CHAPTER VI
SYNTHESIS AND CHARACTERISATION OF Cr(III), Fe(III) AND Co(III)
COMPLEXES WITH BIACYTOL MONOXIME/BENZIL MONOXIME
PHENOXY ACETYL HYDRAZONE

INTRODUCTION:
Recently there has been growing interest for polymeric compounds which are
coordinated between ligands and transition metal complexes. Polymeric metal
complexes show interesting and important characteristics, especially in areas such as
semiconductors\(^\text{[11]}\) heat resistance materials and gas separators. It has been
demonstrated that oximes carrying tetradentate moieties in the same molecule show
high complexing affinity towards transition metal ions\(^\text{[2]}\). On the other hand, the two
hydrogen bridges have been substituted with metal complexes to obtain trinuclear
compounds in order to investigate the magnetic interactions of the metal ions.

Biacetyl monoxime phenoxy acetyl hydrazone is of interest since it has the
ability to chelate metal ion\(^\text{[15]}\) through nitrogen or oxygen donor centres. The neutron
diffraction of dimethyl glyoxime showed\(^\text{[35]}\) the presence of OH–bonds with 1.02 Å
bond length as well as the intramolecular hydrogen bond (OH -- N) with bond length of
2.8 Å in the solid state\(^\text{[9]}\). There are few known\(^\text{[9,15]}\) transition metal complexes
containing aromatic and heterocyclic hydrazone derivatives of biacetyl monoxime.
Also complexes of biacetyl monoximes Schiff bases have been reported\(^\text{[14,15]}\).

Polymeric (1:1) complexes of Cr(III) and Co(III) with terphthahlic acid
hydrazide bis-salicylaldehyde; terphthahlic acid hydrazide bis-2,3,4-tri hydroxy
phenacylidene and terphthahlic acid hydrazide bis-2-dydroxy-5-carboxy
phenacylidene have been synthesised\(^\text{[16]}\).

This report describes the preparation and characterization of some transition
metal complexes of biacetyl monoxime phenoxy acetyl hydrazone on the basis of their
IR, electronic spectra, magnetic moment and molar conductance measurements.
EXPERIMENTAL:

MATERIALS AND METHODS:

Benzoyl monoxime phenoxy acetyl hydrazone was prepared by refluxing benzoyl monoxime (0.1 mol) and phenoxy acetyl hydrazone (0.1 mol) in 100 ml ethanol for 2 hour. The white crystals obtained were filtered, washed and recrystallised from ethanol and dried over anhydrous CaCl₂ (C₁₂H₁₂N₄O₄) similarly by adopting the same procedure benzoyl monoxime phenoxy acetyl hydrazone was prepared (C₁₂H₁₂N₄O₄).

Preparation of Complexes: The [Cr(HBMPXH₂)₂Cl.H₂O] complex was prepared by refluxing a hot solution of H₂BMPCXH₂ (0.002 mol) and chromium chloride hexahydrate (0.001 mol) in 50 ml ethanol for 1 hour. The solid complex was isolated after the addition of diethyl ether with scratching. The [Co(HBMPXH₂)₂Cl.H₂O] was produced by the same procedure using equimolar ratio of CoCl₂.6H₂O and H₂BMPCXH₂. The complex [Fe(HBMPXH₂)₂Cl.H₂O] was isolated by refluxing H₂BMPCXH₂ (0.001 mol) and FeCl₃.6H₂O (0.001 mol) in 50 ml ethanol for 1 hr. On concentration and cooling complex was separated out.

The same method was applied for the isolation of the complexes of benzil monoxime phenoxy acetyl hydrazone. The complexes obtained were filtered, washed with ethanol ether and dried over anhydrous CaCl₂. The metal and chloride contents were analysed using standard methods.

