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New Mixed Ligand Complexes of Co(II) & Ni(II) Containing Isatinazine and Semicarbazone

Z. F. Dawood* and F. J. A. Al-Moula
**Chemistry Department, Education College, Mosul University Mosul-Iraq*

(NJC)

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Abstract

The preparation and characterization of new cobalt(II) and nickel(II) complexes with mixed ligands including isatinazine-IAH_2 and semicarbazone ligands (including benzoin- semicarbazone-$B'SCH_2$ or isatinsemicarbazone-$ISCH_2$ or isatinbis(semicarbazone)-$ISCH_3$) have been carried out in both neutral (or slightly acidic) and basic medium. The resulted complexes have been characterized using metal analysis by atomic absorption spectroscopy and by precipitation methods, relative molecular weight determina- tion, molar conductance measurements, molar refraction, magnetic susceptibilities, infrared and electronic spectra.

The resulted complexes have general formula $[M(IAH_2)(LH_{2,3})](NO_3)_2$ or $[M(IAH_2)(LH_{2,3})NO_3]NO_3$ in neutral (or slightly acidic) medium whereas neutral or negative ionic complexes of the general formula $[M(IAH_2\text{-}y')(LH_{2,3}\text{-}y'')]$ or $Na_w[Co(IAH_{2}\text{-}y')(LH_{2,3\text{-}y''})$ have been resulted in basic medium, (where M= Co(II) or Ni(II); w=1 or 2; y′=1 or 2; y″=1 or 2; $LH_{2,3}$= the ligands $B'SCH_2$ or $ISCH_2$ or $ISCH_3$) in which the ligands acted as neutral or anionic (-1 or -2) in neutral (or slightly acidic) or basic medium, respectively. Accordingly, hexacoordinated mononuclear complexes have been proposed for the resulted complexes had octahedral geometry.

الخلاصة

تم تحضير وتشخيص معقدات جديدة للكوبلت(II) و النيكل(II) مع مزيج من الليكندات التي تشمل إزاتين آزاين-IAH_2 وليكندات السميكاربازون (المتضمنة بنزوين سميكاربازون- $B'SCH_2$ أو إزاتين سميكاربازون- $ISCH_2$ أو إزاتين بس(سميكاربازون)-$ISCH_3$) في كل من الوسطين المتعادل (أو الحامضي قليلا) والقاعدي.

شخصت المعقدات الناتجة بإستخدام التحليل العنصري باستخدام جهاز طيف الامتصاص الذري و الطريقة الترسيبية وحساب الوزن الجزيئي النسبي وقياس التوصيلية الكهربائية والإنكسار المولاري والمغناطيسية واطياف الأشعة تحت الحمراء والإلكترونية. اقترحت الصيغ العامة $[M(IAH_2)(LH_{2,3})NO_3]NO_3$ أو $[M(IAH_2)(LH_{2,3})](NO_3)_2$ في الوسط المتعادل أو الحامضي قليلاً في حين تتكون معقدات متعادلة أو سالبة الشحنة ذات صيغ عامة $[M(IAH_2\text{-}y')(LH_{2,3}\text{-}y'')]$ أو $Na_w[Co(IAH_{2\text{-}y'})(LH_{2,3\text{-}y''})]$ في الوسط القاعدي (حيث M= Co(II) أو Ni(II) و w = 1 أو 2 وy′= 1 أو 2 وy″= 1 أو 2 و $LH_{2,3}$= الليكند $B'SCH_2$ أو $ISCH_2$ أو $ISCH_3$) ، إذ تسلك فيها الليكندات بشكل ليكندات متعادلة أو ذات شحنة سالبة أحادية أو ثُنائية في الوسط المتعادل (أو الحامضي قليلاً) والقاعدي على التوالي.

استنادا الى ذلك اقترح أن المعقدات تكون سداسية التناسق ذات أشكال ثُمانية السطوح أُحادية النواة.

Introduction

Agood deal of work has been reported on the preparation, spectral and structural investigation of azines and their complexes, due to their capability of acting as multidentate donor(1-4). Moreover azines and their complexes had important analytical applications, biological activities and photosensitizers in solar cells(5,6).

An extremely large number of semicarbazone complexes have been reported (7-11). In addition to their ligational properties, semicarbazones formed an important class of biologically active compounds and they were also used as pigments(12-14).

Mixed ligand complexes were of considerable importance in the field of metalloenzymes and other biological activities(15-17). Hence a large body of mixed ligand complexes with transition and non-transition metal ions have been reported(18-20). Due to the importance of such ligands and mixed ligand complexes, we took a modest part in the chemistry of mixed ligands and some articles have been published on their coordination chemistry with transition and non-transition metal ions(21-24).

In the present work, new cobalt(II) and nickel(II) complexes with mixed ligands {isatinazine-IAH_2 and semicarbazone ligands {benzoinsemicarbazone-$B'SCH_2$ or isatinsemicarbazone-$ISCH_2$ or isatinbis(semicarbazone)-$ISCH_3$}(Figure 1) have been prepared and characterized physico-chemically.

