

Synthesis and Characterization of some Mononuclear Mn(II), Fe(II), Co(II), Ni(II), Cu(II) and Zn(II) Complexes containing Bis-(2-thiophenelidene) thiosemicarbazone ligand

Dr. Sahbaa A. Al-Sabaawi
Department of Chemistry
College of Science / University of Mosul

Received: 2/2/2011 ; Accepted: 26/12/2011

Abstract:

A number of new complexes of the general formulae $[M(L_1)_2Cl_2]$ and $[M(L_1)_2(\gamma-pic)_2]Cl_2$ {where L_1 = bis-(2-thiophenelidene) thiosemicarbazone; M = Mn(II), Fe(II), Co(II), Ni(II), Cu(II), Zn(II) and $\gamma-pic$ = 4-methyl pyridine} have been prepared and characterized by molar conductance, magnetic properties and metal contents analysis, infrared, and electronic spectra. The electronic and magnetic susceptibility indicated that the complexes have distorted octahedral geometry either non regular for some complexes due to the differences in the two coordinated ligand and distorted copper complexes due to the above reason and also to Jahn teller effect.

تحضير وتشخيص بعض من معقدات

Zn(II) و Cu(II) , Ni(II), Co(II) , Fe(II) , Mn(II)

أحادية النوى المحتوية على ليكاند بس - (2- ثايوفنيليدين)
ثايوسيميكاربازون

د. صهباي علي احمد السبعاوي
قسم الكيمياء
كلية العلوم / جامعة الموصل

ملخص البحث:

تم تحضير عدد من المعقدات الجديدة ذوات الصيغ العامة $[M(L_1)_2Cl_2]$ و $[M(L_1)_2(\gamma-pic)_2]Cl_2$ {ف L_1 = بس - (2- ثايوفنيليدين) ثايوسيميكاربازون، M = Mn(II) و Fe(II) و Co(II) و Ni(II) و Cu(II) و Zn(II) ، $\gamma-pic$ = 4- ميثيل بريدن}. وتم تشخيص المعقدات المحضرة بواسطة قياسات التوصيلية الكهربائية والمغناطيسية وتعيين المحتوى الفلزي وأطياف الأشعة تحت الحمراء والاطياف الالكترونية، وقد بينت الاطياف

الإلكترونية والعزم المغناطيسي بان المعقدات تمتلك بنية ثماني السطوح غير المنتظمة لبعض المعقدات بسبب كون الليكندين المتناسقين مختلفين والمشوهة لمعقد النحاس للسبب السابق فضلا عن تأثير يان تيلر.

Introduction:

Thiosemicarbazides are of current interest with respect to their biological activity and chemotherapeutic properties. In addition, these compounds have many applications especially as reagents for the microanalytical determination as well as their ability to form chelated complexes with transition metal ions^[1-5].

Thiosemicarbazones and their metal complexes have been extensively studied during recent years mainly due to their various biological activities^[6,7]. They usually acted as chelating ligands specially with transition metal ions, joint through the sulfur and azomethine nitrogen atoms^[8].

A review was published by Lobana *et. al*^[9,10] changing the attachment of the thiosemicarbazone moiety to the 3-position on the heteroaromatic ring often caused a decrease in biological activity. Thiosemicarbazones (TSC) have been synthesized by condensing substituted thiosemicarbazide with thiophene-2- carboxaldehyde. These thiosemicarbazones showed significant improvement in antiamobic activity^[11].

Intercalation of pyridine, 4-methylpyridine and 4-ethylpyridine into the interlayer spaces of Cu(II)-montmorillonite was investigated. The successful intercalation of these compounds through coordination to the interlayer Cu²⁺ cations was confirmed by powder X-ray diffractions and infrared spectroscopy of the products. The presented solid-gas intercalation of pyridine derivatives and in situ complex formation in the interlayer spaces of montmorillonite is a feasible way to prepare clay coordination-intercalation compounds which cannot be obtained in conventional ion-exchange reactions^[12].

