Research Article

Coordination Compounds of Germanium (IV) with Semicarbazones and Thiosemicarbazones and Their Biological Studies

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ABSTRACT

This paper is a report on the synthesis of coordination compounds of germanium (IV) which include the reactions of semicarbazones and thiosemicarbazones from the condensation of semicarbazide/thiosemicarbazide with aldehydes or ketones and germanium (IV) methoxide. The newly synthesized products have been characterized on the basis of elemental analysis, electronic, infrared, ^{1}H NMR and ^{13}C NMR spectral studies. The biological studies of ligands and their corresponding germanium (IV) complexes have been carried out. The metal complexes were found to be more active than the ligands.

Keywords: Semicarbazones and thiosemicarbazones, germanium (IV) methoxide, aldehydes or ketones and biological studies.

INTRODUCTION

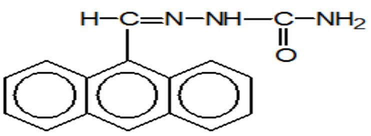
Complexes of semicarbazones and thiosemicarbazones with different transition metal ions[1-6] have been extensively studied. A plethora of references describing the non transition complexes with these ligands has appeared in the literature [7-12].

It revealed that only limited information on the bonding and structural features are available for the non transition derivatives.

Therefore, it is worthwhile to synthesize large number of complexes of germanium with semicarbazones and thiosemicarbazones which are mentioned below.

The pronounced biological activity of metal complexes of these ligands derived from semicarbazide and thiosemicarbazide has created considerable interest in their coordination chemistry.

9-Anthraldehyde semicarbazone



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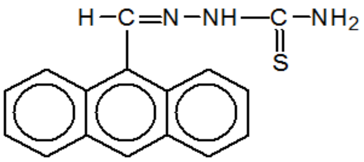

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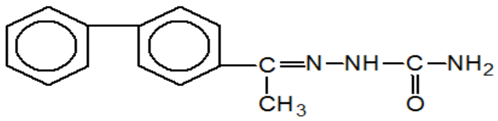
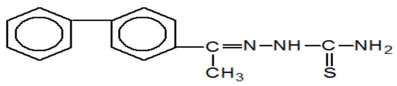
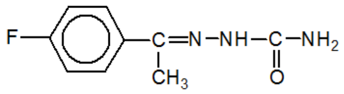


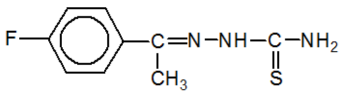
4-Acetyl biphenyl thiosemicarbazone



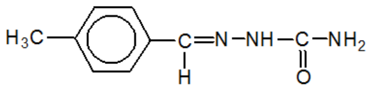
4-Fluoroacetophenone semicarbazone



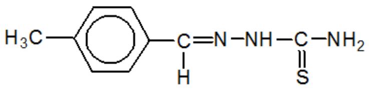
4-Fluoroacetophenone thiosemicarbazone



p-Tolualdehyde semicarbazone



p-Tolualdehyde thiosemicarbazone



MATERIALS AND METHODS

Experimental

Germanium was estimated gravimetrically as GeO_2. Nitrogen and sulphur were estimated by Kjeldahl's method and Messenger's method, respectively[13]. The IR spectra were recorded on FTIR spectrophotometer using a model A-8400 S, Shimadzu in KBr pellets. The electronic spectra were taken with a Toshniwal spectrophotometer in methanol. ^{1}H NMR spectra were recorded on JEOL AL-300 spectrometer in d_6 DMSO or $CDCl_3$ using TMS as internal standard at 90 MHz. ^{13}C NMR spectra were also recorded in d_6 DMSO or $CDCl_3$ using TMS as internal standard at 22.8 MHz. Molar conductance measurements were made in anhydrous dimethyl formamide at 36 ± 1 °C using a model 305 systronics conductivity bridge. Molecular weight determinations were carried out by the Rast Camphor Method.

Synthesis of Ligands

All the ligands were prepared by the condensation of aldehydes/ketones viz. 9-anthraldehyde, 4-acetylbiphenyl, 4-fluoroacetophenone and p-tolualdehyde with semicarbazide/thiosemicarbazide in 1:1 molar ratio using absolute alcohol as the reaction medium. The mixture was heated on a water bath for about half an hour and then allowed to cool at room temperature. The crystals were separated out and recrystallized from the same solvent. The physical properties and analysis have been recorded in Table 1.

