

Preparation, Characterization and Study of Ethyl Pyruvate Aroyl Hydrazone Metal Complexes

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ABSTRACT

Hydrazones derived from aroyl hydrazides and ethyl pyruvate namely; ethyl pyruvate benzoyl hydrazone (EPBH), ethyl pyruvate salicyloyl hydrazone (EPSH), ethyl pyruvate-2-furoyl hydrazone (EPFH) and ethyl pyruvate-2-thiophenoyl hydrazone (EPTH) have been synthesized and used in preparing the corresponding Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) complexes. The ligands undergo deprotonation forming neutral mononuclear octahedral bis-complexes of the type $[M(L-H)_2]$ where L-H = deprotonated EPBH, EPSH, EPFH or EPTH, acting as uni-negative tridentate ligands. The complexes isolated were characterized by elemental analyses, IR, electronic, 1H -NMR spectra, molar conductance and magnetic susceptibility measurements. The bonding and probable structure of the complexes are discussed on the basis of the spectral and magnetic data. The ligands, as well as some of their complexes, screened against Gram-positive and Gram-negative bacteria.

Keywords: Hydrazones, Ethyl Pyruvate, Complexes, Transition Metals.

تحضير وتشخيص ودراسة بعض معقدات الفلزات مع هيدرازونات الأرويل لبايروفات الأثيل

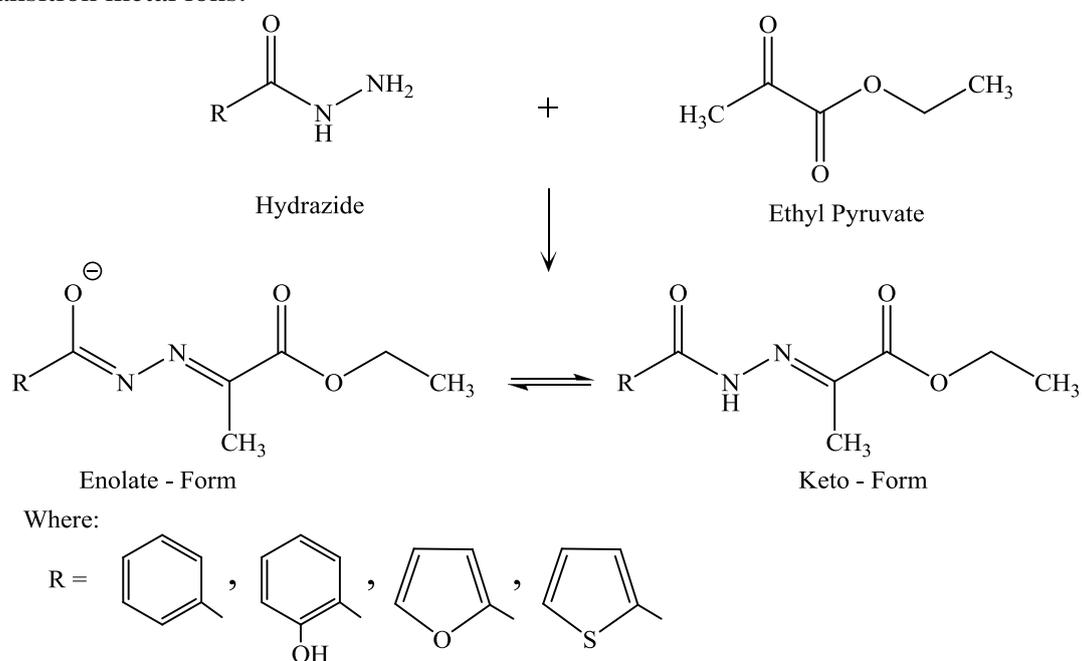
المخلص

حضرت أربعة هيدرازونات مشتقة من هيدرازيدات الأرويل وبايروفات الأثيل وهي: بايروفات الأثيل بنزويل هيدرازون (EPBH) وبايروفات الأثيل ساليسايلول هيدرازون (EPSH) وبايروفات الأثيل 2-فيورويل هيدرازون (EPFH) وبايروفات الأثيل 2-ثايوفينويل هيدرازون (EPTH) واستخدمت بوصفها ليكاندات لتحضير معقدات الأيونات الفلزية Mn(II) و Co(II) و Ni(II) و Cu(II) و Zn(II) و Cd(II). فقدت الليكاندات بروتونات خلال تفاعلاتها مع خلاص العناصر المذكوره اعلاه وكونت معقدات ثنائية (bis-) متعادلة احادية النوى ذوات الصيغة العامة $[M(L-H)_2]$ حيث L-H = الليكاندات EPBH و EPSH و EPFH و EPTH منزوعة البروتون ولها تراكيب ثمانية السطوح سلكت فيها الليكاندات بوصفها ثلاثية السن احادية الشحنة السالبة شخصت المعقدات المحضرة بواسطة تحاليل العناصر واطياف الاشعة تحت الحمراء (IR) والالكترونية (UV-Vis) والرنين النووي المغناطيسي للبروتون (1H -NMR) وقياسات التوصيلية المولارية والحساسية المغناطيسية وتم تحديد اسلوب تناسق الليكاندات والتراكيب المتوقعة اعتماداً على البيانات الطيفية والمغناطيسية. فحصت فعالية الليكاندات وبعض معقداتها ضد نوعين من البكتيريا الموجبة والسالبة.