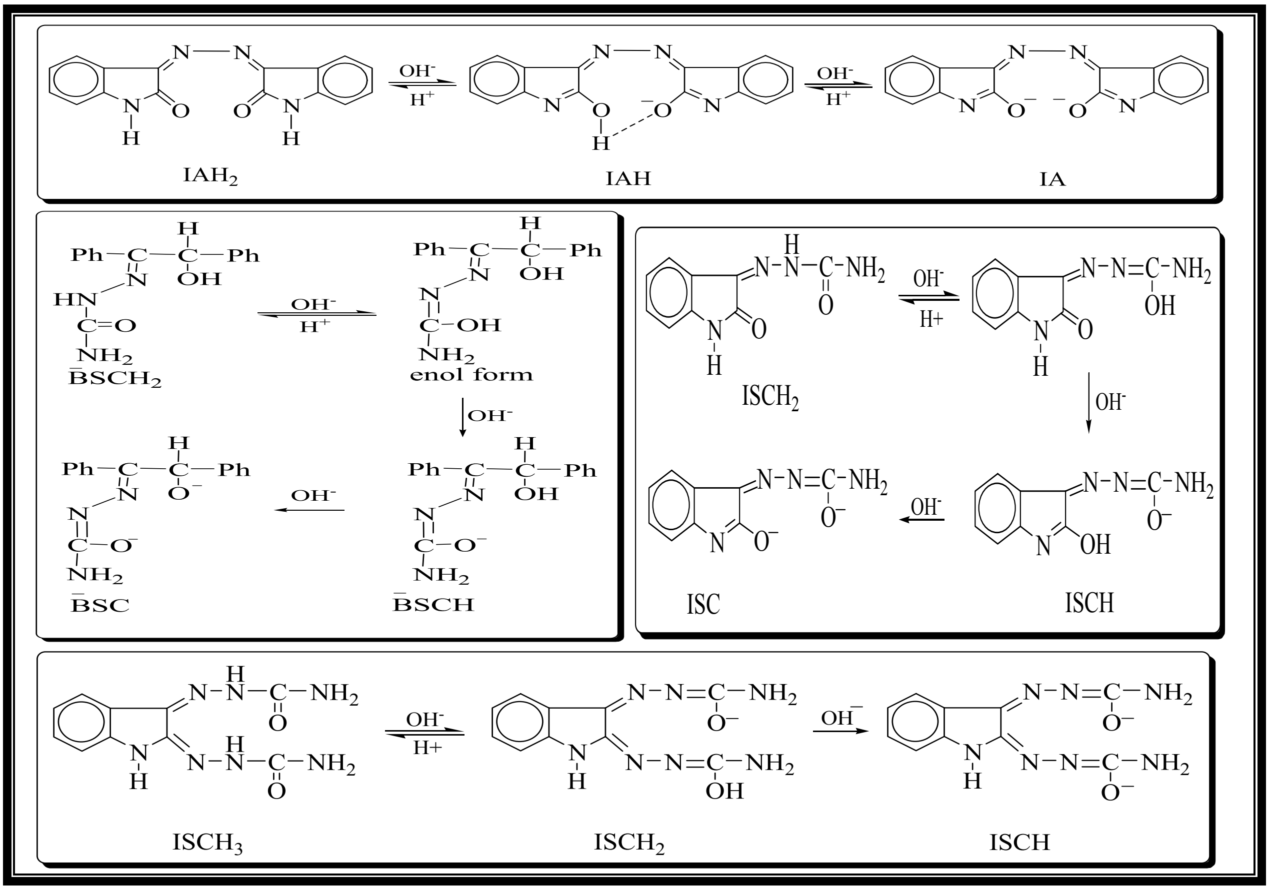


Figure 1: Model structures of the ligands

Experimental

1- Starting Materials:

All the chemicals used were suppli- ed from Fluka, BDH, Aldrich, Merck, Anhdrous LAB-SCAN, U.S.A, ppl;Chem, GCC.

2- Synthetic Methods :

Isatinazine-IAH_2 has been prepared according to literature method(25,26). Semi- carbazone ligands have been prepared according to literature method(25,26).

A general procedure has been adop- ted for the preparation of the complexes in neutral and basic medium .

I- In neutral medium:

A solution of 0.5 gm ($1.7x10^{-3}$ mm) of $Co(NO_3)_2.6H_2O$ or $Ni(NO_3)_2.6H_2O$ in 5 ml water has been added to the solution of 0.49 gm IAH_2 ($1.7x10^{-3}$ mm) and $1.7x10^{-3}$ mm of one of the semicarbazone ligands in a small amount of ethanol and water with heating until a clear solution has been resulted (the amounts in grams were listed in Table 1). The mixtures have been refluxed for three hours followed by evaporation to half volumes then cooled. The products were separated by filteration, washed with petroleum ether and dried at 100 ^oC.

II- In basic medium:

The complexes have been prepared by applying the same amounts used for neutral medium, and after mixing the metal salts with the ligands and heating, sodium hydroxide solution (1M) has been added until pH of the solutions have been adjusted to about 8-9. The mixtures have been heated on a waterbath for half an hour then allowed to stand then cooled. The products were filtered off and washed with petroleum ether and dried at 100 ^oC.