Synthesis of Complexes

Germanium (IV) methoxide was added to the calculated amount of ligands derived from semicarbazide or thiosemicarbazide in 1:2 molar ratio in presence of dry benzene as the reaction medium. The contents were refluxed on refluxing column for about 3-4 hours. After the completion of reaction, the resulting products were dried by removing solvent under reduced pressure and then washed repeatedly with dry cyclohexane.

The products were finally dried in vacuo at 40-50 °C. The analytical data and physical properties have been recorded in Table-2.

RESULTS AND DISCUSSION

The reactions of germanium (IV) methoxide with semicarbazones and thiosemicarbazones in dry benzene medium can be represented by the following equation:

$$Ge(OCH_3)_4 + 2\overset{\frown}{N\ SH} \xrightarrow{1:2} Ge(OCH_3)_2(\overset{\frown}{N\ S})_2 + 2CH_3OH,$$

Where $2\overset{\frown}{N\ \ SH}$ represents the donor sets of ligands.

The above reactions are quite facile and the resulting complexes obtained as coloured solids. The molar conductance values of 10^{-3} M solutions in DMF lies in the range of 10-18 ohm^{-1} cm^{2} mol^{-1} indicating non-electrolytic nature of the complexes. Molecular weight determinations show them to be monomeric in nature.

Electronic Spectra

The electronic spectra of the ligands exhibited two bands at ~ 338 nm and ~ 410 nm. The band at ~ 338 nm was due to transition within benzene ring and it remains unchanged in the spectra of the corresponding complexes.

The band around 410 nm was due to $n \rightarrow \pi^*$ transition of the non-bonding electrons present on the nitrogen atom of the azomethine group. This band shows shifting due to coordination of azomethine nitrogen to the central metal atom.

Infrared Spectra

The spectra of ligands exhibited a strong band due to *v*(C=N)[14] stretching at 1620 cm^{-1}, which get shifted to lower frequency side indicating the coordination of azomethine nitrogen to the germanium atom. A broad band in the region ~ 3100-2850 cm^{-1} due to *v*(NH / OH) appeared in the spectra of the ligands. The band due to *v*(NH) vibration in the spectra of complexes remain absent showing coordination of azomethine nitrogen through oxygen/sulfur atom.

The new bands appeared in the region 895 cm^{-1}, 410-415cm^{-1} and 680 cm^{-1} are due to *v*(Ge-O), *v*(Ge-S) and *v*(Ge←N) modes respectively.

^{1}H NMR Spectra

The ^{1}H NMR spectra of ligands showed a singlet at δ3.50 ppm due to NH_2 protons remain almost unchanged in the spectra of germanium complexes, while the ligands also exhibited NH proton signal at δ10.09 ppm, remain absent in the corresponding complexes.

These signals clearly indicate the non involvement of NH_2 group in coordination.

A sharp signal at δ8.45 ppm was observed due to $H-\underset{|}{C}=N$ group and this is shifted downfield in the spectra of complexes due to coordination of azomethine nitrogen to the metal atom.

The downfield shift of the signal at δ~ 1.85 ppm due to methyl protons of [–C(CH_3)=N–] group indicates the coordination through azomethine nitrogen. The aromatic protons show signals at δ 7.85-6.98 ppm in the spectra of ligands which remain unaltered in the spectra of germanium complexes.

^{13}C NMR Spectra

The ^{13}C NMR spectra of ligands and their corresponding germanium complexes were recorded in Table-3. A considerable shift in the position of carbons attached to different participating group clearly indicate the bonding pattern of the complexes.

On the basis of above spectral studies, the octahedral geometry has been suggested for these complexes.