INTRODUCTION

Aroyl hydrazones are multipurpose class of ligands having a range of biological and chemical activities. Hydrazones exhibit physiological and biological activities in the treatment of several diseases such as tuberculosis, leprosy and mental disorder (Suvarapu *et al.*, 2012; Rollas and Kucukguzel, 2007), for the treatment of iron overload disease (Bernhardt *et al.*, 2008), and as inhibitors for many enzymes (Tamasi *et al.*, 2005). Hydrazones also act as herbicides, insecticide,

nematicides, rodenticides and plant growth regulators. Furthermore they are extensively used as analytical reagents for analysis of metal ions (Suvarapu *et al.*, 2012). Recently, a few reports on transition metal complexes of hydrazones derivatives with potential anticancer activity were published (Pathan *et al.*, 2012, Alagesan *et al.*, 2013; Pathan and Gudasi, 2013; Santini *et al.*, 2014). Apart from biological applications, hydrazones act as potential donors for different metal ions (Jinglin *et al.*, 2014; Singh and Singh, 2013). These ligands contain an amide bond and are capable of undergoing keto-enol tautomerism (Scheme1), they can coordinate to central metal ions through nitrogen and oxygen atoms. In general they coordinate to central metal ions in the keto form when complexing with metal chlorides, nitrates, thiocyanates and in the enolic form with metal acetates (Al-Daher and Mustafa, 2013). Their coordination behavior also depends upon the pH of the medium, the nature of the substituents and the metal ion. Relatively few reports are available on the coordination behavior of α -keto ester aroyl hydrazones (Sonika and Malhotra, 2011; Pathan *et al.*, 2012; Pathan and Gudasi, 2013). These ligands might have interesting ligational features since they contain additional donor sites, i. e. the ester carbonyl oxygen and heterocyclic donor atoms in addition to the amide carbonyl oxygen and azomethine nitrogen atoms. The present paper describes the synthesis, characterization and antibacterial activities of ethyl pyruvate aroyl hydrazones of some transition metal ions.



Scheme 1

EXPERIMENTAL

Material and Measurements:

All chemicals used were reagent grade from B.D.H., Fluka or Merck chemical companies, used as supplied except ethyl-2-furoate and ethyl thiophene-2-carboxylate, prepared by esterification of 2-furoic acid and thiophene-2-carbonyl chloride, respectively (Furniss *et al.*, 1989). The infrared spectra (4000-400) cm^{-1} of the ligands and complexes were recorded on Tensor 27 Bruker FT-IR and/or Nicolet iS10 Thermo Scientific FT-IR spectrophotometers as KBr discs. The UV-Vis spectra were recorded at room temperature on UV-1650 PC Shimadzu and/or SPECORD 50 Analytik Jena spectrophotometers using DMF as solvent in 1cm quartz cures. Molar conductance's of the complexes were determined in absolute ethanol and DMF (10^{-3} M solutions) at room temperature using PMC3 Jenway and/or Seven CompactTM S230 Mettler Toledo conductivity meters. Magnetic susceptibilities were measured with BM6 Bruker instrument at

ambient temperature. The necessary diamagnetic corrections for ligands were done using Pascal's tables. Melting points were obtained on 9300 Electrothermal melting point apparatus in open capillaries. The C.H.N.S. elemental analyses were performed on Elemental Combustion System (ECS 4010) Costech Instrument. $^1\text{H-NMR}$ spectra were recorded in DMSO solution using TMS as internal standard on AVANCE (III) 400MHz Bruker spectrophotometer. The metal content of complexes was determined spectrophotometrically using 55AA Agilent Technologies atomic absorption spectrometer.

Preparation of the Ligands

Preparation of Acid Hydrazides

Benzoyl hydrazine, salicyloyl hydrazine, 2-furoic acid hydrazide and thiophene-2-carboxylic acid hydrazide were prepared by the reaction of the corresponding ethyl esters with hydrazine hydrate as described previously (Al-Saady and Al-Daher, 2000).

Preparation of Hydrazones

These were prepared according to the literature method (Pathan *et al.*, 2012), by reacting equimolar amounts of ethyl pyruvate and acid hydrazide in absolute ethanol as shown in Scheme 1.