A new synthetic route to isothiocyanate-containing materials is presented. Eight isothiocyanate-4-methylpyridine (γ -picoline) compounds were prepared by refluxing metal powders with thiourea in γ -picoline^[13].

The present paper described the synthesis and characterization of L₁= bis-(2-thiophenelidene) thiosemicarbazone, and the preparation of their new complexes with Mn(II), Fe(II), Co(II), Ni(II), Cu(II) and Zn(II).

Experimental:

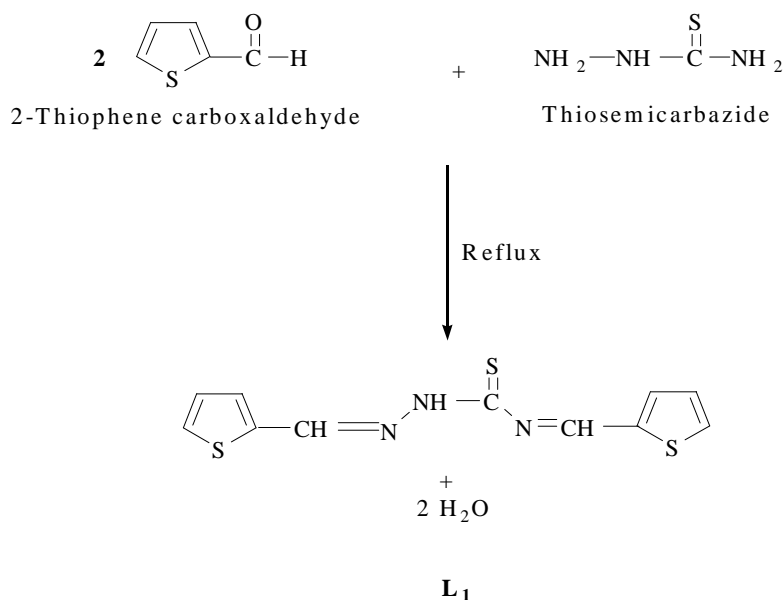
Physical measurement:

Electronic spectra were recorded on Shimadzu UV/Vis, spectrophotometer UV-160 at room temperature, The measurements were recorded using a concentration of 10^{-3} M of the two ligands and their complexes in N,N-dimethylformamide (DMF). Infrared spectra ($4000-200\text{ cm}^{-1}$) were recorded on a FTIR Bruker Tensor 27 co. spectrophotometer by KBr, CsI discs. Metal contents analyses were made on Shimadzu AA 670 atomic absorption spectrophotometer. The magnetic moments were carried out at 25°C on the solid states by Faraday method using Bruker BM6 instrument. The molar conductance of 10^{-3} M solution of metal complexes in (DMF) were measured at 25°C using Jenway 4070 conductivity meter . Melting point were determined on a Buchi 510 melting point apparatus and were uncorrected. The primary materials;

2-thiophene carboxaldehyde, thiosemicarbazide and all the metal salts that are used in the experiment were supplied (Fluka, BDH).

A . Preparation of the ligands:

The ligand L_1 has been synthesized according to the following procedure ^[14]. Treatment of 2-thiophene carboxaldehyde (2.24 g, 0.02 mol) in (10 ml) ethanol with thiosemicarbazide (0.91 g, 0.01 mol) in (10 ml) ethanol. Then the mixture was refluxed for 7 h. in presence of 2 ml conc. HCl, the (greenish yellow) solid was appeared then the mixture cooled and filtered off, washed with cold ethanol and dried in vacuum,recrystallization by propanol (Scheme(1)).