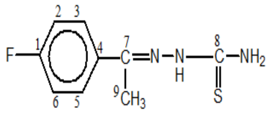


Figure 1: L^{6}H ($C_9H_{10}N_3SF$)

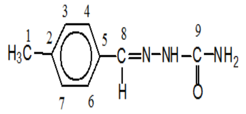


Figure 2: L^{7}H ($C_9H_{11}N_3O$)

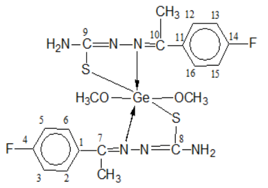


Figure 3: Ge.$C_{20}H_{24}N_6O_2S_2F_2$

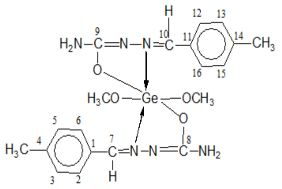


Figure 4: Ge.$C_{20}H_{26}N_6O_4$

Biological Studies

The antifungal activities of ligands and their corresponding germanium complexes were tested against A.flavus, R.phaseoli, F.oxysporum, etc. The results showed that the complexes are more active than the ligands. The antibacterial activities of the complexes have been carried out against bacteria like S.aureus, E.coli, P.fluorescens etc. using nutrient agar medium by the well diffusion method. The biological activity of the ligands and their corresponding complexes have been described in Table-4. The above values clearly indicate that the zone of inhibition area is greater for the metal complexes than the standard. The increase in antibacterial activity is due to faster diffusion of metal complexes or due to the combined effect of the metal and ligand. Such increased activity of the metal chelates can be explained on the basis of Overtone's concept and Chelation theory[15]. The complexes exhibited higher activities than the standard.

Table 1: Elemental Analysis and Physical Properties of Semiscarbazones and Thiosemicarbazones.

S. No.	Ligands	Colour & State	Melting point (°C)	Analysis: Found (Calcd.) (%)				Molecular weight: Found (Calcd.)
				C	H	N	S	
1.	$C_{16}H_{13}N_3O$ (L^1H) 9-Anthraldehyde semicarbazone	Orange powder solid	220° (d)	72.64 (72.99)	4.67 (4.97)	15.70 (15.96)	-	258.37 (263.26)
2.	$C_{16}H_{13}N_3S$ (L^2H) 9-Anthraldehyde thiosemicarbazone	Yellowish Orange solid	190°	68.34 (68.79)	4.61 (4.68)	14.84 (15.04)	11.26 (11.47)	274.44 (279.33)
3.	$C_{15}H_{15}N_3O$ (L^3H) 4-Acetylbiphenyl semicarbazone	Yellow powder solid	240°(d)	70.08 (71.13)	5.62 (5.96)	16.48 (16.59)	-	243.37 (253.26)
4.	$C_{15}H_{15}N_3S$ (L^4H) 4-Acetylbiphenyl thiosemicarbazone	White powder solid	180°	66.53 (66.88)	5.59 (5.60)	15.49 (15.60)	11.69 (11.90)	257.44 (269.33)
5.	$C_9H_{10}N_3OF$ (L^5H) 4-Fluoroacetophenone semicarbazone	Shiny white solid	190°	54.75 (55.00)	4.98 (5.00)	21.80 (22.00)	-	190.28 (195.17)
6.	$C_9H_{10}N_3sf$ (L^6H) 4-Fluoroacetophenone thiosemicarbazone	Shiny cream solid	140°	50.65 (51.00)	4.97 (5.00)	19.89 (20.00)	14.79 (15.00)	201.35 (211.24)
7.	$C_9H_{11}N_3O$ (L^7H) p-tolualdehyde semicarbazone	Shiny cream solid	190°	60.64 (61.00)	5.96 (6.00)	23.88 (24.0)	-	167.32 (177.21)
8.	$C_9H_{11}N_3S$ (L^8H) p-tolualdehyde thiosemicarbazone	Shiny white solid	145°	55.79 (56.00)	5.95 (6.00)	21.80 (22.00)	16.77 (17.00)	183.36 (193.27)

Table 2: Reactions of Germanium (IV) Methoxide with Semicarbazones and Thiosemicarbazones.