To a solution of acid hydrazide (0.01 mol) [1.36 g, benzoyl hydrazine, 1.52 g, salicyloyl hydrazine, 1.26 g, 2-furoic acid hydrazide or 1.42 g, thiophene-2-carboxylic acid hydrazide] in absolute ethanol (25 mL) was added to the solution of ethyl pyruvate (1.16 g, 0.01 mol) in absolute ethanol (10 mL), the mixture was stirred for 24 h at room temperature. The reaction mixture was then left to stand overnight. The crystalline precipitate formed was filtered and washed with cold absolute ethanol (3 mL) and with diethyl ether (5 mL) and finally dried in an oven at (70-80) °C.

Preparation of the Complexes:

The complexes were prepared by reacting the corresponding metal acetate or metal chloride with each ligand (1:2) molar ratio in absolute ethanol or acetone in presence or absence of triethyl amine, according to the following procedures:

a. The complexes $[\text{M}(\text{EPBH-H})_2]$, M = Co(II), Ni(II), Cu(II), Zn(II):

A solution containing metal acetate (0.001 mol) [0.249 g, $\text{Co}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$; 0.249g, $\text{Ni}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$; 0.199g, $\text{Cu}(\text{CH}_3\text{COO})_2 \cdot \text{H}_2\text{O}$; 0.21 g, $\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$] in (10 mL) absolute ethanol was added with continuous stirring to (10 mL) ethanolic solution of EPBH (0.468 g, 0.002 mol). The mixture was further stirred for 12 h at room temperature, upon which precipitate formed. The solid complex was separated by filtration, washed with absolute ethanol (5 mL) then with ether (5 mL) and dried in an oven at (70-80) °C.

b. The complex $[\text{Cu}(\text{EPFH-H})_2]$:

This was prepared in similar way as in (a) above expect that (0.448 g, 0.002 mol) of the ligand EPFH and acetone as solvent were used.

c. The complexes $[\text{Mn}(\text{L-H})_2]$, L = EPBH, EPSH, EPFH and EPTH:

$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ (0.198 g, 0.001 mol) was dissolved in absolute ethanol (10 mL) and added to a solution (0.002 mol) of the ligands [0.468 g, EPBH; 0.500 g, EPSH; 0.448 g, EPFH; 0.480 g, EPTH] and triethyl amine (0.202 g, 0.002 mol) in absolute ethanol (10 mL) with continuous stirring, the mixture was stirred at room temperature for 12 h. The precipitated complexes was then filtered, washed and dried as in (a) above.

d. The complexes $[\text{Cd}(\text{L-H})_2]$, L = EPBH, EPSH, EPFH and EPTH:

These were prepared as in (c) above expect that $\text{Cd}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$ (0.302 g, 0.001 mol) was used.

e. The complexes $[\text{M}(\text{L-H})_2]$, M = Co(II), Ni(II), Zn(II); L = EPSH, EPFH and EPTH; M = Cu(II), L = EPSH and EPTH:

Metal acetate hydrates mentioned above (0.001 mol) was dissolved in hot absolute ethanol (10 mL) and added to hot ethanolic solution (15 mL) of the ligand (0.002 mol) with continuous stirring. The mixture was then refluxed for 3 h. The solid formed was filtered, washed and dried as in (a) above.

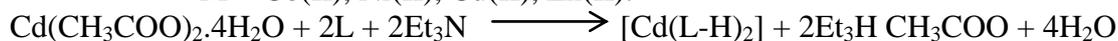
Antibacterial Activity

Antibacterial activity was evaluated using agar diffusion method (Kethcum, 1988). Gram-positive bacteria *Serratia marcescens* and Gram-negative bacteria *Bacillus Cereus* were cultivated in nutrient agar on petri dishes. The test solution was prepared by dissolving (10 mg) of the tested substances in DMSO (1 mL). A 6 mm diameter filter discs were soaked in the tested solutions. After 2 h cultivation at 37 °C, diameter of zones of inhibition was determined. DMSO was inactive under applied conditions.

RESULTS AND DISCUSSION

The pyruvate-based hydrazones (EPBH, EPSH, EPFH and EPTH) were synthesized in good yields by condensation of synthesized acid hydrazides with ethyl pyruvate at room temperature (Scheme 1, Table 1). After crystallization from absolute ethanol the hydrazones were obtained as white to pale yellow solids and characterized by IR and ¹H-NMR spectroscopy (Tables 1,3,5). Analytical data (Tables 1, 2) indicate that reactions between metal(II) acetates and manganese(II) chloride in presence of triethyl amine with the ligands EPBH, EPSH, EPFH and EPTH occur in 1:2 (M:L) molar ratio. In all complexes the ligands enolize and deprotonate during complexation.

The reactions may be written as:



All the complexes have been obtained as solids. They are insoluble in most organic solvents like chloroform, benzene, cyclohexane and diethyl ether and they have low solubility in ethanol and methanol but more soluble in DMF and DMSO. Most of the complexes melt in the temperature range (174-280) °C which may indicate the non-polymeric nature of complexes, few melt with decomposition. 10⁻³ M solutions of the complexes in absolute ethanol and DMF at room temperature show low molar conductance values (3.8-16.1) and (2.9-23.9) Ω⁻¹cm²mol⁻¹ respectively, indicating that they are non-electrolytes (Geary, 1971).

