Mn(III) heterochelates: Synthesis, Spectroscopic, Thermal and In-Vitro Biological screening

Chintan P. Somaiya*[1], Dinesh S. Patel[1], Darshan H. Jani[2]

1.Shree P.M Patel Institute of Post Graduate Studies and Research in Science, Anand-388001, Gujarat (India),
Recognized Research Center of Sardar Patel University, V.V. Nagar, India.
For Ph. D (Applied Chemistry), Ph. D (Forensic science) & M. Phil (Chemistry)
2. Department of Chemistry, Om Science College, BKNM University, Junagadh, Gujarat (India)

Abstract

In this work novel organic based compound sulphonamide phenyl hydrazone derivatives and their thermal and biological activities were investigated. A new series of sulphonamide phenyl hydrazone containing ligand and their Mn(III) based heterochelate were synthesized by various acyl chloride. The structure of sulphonamide phenyl hydrazone ligands were confirmed by ^{1}H NMR, IR, Elemental analysis and their heterochelates were confirmed by thermal studies (TGA/DTG & DSC) and FAB Mass spectroscopy. All the synthesized compounds were screened for their In-Vitro biological study against Gram^{+ve} (*Bacillus megaterium)* and Gram^{-ve} (*E.coli*) microorganism. The results confirmed that sulphonamide phenyl hydrazone based heterochelates have a great potential and significant for further investigation.

Keywords: Heterochelate, Biological Activity, sulphonamide phenyl hydrazone, acyl pyrazolone, Schiff base, Thermal Studies

Introduction:

Pyrazolone, particularly acyl pyrazolone and its derivatives are well known for their potential applications in different fields such as thermal [1], fluorescence [2], analytical [3], DNA binding [4,5], Kinetic studies [6,7], Catalyst [8,9], dyes and pigments [10] and In-vitro biological studies [11-13] . Acyl pyrazolone is also known for two important characteristics as an important class of β-diketone compound and the tautomeric effect of enol form and keto form in solid or solution state [14].

Coordination chemistry is a fast budding field and the coordination chemistry of pyrazolone is usually reported with transition metals due to several electrons rich contributor sites [15,16] and its variety of applications[17-23]. In view of the significance of transition metal compounds and our curiosity in the chemistry of coordination compounds of pyrazolone based ligands [24,25] in present work we describe synthesis, spectroscopic, thermal and In vitro biological studies of some novel acyl pyrazolone based Mn(III) heterochelates and the general structure is shown in **Figure 1**.

Experimental

Materials

All the chemicals used were of analytical grade and used without further purification. The compounds l-phenyl-3-methyl-5-pyrazolone was purchased from Sigma Ltd (India). Acylchlorides were purchased from spectrochem, Mumbai used-without further purification.

Methods

FT-IR spectra were recorded as KBr pallets on Nicolet-400D spectrophotometer.^{1}H NMR spectra were recorded on Advance 400 Bruker FT-NMR instrument in DMSO-d_6 solvent. The FAB-mass spectrum of heterochelate was recorded with JEOL SX-102/DA-6000 mass spectrometer. Simultaneous TGA/DTG and DSC were obtained by a model 5000/2960 SDT. The experiment was performed in N_2 atmosphere at heating rate of 10^oCmin^{-1}.

General Procedure for Ligands

A 1:1 Molar ratio of 4-acyl-3-methyl-1-phenyl-2-pyrazo-lin-5-one (amphp) with 4-sulfonamide phenyl hydrazine in 50 ml of methanol heated for 3-4 hours by adding catalytic amount of acetic acid and check reaction completion by TLC. Obtained product crystallized by 50 ml of methanol and washed with diethyl ether so primrose cream solid was obtained. Final ligands are confirmed with ^{1}H NMR, Mass and IR spectroscopic technique.

4-Acylated hydrazine-pyrazolone M.F-$C_{18}H_{19}N_5O_3S$ Yield 78%; M.P. 218°C; light pink; FT-IR (KBr,cm^{-1}): 3340 ν(O–H), 3240 ν(N–H), 1625 ν(C=O), 1543 ν(C=N); ^{1}H NMR (400 MHz,DMSO-d_6): δ (ppm)=2.3 (3H, s, -CH_3); 2.48-2.49 (3H, s, -CH_3); 6.86-7.98 (Ar-H). Elemental analysis found (%) C, 56.12; H, 4.99; N, 18.09; O, 12.47 S, 8.33 calculated for $C_{18}H_{19}N_5O_3S$: C, 56.09%; H, 4.97%; N, 18.17% O, 12.45% S, 8.32%.

4-Propiyonal hydrazine-pyrazolone M.F- $C_{19}H_{21}N_5O_3S$ Yield 76%; M.P. 215°C Cream powder; FT-IR (KBr,cm^{-1}): 3348 ν(O–H), 3251 ν(N–H), 1600 ν(C=O), 1539 ν(C=N); ^{1}H NMR (400 MHz,DMSO-d_6): δ (ppm) = 2.5 (3H,s,-CH_3); 1.20-1.24 (3H,t,-CH_3);2.76-2.78(2H,q,-CH_2) 6.89-7.99 (Ar-H). Elemental analysis found (%) C, 57.15; H, 5.32; N, 5.34; N, 17.55 S, 8.05 O, 12.08 calculated for $C_{19}H_{21}N_5O_3S$: C, 57.13%; H, 5.30%; N, 17.53 % S, 8.03% O, 12.02%.

