.2281	0.9966	-6.0304

IC₅₀: the half maximal inhibitory concentration

Conclusion:

In this study, we examined the preparation for some metal complexes produced by the reaction of the tridentate Azo ligand with metal ions Cu(II), Co(II), Cd(II) and Ru(III). The metal ions complexes study their physical characteristics and many analyses. Collection of information demonstrated

from the electronic, infrared, and mass spectrum as well as magnetic moments and molar conductance and atomic absorption indicated that most Cu (II), Co (II), and Cd (II) complexes contain four coordinates and have tetrahedral geometry, while Ru (III) complex was found to have octahedral geometry. Molar conductivity measurements of the prepared

Complexes indicate that complexes with the formula $[M(L_2)(H_2O)]$ where $M(II) = Co, Cu, Cd$ and the formula of Ru (III) $[Ru(L_2)(H_2O)_2Cl]$. All complexes were (non -electrolyte). The metal complexes' antioxidant activity was evaluated against the DPPH radical and compared to that of a common natural antioxidant Gallic acid to observe the produced compounds. The results demonstrated that the metal complexes have more antioxidant activity than ligand and Gallic acid.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Baghdad.

Authors' contributions statement:

The authors M. Q. A. and A. A. S. Al. conceived, planned and carried out the experiments and the simulations. The authors contributed to sample preparation and contributed to the interpretation of the results and took the lead in writing the manuscript. The authors provided critical feedback and helped shape the research, analysis and manuscript.

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تحضير وتشخيص معقدات فلزية جديدة الكوبلت (II) و النحاس (II) والكاديوم (II) وروثنيوم (III) مع ليكاند أزو جديد-5-(2-H1-أندول-2-يل-أثيل داينزيل-2-أمينو فينول)، دراسات الحرارية ومضادات أكسدة

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الخلاصة:

حضرت معقدات فلزية جديدة النحاس (II) والكوبلت (II) والكاديوم (II) وروثنيوم (III) مع ليكاند أزو جديد (2-2-1-أندول-2-أثيل داينزيل-5-أمينو فينول) بتفاعل بسيط من تربنامين مع مركب 3-أمينو فينول. هياكل المركبات المحضرة شخّصت بواسطة الأشعة فوق البنفسجية-المرئية، الأشعة تحت الحمراء، طيف الكتلة والتحليل الدقيق للعناصر بالإضافة إلى القياسات المغناطيسية والتوصيلية المولارية وتم دراسة الاستقرار الحرارية بواسطة ومنحنى التحلل الحراري. وأظهرت المعلومات التحليلية أن جميع المعقدات تصل إلى نسبة 1 : 1 ليكاند - فلز. اليكاند ثلاثي السن يرتبط عن طريق ذرة النتروجين لمجموعة الأزو ومجموعة الأمين و ذرة الاوكسجين لمجموعة الفينول. معقدات النحاس الثنائي والكوبلت الثنائي والكاديوم الثنائي رباعية السطوح اما وروثنيوم الثلاثي ثماني السطوح. الفعالية كمضادات أكسدة لمركبات تم تقديرها ضد الجذر الحر (1-1-داي فينيل 2-بكريل هيدرازيل) تمت المقارنة مع المادة القياسية حامض الكالبيك. برهنت النتائج ليكاند له قابلية جيدة على كبح الجذور الحرة أكثر مما هو في المعقدات وحامض الكالبيك.

الكلمات المفتاحية: ازوليكاند، فعالية الأكسدة، حامض الكالبيك، الدراسات الحرارية، مطيافية الكتلة.