3-Analytical and Physical Measurements :

Nickel contents have been determined by atomic absorption spectroscopy and cobalt contents have been determined by applying precipitation method after the decomposition of the complexes with con- centrated nitric acid(27). Sodium contents have been determined using flame photo-metry(28). Relative molecular weights of the ligands and their complexes have been determined cryoscopically {decreasing in freezing point}(28). Molar Refraction mea- surements(28) have been carried out with Atago Illumination, Atago Co-LTD, Japan using 10^{-3} M dimethylformamide solution. Conductivity measurements have been carried out with an electrolytic conductivi- ty measuring set LF-42 and Multiline f/SET-2WTW Wissenschaf Tecchnische Werkstattem 82362 Weiheim using 10^{-3} M dimethylformamide solution at 25 ^oC. The infrared spectra has been recorded on FT-IR Bruker type Tensor 27 in the range 400-4000 cm^{-1} using KBr pellets. Electronic spectra has been record-ed on Shimadzu UV-1650 PC UV-Vissible Spectrophoto-meter for 10^{-3} M solutions of the ligands and their complexes in dimethylformamide at 25 ^oC, using a 1cm cell. Magnetic susceptibility of the complexes have been measured by Bruker-BM6 .

Results and Discussion

The reaction of cobalt(II) or nickel (II) nitrate, isatinazine and the semicarbaz- one ligands in 1:1:1 molar ratio in both neutral and basic medium may be represe- nted by the following equations :

$M(NO_3)_2.6H_2O + IAH_2 + LH_y \rightarrow [MIAH_2)(LH_{2,3})_2](NO_3)_2 + 6H_2O$

$M(NO_3)_2.6H_2O + IAH_2 + LH_y \rightarrow [M(IAH_2)(LH_{2,3})_2NO_3]NO_3 + 6H_2O$

$M(NO_3)_2.6H_2O + IAH_2 + LH_y + 2NaOH \rightarrow [M(IAH)(LH_{1,2})] + 2NaNO_3 + 8H_2O$

$Co(NO_3)_2.6H_2O+IAH_2+LH_y+(2+w)NaOH \rightarrow Na_w[M(IAH_{2-y'})(LH_{2,3-y''})]+(2)NaNO_3+(6+2+w)H_2O$
where LH_y= $B'SCH_2$, $ISCH_2$ or $ISCH_3$; y'= 1or 2; y"=1 or 2; w=1 or 2;.

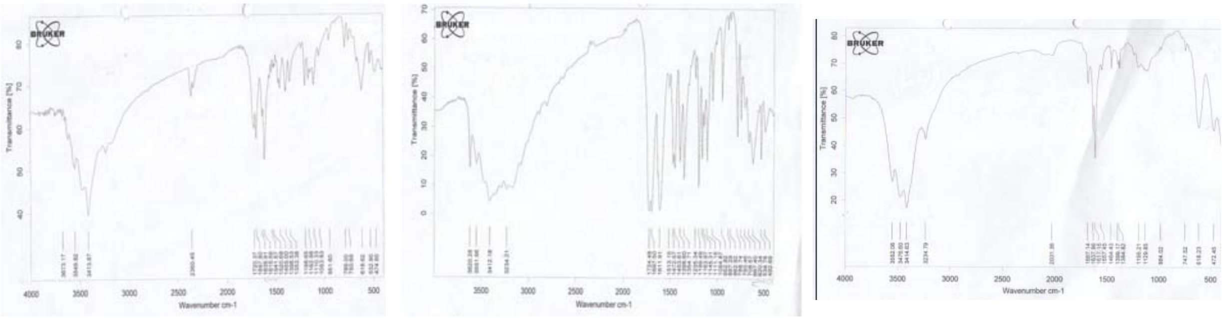
The resulted complexes were colored solid, soluble in dimethylformamide. Cobalt and nickel contents and relative molecular weights revealed that the complexes had the composition $[M(IAH_2)(LH_{2,3})_2](NO_3)_2$ and $[M(IAH_2)(LH_{2,3})NO_3]NO_3$ in neutral (or slightly acidic) medium and $[M(IAH)(LH_{1,2})]$ or $Na_w[M(IAH_{2-y'})(LH_{2,3-y''})]$ in basic medium (Table 1). The values of the molar conductivities (107.00-133.38, 52.47-94.78 and 6.23-25.88 $\Omega^{-1}cm^2mol^{-1}$) approached those expected for 1:2, 1:1 and non electrolytes(29). For complexes prepared in neutral and basic medium, respectively. The room temperature (25 °c) magnetic moments of cobalt(II) and nickel(II) complexes lied in the range 1.65-1.99, 3.44 and 2.14-3.00 B. M indicated the presence of one unpaired, three unpaired and two unpaired electrons, respectively(30), assigned to a monomeric structure, having low spin and high spin octahedral geometries, respectively (Table 1). The molar refractance of the complexes in 10^{-3} M dimethylformamide solution were in the range 1.435500x10^{-4}- 1.435579 x10^{-4}.