4-Butyryl hydrazine-pyrazolone M.F- $C_{20}H_{23}N_5O_3S$ Yield 76%; M.P. 218°C; White powder; FT-IR (KBr,cm^{-1}): 3358 ν(O–H), 3226 ν(N–H), 1618 ν(C=O), 1531 ν(C=N); ^{1}H NMR (400 MHz,DMSO-d_6): δ (ppm) = 2.5 (3H,s,-CH_3); 1.60-1.64 (2H,q,-CH_2),2.71-2.75(2H,m,-CH_2);0.97-1.60(3H,t,-CH_3); 6.89-7.99 (Ar-H). Elemental analysis found (%) C, 58.12; H, 5.64; N, 16.96; S, 7.77 O, 11.63 S, 7.77 calculated for $C_{20}H_{23}N_5O_3S$: C, 58.09%; H, 5.61%; N, 16.94% S, 7.75% O, 11.61%.

4-Benzoyal hydrazine-pyrazolone M.F- $C_{23}H_{21}N_5O_3S$ Yield 71%; M.P. 256°C Light pink powder; FT-IR (KBr,cm^{-1}): 3342 ν(O–H), 3182 ν(N–H), 1595 ν(C=O), 1516-3 ν(C=N); ^{1}H NMR (400 MHz,DMSO-d_6): δ (ppm) = 1.88 (3H,s,-CH_3); 6.86-7.98(Ar-H) . Elemental analysis found (%) C, 61.75; H, 4.71; N, 15.67; O, 10.75; S, 7.16; calculated for $C_{23}H_{21}N_5O_3S$: C, 61.73%; H 4.73%; N, 15.65% S, 7.16% O, 10.73%.

4-Nitrobenzoyal hydrazine-pyrazolone M.F- $C_{23}H_{20}N_6O_5S$ Yield 62%; M.P.261°C; yellow powder; FT-IR (KBr,cm^{-1}): 3200 ν(O–H), 3076 ν(N–H), 1597 ν(C=O), 1558 ν(C=N); ^{1}H NMR (400 MHz,DMSO-d_6): δ (ppm) = 1.92 (3H,s,-CH_3); 7.14 -8.26(Ar-H). Elemental analysis found (%) C, 56.11; H, 4.12; N, 17.09; S, 6.53; O, 16.27; calculated for $C_{23}H_{20}N_6O_5S$: C, 56.09%; H, 4.09%; N, 17.06 % S, 6.51% O, 16.24%.

General Procedure for Heterochelates

A general method has been adopted for the preparation and isolation of heterochelate. Hot methanolic solution of $Mn(CH_3COO)_3.2H_2O$ (10mmol) and solution of respective Schiff bases (10mmol) were mixed in1:1 molar ratio. The mixture was heated for 4-hour at 70^{0}c and kept it overnight at room temperature. The obtained colored crystals were washed with water, methanol and finally with diethyl ether and dried in air.

Result and Discussion

The structural investigation of all the prepared Schiff base ligands and heterochelates were carried out using elemental analysis, IR, ^{1}H NMR, FAB-Mass spectra, TGA/DTG and DSC analysis. The ^{1}H NMR data of Schiff base ligands are given in experimental section. The analytical and physical data of heterochelates are given in **Table1.** Heterochelates were sparingly soluble in methanol and completely soluble in DMF and DMSO. All the heterochelates were stable in air for extended period of time.

^{1}H NMR spectra of ligands

The tautomerism of pyrazolone is a subject of considerable number of studies [26,27].. The ^{1}H NMR studies of Schiff base ligands were carried out in DMSO-d_6 at room temperature. The data are represented in experimental section in case of ^{1}H NMR spectra of ligand two sharp singlet equivalent to one and two protons observed in the range of 12-13 δ ppm corresponding to -OH group [28,29]. This Signal disappeared when a D_2O exchange experiment was carried out. Aromatic protons are observed in the range of 6.8-9.0 δ ppm and singlets for methyl group in Schiff base ligands are observed in the range of 1.5 to 3.0 δ ppm. The NMR spectrum of L_2H is shown in **Figure 2**. In some case signals of –NH protons are merged with aromatic protons and all of these signals are closely spaced in NMR spectrum so it is difficult to assign each signal to a particular aromatic and –NH protons unambiguously [30]. On the basis of ^{1}H NMR spectroscopic data it is observed that Schiff base ligand exists in Keto-Enol form in solution state.

Infrared Spectra

In order to study the binding mode of Schiff base (L_1 to L_5) to the Mn(III) ion in the heterochelates the IR spectra of Schiff base were compare with spectra of corresponding heterochelates. The Schiff base ligand in this investigation exhibits a broad band centered at 3199 to 3348 cm^{-1} this indicates the involvement of the 5-OH group in intramolecular H-bonding [31-34]. With the lone pair of azomethine it also suggests that the ligand exist in enol form of solid state. The Schiff base ligand (L_1 to L_5) shows a sharp and strong band of a υ(C=N) of the acyclic azomethine group at 1539 to 1595 cm^{-1}. The observed low energy shift of this band in the heterochelates and appearing at 1533 to 1502 cm^{-1} suggest the co-ordination of azomethine nitrogen [35,36]. The IR spectra of heterochelates shows a considerable negative shift of 25-30 cm^{-1} in υ(C=O) absorption of the pyrazolone group indicating a decrease in the stretching force constant of υ(C=O) as a consequence of co-ordination through the oxygen atom of the ligand. All of this data confirms the fact that (L_1 to L_5) behave as a dinegative bidentate ligand and forming a conjugate chelate ring with the ligand existing in the heterochelate in the enolic form.