Results and Discussion: The analytical data of the complexes are in agreement with their molecular formulae as shown in table (6.1). All the complexes are stable at room temperature, non hygroscopic insoluble in water and readily soluble in DMF and DMSO. The molar conductivity data show that the complexes are non electrolytes in nature.
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Complex</th>
<th>C (%)</th>
<th>H (%)</th>
<th>N (%)</th>
<th>Cl (%)</th>
<th>Metal (%)</th>
</tr>
</thead>
</table>
| 1.   | [Cl(C_{12}H_{14}N_{2}O_{5})_{2}Cl(H_{2}O)]  
(Greenish) | 47.70 (47.88) | 4.83 (4.98) | 13.82 (13.90) | 5.80 (5.90) | 8.50 (8.64) |
| 2.   | [Cr(C_{12}H_{14}N_{2}O_{5})_{2}Cl(H_{2}O)]  
(Grey) | 61.98 (62.15) | 4.35 (4.47) | 9.80 (9.88) | 4.0 (4.17) | 0.016 (0.12) |
| 3.   | [Fe(C_{12}H_{14}N_{2}O_{5})_{2}Cl(H_{2}O)]  
(Blackish) | 47.45 (47.57) | 4.80 (4.95) | 13.70 (13.87) | 5.72 (5.86) | 9.10 (9.22) |
| 4.   | [Fe(C_{12}H_{14}N_{2}O_{5})_{2}Cl(H_{2}O)]  
(Dark Black) | 61.75 (61.87) | 4.32 (4.45) | 9.73 (9.84) | 4.0 (4.16) | 6.42 (6.54) |
| 5.   | [Co(C_{12}H_{14}N_{2}O_{5})_{2}Cl(H_{2}O)]  
(Reddish Brown) | 47.22 (47.33) | 4.80 (4.93) | 13.70 (13.80) | 5.70 (5.83) | 9.54 (9.68) |
| 6.   | [Co(C_{12}H_{14}N_{2}O_{5})_{2}Cl(H_{2}O)]  
(Reddish Brown) | 61.70 (61.87) | 4.32 (4.45) | 9.72 (9.84) | 4.02 (4.16) | 6.78 (6.90) |
MAGNETIC MEASUREMENTS:

[Cr(Sn, H2O)6]2+ and [Cr(CO, H2O)6]2+

The magnetic moments of the complexes, under study, are 3.85 and 3.84 B.M., respectively. These values indicate that these complexes have three unpaired electrons and fall in the range required for octahedral configuration.[17]

[Fe(C2O4, H2O)6]2+ and [Fe(CO, H2O)6]2+

The magnetic moment values of the complexes under study are 5.90 and 5.92 B.M. respectively. These values fairly agreed with the value suggested for high spin octahedral complexes[18] of Fe3+.

[Co(Sn, H2O)6]2+ and [Co(CO, H2O)6]2+

The weak paramagnetic character of Co3+ complexes is ascribed to second order Zeeman effect with high ligand field term[19]. Both the complexes are diamagnetic in nature. The magnetic moment values (0.40 and 0.42 B.M.) show the octahedral nature of the complexes involving dsp3 hybridization.

REFLECTANCE SPECTRA:

Cr(III) Complexes:

Reflectance spectra of Cr(III) complexes agree with the octahedral stereochemistry[20-22]. Cr(III) has 3d6 electronic configuration with 4A2g ground state. In octahedral field three transitions

4A2g → 4T1g (F),

4A2g → 4T2g (F), and

4A2g → 4T1u (P).

Generally octahedral Cr(III) complexes show three bands around 16,000, 23,000 and 35,000 cm⁻¹. The reflectance spectra of the present Cr(III) complexes show bands in 22,040-21,800 and 15,400-15,520 cm⁻¹ range with a shoulder at 20,400 cm⁻¹. The bands at 21,600-21,810 and 15,375-15,480 cm⁻¹ have been assigned to 4A2g → 4T2g and 4A2g → 4T1u transitions respectively. The shoulder around 20,120 cm⁻¹ might be due to tetragonal distortion[23].
The bands observed in the range 18,000–25,000 cm\(^{-1}\) may be considered as the split components of the \(^{4}T_{2g}\) (oh) and \(^{4}T_{1g}\) (oh) terms despite their high molar extinction coefficients. Similar high extinction coefficients were observed for band in this region in the chromium(III) complexes of \(N\)-substituted salicylaldimines\(^{24-26}\), \(N,N\)-ethylened bis (salicylaldimines) and \(N,N\)-ethylen bis (acetyl acetonatoiminate). If these are the (d–d) bands, then the high molar extinction coefficients are possibly\(^{27}\) due to contributions from ligand transitions. However, according to Yamada\(^{28,29}\) et al. the (d–d) bands in such chelates might appear ~15,000 cm\(^{-1}\), which in the present case are masked by more intense bands.