The infrared spectra of semicarbazone ligands (Table 3, Figue 2) showed a strong band at 1685.15-1697.80 cm^{-1} attributed to the C=O group(31) shifted towards a lower frequency on coordination in neutral medium, indicating the forma-tion of a chelation between the oxygen of the C=O group and the metal ion(31). Meanwhile, in basic medium, this band was disappeared in the complexes and a new band has been observed at 1102.34-1206.87 cm^{-1} due to C-O group, thereby establishing coordination of the ligand through the enolic oxygen atom(8,31). The next strong band at 1611.91-1637.93 cm^{-1} attributed to C=N group(31) shifted towards a lower frequency on coordination due to the decrease of the bond order as a result of metal nitrogen bond formation(312). The appearance of strong bands at 1630.00-1635.00 cm^{-1} and 1570.00-1580.00 cm^{-1} attributed to $\upsilon_{(C=N)}$ + $\upsilon_{(O-C=N)}$ and azine chromophore $\upsilon_{(C=N-N=C)}$, respecttively, supported the formation of enolic structure in basic medium(9,31). The position band of the ligand in the range 3234.21-3235.86 cm^{-1} remained unaltered in the complexes prepared in neutral medium indicating that there is no coordination through the NH group(8,,31). whereas in basic medium, this band is disappeared in basic medium due to the enolic form. The other bands at 3390.00-3410.00 cm^{-1} and 1468.50-1490.31 cm^{-1} attributed to υ_{NH2} and δ_{NH2}(31). These bands remained unaltered on complexation indicating that there is no coordination through this group and the metal ion(21,31). The infrared spectra of $B'SCH_2$ ligand showed a wide band at 3552.28 cm^{-1} due to the stretching vibrat- ion of phenolic hydroxyl shifted to a lower frequency on complexation(31).The other band observed at 1330.37 cm^{-1} attributed to the bending vibration of phenolic OH shifted to a lower frequency on complexation (31) indicating the coordination of this gro- up with the metal ion. Moreover the appearance of a band at 1109.16 cm^{-1} which belongs to $\upsilon_{(C-O)}$ is shifted to higher frequency 1153.42-1207.91 cm^{-1} on complexation indicating the coordination of oxygen atom(31). The infrared spectra of $ISCH_2$ showed band at 1720.37 cm^{-1} attributed to $\upsilon_{C=O}$ observed in the same position in complex 3 indicating the uncoordination of this group to the metal ion, whereas in complex 9 this band shifted towards a lower frequency

1637.91 cm^{-1} due to the coordination of this group to the metal ion(31). Meanwhile in basic medium this band was disappeared due to the formation of the enol isomer which was supported by the appearance of a band (Table 3) assign- ed to υ_{C-O}(21,22,31).

The infrared spectra of IAH_2 (Figure 2) showed band at 1637.93 cm^{-1} due to $\upsilon_{C=N}$(22,31). On coordination this band was splitted into two bands, one appeared at the same position, whereas the other band observed at lower frequency. This demonstrated that only one nitrogen atom was coordinated to the metal ion(1,2,31). Moreover the positive shift in N–N vibration on complexation can be added as a further support to the coordination of the azine nitrogen to the metal ion(3,31). The next band at 1687.14 cm^{-1} attributed to $\upsilon_{C=O}$ shifted towards a lower frequency (Table 3) for complexes prepared in neutral (or slightly acidic) medium(31). Meanwhile in basic medium this band disappeared in the complexes and a new band was observed at 1152.12-1169.15 cm^{-1} due to υ_{C-O}, thereby establishing coordination of the ligand through enolic oxygen atom(1,2,31).

On the other hand the spectra of the complexes prepared in neutral (or slightly acidic) medium showed new bands around 1384.50-1399.82 cm^{-1} due to ionic nitrate (30), In addition, complexes 1, 3, 7 and 11 showed bands at 1468.50-1490.31 cm^{-1}, 1353.22-1374.90 cm^{-1} and 920.75-999.05 cm^{-1} due to $\upsilon_{s(NO3)}$, $\upsilon_{as(NO3)}$ and υ_{NO} (υ_2, υ_1, υ_5), respectively(31).The difference $\Delta\upsilon$ equ- el to 115.00-115.14 cm^{-1} which supported the bonding of nitrato group as monoden- tate ligand through the oxygen atom. The spectra of all the complexes showed new bands at 400.00-484.91 and 452.31-553.03 cm^{-1} due to υ_{M-N} and υ_{M-O}, respectively (19,20,31). The presence of these bands supp- orted the formation of the complexes under investigation.



$ISCH_2$ $ISCH_3$ IAH_2

$[Co(IAH_2)(ISCH_2)NO_3]NO_3$ $[Co(IAH_2)(ISCH_3)](NO_3)_2$

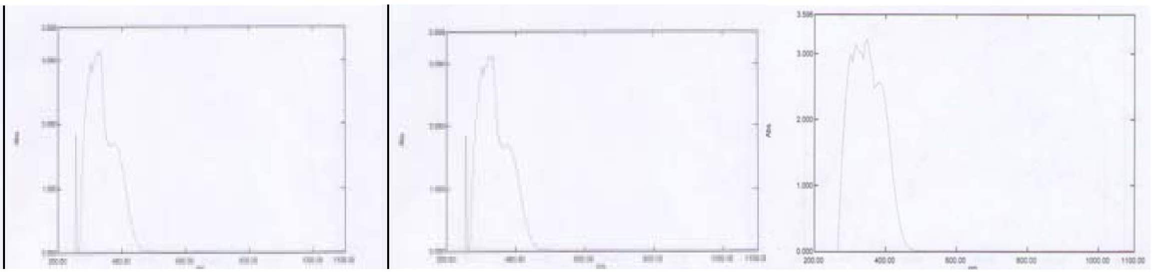
Figure 2: Infrared spectra of the ligands $ISCH_2$, $ISCH_3$, IAH_2 and their complexes