Table1: Physical properties and analytical data of the ligands and complexes

Complex No	Formula	Color	M. p. (°C)	Yield%	M% Calculated/(Found)	Λ_M^M ($\Omega^{-1} \text{cm}^2 \text{mol}^{-1}$)	
						EtOH	DMF
L ₁	EPBH (C ₁₂ H ₁₄ N ₂ O ₃)	White	112	94	.....	.....	.....
1	[Mn(EPBH-H) ₂]	Orange	264	63	10.55 / (10.51)	7.9	10.4
2	[Co(EPBH-H) ₂]	Dark orange	256	76	11.23 / (11.18)	13.1	13.6
3	[Ni(EPBH-H) ₂]	Golden	248	63	11.19 / (11.19)	7.5	2.9
4	[Cu(EPBH-H) ₂]	Orange	202	79	12.00 / (12.02)	8.3	6.1
5	[Zn(EPBH-H) ₂]	Pale yellow	256	81	12.30 / (12.32)	12.9	18.3
6	[Cd(EPBH-H) ₂]	Pale yellow	222	79	19.43 / (19.00)	7.1	14.7
L ₂	EPSH (C ₁₂ H ₁₄ N ₂ O ₄)	Yellow	126	71	.....	.....	.....
7	[Mn(EPSH-H) ₂]	Pale brown	264	83	9.94 / (9.82)	12.3	13.8
8	[Co(EPSH-H) ₂]	Golden	198	77	10.58 / (10.43)	8.6	12.9
9	[Ni(EPSH-H) ₂]	Pale green	280	78	10.55 / (10.38)	10.7	19.4
10	[Cu(EPSH-H) ₂]	Yellow	236	61	11.32 / (11.20)	11.3	15.7
11	[Zn(EPSH-H) ₂]	Pale yellow	266	86	11.60 / (11.52)	7.6	17.0
12	[Cd(EPSH-H) ₂]	Pale yellow	278	77	18.41 / (18.76)	6.9	23.8
L ₃	EPFH (C ₁₀ H ₁₂ N ₂ O ₄)	Pale yellow	132	89	.....	.....	.....
13	[Mn(EPFH-H) ₂]	Orange	246	71	10.97 / (10.85)	7.3	11.5
14	[Co(EPFH-H) ₂]	Dark pink	220	76	11.67 / (11.49)	14.7	8.9
15	[Ni(EPFH-H) ₂]	Golden	264	82	11.63 / (11.33)	10.6	7.4
16	[Cu(EPFH-H) ₂]	Orange	192	73	12.47 / (12.42)	16.1	18.7
17	[Zn(EPFH-H) ₂]	Pale brown	240	84	12.78 / (12.63)	8.7	23.9
18	[Cd(EPFH-H) ₂]	White	174	81	20.13 / (19.99)	5.1	6.6
L ₄	EPTH (C ₁₀ H ₁₂ N ₂ O ₃ S)	Pale yellow	118	87	.....	.....	.....
19	[Mn(EPTH-H) ₂]	Orange	258 d	75	10.31 / (10.42)	7.4	17.9
20	[Co(EPTH-H) ₂]	Pinkish red	276	80	10.98 / (10.83)	13.8	21.8
21	[Ni(EPTH-H) ₂]	Dark orange	318 d	76	10.94 / (10.68)	10.2	6.5
22	[Cu(EPTH-H) ₂]	Dark brown	214	88	11.73 / (11.30)	3.8	17.7
23	[Zn(EPTH-H) ₂]	Dark yellow	206	63	12.03 / (12.05)	13.7	12.9

Complex No	Formula	Color	M. p. (°C)	Yield%	M% Calculated/(Found)	Λ_M^{Δ} ($\Omega^{-1}\text{Cm}^2\text{mol}^{-1}$)	
						EtOH	DMF
24	[Cd(EPTH-H) ₂]	Yellow	210 d	54	19.04 / (19.12)	10.2	23.7

d = decomposition temperature.

Table 2: Elemental analysis of complexes (C.H.N.S)

Complex No	Formula	Elemental analysis, Calculated / (Found)			
		C%	H%	N%	S%
2	[Co(EPBH-H) ₂]	54.86 / (53.60)	4.95 / (4.99)	10.67 / (10.65)	.....
3	[Ni(EPBH-H) ₂]	54.89 / (54.08)	4.96 / (4.95)	10.67 / (10.75)	.....
8	[Co(EP SH-H) ₂]	51.71 / (52.19)	4.67 / (4.12)	10.06 / (11.06)	.....
9	[Ni(EP SH-H) ₂]	51.73 / (50.32)	4.67 / (4.99)	10.06 / (10.68)	.....
20	[Co(EPTH-H) ₂]	44.70 / (44.16)	4.10 / (3.30)	10.43 / (10.46)	11.92 / (12.00)
21	[Ni(EPTH-H) ₂]	44.72 / (44.51)	4.10 / (3.37)	10.43 / (10.55)	11.92 / (11.98)