Scheme (1) : Preparation and structure of the ligand L_1

B. Preparation of the complexes:

A hot ethanolic solution of the ligand L_1 (0.56 g , 0.02 mol) and ethanolic solution of the corresponding metal salt { $MnCl_2 \cdot 4H_2O$ (0.19 g, 0.01 mol) or $FeCl_2$ (0.12 g , 0.01 mol) or $CoCl_2 \cdot 6H_2O$ (0.27 g , 0.01 mol) or $NiCl_2 \cdot 6H_2O$ (0.23 g , 0.01 mol) or $CuCl_2 \cdot 2H_2O$ (0.13 g, 0.01 mol and $ZnCl_2$ (0.13g , 0.01 mol)} in (20 ml) of ethanol were mixed together with stirring . The mixture has been refluxed for 4 hours , on cooling , a colored precipitate has been formed which was filtered off , washed with cold EtOH and dried under vacuum.

C. Preparation of the mixed ligand complexes:

The complex No.(2) was prepared by adding an excess of 4-methyl pyridine (0.07 g , 0.02 mol) dissolved in ethanol (10 ml) to (0.27 g , 0.01 mol) complex separately and refluxed for about 3 hours. On cooling a coloured precipitate has been formed which was filtered off, washed with cold EtOH and dried under vacuum, and the other complexes No.(4, 6, 10, 12) were prepared by applying the same procedure.

Results and discussion:

The complexes of Mn(II), Fe(II), Co(II), Ni(II), Cu(II) and Zn(II) with the ligand L_1 =[bis-(2-thiophenelidene)thiosemicarbazone] were air stable solids and colored (Table 1). The molar conductivities of the complexes in DMF indicated the presence of two types of complexes , a nonelectrolytic nature ($14-30 \text{ ohm}^{-1} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$)^[15] for Mn(II), Fe(II), Co (II), Ni(II), Cu(II) and Zn(II) complexes where as 1:2 electrolytes ($135-167 \text{ ohm}^{-1} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$)^[16] for the mixed ligand complexes (Table 1).

IR spectra:

The most important infrared spectra of the two ligands and their complexes are listed in Table 2. The IR spectra of the ligand showed band at 3202 cm^{-1} in the ligand spectrum assigned to $\nu_{(NH)}$, this band has been shifted to lower frequency on complication^[17]. Upon comparison it was shown that the $\nu_{(C=N)}$ was found to be splitted at 1610 cm^{-1} and 1606 cm^{-1} as we expected for the two type of C=N present in the complex . The two bands still splitted in the complexes and shifted to lower frequencies (Table 2) indicating the participation of azomethine nitrogen in coordination^[18,19]. The spectra of the ligand showed band at the region 1173 cm^{-1} due to $\nu_{(C=S)}$ in the spectra of some complexes this band undergoes little shift and appears at the range ($1164-1172$) cm^{-1} which indicates that this band dose not involve in coordination, in the spectra of the other complexes this band appears at the range ($1143-1158$) cm^{-1} showing that the coordination occurs through the sulfur of C=S bond with the metal ion^[20]. The infrared spectra of γ -picoline ligand showed band

at 1625cm^{-1} attributed to ($\text{C}\equiv\text{N}\equiv\text{C}$) group, this band was shifted to lower frequency ($1562\text{-}1589$) cm^{-1} in the IR spectra of the complexes No. (2, 4, 6, 8, 10 and 12) indicating the coordination of this group with the metal ion^[21].

The other new bands in the range ($418\text{-}459$) cm^{-1} in the spectra of the complexes were assigned to $\nu_{(\text{M-N})}$ ^[22] while the $\nu_{(\text{M-N})}$ for (γ -picoline) ligand are in good agreement with the reported values of Nakamoto^[16] which fall in the region ($238\text{-}317$) cm^{-1} . The bands occurring at ($350\text{-}390$) cm^{-1} and ($269\text{-}303$) cm^{-1} have been assigned to the $\nu_{(\text{M-S})}$ and $\nu_{(\text{M-Cl})}$ modes, respectively. The spectrum of the ligand showed $\nu_{(\text{N-N})}$ at ($918\text{-}953$) cm^{-1} . The thiophene ring remained unchanged when passing from ligands to complexes at ≈ 837 cm^{-1} ^[20, 22].