Thermal Studies

Each decomposition process follows the trend

$$\text{Solid-1} \xrightarrow{heat} \text{Solid-2 + Gas}$$

This process comprises of several stages.
The thermal fragmentation scheme for heterochelates $[Mn(Ln)_2Ac.H_2O].xAc.yH_2O$ is as shown below

$$[Mn(Ln)_2Ac.H_2O].xAc.yH_2O \xrightarrow[\text{removal of crystaline } Ac + H_2O]{50-421\,^\circ C} [Mn(Ln)_2Ac.H_2O] + xAc.yH_2O$$

$$[Mn(Ln)_2Ac.H_2O] \xrightarrow[\text{removal of coordinated } Ac + H_2O]{422-614\,^\circ C} [Mn(L_n)_2]$$

$$[Mn(L_n)_2] \xrightarrow[\text{removal of ligand}]{614-900\,^\circ C} MnO$$

Ln	x(Ac)	y(H_2O)
1.	2	1.5
2.	2	3
3.	1	1.5
4.	-	1
5.	1	0.5

TG/DTG curves of heterochelates $[Mn(L_4)_2Ac.H_2O].H_2O$ are represented in **Graph 1**.The decomposition of heterochelates $[Mn(L_4)_2Ac.H_2O]H_2O$ takes place in three stage. The thermal dehydration and deacetylation of this heterochelates take place in a single step between 50 to 187°C with mass loss of 9.77% (10.67%). One mol of crystalline and coordinated H_2O molecule and one mol of coordinated acetyl molecule may remove in this stage. This process is accompanied by endothermic effect at 95.1°C. The second step which occurs in the temperature range of 188 to 422°C corresponds to decomposition of some part of the L_4 ligand, the observed mass loss of 55.59% (55.76%). The endothermic peak at 246°C corresponds to this stage is given by DSC curve.

The third stage is related to the decomposition of remaining part of L_4 Ligand and estimated amount of MnO in temperature range of 423 to 900°C accompanied by mass loss 21.22% (21.43%). The overall mass loss observed is 86.58% as compare to theoretical value 87.86% and thermodynamic data of heterochelates are reported in **Table 2** and DSC curves of Mn(III) heterochelates are shown in **Graph 2**.

FAB Study

The recorded FAB mass spectrum **Figure 3** and the molecular ion peak for the heterochelate $[Mn(L_2)_2Ac{\cdot}H_2O]{\cdot}2Ac{\cdot}3H_2O$ were used to confirm the molecular formula. The proposed fragmentation pattern is shown in **Scheme (1).** The first peak at m/z=1043 represents the molecular ion peak of heterochelates. **Scheme (1)** demonstrates the possible degradation path way for the investigated heterochelates. The primary fragmentation of the heterochelate take place due to the loss of coordinated 3 molecules of H_2O and two molecules of CH_3COO molecule from the species **(a)** to give species **(b)** with peak at m/z=872. Further degradation yields species **(c)** with loss of $C_{19}H_{20}N_5O_3S$ and CH_3COO. Species **(c)** further degrade to species **(d)** and **(e)** with loss of MnO. The sharp peak (base

peak) observed at m/z=454 represent the stable species **(c)** with 99% abundance. The measured molecular weight for all the suggested degradation steps was with expected value [37].

Zone of Inhibition

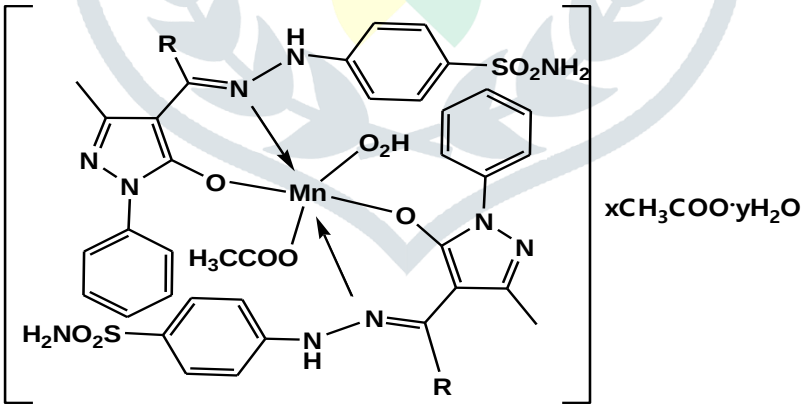
A stock solution of 10 mg ml^{-1} was made by dissolving compound in minimum amount of DMF and making it up to the mark with double distilled water. The medium was made up by dissolving bacteriological agar (20g) and Luria broth (20g; SRL, India) in 1-liter distilled water. The mixture was autoclave for 15 min at 120^0C and then dispensed into sterilized Petri dishes, allowed to solidify and then used for inoculation. The target microorganism cultures were prepared separately in 15 ml of liquid Luria broth medium for activation. Inoculation was done with the help of micropipette with sterilized tips; 100 µl of activated strain was placed on to the surface of an agar plate and spread evenly over the surface by means of a sterile, bent glass rod. Then two wells having diameter of 10 mm were made using a sterilized borer in each plate. Application of disks Sterilized stock solutions (10mgml^{-1}) were used for the application in the well of earlier inoculated agar plates. When the disks were applied, they were incubated at 30^0C (Gram^{+ve}) and 37^0C (Gram^{-ve}) for 24 hours. The zone of inhibition was then measured (in mm) around the disk shown in **Figure 4** The control experiments were performed with only the equivalent volume of solvents without added test compounds and the zone of inhibitions was measured (in mm) shown in **Table 3 [**38].

Applications

All the synthesized ligands namely L1-L5 and their heterochelates ML1-ML5 (where M = Mn) where screened against the bacterial strains. The antimicrobial screening data **(Table 3)** shows that heterochelate exhibit more inhibitory effects towards gram +ve and gram -ve bacteria then the parent ligand. The ligands (L_4) and heterochelates (MnL_2) are much powerful bactericides against *E.coli.*The increased activities of the heterochelates as compared to ligands can be explained on the basis of overtone concept [39] and chelation theory [40].

Conclusion

The design and synthesis of new sulphonamide phenyl hydrazone ligand have been successfully demonstrated FT-IR and ^{1}H NMR and Mass Spectral studies reveal that ligand exists in tautomeric enol form both in solid and solution state with intra molecular H-bonding. We have synthesized a series of some novel Mn(III) heterochelates with sulphonamide phenyl hydrazone derivative and characterize their properties. All the synthesized compounds were screened for their bioassay. The heterochelates exhibit strong activities against Gram^{+ve} *(Bacillus Magaterium*) and Gram^{-ve} *(E.coli*) organisms in comparison with ligand and drug penicillin. Some of the ligands and heterochelates were more active against one or more bacterial strain introducing a novel class of metal based bactericidal agents.