Infrared Spectra

The IR spectra of all complexes (1-24) Table 3 were recorded and compared with those of the free ligands EPBH, EPSH, EPFH and EPTH to study the structural changes in the ligands upon complexation. Remarkable differences between the IR spectra of the ligands and those of the corresponding complexes were observed. The IR spectral bands observed at the ranges (3238-3171), (1720-1714), (1676-1648), (1629-1603) and (990-980) cm^{-1} in the spectra of the free ligands are assigned to $\nu(\text{N-H})$, $\nu(\text{C=O})$ ester, $\nu(\text{C=O})$ amide, $\nu(\text{C=N})$ and $\nu(\text{N-N})$ respectively (Sonika and Malhotra, 2011). The bands due to $\nu(\text{N-H})$ and $\nu(\text{C=O})$ amide are not observed in the spectra of the metal complexes due to enolization of the carbonyl group of acid hydrazide moiety. Then deprotonation of hydrazine NH and subsequent coordination through the enolate functionality (Pathan and Gudasi, 2013). The appearance of new $\nu(\text{C-O})$ band in all metal complexes spectra at the range (1227-1207) cm^{-1} also suggests bonding of the ligands to the metal ions through deprotonated (C-O) group (Sonika and Malhotra, 2011; Lei *et al.*, 2014). The strong intensity bands appearing at the range (1720-1714) cm^{-1} in the spectra of the free ligands that assigned to $\nu(\text{C=O})$ of pyruvate moiety have been shifted to lower wave number by (34-68) cm^{-1} in the spectra of the metal complexes indicating the coordination of carbonyl oxygen via breakdown of the intermolecular hydrogen band (Pathan and Gudasi, 2013; Ali *et al.*, 2001). The spectra of the complexes also show two $\nu(\text{C=N})$ at the range (1608-1583) and (1581-1546) cm^{-1} . The first one appears due to down shift of $\nu(\text{C=N})$ of free ligands by (7-46) cm^{-1} on coordination with metals and the second one result due to enolization of the ligand (Singh *et al.*, 2011). Furthermore, the $\nu(\text{N-N})$ has been shifted to higher frequencies (21-42) cm^{-1} in the complexes compared to the free ligands due to the increase in the double bond character offsetting the loss of electron density via donation to the metal, thereby providing further confirmation that the coordination of hydrazone ligand involves the azomethine nitrogen atom (Sathyadevi *et al.*, 2012). The band observed in the spectrum of the free ligand EPFH at 1086 cm^{-1} assigned for $\nu(\text{C-O-C})$ stretching vibration of furan ring (Shivakumar *et al.*, 2008; Al-Daher and Mustafa, 2013) is almost unaltered in the spectra of the metal complexes indicating non-participation of the furan ring oxygen atom in bonding with metal (Bikas *et al.*, 2013). The band observed at 858 cm^{-1} due to $\nu(\text{C-S-C})$ of thiophene ring in the

spectrum of the free ligand EPTH remain almost at the same position in the spectra of its complexes (857-856) cm^{-1} which indicate non-involvement of thiophene sulfur atom in bonding (Singh *et al.*, 2011). The stretching frequency of the phenolic OH group of the free ligand EPSH appears as a broad band at 3400 cm^{-1} , which in the corresponding complexes is observed at the range (3448-3423) cm^{-1} indicating non-involvement of the OH group in coordination (Mondal *et al.*, 2013). The shift of the OH group to higher frequencies in the spectra of the complexes may be due to decrease in hydrogen bonding on complex formation. The non-ligand bands in the (584-531) and (473-420) cm^{-1} ranges have been tentatively assigned to ν (M-O) and ν (M-N) respectively (Pathan *et al.*, 2012). Thus IR spectra of all the complexes show involvement of enolic oxygen, ester carbonyl and azomethine nitrogen atoms in coordination and the ethyl pyruvate aroyl hydrazones act as uni-negative tridentate legends.