The values of \(10D_q\), B, β, L.F.S.E. spin orbit coupling constant (\(λ\)) and Lande's splitting factor (\(g\)) have been calculated and reported in Table (6.7). The calculated values are in accordance with those found for octahedral complexes of Cr(III).

**Fe(III) Complexes:**

The reflectance spectra of Fe(III) complexes exhibit bands in the range 16,745–16,900 cm\(^{-1}\), 21,700–21,900, 850 cm\(^{-1}\) and 24,900–25,200 cm\(^{-1}\), these bands are tentatively assigned as:

\[^{5}A_{1g} \rightarrow ^{4}T_{1g} (G), \]

\[^{5}A_{1g} \rightarrow ^{4}T_{2g} (G), \]

\[^{5}A_{1g} \rightarrow ^{4}E_{g} (G)\]

The band observed at about 29,050 cm\(^{-1}\) is expected to be the charged transfer band (L→M). The bands observed at around 17,400 cm\(^{-1}\) and 29,400 cm\(^{-1}\) may possibly be due to the split of \(^{4}T_{1g}\) and thus the complexes possess distorted octahedral configuration and D4h symmetry\(^{21}\). Corresponding to D4h symmetry, the values of \(D_q\), Dt, \(δσ\), and \(δπ\) are calculated with the help of the following equations:

\[^{5}A_{1g} \rightarrow ^{4}T_{1g} (G) - 10 Dq(xy) - 35/4 Dq \]

\[Dt = 4/7 (Dq\bar{E} - Dq\bar{Z}) \]

\[δσ = 3/8 \Delta \]

\[δπ = \sqrt{2} - 1/2 \Delta \]
TABLE 6.2
REFLECTANCE SPECTRAL BANDS AND STRUCTURAL PARAMETERS OF COMPLEXES OF Cr(III) WITH BIACETYL, MONOXIME PHENOXY ACETYL HYDRAZONE AND BENZIL MONOXIME PHENOXY ACETYL HYDRAZONE

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Complex</th>
<th>Bands (cm(^{-1}))</th>
<th>10 Dq (cm(^{-1}))</th>
<th>B (cm(^{-1}))</th>
<th>(\beta)</th>
<th>L.F.S.E. (K.Cal./Mole)</th>
<th>(\lambda) (cm(^{-1}))</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>[Cr(C(<em>{12})H(</em>{12})N(<em>{2})O(</em>{3})Cl(H(_{2})O)]</td>
<td>22,040 15,520 20,400</td>
<td>22,040 898</td>
<td>0.86</td>
<td>75.42</td>
<td>28.44</td>
<td>2.02</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>[Cr(C(<em>{22})H(</em>{12})N(<em>{2})O(</em>{3})Cl(H(_{2})O)]</td>
<td>21,810 15,375 20,120</td>
<td>21,810 889.44</td>
<td>0.86</td>
<td>75.13</td>
<td>42.28</td>
<td>1.98</td>
<td></td>
</tr>
</tbody>
</table>
Parameters $10Dq$, $B$ and $\beta$ for the present complexes have been calculated and are reported in Table (6.5).

**Co(III) Complexes:**

In the reflectance spectra of complexes, three bands have been observed in the range $19,250 - 19,500$ cm$^{-1}$, $25,980 - 26,460$ cm$^{-1}$ and $34,000 - 34,250$ cm$^{-1}$, of which the first two bands may be assigned to the following transitions:

\[ ^1A_{1g} \rightarrow ^1T_{1u} \quad \text{and} \quad ^1A_{1g} \rightarrow ^1T_{1g} \]

respectively. The third band may be due to charge transfer transition. The observed spectral bands are in well agreement with the octahedral geometry\(^{25}\) of Co(III). The values of parameters $Dq$, $B$ and $\beta$ have been calculated and tabulated in Table (6.4). Strong reduction in $\beta$ indicates partial overlapping of the $3d$-orbitals with $\sigma$ and $\pi$ orbitals of surrounding donor atoms resulting in the increase of the stability of the complexes.