Electronic spectra and magnetic moments:

The electronic spectral bands of the two ligands and their complexes, also the magnetic moment values for the complexes were listed in Table (3).

Manganese (II) complexes:

The electronic spectra exhibited band in the visible region at 26595 , 26737 cm^{-1} , respectively for the two manganese (II) complexes these bands may be assigned to the transitions ${}^6\text{A}_{1g} \rightarrow {}^4\text{T}_{1g}$ (G) and ${}^6\text{A}_{1g} \rightarrow {}^4\text{T}_{2g}$ (P), respectively. The bands appeared at 30303 , 32016 cm^{-1} due to charge transfer^[23]. The magnetic moment values 5.87 , 5.93 B.M for the manganese (II) complexes were in accordance with those having octahedral structure having five unpaired electrons.

Iron (II) complexes:

The electronic spectra of the two Fe(II) complexes showed a band in the visible region at 10131 , 13089 cm^{-1} , respectively attributed to the ${}^5\text{T}_{2g} \rightarrow {}^5\text{E}_g$ transition and could be assigned to octahedral structure^[23]. The values of the magnetic moment were 4.68 , 4.85 B.M have been in well accordance with those having octahedral geometry.

Cobalt (II) complexes:

The magnetic moment of Co(II) complexes were 4.17 , 4.68 B.M (the higher values were due to orbital contribution) indicating an octahedral geometry^[23-25]. The electronic spectra showed band in the positions (1) 10695 , 10989 cm^{-1} , (2) 12886 , 16181 cm^{-1} , (3) 15772 , 18796 cm^{-1} , respectively for the two cobalt (II) complexes these bands may be assigned to the transition ${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{T}_{2g}(\text{F})(\nu_1)$, ${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{A}_{2g}(\nu_2)$ and ${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{T}_{1g}(\text{P})(\nu_3)$, respectively the fourth band was due to

the charge transfer ^[23-25]. The bands appear at 33557, 35842 cm⁻¹ due to charge transfer.

The ligand field parameter B and the ligand field splitting energy (10Dq) in case of cobalt (II) complexes have been calculated, the values of B, β , ν_2/ν_1 suggested octahedral geometry for all the complexes ^[26]. Racah parameter gives useful information about the covalency in the metal – ligand bonds (when Racah parameter decreased the covalence character's of the bond between the metal ion and ligand increased). The value of Racah parameter explain clearly the position of electrons cloud near the metal ion or the ligand molecule i.e: the type of coordination bond between them^[27].