Sr. No.	Ligand	R	x	y
1	L_1	$-CH_3$	2	1.5
2	L_2	$-CH_2CH_3$	2	3
3	L_3	$-CH_2CH_2CH_3$	1	1.5
4	L_4	$-C_6H_5$	-	1
5	L_5	$-C_6H_5NO_2$	1	0.5

Figure 1: The suggested structure of Heterochelate

Table 1: Analytical and physical data of Heterochelates

Compounds	Formula Weight	Color (%Yield)	Analysis (%) Found(Cal)					
			C	H	Mn	N	O	S
$[Mn(L_1)_2Ac{\cdot}H_2O]{\cdot}2Ac{\cdot}1.5H_2O$	1047	Greenish yellow (71)	49.86 (49.84)	4.44 (4.40)	6.08 (6.00)	15.32 (15.29)	17.49 (17.47)	7.08 (7.00)
$[Mn(L_2)_2Ac{\cdot}H_2O]{\cdot}2Ac{\cdot}3H_2O$	1043	Brown (73)	50.93 (50.90)	4.73 (4.70)	5.85 (5.82)	14.87 (14.84)	16.98 (16.95)	6.82 (6.79)
$[Mn(L_3)_2Ac{\cdot}H_2O]Ac{\cdot}1.5H_2O$	1044	Cream (69)	51.94 (51.90)	5.01 (4.98)	5.69 (5.65)	14.43 (14.41)	16.49 (16.46)	6.64 (6.60)
$[Mn(L_4)_2Ac{\cdot}H_2O]H_2O$	1046	Light yellow (68)	55.48 (55.44)	4.29 (4.26)	5.31 (5.28)	13.49 (13.47)	15.41 (15.38)	6.21 (6.17)
$[Mn(L_5)_2Ac{\cdot}H_2O]Ac{\cdot}0.5H_2O$	1184	Dark yellow (73)	51.08 (51.02)	3.78 (3.75)	4.89 (4.86)	14.91 (14.87)	19.87 (19.82)	5.71 (5.67)