Table 3: Characteristic IR spectral bands of the ligands and their complexes

Complex No	ν (N-H)	ν (C=O) Ester	ν (C=O) Amide	ν (C=N)	ν (C-O)	ν (N-N)	ν (C-X-C) X = S or O	ν (O-H)	ν (M-N)	ν (M-O)
L ₁	3184 m	1714 s	1676 s	1614 m	.....	990 w	.....	.....	.....	.....
1	1660 s	.....	1593 s 1577 m	1214 m	1023 m	.....	.....	541 w	469 m
2	1658 s	.....	1593 s 1578 m	1219 m	1014 m	.....	.....	544 w	459 w
3	1655 s	.....	1591 m 1576 m	1217 m	1024 m	.....	.....	555 w	447 w
4	1664 s	.....	1590 m 1576 m	1221 m	1022 m	.....	.....	551 w	447 w
5	1680 s	.....	1597 s 1560 m	1214 m	1022 m	.....	.....	540 w	443 w
6	1666 s	.....	1593 s 1577 m	1211 m	1022 m	.....	.....	536 w	451 w
L ₂	3238 m	1720 s	1672 s	1603 s	.....	980 m	.....	3400 m	.....	.....
7	1665 s	.....	1596 s 1581 s	1226 m	1018 m	.....	3433 m	571 w	428 w
8	1660 s	.....	1589 s 1571 m	1220 m	1016 m	.....	3423 m	569 w	425 w
9	1661 m	.....	1587 s 1560 m	1222 m	1012 m	.....	3424 m	531 w	427 w
10	1670 m	.....	1595 s 1546 s	1222 m	1013 m	.....	3447 m	584 w	420 w
11	1683 s	.....	1587 s 1558 m	1223 m	1021 m	.....	3446 m	542 w	473 w
12	1674 s	.....	1589 s 1564 m	1227 m	1022 m	.....	3448 m	571 w	424 w
L ₃	3181 m	1717 s	1668 s	1629 m	.....	985 w	1086 m	.....	.....	.....
13	1660 s	.....	1601 m 1569 s	1216 m	1012 m	1088 s	.....	540 w	458 w
14	1654 m	.....	1583 m 1560 m	1224 m	1012 m	1090 m	.....	551 w	458 w
15	1649 s	.....	1598 m 1570 s	1219 m	1006 m	1091 s	.....	548 w	458 w
16	1655 s	.....	1603 m 1569 s	1222 m	1007 m	1088 s	.....	546 w	453 w
17	1672 s	.....	1608 m 1573 s	1223 m	1006 m	1088 s	.....	536 w	453 w
18	1658 m	.....	1601 m 1562 m	1215 m	1022 m	1091 m	.....	536 w	459 w
L ₄	3171 m	1716 s	1648 s	1618 m	.....	983 w	858 m	.....	.....	.....
19	1655 s	.....	1589 m 1560 m	1212 m	1017 m	857 m	.....	543 w	445 w

Complex No	ν (N-H)	ν (C=O) Ester	ν (C=O) Amide	ν (C=N)	ν (C-O)	ν (N-N)	ν (C-X-C) X = S or O	ν (O-H)	ν (M-N)	ν (M-O)
20	1654 s	.....	1590 m 1576 m	1215 s	1016 m	856 m	.....	547 w	439 w
21	1652 s	.....	1589 m 1562 m	1216 s	1020 m	857 m	.....	540 w	443 w
22	1658 m	.....	1590 m 1556 m	1215 m	1023 m	856 m	.....	551 w	435 w
23	1676 s	.....	1599 m 1560 m	1213 s	1020 m	856 m	.....	531 w	430 w
24	1666 s	.....	1589 m 1568 m	1207 s	1012 m	856 m	.....	542 w	440 w

Magnetic Moments

The magnetic moments of the complexes measured at room temperature are shown in Table 4. The Mn(II) complexes show magnetic moment values at the range (5.98-6.08) BM, which are appreciably close to the calculated spin-only value (5.91) BM, for five unpaired electrons and reveals high spin state (Cotton *et al.*, 1999). The magnetic moment of Co(II) complexes are in the range (4.82-5.13) BM, indicating octahedral Co(II) complexes. For Ni(II) complexes the magnetic moment values are at the range (2.83-3.13) BM, indicating the octahedral configuration, with two unpaired electrons. The effective magnetic moment values of Cu(II) complexes are at the range (1.82-2.05) BM, which support a monomeric structural formulation of these compounds, (Pathan *et al.*, 2012). Zn(II) and Cd(II) complexes are diamagnetic as expected for d^{10} configurations (Cotton *et al.*, 1999).

Electronic Spectra

Electronic spectra of the ligands and their complexes (Table 4) were measured in DMF. The free ligands exhibited strong absorptions at $(32362-33333) \text{ cm}^{-1}$ and $(30488-31646) \text{ cm}^{-1}$ due to intra-ligand $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ transitions respectively. The bathochromic shift of these absorptions upon complexation is due to donation of a lone pair of electrons to the metal, indicating the coordination of the ligands to the metal ions (Pathan *et al.*, 2012). The extremely pale color high spin Mn(II) complexes electronic spectra don't show any d-d transitions bands due to spin-forbidden as well as parity-forbidden transitions in octahedral environments (Cotton *et al.*, 1999). The electronic spectra of Co(II) complexes showed d-d transitions at $(18692-20661) \text{ cm}^{-1}$, $(13333-15480) \text{ cm}^{-1}$ and $(9940-10526) \text{ cm}^{-1}$ assignable to ${}^4T_{1g}(F) \rightarrow {}^4T_{1g}(P)$, ${}^4T_{1g}(F) \rightarrow {}^4A_{2g}(F)$ and ${}^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$ respectively, indicating octahedral geometry. In the Ni(II) complexes spectra three bands were observed at the ranges $(22831-25907) \text{ cm}^{-1}$, $(15408-17331) \text{ cm}^{-1}$ and $(9747-9921) \text{ cm}^{-1}$ assignable to ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(P)$, ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$ and ${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)$. These bands are characteristic for octahedral symmetry (Adly and Taha, 2013; Pathan *et al.*, 2013). The electronic spectra of Cu(II) complexes showed one broad band at the range $(13550-15361) \text{ cm}^{-1}$ which might assigned to ${}^2E_g \rightarrow {}^2T_{2g}$ transition, suggesting an octahedral geometry around Cu(II) ions (Cotton *et al.*, 1999). The strong absorption bands observed at the range $(24155-28818) \text{ cm}^{-1}$ in all the complexes assigned to charge transfer transitions.