**IR–Studies:** The infrared spectra of the complexes show some band shifts which reveal the coordination modes of the ligands with the metal ion in the present complexes. The main vibrational bands (cm$^{-1}$) of bisacetyl monoxime phenoxy acetyl hydrazone (H$_2$BMPxH) and benzil monoxime phenoxy acetyl hydrazone (H$_2$[BMPxH]) and its complexes are reported. The IR–spectrum of the free ligand shows three intense bands at 1690, 1640 and 1400 cm$^{-1}$ assigned to $\nu$(C=O)$^{30}$, $\nu$(C=N) imine$^{31}$ and $\nu$(C=N) oxime$^{32}$ respectively. The medium intense bands at 1020 and 980 cm$^{-1}$ are attributed to $\nu$(NO) and $\nu$(N=N) stretches$^{33}$. The two bands observed at 3300 and 3200 cm$^{-1}$ are probably due to $\nu$(N–OH) oxime and $\nu$(NH)$^{34}$ and broad nature of the $\nu$(OH) stretching vibration and its wave number suggests the intramolecular hydrogen bonding$^{35}$. Also the broad weak bands in the regions 1960-1800 and 2400-2300 cm$^{-1}$ may support the presence of intra molecular hydrogen bonding (OH–N). The free ligand shows band for $\nu$(NH)-3280-3340 cm$^{-1}$ which do not shifted in the complexes suggesting that the ligand acts in keto form$^{36}$. 
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Complex</th>
<th>Bands (cm⁻¹)</th>
<th>ℏ( cm⁻¹)</th>
<th>β</th>
<th>Dt</th>
<th>Dqξ</th>
<th>δσ</th>
<th>δξ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[Fe(C₂H₆N₂O₂Cl)₂Cl(H₂O)]</td>
<td>16,745</td>
<td>7.676</td>
<td>697</td>
<td>0.58</td>
<td>-1036</td>
<td>2581</td>
<td>-288</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21,900</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>25,200</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>[Fe(C₂H₆N₂O₂Cl)₂Cl(H₂O)]</td>
<td>16,855</td>
<td>7.725</td>
<td>702</td>
<td>0.55</td>
<td>-1043</td>
<td>2598</td>
<td>-290</td>
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<tr>
<td></td>
<td></td>
<td>21,700</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>25,100</td>
<td></td>
<td></td>
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<tr>
<td>S.No.</td>
<td>Complex</td>
<td>Observed Bands (cm(^{-1}))</td>
<td>Assignments</td>
<td>10Dq (cm(^{-1}))</td>
<td>B (cm(^{-1}))</td>
<td>(\beta)</td>
<td>L.F.S.E. (K.Cal/mole)</td>
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<tr>
<td>1</td>
<td>[Co(C(_6)H(_4)N(_3)O (_2)Cl(_2)(H(_2)O))]</td>
<td>19.500</td>
<td>(\Lambda_{4g} \rightarrow \Lambda_{1'_{1g}})</td>
<td>19.500</td>
<td>513</td>
<td>0.366</td>
<td>22.25</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>26.460</td>
<td>(\Lambda_{3g} \rightarrow \Lambda_{1'_{2g}})</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>34.000</td>
<td>C.T. band</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>[Co(C(_6)H(_4)N(_3)O (_2)Cl(_2)(H(_2)O))]</td>
<td>19.380</td>
<td>(\Lambda_{4g} \rightarrow \Lambda_{1'_{1g}})</td>
<td>19.380</td>
<td>510</td>
<td>0.364</td>
<td>22.14</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>26.010</td>
<td>(\Lambda_{3g} \rightarrow \Lambda_{1'_{2g}})</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>34.385</td>
<td>C.T. band</td>
<td></td>
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</tr>
</tbody>
</table>
The uncomplexed ligand exhibit amide-I ($\nu_{C=\text{N}} - \nu_{C=\text{O}}$), amide-II and amide-III bands (in the ranges 1630–1665, 1610–1620, 1565–1565, 1490–1495 and 1265 cm$^{-1}$ respectively$^{17, 38}$). These bands remain static in the complexes suggesting keto form of the ligands. Complexes show IR-bands at 3500, 1605, 890 and 760 cm$^{-1}$ assigned to $\nu$(OH), $\nu$(H$_2$O), $\gamma$(H$_2$O) and $\nu$(H$_2$O) stretches of the coordinated water molecules respectively. On drying these complexes up to 120°C, no water molecules are lost indicating their presence in the coordination sphere.