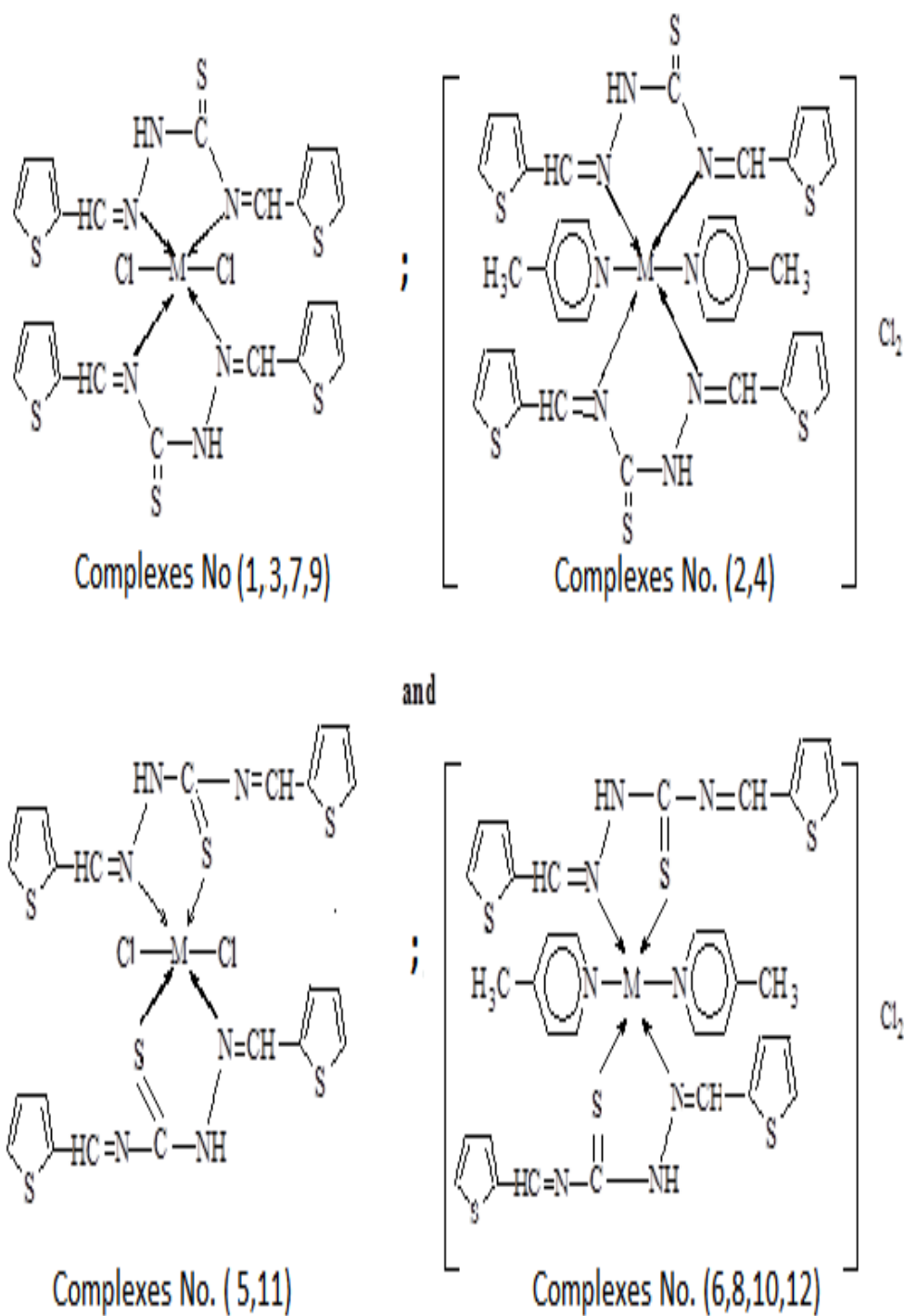
Nickel (II) complexes:

The two Ni(II) complexes exhibited magnetic moment values 3.07 and 3.12 B.M these values showed the presence of 2 unpaired electrons which lead to octahedral environment around Ni (II) ions, the high values of magnetic moment (from 2.87 B.M) were due to the orbital contribution^[28]. The electronic spectra of the complexes showed three bands at (1) 10162-10183 cm⁻¹ (2) 15364-16792 cm⁻¹ and (3) 24038-26455 cm⁻¹ due to three spin allowed transitions ${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)(\nu_1)$, ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)(\nu_2)$ and ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(P)(\nu_3)$, respectively, indicating that the complexes had octahedral geometry, The ligand field parameter B and the ligand field splitting energy (10Dq) in case of nickel (II) complexes have been calculated, the values of B, β , ν_2/ν_1 suggested octahedral geometry for all the complexes ^[26,27].

Copper (II) complexes:

The magnetic moment of the Cu(II) complexes are 1.78 and 1.84 B.M which were due to the presence of one unpaired electron. The electronic spectra showed one band at which assigned to the ${}^2E_{2g}(F) \rightarrow {}^2T_{2g}$ transition in distorted octahedral structure around the Cu(II) ions ^[29,30].