Table 4: Electronic spectra and magnetic susceptibility data of the ligands and their complexes

Complex No	μ_{eff} (B.M.)	Electronic Spectra Cm^{-1}
L ₁	.....	32680, 31646
1	6.08	31056, 29412, 25381
2	4.82	30488, 29851, 26178, 20080, 13333, 10504
3	3.13	30120, 29586, 27778, 25907, 15625, 9747
4	1.86	30675, 29412, 27778, 13889
5	Diamagnetic	31348, 29499, 25510
6	Diamagnetic	31056, 29240, 25381
L ₂	.....	32362, 30488
7	5.99	31250, 29240, 24390
8	5.06	30488, 28571, 24155, 18692, 15480, 9940
9	2.83	30488, 29412, 27397, 25381, 16181, 9747
10	1.82	30303, 28736, 25773, 13550
11	Diamagnetic	30675, 28986, 27778
12	Diamagnetic	30120, 28736, 27701
L ₃	.....	32895, 31348
13	6.01	30960, 29070, 28090
14	5.13	30395, 29851, 28329, 19380, 14684, 10320
15	3.10	30769, 29674, 28409, 23364, 15408, 9804
16	2.05	30675, 29762, 27473, 15361
17	Diamagnetic	30211, 29240, 28169
18	Diamagnetic	30303, 29586, 28818
L ₄	.....	33333, 31056
19	5.98	30864, 29851, 27473
20	4.97	30120, 28736, 27548, 20661, 14925, 10526
21	3.02	30303, 28902, 27701, 22831, 17331, 9921
22	1.96	30864, 28736, 27933, 13736
23	Diamagnetic	30864, 29586, 27933
24	Diamagnetic	31447, 29586, 27624

¹H-NMR Spectra

¹H-NMR spectra of the ligands EPBH and EPTH and their Zn(II) complexes were recorded in DMSO-d₆ solution. The relevant spectroscopic data were collected in Table 5. The ¹H-NMR spectra of the free ligands EPBH and EPTH show a singlet at 10.98 ppm and 11.30 ppm respectively and are absent in the spectra of Zn(II) complexes thus indicating deprotonation of the –NH–CO– group confirming that both ligands coordinate to Zn(II) in the enolate form after deprotonation (Sonika and Malhotra, 2011). The triplet signal for –CH₃ methyl protons of ester appears at (1.28-1.34) ppm and the quartet for methylene protons at (4.18-4.23) ppm. The methyl protons attachment to azomethine group was observed as singlet at (2.11-2.17) ppm. The slight downfield shift (2.39-2.45) ppm observed for the CH₃–C=N– protons in the spectra of Zn(II) complexes indicate the coordination of nitrogen to the Zn(II) ion. (Pathan and Gudasi, 2013). The phenyl protons of EPBH appear as multiplet at (7.50-7.88) ppm and the thiophene protons at (7.11-8.17) ppm, these were almost unaltered in the spectra of Zn(II) complexes, which may suggest non-involvement of thiophene sulfur atom in coordination.

Table 5: ¹H-NMR spectra data of the ligands EPBH, EPTH and their deprotonated Zn(II) complexes

Protons	EPBH	[Zn(EPBH-H) ₂]
Methyl Protons CH ₃ CH ₂ -O-	1.28 (t, 3H)	1.27 (t, 3H)
Methylene Protons CH ₃ CH ₂ -O-	4.23 (q, 2H)	4.29 (q, 2H)
Methyl Protons CH ₃ -C=N-	2.17 (s, 3H)	2.45 (s, 3H)
Aromatic Protons C ₆ H ₅ -	7.50 – 7.88 (m, 5H)	7.42 – 8.19 (m, 5H)
Amide –CONH– Proton	10.98 (s, H)	.....
Protons	EPTH	[Zn(EPTH-H) ₂]
Methyl Protons CH ₃ CH ₂ -O-	1.34 (t, 3H)	1.29 (t, 3H)
Methylene Protons CH ₃ CH ₂ -O-	4.18 (q, 2H)	4.27 (q, 2H)
Methyl Protons CH ₃ -C=N-	2.11 (s, 3H)	2.39 (s, 3H)
Thiophene Protons C ₄ H ₃ S-	7.11 – 8.17 (m, 3H)	7.05 – 8.17 (m, 3H)
Amide –CONH– Proton	11.30 (s, 1H)	.....