S. No.	Reactant	Ligands	Molar ratio	Product colour & state	M.P. (°C)	Analysis %			Molecular weight: Found (Calcd.)
						N	S	Ge	
1.	$Ge(OCH_3)_4$	$C_{16}H_{13}N_3O$	1:2	$Ge.C_{34}H_{30}N_6O_4$	205°	12.56 (12.74)	-	10.86 (11.01)	651.02 (659.24)
2.	$Ge(OCH_3)_4$	$C_{16}H_{13}N_3S$	1:2	$Ge.C_{34}H_{30}N_6O_2S_2$	185°	12.01 (12.15)	9.11 (9.27)	10.36 (10.50)	682.99 (691.36)
3.	$Ge(OCH_3)_4$	$C_{15}H_{15}N_3O$	1:2	$Ge.C_{32}H_{34}N_6O_4$	205°	13.00 (13.14)	-	11.21 (11.35)	630.46 (639.25)
4.	$Ge(OCH_3)_4$	$C_{15}H_{15}N_3S$	1:2	$Ge.C_{32}H_{34}N_6O_2S_2$	186°	12.36 (12.51)	9.44 (9.55)	10.68 (10.81)	661.37 (671.37)
5.	$Ge(OCH_3)_4$	$C_9H_{10}N_3OF$	1:2	$Ge.C_{20}H_{24}N_6O_4F_2$	185°	15.95 (16.06)	-	13.72 (13.88)	514.81 (523.03)
6.	$Ge(OCH_3)_4$	$C_9H_{10}N_3SF$	1:2	$Ge.C_{20}H_{24}N_6O_2S_2F_2$	185°	15.00 (15.13)	11.41 (11.55)	12.96 (13.07)	544.72 (555.15)
7.	$Ge(OCH_3)_4$	$C_9H_{11}N_3O$	1:2	$Ge.C_{20}H_{26}N_6O_4$	206°	16.13 (16.31)	-	13.95 (14.09)	506.89 (515.11)
8.	$Ge(OCH_3)_4$	$C_9H_{11}N_3S$	1:2	$Ge.C_{20}H_{26}N_6O_2S_2$	206°	15.21 (15.35)	11.60 (11.71)	13.12 (13.26)	538.86 (547.23)

Table 3: ^{13}C NMR Spectral Data (δ ppm) of Ligands and their Germanium (IV) Complexes.

Compounds	Chemical shifts in δ ppm														
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
L^6H ($C_9H_{10}N_3SF$)	164.4	115.6	130.6	126.8	130.6	115.6	179.2	186.0	-	-	-	-	-	-	-
$Ge.C_{20}H_{24}N_6O_2S_2F_2$	124	130	116	162	116	130	163	163	163	163	124	130	116	162	116
L^7H ($C_9H_{11}N_3O$)	20.9	134.7	129.1	129.1	134.7	129.1	129.1	179.0	161.0	-	-	-	-	-	-
$Ge.C_{20}H_{26}N_6O_4$	126	128	129	138	129	128	163	163	163	163	126	128	129	138	129

Table 4: Antimicrobial activity of ligands and their corresponding germanium (IV) complexes.

Microorganisms		$C_{16}H_{13}N_3S(L^2H)$		$Ge.2(L^2H)$		$C_{15}H_{15}N_3O(L^3H)$		$Ge.2(L^3H)$	
		100 ppm	200 ppm	100 ppm	200 ppm	100 ppm	200 ppm	100 ppm	200 ppm
F. oxysporum	IZ (AI)	24 (0.92)	38 (1.06)	26 (1.00)	40 (1.11)	12 (0.46)	20 (0.56)	14 (0.54)	22 (0.61)
R. phaseoli	IZ (AI)	12 (0.50)	18 (0.50)	14 (0.58)	20 (0.56)	22 (0.92)	34 (0.94)	24 (1.00)	36 (1.00)
A. flavus	IZ (AI)	26 (1.00)	38 (1.90)	28 (1.08)	40 (2.00)	14 (0.54)	32 (1.60)	16 (0.62)	34 (1.70)
S. aureus	IZ (AI)	16 (0.89)	38 (1.12)	18 (1.00)	40 (1.18)	10 (0.56)	22 (0.65)	12 (0.67)	24 (0.71)
E. coli	IZ (AI)	20 (1.00)	38 (1.00)	22 (1.10)	40 (1.05)	12 (0.60)	20 (0.53)	16 (0.80)	22 (0.58)
P.fluorescens	IZ (AI)	10 (0.38)	18 (0.50)	12 (0.46)	20 (0.56)	8 (0.31)	10 (0.28)	10 (0.38)	12 (0.33)

IZ = Inhibition zone (diameter in mm); AI = Activity index (inhibition zone of test compounds / inhibition zone of standard) $L^2H = C_{16}H_{13}N_3S$; $L^3H = C_{15}H_{15}N_3O$

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