As the spectra of Zn(II) complexes were not well resolved, there were not interpreted but they μ_{eff} values showed that they are diamagnetic as expected. On the basis of the above results the proposed structures for the metal (II) complexes were shown in Fig (1).



M= Mn(II) , Fe(II) , Co(II) , Ni(II) , Cu(II) and Zn(II)

Fig (1): Suggested structure of the complexes $[M (L_1)_2Cl_2]$ and $[M (L_1)_2(\gamma - pic)_2]Cl_2$

Table (1) : Some analytical and physical properties of the complexes .

No.	Compound	Colours	M.p °C	Yield %	Molar conductance $\text{Ohm}^{-1} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$	Salts	Metal analysis found (calculated)%
	L_1	Greenish yellow	190	61	---	----	---
	$\gamma\text{-pic}$	Brown	145(Bb)	75	---	----	---
1.	$[\text{Mn}(L_1)_2\text{Cl}_2]$	Brown	213	82	27	$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$	8.03 (8.17)
2.	$[\text{Mn}(L_1)_2(\gamma\text{-pic})_2] \text{Cl}_2$	Pale brown	247	44	148	$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$	6.22 (6.31)
3.	$[\text{Fe}(L_1)_2\text{Cl}_2]$	Brown	263	52	14	FeCl_2	8.15 (8.26)
4.	$[\text{Fe}(L_1)_2(\gamma\text{-pic})_2] \text{Cl}_2$	Brown	271	64	135	FeCl_2	6.32 (6.51)
5.	$[\text{Co}(L_1)_2\text{Cl}_2]$	Dark brown	206	90	22	$\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	8.56 (8.70)
6.	$[\text{Co}(L_1)_2(\gamma\text{-pic})_2] \text{Cl}_2$	Brown	223	49	167	$\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	6.64 (6.71)
7.	$[\text{Ni}(L_1)_2\text{Cl}_2]$	Green	294	84	30	$\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$	8.53 (8.67)
8.	$[\text{Ni}(L_1)_2(\gamma\text{-pic})_2] \text{Cl}_2$	Dark green	255	59	150	$\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$	6.62 (6.83)
9.	$[\text{Cu}(L_1)_2\text{Cl}_2]$	Dark green	216	70	19	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	9.91 (9.24)
10.	$[\text{Cu}(L_1)_2(\gamma\text{-pic})_2] \text{Cl}_2$	Green	303	36	156	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	7.13 (7.21)
11.	$[\text{Zn}(L_1)_2\text{Cl}_2]$	White	241	69	21	ZnCl_2	9.41 (9.53)
12.	$[\text{Zn}(L_1)_2(\gamma\text{-pic})_2] \text{Cl}_2$	White	289	55	143	ZnCl_2	7.32 (7.44)

Table (2) : Selected I.R bands and their assignment in cm^{-1} .