The IR-spectrum of the complexes shows that H$_2$BMPxH and H$_2$BBMPxH behaves as a mononegative bidentate ligand coordinating through (C=O) imine and the deprotonated oxime oxygen (NO$^-$). This mode of chelation is expected due to$^{19, 20}$ the disappearance of $\nu$(OH) stretch$^{15}$, the shift of $\nu$(C=N) imine to lower wave number$^{17, 38}$ with the remaining $\nu$(C=O) stretch nearly in the same position, indicates its non participation in coordination.$^{41}$

The characteristic absorption bands of the free ligand are shifted on complexation and new vibration bands characteristic of complexes appeared showing that H$_2$BMPxH/H$_2$BBMPxH behaves in a bidentate manner.

The infra red spectra of all the complexes are similar indicating the presence of the same ligands throughout the series. The absence of $\pi$C=O stretching frequencies and the appearance of a strong band at around 1625 cm$^{-1}$ attributed to the coordinated $\pi$C=N stretching mode suggest the condensation of the diacetyl monoxime/benzil monoxime with phenoxy acetyl hydrazine$^{42}$

The infrared spectra of ligands show no characteristic absorption bands assignable to either C=O or NH$_2$ groups indicating the formation of ligands. Strong bands appearing in the region 1584–1576 cm$^{-1}$ are attributed to $\nu$(C=N) in both ligands. The strong as well as sharp bands at 1220 cm$^{-1}$ are due to the (N=O) stretching vibration. The strong bands observed around $\approx$775 cm$^{-1}$ are assigned to (C=N=O) deformation vibration. Bands characteristic of methyl groups of diacetyl monoxime are observed in the 1454–1458 $\left[\nu_{as}(C=\text{H}_{11})\right]$ and 1380–1386 cm$^{-1}$ $\left[\nu_{asy} (C-\text{CH}_3)\right]$ regions in the IR spectra of both the ligands$^{43}$.
The phenyl ring exhibits several bands in the lower energy region. Thus the bands at 1260, 1130 and 990 cm\(^{-1}\) are attributed to the phenyl group. The broad bands at around 2300 cm\(^{-1}\) are assigned to \(\nu(\text{OH})\) vibrations of the ligands. It is observed that (Co–CT) transitions of present alkyl cobalt complexes are comparable with different popular in plane ligands such as dimethyl glyoxime and diphenyl glyoxime reported by Schrzanzer\(^{111}\) et al and Gupta et al\(^{15}\). In the IR–spectra of the complexes, the broad band observed at 2390 cm\(^{-1}\) in the free ligands shifted to 2400 cm\(^{-1}\). This is attributed to the \(\nu(\text{OH})\) of hydrogen bond. Strong bands appeared at 1584 and 1576 cm\(^{-1}\) are shifted to lower wave number suggesting the participation of azomethine nitrogen in coordination. Appearance of only one band at 1220 cm\(^{-1}\) in the free ligands and presence of two bands at 1220 and 1075 cm\(^{-1}\) in the spectra of complexes account for two non-identical –\(\text{N}–\text{O}–\text{H}\) linkages i.e. >\(\text{C}–\text{N}–\text{O}–\text{H}\) and >\(\text{C}–\text{O}–\text{N}–\text{H}\)\(^{45}\) in the complexes. Bands characteristic of \(\text{C}–\text{CH}_3\) symmetric and asymmetric deformations occur in the 1370–1384 and 1430–1450 cm\(^{-1}\) regions respectively. Compound having\(^{15,17}\) >\(\text{CONHN}–\text{C}\) group, show keto-ene tautomerism as >\(\text{CONHN}–\text{C}–\text{N}\)\(^{\text{NC}}\) and coordinate to either of the forms (amide–imido). Present compounds take part in chelation in amide form\(^{18,19}\).