The electronic spectra in the ultra-violet region (Table 4, Figure 3) of the ligands showed two bands in the regon 400000.00-43859.65 cm^{-1} and 30120.48 - 33112.58 cm^{-1} corresponding to $\pi\rightarrow\pi^*$ and $n\rightarrow\pi^*$ transitions(32), respectively. On complexation a blue shift was observed due to the polarization in the C=N bond caused by the elemental ligand electron inter-action during the chelation.The electronic spectra of cobalt(II) complexes (Table 5, Figure 3) showed bands at 7751.99-10183.29 cm^{-1},11627.90- 7920.00 cm^{-1} and 16666.67-23696.60 cm^{-1} (υ_1, υ_2 and υ_3) due to the transitions $^4T_1g(F)\rightarrow{}^4T_2g(F)$, $^4T_1g(F)\rightarrow{}^4A_2g(F)$ and $^4T_1g(F) \rightarrow {}^3T_1g(P)$, respectively(32,33). The ligand field parameter B and the ligand field splitting energy (10Dq) in case of cobalt(II) complexes have been calculated (33,34). The values of β of cobalt(II) complexes are between 0.73-0.99 clearly indicated the covalent character of the bond concerned. The value of Dq/B which were in the range 0.8-1.6 suggested octahedral geometry for cobalt(II) complexes.

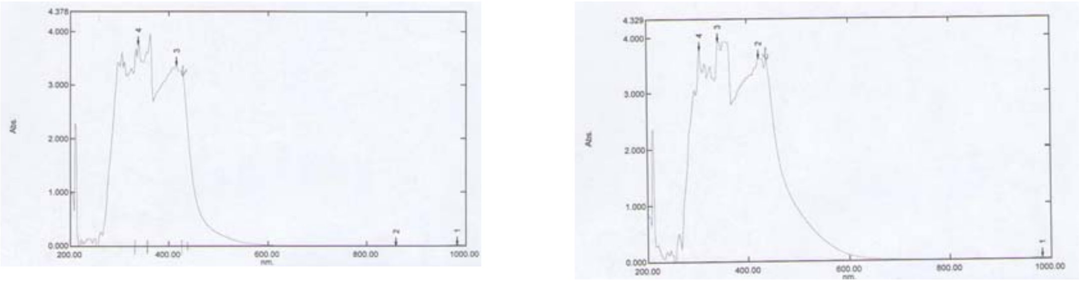
The electronic spectra of nickel(II) complexes (Table 4) showed bands (υ_1, υ_2 and υ_3) at 10141.98-10204.08 cm^{-1}, 11135.85-16839.43 cm^{-1} and 23041.40-28901.70 cm^{-1} due to $^3A_2g(F)\rightarrow{}^3T_2g(F)$, $^3A_2g(F)\rightarrow{}^3T_1g(F)$ and $^3A_2g(F)\rightarrow{}^3T_1g(P)$, transitions respectively(32,33). The ligand field parameter B and the ligand field splitting energy (10Dq) in case of nickel (II) complexes have been calculated(33,34). The values of β of nickel(II) complexes are between 0.77-0.99 clearly indicated the covalent character of the bond concerned. The value of Dq/B which were in the range 0.95-1.30 suggested octahedral geometry for nickel(II) complexes$^{(34)}$.The values of CFSE of cobalt(II) and nickel(II) complexes have been also determined (as shown below) which were in the range 5125.74-9404.25 cm^{-1} and 12170.40-13892.40 cm^{-1}, respectively.

CFSE= ({o.4 x no. of electrons in t_2g} – {0.6 x no. of electrons in eg})Δo (where Δo = 10Dq).

The electronic spectral data suggested octahedral geometry for all the complexes$^{(33-34)}$.



ISCH$_2$ IAH$_2$ ISCH$_3$



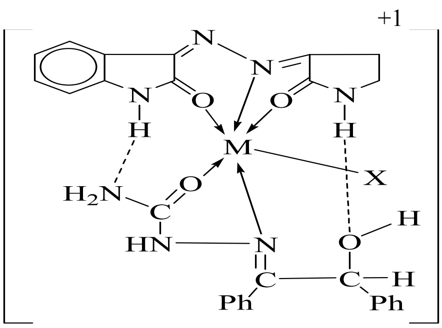
[Co(IAH$_2$)(ISCH$_2$)NO$_3$]NO$_3$ [Co(IAH$_2$)(ISCH$_3$)](NO$_3$)$_2$

Figure 3: Electronic spectra of the ligands ISCH$_2$, ISCH$_3$,IAH$_2$ and their complexes

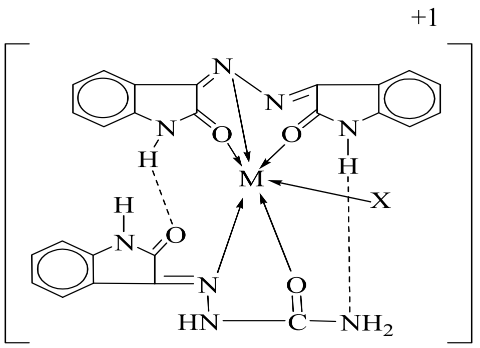
Conclusion:

According to the analytical, physical and spectral data, some observations have been achieved that lead to establish the following points:

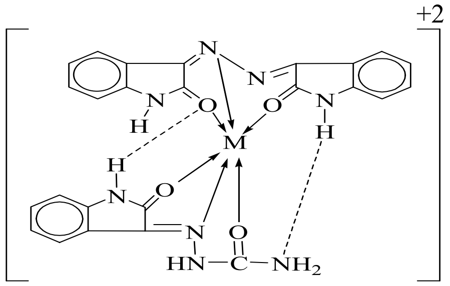
1. IAH$_2$ ligand acted as tridentate chelating ligand joint to the metal ion through the azomethine nitrogen and the two oxygen atoms of the carbonyl groups.
2. B'SCH$_2$ ligand acted as either bidentate or tridentate chelating ligand joint to the metal ion through N atom and one or two O atoms.
3. ISCH$_2$ ligand acted as either bidentate or tridentate chelating ligand joint to the metal ion through N atom and one or two O atoms.
4. ISCH$_3$ ligand acted as either bidentate or tridentate chelating ligand joint to the metal ion through the two N atoms or through the two N and one O atoms.
5. Cobalt(II) and nickel(II) ions have been probably hexacoordinated, leading to octahedral geometries (Figure 4).



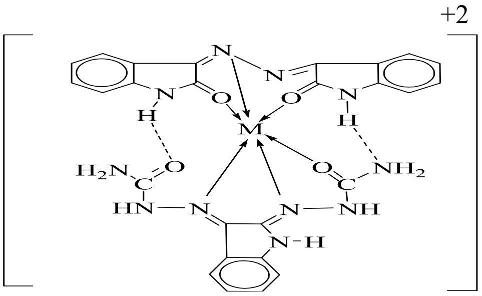
$[Co(B'SCH_2)(IAH_2)(NO_3)]NO_3$
$[Ni(B'SCH_2)(IAH_2)NO_3]NO_3$
1, 7