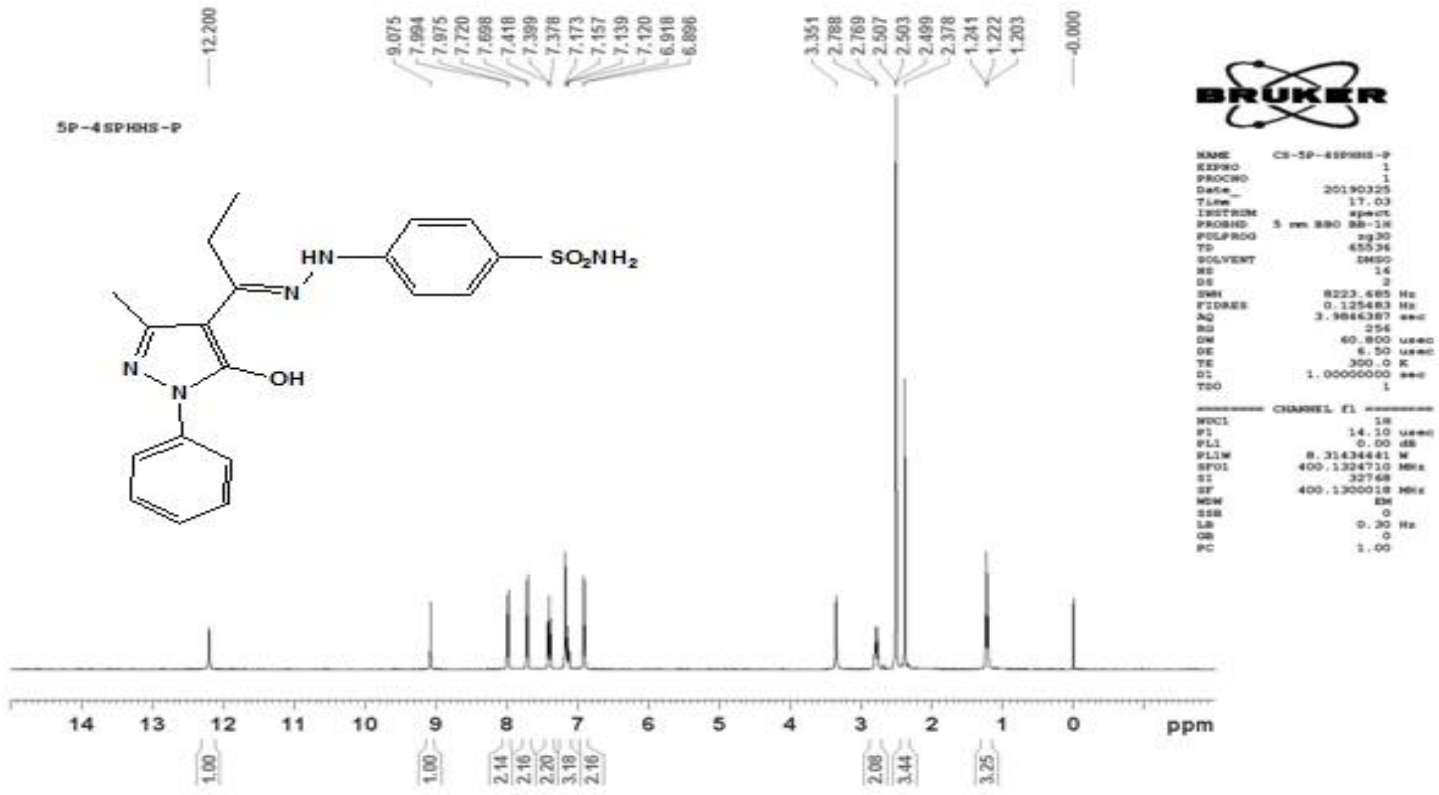
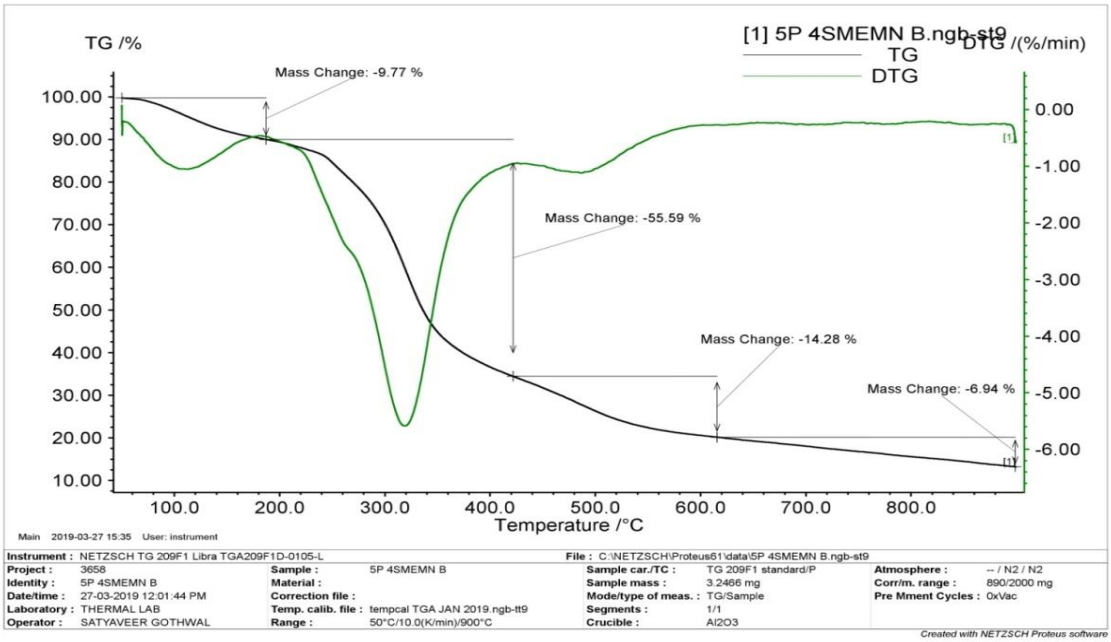
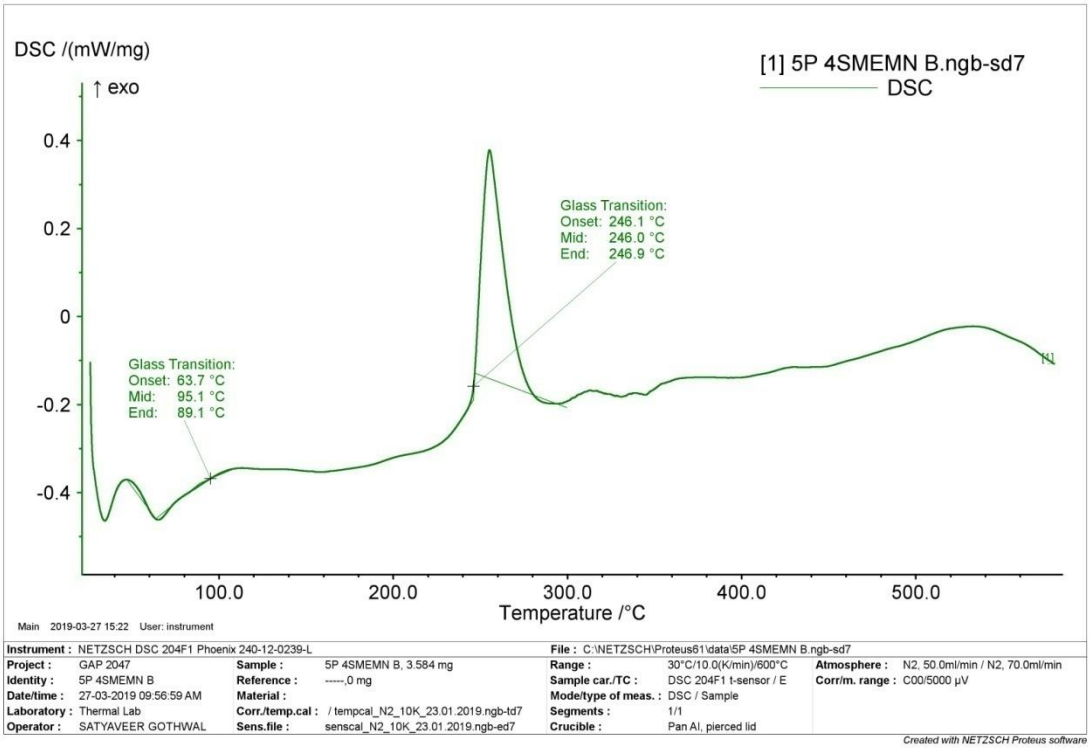