q = quartet; t = triplet; s = singlet; m = multiplet

Antibacterial Activity

The tested compounds were screened in vitro for their antibacterial activity against Gram-positive (*Bacillus cereus*) and Gram-negative (*Serratia marcescens*) bacteria. The antibacterial results are given in Table 6, compared with those of the standard drugs amoxicillin and erythromycin. The results evidently show that the ligands and all tested complexes except complex (17) were inactive against the Gram-negative bacteria *Serratia marcescens*. On the other hand, the ligands EPBH, EPFH and EPTH were active against the Gram-positive bacteria *Bacillus cereus*, but have a weak inhibitory activity as compared with erythromycin and more closer to those of amoxicillin. The tested complexes exhibited lower inhibition activity as compared with their corresponding ligands except complex (10), which mean that the metal ion causes reduction in the antibacterial activity of the ligands against this type of bacteria.

Table 6: Antibacterial activity of the investigated compound

Complex No	Compound	<i>Serratia marcescens</i>	<i>Bacillus cereus</i>
L ₁	EPBH (C ₁₂ H ₁₄ N ₂ O ₃)	R	S (9 mm)
L ₂	EPSH (C ₁₂ H ₁₄ N ₂ O ₄)	R	R
L ₃	EPFH (C ₁₀ H ₁₂ N ₂ O ₄)	R	S (10 mm)
L ₄	EPTH (C ₁₀ H ₁₂ N ₂ O ₃ S)	R	S (12 mm)
4	[Cu(EPBH-H) ₂]	R	R
5	[Zn(EPBH-H) ₂]	R	R
10	[Cu(EPSH-H) ₂]	R	S (8 mm)
11	[Zn(EPSH-H) ₂]	R	R
16	[Cu(EPFH-H) ₂]	R	S (8 mm)
17	[Zn(EPFH-H) ₂]	S (12 mm)	R
22	[Cu(EPTH-H) ₂]	R	S (9 mm)
.....	Amoxicillin	R	S (16 mm)
.....	Erythromycin	S (8 mm)	S (46 mm)

R = Resistant, S = Susceptible.

CONCLUSION

New Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) complexes of four ethyl pyruvate aroyl hydrazones (EPBH, EPSH, EPFH and EPTH) have been prepared and characterized by conventional measurements. The data revealed that all the complexes are monomeric and have an octahedral geometry (Fig. 1). The ligands act as ONO tridentate monobasic chelating ligands coordinated through the enolate oxygen, the imine nitrogen and the ester carbonyl group oxygen atoms. The ligands and their Cu(II) and Zn(II) complexes were tested against Gram-positive and Gram-negative bacteria which indicate that most of them are inactive against the used Gram-negative bacteria and low activity against the used Gram-positive bacteria compared with standard drugs.

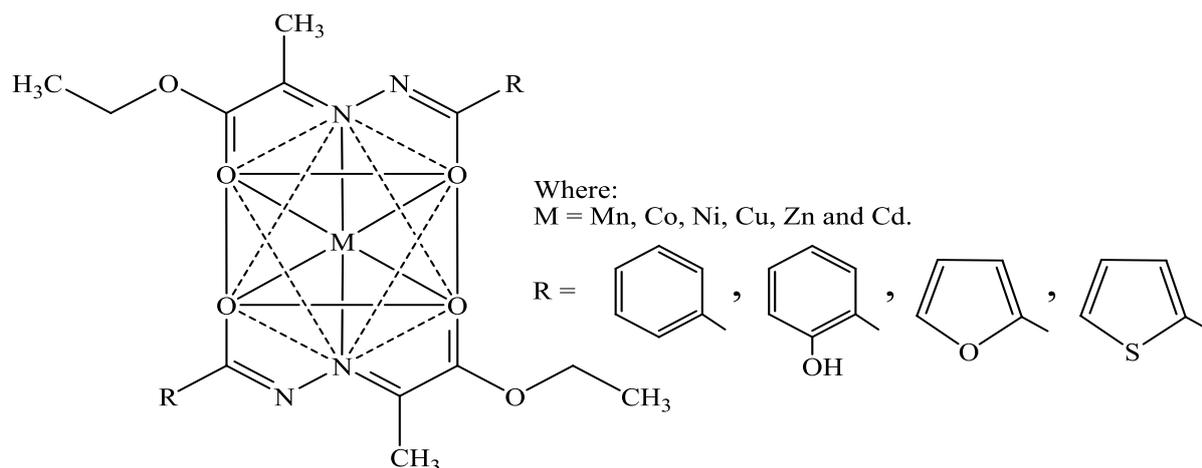


Fig. 1: Proposed structure for the prepared complexes.

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