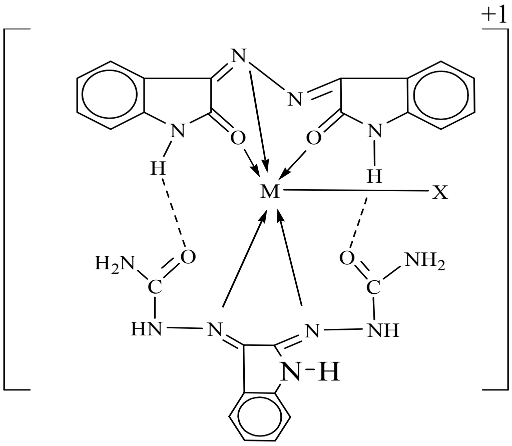
$[Co(ISCH_2)(IAH_2)NO_3]NO_3$
3



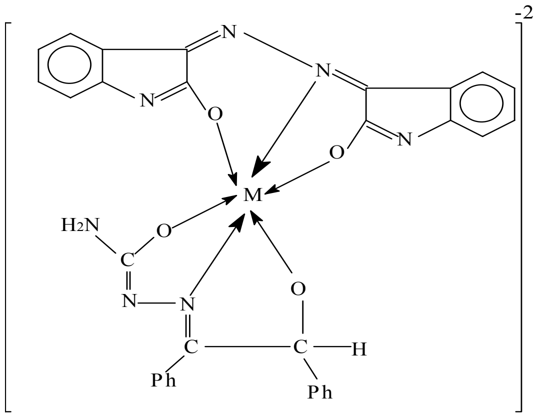
$[Ni(ISCH_2)(IAH_2)](NO_3)_2$
9



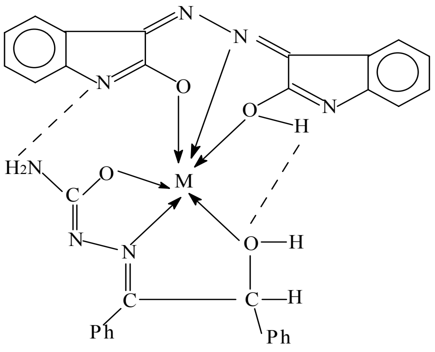
$[Co(ISCH_3)(IAH_2)](NO_3)_2$
5

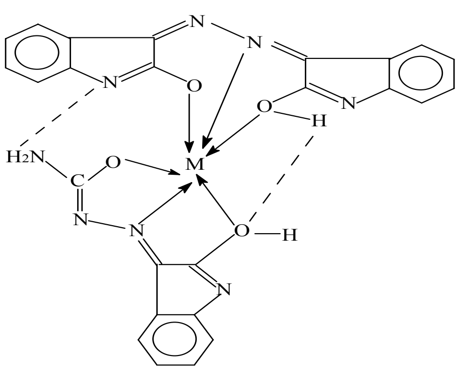


$[Ni(ISCH_3)(IAH_2)NO_3]NO_3$
11



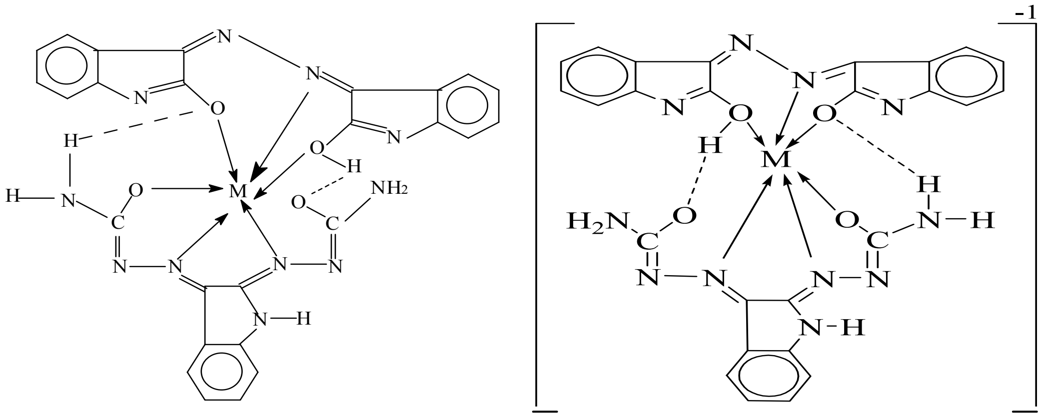
$Na_2[Co(B'SC)(IA)]$
2





[Ni(B'SCH)(IAH)]
8

[Co(ISCH)(IAH)]; [Ni(ISCH)(IAH)]
4, 10



$[Ni(ISCH_2)(IAH)]$
12

$Na[Co(ISCH)(IAH)]$
6

Figure 2: Proposed structures of the complexes

Table 1- Amounts, medium for the preparation of the complexes

No.	Wt. of $B'SCH_2$	Wt. of $ISCH_2$	Wt. of $ISCH_3$	Wt. of IAH_2	Medium	% yield	Complex
1	0.46	-	-	0.49	Neutral	84.25	$[Co(B'SCH_2)(IAH_2)(NO_3)]NO_3$
2	0.46	-	-	0.49	Basic	99.00	$Na_2[Co(B'SC)(IA)]$
3	-	0.35	-	0.49	Neutral	81.89	$[Co(ISCH_2)(IAH_2)NO_3]NO_3$
4	-	0.35	-	0.49	Basic	85.10	$Co(ISCH)(IAH)$
5	-	-	0.62	0.49	Neutral	71.73	$[Co(ISCH_3)(IAH_2)](NO_3)_2$
6	-	-	0.62	0.49	Basic	86.00	$Na[Co(ISCH)(IAH)]$
7	0.46	-	-	0.49	Neutral	81.88	$[Ni(B'SCH_2)(IAH_2)NO_3]NO_3$
8	0.46	-	-	0.49	Basic	99.00	$Ni(B'SCH)(IAH)$
9	-	0.35	-	0.49	Neutral	86.20	$[Ni(ISCH_2)(IAH_2)](NO_3)_2$
10	-	0.35	-	0.49	Basic	97.78	$Ni(ISCH)(IAH)$
11	-	-	0.62	0.49	Neutral	71.01	$[Ni(ISCH_3)(IAH_2)NO_3]NO_3$
12	-	-	0.62	0.49	Basic	97.00	$Ni(ISCH_2)(IAH)$

Table 2- Some analytical and physical properties

No.	Color	Mp or d*	$^{\wedge}_{M}$ $\Omega^{-1}cm^2mol^{-1}$	M% calc.(obs.)	Na% calc.(obs.)	M.Wt calc.(obs.)	Ref. $x10^{-4}$	M_{eff} B.M
1	Yellowish brown	110	79.73	7.95 (7.85)	-	742 (759)	1.435558	1.82
2	Brown	180	107.00	8.91 (8.50)	6.9 (6.9)	662 (660.5)	1.435554	1.93
3	Yellowish brown	230	88.42	8.71 (8.93)	-	677 (660.5)	1.435500	1.99
4	Greenish brown	204	6.23	10.70 (9.85)	-	551 (554)	1.435565	1.66
5	Yellowish brown	207	133.38	7.07 (6.48)	-	834 (825)	1.435561	3.44
6	Dark brown	188	52.47	8.07 (8.01)	3.2 (3.2)	731 (734)	1.435552	1.65
7	Redish brown	160	94.78	7.95 (7.50)	-	742 (743)	1.435540	2.86
8	Brown	200	25.88	9.53 (9.32)	-	616 (660)	1.435579	2.14
9	Dark brown	205	128.86	8.67 (8.41)	-	677 (701)	1.435557	2.93
10	Brown	225	15.80	10.65 (9.91)	-	550 (554)	1.435560	2.43
11	Brown	197	85.60	7.04 (7.15)	-	834 (825)	1.435562	3.00
12	Dark brown	221	9.08	8.34 (8.41)	-	707 (701)	1.435575	2.87

Calc. = calculated; obs. = observed; $^{\wedge}_{M}$ = molar conductance

Table 3- Some important bands in the infrared spectra of the ligands and their cobalt(II) and nickel(II) complexes