Figure 2: NMR spectrum of L_2



Graph 1: TGA/DTG Analysis of $[Mn(L_4)_2Ac\cdot H_2O]H_2O$



Graph 2: DSC curve of $[Mn(L_4)_2Ac\cdot H_2O]H_2O$

Table 2: Thermo analytical results of Heterochelates

Sr. no.	Heterochelates	Temp. Range	Mass Loss (%) Obs. (Cal.)	Analysis
1	[Mn(L1)2Ac.H2O].2Ac..1.5H2O	50-173	15.64 (13.85)	Two crystalline Ac and 1.5 H2O may loss.
		174-321	7.29 (7.35)	Coordinated Ac & H2O may loss.
		322-533	41.99 (42.44)	Some part of ligand may loss.
		534-900	14.41(14.53)	Remaining part of ligand removed by leaving oxide as MnO.
2	[Mn(L2)2Ac.H2O].2Ac.3H2O	50-188	10.77 (10.80)	Two crystalline Ac and 3 H2O may loss.
		189-325	7.17 (7.36)	Coordinated Ac & H2O may loss.
		326-614	44.31 (45.33)	Some part of ligand may loss.
		615-900	22.31(22.35)	Remaining part of ligand removed by leaving oxide as MnO.
3	[Mn(L3)2Ac.H2O]Ac.1.5H2O	50-183	7.99(8.23)	Crystalline Ac & 1.5 H2O may loss.
		184-323	7.19(7.37)	Coordinated Ac & H2O may loss.
		324-515	39.13 (40.0)	Some part of ligand may loss.
		516-900	28.21(28.23)	Remaining part of ligand removed by leaving oxide as MnO.
4	[Mn(L4)2Ac.H2O]H2O	50-187	9.77(10.67)	One crystalline H2O & Coordinated Ac and H2O may loss.
		188-422	55.59(55.76)	Some part of ligand may loss.
		423-900	21.22(21.43)	Remaining part of ligand removed by leaving oxide as MnO.
5	[Mn(L5)2Ac.H2O]Ac.0.5H2O	50-193	3.53(3.58)	Crystalline Ac and 0.5 H2O may loss.
		194-313	3.99(4.05)	Coordinated Ac and H2O may loss.
		314-426	54.35(54.73)	Some part of ligand may loss.
		427-900	19.43(19.98)	Remaining part of ligand removed by leaving oxide as MnO.

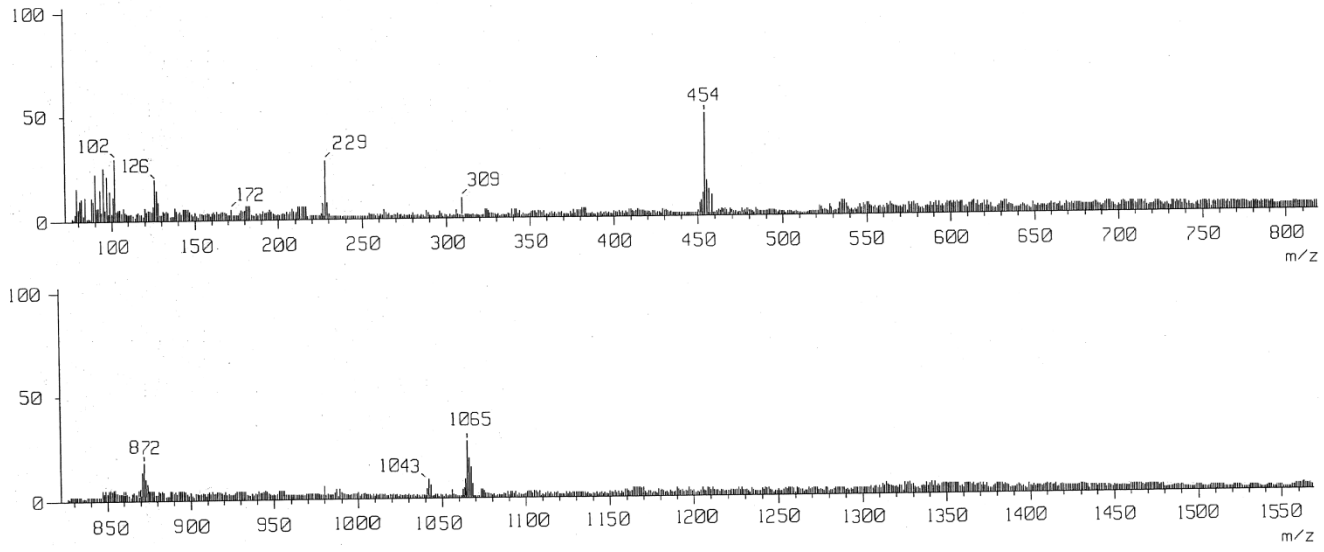
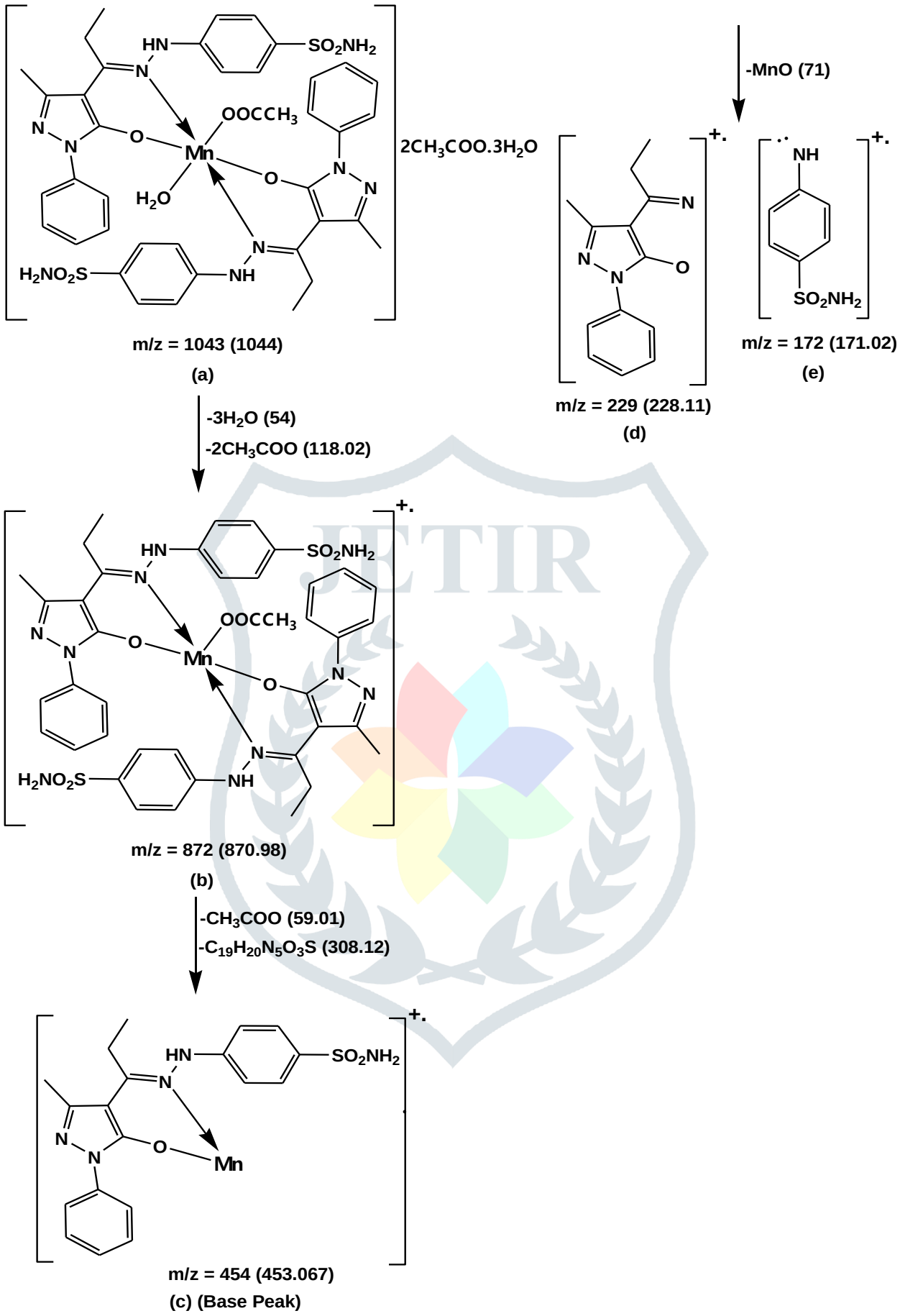