Thus on the basis of above discussion following structures can be proposal.
Fig. (6.1) IR SPECTRA OF COMPLEXES

I,  [Cr (C_{12}H_{14}N_{2}O_{3})_{2} Cl(H_{2}O)]  II,  [Cr (C_{25}H_{18}N_{2}O_{3})_{2} Cl(H_{2}O)]

III,  [Fe (C_{12}H_{14}N_{2}O_{3})_{2} Cl(H_{2}O)]
\[
\begin{array}{c}
\text{M} = \text{Fe}^{3+}, \text{Cu}^{2+}, \text{Cr}^{3+} \\
R = \text{NH} - C - \text{CH}_2 - O - \text{C}_6\text{H}_5
\end{array}
\]
Fig. (6.2) IR SPECTRA OF COMPLEXES

I, \([\text{Fe} (\text{C}_{22} \text{H}_{18} \text{N}_{3} \text{O}_{3})_2 \text{Cl(H}_2\text{O})]\)    II, \([\text{Co} (\text{C}_{12} \text{H}_{14} \text{N}_{3} \text{O}_{3})_2 \text{Cl(H}_2\text{O})]\)

III, \([\text{Co} (\text{C}_{22} \text{H}_{18} \text{N}_{3} \text{O}_{3})_2 \text{Cl(H}_2\text{O})]\)
### Table 6.5

**Main IR Frequency Bands (cm⁻¹) of Cu(II), Fe(III) and Co(III) Complexes with BiaCetyl Monoxime Phenoxy Acetyl Hydrazone and Benzil Monoxime Phenoxy Acetyl Hydrazone**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Compound</th>
<th>ν(C=O)</th>
<th>ν(NHCO)</th>
<th>ν(N–N)</th>
<th>ν(M–O)</th>
<th>ν(M–N)</th>
<th>ν(M–Cl)</th>
<th>ν(OH), ν(H₂O) &amp; ν(H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>[Cr(C₁₂H₁₁N₂O₅Cl(H₂O)]</td>
<td>1,585 (st)</td>
<td>1,570, 1,355</td>
<td>990 (w)</td>
<td>510 (m)</td>
<td>430 (m)</td>
<td>240 (m)</td>
<td>3,500, 898, 705</td>
</tr>
<tr>
<td>2.</td>
<td>[Cr(C₁₂H₁₁N₂O₅Cl(H₂O)]</td>
<td>1,580 (st)</td>
<td>1,575, 1,350</td>
<td>995 (w)</td>
<td>518 (m)</td>
<td>438 (m)</td>
<td>245</td>
<td>3,450, 840, 730</td>
</tr>
<tr>
<td>3.</td>
<td>[Fe(C₁₂H₁₁N₂O₅Cl(H₂O)]</td>
<td>1,580 (st)</td>
<td>1,572, 1,355</td>
<td>995 (w)</td>
<td>500 (m)</td>
<td>450 (m)</td>
<td>240</td>
<td>3,445, 835, 740</td>
</tr>
<tr>
<td>4.</td>
<td>[Fe(C₂₂H₁₉N₂O₅Cl(H₂O)]</td>
<td>1,580 (st)</td>
<td>1,574, 1,355</td>
<td>990 (w)</td>
<td>510 (m)</td>
<td>440 (m)</td>
<td>250</td>
<td>3,440, 840, 740</td>
</tr>
<tr>
<td>5.</td>
<td>[Co(C₁₁H₁₂N₂O₅Cl(H₂O)]</td>
<td>1,585 (st)</td>
<td>1,570, 1,355</td>
<td>995 (w)</td>
<td>505 (m)</td>
<td>445 (m)</td>
<td>245</td>
<td>3,450, 835, 740</td>
</tr>
<tr>
<td>6.</td>
<td>[Co(C₂₂H₁₉N₂O₅Cl(H₂O)]</td>
<td>1,580 (st)</td>
<td>1,568, 1,352</td>
<td>990 (w)</td>
<td>510 (m)</td>
<td>450 (m)</td>
<td>250</td>
<td>3,445, 840, 735</td>
</tr>
</tbody>
</table>
CHAPTER VI
REFERENCES