No.	**Semi**				**Azine**					υ_{NO3} **(ionic)**	υ_{NO3} **(s)**	υ_{NO3} **(as)**	υ_{N-O}	υ_{M-N}	υ_{M-O}	**Other bands**
	$\upsilon_{C=N}$	$\upsilon_{C=O}$	υ_{C-O}	υ_{N-H}	$\upsilon_{C=N}$	$\upsilon_{C=O}$	υ_{C-O}	$\upsilon_{N-H(C)}$	υ_{N-N}							
IAH_2	-	-	-	-	1637.96	1687.14	-	3234.79	950.00	-	-	-	-	-	-	-
$B'SCH_2$	1637.93	1685.15	-	3235.86	-	-	-	-	-	-	-	-	-	-	-	υ_{C-O} (1109.16); υ_{O-H} (3552.28)
$ISCH_2$	1635.91	1697.80	-	3234.21	-	-	-	-	-	-	-	-	-	-	-	$\upsilon_{C=O}$ (1720.37)
$ISCH_3$	1611.91	1697.50	1399.82	3234.21	-	-	-	-	-	-	-	-	-	-	-	-
1	1617.41	1637.43	-	3233.68	1600.00 1636.71	1632.11	-	3233.68	982.11	1399.82	1470.18	1355.18	999.05	401.96 412.01	477.50 521.33	υ_{C-O} (1153.42)
2	1617.34	-	1156.99	-	1558.00 1638.87	-	1152.12 1153.42	-	1000.00	-	-	-	-	405.32 410.01	475.53 482.13	-
3	1616.40	1641.50	-	3232.58	1611.23	1637.15	-	3235.01	1000.00	1399.53	1480.50	1365.50	980.50	400.00 405.00	480.36 485.99	$\upsilon_{C=O}$ (1723.24)
4	1557.72	-	1147.26 1163.02	-	1616.93 1637.65	-	1153.91 -	-	970.05	-	-	-	-	401.99 409.12	474.16 492.10	υ_{C-O} (1206.87)
5	1511.89 -	1636.12 1698.79	-	3235.68 -	1615.13 1637.11	1540.00	-	3234.77	998.01	1397.56	-	-	-	412.53 436.12	454.41 462.31	-
6	1557.59 -	-	1155.10	3234.10	1617.69 1637.32	-	1169.15	-	985.00	-	-	-	-	400.09 405.13	471.74 452.31	-
7	1551.42 -	1656.92	-	3234.00	1589.00 1638.12	1588.31	-	3231.99	979.28	1384.50	1490.31	1374.90	928.29	445.53 402.12	503.15 525.16	υ_{C-O} (1207.91)
8	1586.49 -	-	1165.32 1153.21	-	1606.39 1637.00	-	1158.13	-	1000.78	-	-	-	-	484.91 453.32	528.93 553.03	-
9	1617.73 -	1599.00	-	3236.68	1600.12 1637.77	1640.53	-	3236.68	995.56	1384.50	-	-	-	405.11 400.09	479.06 481.32	$\upsilon_{C=O}$ (1637.91)
10	1617.07 -	-	1108.58 1123.45	-	1595.00 1637.75	-	1157.20	-	987.54	-	-	-	-	401.92 400.00	475.38 487.31	υ_{C-O} (1207.41)
11	1588.21 -	1645.02	-	3234.73	1617.06 1637.94	1655.03	-	3235.13	988.06	1384.95	1468.50	1353.22	920.75	400.90 412.32	475.30 482.13	-
12	1586.43 -	-	1206.87 1102.34	-	1514.21 1636.14	-	1167.93	-	-	-	-	-	-	429.64 401.00	497.12 512.96	-

Table 4- Electronic spectral data in uv region of ligands and their complexes

No.	$n\rightarrow\pi^*$; cm^{-1}	$\pi\rightarrow\pi^*$; cm^{-1}	No.	$n\rightarrow\pi^*$; cm^{-1}	$\pi\rightarrow\pi^*$; cm^{-1}
B'SCH_2	33112.582	40000.000	5	30500.000	36783.783
$ISCH_2$	30120.481	37037.037	6	30050.750	34100.000
$ISCH_3$	31446.540	43859,649	7	30200.500	33883.833
IAH_2	30864.197	40000.000	8	30050.000	34050.500
1	30303.030	33112.582	9	29940.119	33783.783
2	30000.000	32679.788	10	31333.333	36363.636
3	31150.333	35682.539	11	30859.790	33444.444
4	31069.767	39682.539	12	30303.030	35353.535

Table 5- Electronic spectral data of cobalt(II) and nickel(II) complexes

No.	υ_1	υ_2	υ_3	B	υ_3/B	Dq	**10Dq**	Dq/B	β	C.T	C.F.S.E
1	10162.60	17920.00*	19607.80	707.00	27.73	1131.20	11312.00	1.60	0.73	29411.76	20361.60
2	10183.20	17850.00*	21000.00	809.56	25.94	1133.384	11333.84	1.40	0.83	30864.19	20400.91
3	10162.60	11627.90	22222.00	956.61	23.32	1052.270	10522.70	1.10	0.99	29585.79	18940.86
4	7751.99*	16666.67	23364.48	932.34	25.06	1212.044	12120.44	1.30	0.96	29069.76	21816.79
5	10162.60	16666.67*	23696.60	913.52	25.94	1276.922	12789.22	1.40	0.94	29239.76	10231.37
6	10183.29	11682.24	16666.67	800.89	20.81	640.714	6407.17	0.80	0.83	29585.70	11532.98
7	10162.60	11655.00	28409.00	1016.20	27.95	1016.200	10162.00	1.00	0.94	29500.00	12194.40
8	10183.29	11135.85	26666.67	960.60	27.76	1018.300	10183.00	1.00	0.89	29940.11	12219.60
9	10162.60	16839.43*	23041.40	830.00	27.76	1016.200	10162.00	1.22	0.77	28248.50	12194.40
10	10141.98	16805.30*	24038.40	865.90	27.76	1014.200	10142.00	1.20	0.80	30864.19	12170.40
11	10162.60	11682.24	23809.50	1069.70	22.26	1016.200	10162.00	0.95	0.99	29940.11	12194.40
12	10204.08	13227.50	28901.70	840.50	32.15	1157.700	11577.00	1.30	0.82	29761.90	13892.40

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