Figure 3: FAB Mass Spectrum of [Mn(L$_2$)$_2$Ac.H$_2$O].2Ac.3H$_2$O



Scheme 1: The Suggested Fragmentation pattern of $[Mn(L_2)_2Ac.H_2O].2Ac.3H_2O$

Table3: Antimicrobial Effects of the Ligands and their Heterochelates

Sr. No.	Compounds	Gram^{+ve}	Gram^{-ve}
		Bacillus Megaterium	**E.Coli**
Ref. Drug	Penicillin	35	20
1	L_1	17	10
2	L_2	10	06
3	L_3	06	07
4	L_4	**20**	**30**
5	L_5	15	**20**
6	MnL_1	06	05
7	MnL_2	15	**20**
8	MnL_3	**23**	**15**
9	MnL_4	13	11
10	MnL_5	08	08

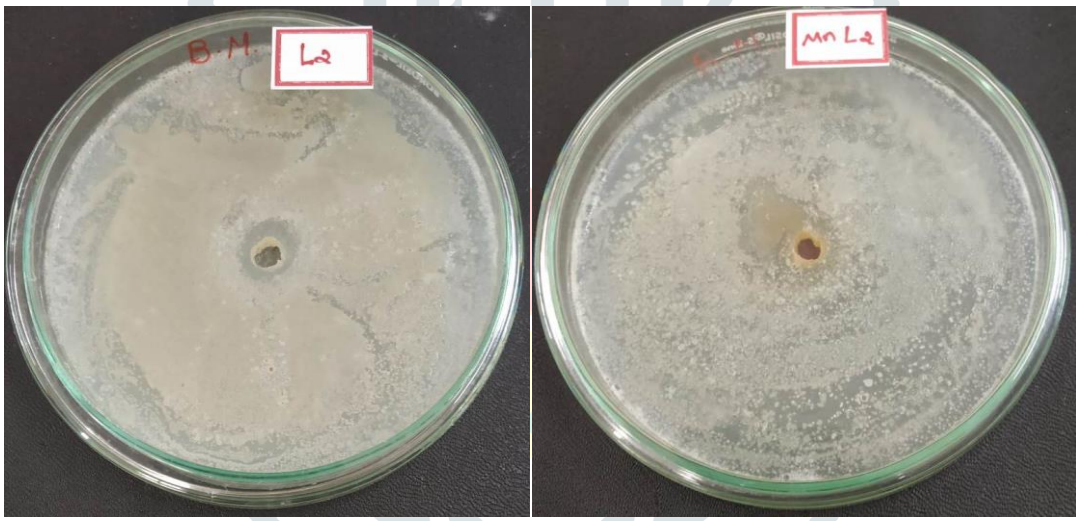


Figure 4: Zone of inhibition (mm) of Ligand and its Heterochelates

References

1. C.K. Modi, D.H. Jani, *J. Therm Anal Calorim.*, 102(3), **2014,** 1001.
2. C.K. Modi, D.H.Jani, H.S. Patel and H.M. Pandya, *spectrochimica Acta.*, 75A, **2010**, 1321.
3. (a) M.F Ikander, L.Saved, A.F.M Hefny, S.E Zayan, *J.Inorg. Nucl.Chem*, 38, **1976,** 2209.
   (b) H. Adams, D.E. Fenton, C. Minardi, E. Mura, M. Angelo, *Inorg. Chem. Commun.*,3, **2000,** 24.
   (c) Z.Y. Yang, R.D. Yang, F.S. Li, K.B. Yu, *Polyhedron*, 19, **2000,** 2599.
4. S.Sathiyaraj, K. Sampath, C. Jayabalakrishnan., *Chem.*, 44, **2014,** 161.
5. K. M. Vyas, R. N. Jadeja, D. Patel, R. V. Devkar, V. K. Gupta, *Polyhedron*, 80, **2014,** 20.
6. J. Hu, L. Liu, D. Jia, J. Guo, X. Xie, D. Wu, R. Sheng, *Chem.*, 217, **2011,** 117.
7. B. Pang, G. Liu, L. Liu and D. Jia, *Tetrahedrone*, 61, **2005,** 5926.
8. K.C Gupta, A.K. Sutar, Coord. *Chem. Rev.*, 252, **2008,** 1420.
9. R. Kumar, G. Mani, *Dalton Trans.* 44**, 2015,** 6896.
10. K. Nejati, Z. Rezvani, B. Massoumi. *Dyes Pigments*, 75, **2007,** 653.
11. (a) M.F Ikander, L. Saved, A.F.M Hefny, S.E Zayan, *J.Inorg. Nucl.Chem*, 38, **1976,** 2209.

(b) H. Adams, D.E. Fenton, C. Minardi, E. Mura, M. Angelo, *Inorg. Chem. Commun.*, 3, **2000,** 24.

c) Z.Y. Yang, R.D. Yang, F.S. Li, K.B. Yu, *Polyhedron*, 19, **2000,** 2599.

12. C.K. Modi and D.H. Jani, *Appl. Organometal. Chem.*, 25, **2011,** 429.
13. M Alaudun, P.G. Sushama, A.M Dorothy, *Indian J Chem*, 42, **2003,** 1617.
14. O.N. Kataeva, A.T. Gubaidullin, I.A.Litvinov, O.A. Lodochnikova, L.R. Islamov, A.I.Movchan, G. A. Chmutova, *J. Mol. Struct*., 610, **2002,** 175.
15. (a) M.F Ikander, L. Saved, A.F.M Hefny, S.E Zayan, *J.Inorg. Nucl.Chem*, 38, **1976**, 2209.

(b) H. Adams, D.E. Fenton, C. Minardi, E. Mura, M. Angelo, *Inorg. Chem. Commun*., , 3, **2000**,24 .