No.	Compound	ν (NH)	ν (C-N)	ν (C \equiv N \rightarrow C) for γ -pic	ν (C=S)	Thiophene ring	ν (N-N)	ν (M-N)	ν (M-N) for γ -pic	ν (M-S)	ν (M-Cl)
	Ligand	3202	1610, 1606	---	1173	837	939	---	---	---	---
	γ -pic	---	---	1625	---	---	---	---	---	---	---
1.	[Mn(L ₁) ₂ Cl ₂]	3136	1597, 1583	---	1164	837	942	434	---	---	293
2.	[Mn(L ₁) ₂ (γ -pic) ₂] Cl ₂	3134	1586, 1584	1573	1170	836	939	420, 438	317	---	---
3.	[Fe(L ₁) ₂ Cl ₂]	3172	1585, 1579	---	1172	850	918	418	---	---	269
4.	[Fe(L ₁) ₂ (γ -pic) ₂] Cl ₂	3153	1578, 1573	1562	1169	832	953	419, 442	259	---	---
5.	[Co(L ₁) ₂ Cl ₂]	3178	1597, 1581	---	1146	841	926	428	---	376	285
6.	[Co(L ₁) ₂ (γ -pic) ₂] Cl ₂	3161	1596, 1588	1589	1143	857	952	410, 428	238	390	---
7.	[Ni(L ₁) ₂ Cl ₂]	3147	1583, 1577	---	1171	837	939	436	---	---	290
8.	[Ni(L ₁) ₂ (γ -pic) ₂] Cl ₂	3179	1608, 1579	1567	1148	833	951	435, 452	270	360	---
9.	[Cu(L ₁) ₂ Cl ₂]	3149	1588, 1583	---	1169	837	939	459	---	---	303
10.	[Cu(L ₁) ₂ (γ -pic) ₂] Cl ₂	3144	1601, 1582	1574	1158	831	930	432, 446	248	370	---
11.	[Zn(L ₁) ₂ Cl ₂]	3153	1595, 1580	---	1155	837	939	457	---	355	277
12.	[Zn(L ₁) ₂ (γ -pic) ₂] Cl ₂	3170	1595, 1588	1580	1148	834	947	408, 446	277	385	---

Table (3) : Magnetic moment and electronic spectral data of the complexes.

No.	Compound	μ_{eff} B.M (25°C)	λ_{max} (cm ⁻¹)	B	β	ν_2/ν_1	10 Dq	C. F. S. E
1.	[Mn(L ₁) ₂ Cl ₂]	5.93	26737, 32016	----	----	----	----	----
2.	[Mn(L ₁) ₂ (γ -pic) ₂]Cl ₂	5.87	26595, 30303	----	----	----	----	----
3.	[Fe(L ₁) ₂ Cl ₂]	4.68	13089, 33333	----	----	----	----	----
4.	[Fe(L ₁) ₂ (γ -pic) ₂]Cl ₂	4.85	10131, 32894	----	----	----	----	----
5.	[Co(L ₁) ₂ Cl ₂]	4.17	10695, 12886, 15772, 35842	228.46	0.23	1.20	10695	19251
6.	[Co(L ₁) ₂ (γ -pic) ₂]Cl ₂	4.68	10989, 16181, 18796, 33557	134.00	0.13	1.47	10989	19780
7.	[Ni(L ₁) ₂ Cl ₂]	3.07	10162, 15364, 26455, 31645	755.53	0.73	1.51	10162	12194
8.	[Ni(L ₁) ₂ (γ -pic) ₂]Cl ₂	3.12	10183, 16792, 24038, 30487	685.4	0.66	1.64	10183	12219
9.	[Cu(L ₁) ₂ Cl ₂]	1.84	13089, 30303	----	----	----	----	----
10.	[Cu(L ₁) ₂ (γ -pic) ₂]Cl ₂	1.78	11792, 26455	----	----	----	----	----
11.	[Zn(L ₁) ₂ Cl ₂]	Diamagnetic	31645, 32051	----	----	----	----	----
12.	[Zn(L ₁) ₂ (γ -pic) ₂]Cl ₂	Diamagnetic	31056, 34722	----	----	----	----	----

References:

1. R. R. Amin and K. F. Al-Towery, *J. Basic Appl. Sci.* 3, 2, (2007).
2. E. Asmy, A. Hassanian and M. M. Abdel-Rhman, *World Wide Science. Org.*, 1, 1, (2010) .
3. E. W. Y. Tido, C. Faulmann, R. Roswanda, A. Meetsma and P. J. V. Koningsbruggen, *Dalton Trans.*, 39, 1643-1651, (2010) .
4. P. M. Reddy, K. Shanker, R. Rohini and V. Ravinder, *Inter. J. Chem. Tech. Res.*, 1, 2, 367-372, (2009) .
5. V. B. Arion, P. Rapta, J. Telser, S. S. Shora, M. Breza, K. Lušpai and J. Kožišek, *Inorg. Chem.*, 1-3, (2011) .
6. H. Beraldo and D. Gambino, *Mini- Rev- Chem.* 4,31, (2004).
7. J.S. Casas , M.S. G. Tasende and J. Sordo , *Coord . Chem. Rev.* 209,197, (2000).
8. H.A. Tang , L.F. Wang and R. D. yang , *Transition Met. Chem.* 28, 395, (2003).
9. T. S. Lobana , P. Kumari , M. Zeller and R. J. Butcher , *Inorg. Chem. Commun.* 11 (9) , 972-974, (2008).
10. T. S. Lobana , G. Bawa , A. Castineiras , R. J. Butcher and M. Zeller , *Organometallic* , 27(2), 175-180, (2008).
11. S. Singh , F. Athar , M.R. Maurya and A. Azam, *European J. of Med. Chem.* 41(5) , 592-598 , (2006).
12. E. J?na, E. Rudinsk?, M. Kubranova, M. Sapietov?, M. Pajt?šov? and V. Jorik, *Chem. Pap.* 59(4), 248-250, (2005).
13. J. D. Harris, W. E. Eckles, A. F. Hepp, S. A. Duraj, D. G. Hehemann, p. E. Fanwick and J. Richardson, *NASA/TP*, 211890, 1-23, (2003).
14. S. Chaudra and L.K. Gupta , *Spectrochim. Acta* , A60 , 2767, (2004).
15. W.J. Geary , *Coord. Chem. Rev.*, 7, 81-122, (1971).
16. K. Nakamoto, " *Infrared and Ramon Spectra of Inorganic and Coordination Compounds*" , 4th Ed. Wiley- Interscience , New york (1986).
17. P. K. Panchai , P.B. Pansuriya and M.N. Patel , *J. Enzy. Inhib. Med. Chem.*, 21 (4), 453-458, (2006).
18. M.M. Abd- Elazaher , *J. Chin. Chem. Soc.*, 48, 153-158, (2001).
19. C.R. Kowol , R. Berger , R. Eichinger , A. Roller , M.A. Jakupec , P.P. Schmidt , V. B. Arion and B. K. Keppler, *J. Med. Chem.*, 50(6) , 1254-1265, (2007).
20. S. Gronowitz , A. R. Katritsky and R. E. Reavill , *J. Chem. Soc.*, 3881 , (1963).
21. L. J. Boucher and J. C. Bailar, *J. Inorg. Nucl. Chem.*, 27, 1093, (1965).

- 22.K. Alomar , M. A. Khan , M. Allain and G. Bout, Polyhedron , 28, 1273-1280, (2009) .
- 23.A. B. P. Lever, " Crystal Field Spectra and Electronic Spectroscopy" , Wiley Inter Science , New York , 101 , (1970).
- 24.F. Athar , F. Arjmand and S. Tabassum , Trans . Met . Chem. ,26 ,426, (2001).
- 25.S. Chandra and A. Kumar , J. Saudi Chem. Soc., 11, 2,299-306, (2007).
26. A. B. P. Lever, J. Chem. Edu., 45, 11, 711-712, (1968) .
- 27.G. Wulfsberg, "Inorganic Chemistry", university Science books, 890, (2000).
28. S. Chandra and L. K. Gupta, Synth. React. Met._Org. Chem., 31(4), 661-672, (2001).
- 29.A. B. P. Lever " Inorganic Electronic Spectroscopy " , Elsevier , Amsterdam, 168, (1968).
30. I. A. Mustafa , M. J. Mohammed and M. S. Noori , Raf. Jour. Sci., 12,2,40-49, (2001).

This document was created with Win2PDF available at <http://www.daneprairie.com>.
The unregistered version of Win2PDF is for evaluation or non-commercial use only.