(c) Z.Y. Yang, R.D. Yang, F.S. Li, K.B. Yu, *Polyhedron*, 19, **2000**, 2599 .

16. C.K. Modi and D.H. Jani, *Appl. Organometal. Chem.*, 25, 2011, 429.
17. F. Yraola, G.V. Silvia, J. Ferna´ndezRecio, F. Albericio , A. Zorzano, L. Marti and Royo., *M.J. Med. Chem*. 49, **2006**, 6197.
18. M.R. Manrao, Balbir, K.M Gill, V. K. and Sharma, J. R.J. *Indi. Chem. Soc*. 86(5), **2009**, 531.
19. N. Kanoongo, S. Bohra, , R. Mathurand, N.K Mathur, *Trans. Met. Chem.* 17(4), **1994**, 18.
20. N. Raman, S. Johnson, J. Joseph, A. Sakt hivel and Dhaveethu, J. J. Chil. *Chem. Soc.* 53(3), **2008**,1599.
21. H .O. William, J. M. Ostman, and O. R. Charles, *Carbohydrate Research*, 326 (2), **2000**, 104.
22. D. Kumar, A. Syamal, and A. K. Singh, *Indi. J. Chem.* 42A (2), **2003**, 18 .
23. K. Singh, R. V. Singh, and J. P. Tandon, *J. für Praktisc. Chem*., 330, **2004**, 621.
24. R. N. Jadeja, J. R. Shah, *Polyhedron.*, 26, **2007**, 1677.
25. C. P. Somaiya, D. S. Patel, D. H. Jani, *J. Of Applicable Chemistry*, 8(3), **2019**, 1135.
26. Y. Akama, A. Tong, N. Matsumoto, T. Ikeda, S. Tanaka, *Vibr. Spectrosc.*,13,**1996**,113.
27. Y.Akama, A.Tong, *Microchem.J*, 53,**1996**, 34.
28. J.M. Kauffmann, M. Alafandy, R. Willem, B. Mahieu, M. Alturky,M. Biesemans, F. Legros, F.Camu, M. Gielen,*Inorg.Chim. Acta.*, 255,**1997**,175.
29. J. Kidri, D. Hadi, D. Kocjan, V. Rutar,*Org. Magnet. Reson.*,15, **2004**, 280.
30. R.N. Jadeja, J.R. Shah,*Polyhedron.*,26,**2007**,1677–1685.
31. C.K Modi, B.T Thaker, *J. Theram Anal Calorim.*, 94(2),**2008**,567-77.
32. K.R. Surati B.T Thaker,*J.coordchem.*, 59,**2006**,1191-2002.
33. F. Marchetti, C. Pettinari, R. Pettinari, A. Cingolani, A. Rossi, M. Caruso,*J.organomet Chem.*, 645,**2002**, 134-45.
34. F. Marchetti, C. Pettinari, R. Pettinari, A. Cingolani, D. Leonesi and A. Lorenzotti,*Polyhydron*, 18, **1999**, 3041-50.
35. G.Xu , L. Liu, L. Zhang, G. Liu, D. Jia, J. Lang.*Struct Chem.*,16, **2005**,431-38.
36. C.K Modi, B.T Thaker,*Indian J.Chem.*,41A,**2002**,2544-7.
37. S.H. Patel, P.B. Pansuriya, M.R. Chhasatia, H.M. Parekh, M.N. Patel,*J. Therm. Anal. Calorim.*,91, **2008**, 413.
38. G. J. Kharadi, K. D. Patel, *Appl. Organomet, Chem., 23*(10), **2009**,391.
39 Z. H. Chohan, K. M. Khan, C. T. Supuran, *Appl. Orgonomet. Chem.*, 18, **2004**, 305.
40. G. Tweedy, *Phytopothology*, 55, **1964**, 910.