Chapter-6
Chapter 6

Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carboldoxime: synthesis, characterization, DNA binding and chemical oxidative cleavage studies

6.1. Introduction

The name oxime is a contraction of oxy-imine. The oxime group is amphiprotic with a slightly basic nitrogen atom and a mildly acidic hydroxyl group. Oximes have played a noted role in the development of coordination chemistry [1,2]. Werner recognized that the observed isomerism of oximes is due to the different spatial arrangement of the groups attached to the C=N moiety[3,4]. In 1905, Tschugaeff, discovered the vicinal dioxime metal complex bis-dimethylgloximatonickel(II)[5], initiating an area of coordination chemistry which has been widely explored during the past century. The first vic-oxime quasi-macrocyclic complexes were prepared by Uhlig and Friedrich[6] in 1966. Since the time, many oxime ligands and their metal complexes have been reported.

The oximes and their complexes constitute an important class of compounds having versatile reactivities [7]. The complexing properties of dioximes with respect to transition metal cations have been isolated and characterized [7–9]. Due to the presence of mildly acidic hydroxyl groups and slightly basic azomethine groups, vic-dioximes are amphoteric ligands that form corrin-type square-planar, square-pyramidal and octahedral complexes with transition metal ions such as nickel(II), copper(II), palladium(II), cobalt(II) and cobalt(III) as the central atoms [10]. Vicinal dioxime metal complexes, initiating an area of coordination chemistry, have been widely explored during the past
Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carbaldoxime:

century [11]. Incorporation of a vic-dioxime moiety on the macrocyclic provides an
efficient binding site for transition metal ions by formation of an MN₄ core with two
additional hydrogen bridges [12]. The investigations of the redox properties of these
types of complexes are also of great interest in terms of their various technological
applications [13,14], such as; analytical reagents for trace element analysis [7, 12]. The
metal complexes of vic-dioximes have been examined as compounds with columnar
stacking, which is thought to be the reason for their semiconducting properties [15]. vic-
Dioximes have also received considerable attention as model compounds which mimic
bio-functions such as the reduction of vitamin B¹² [7, 16]. Some of the ligands used for
synthesis of coordination compounds are as follows.

![Chemical structures](image)

\[ \text{dmgH}_2 \ (62) \quad \text{preH}_2(63) \quad (\text{dmgBF}_2)_2 \ (64) \quad \text{cyclops} \ (73-75) \]

\[ n = 2 \ 	ext{Hexao} \quad 3 \ 	ext{Hpnao} \quad 4 \ 	ext{Hbnao} \quad 5 \ 	ext{Hpentao} \ (65) \]

\[ \text{H}_2\text{Salox} \ (66) \quad \text{XABO} \ (67) \]
The synthesis of vic-dioxime ligands and their transition metal complexes containing crown ethers [17], monoaza crown ethers [18], ferrocene groups [19], tetrathiamacrocycles [20], or N₂O₂ macrocycles [21] and dendritic groups [22] have been recently reported.

6.1. Importance of sulfur/selenium containing compounds

On the other hand, the current research interest in the development of the chemistry of new synthetic organic and mixed ligand complexes containing S/Se atom along with N-atom with an ability to bind and cleave double stranded DNA under physiological conditions are coming up. They have potential utility in medicinal
Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carbaldoxime: applications and in genomic research as diagnostic agents as probes for conformational studies of nucleic acid and as footprinting agents [23].

The literature survey reveals that, when a photosensitizing ligand or a DNA binder are covalently bonded to a metal centre, the complex becomes cleavage-active. Mechanistic studies have revealed that metal-assisted light-induced DNA cleavage involves photo-excitation of the charge transfer and $d-d$ bands. Recently, Chakravarty et al. [24] reported that DNA binding and cleavage activity of metal complexes containing sulphur ligands. They found that the sulphur containing ligands act as photosensitizers and the photosensitizing effect is greater when the sulphur is bound to the metal centre and the concerned moiety lacks $\pi$-conjugation. The choice of sulphur-containing ligand is based on the fact that thio or thione moieties are known to show efficient inter system crossing to the triplet state on photo-irradiation [25-27].

From a chemical point of view, selenium (Se) resembles sulfur (S) in many of its properties. Thus, Se and S may be considered to be isosteric, as originally defined by Langmuir in 1919. Studies examining the relationship between the intake of dietary selenium and the risk of various cancers have shown that low selenium intake is associated with higher cancer rates, including liver cancer. In addition, the naturally occurring selenium-containing amino acids, such as selenomethionine and selenocysteine, some fused synthetic organoselenium compounds p-methoxybenzeneselenol, benzylselenocyanate, 1,4-phenyleneselenocyanate, p-methoxybenzyl selenocyanate and 1,4-phenylenbis (methylene) selenocyanate shows anticancer activities. It also plays an important role in decreasing oxidative stress in HIV-infected cells and possibly suppressing the rate of HIV replication [29-32].
Present work

Since, N and S/Se containing compounds are more useful in nucleic acid chemistry as anti tumour agents in cancer therapy, the design and development of new complexes containing this type of atoms attracted the researchers in recent years. Hence we have synthesized the transition metal complexes of Co(III) and Ni(II) metal ions containing N and S/Se donar atoms and studied their DNA binding as well as cleavage studies.

6.2. Experimental Section

6.2.1. Synthesis of 3-((hydroxyimino)methyl)quinoline-2-thiol/seleno ligand [hmtH / hmseH]

The 2-chloro-3-formylquinoline (1.93 g, 0.01 mol) reacts with NaHSe /Na2S gave 2-thiol/seleno-3-formylquinoline 2a. Then, the reaction mixture of 2a react with hydroxylamine hydrochloride (2 g, 0.002 mol) in water (5 mL) and sodium hydroxide solution (4N), in presence of ethanol (70 mL). The mixture was refluxed at 75-80 °C for one hour with constant stirring. The completion of the reaction was monitored by TLC, eluting the phase by ethyl acetate: carbon tetrachloride (60:40). The reaction mixture containing 3a (hmtH) was cooled, poured into ice-cold water and acidified with (4N HCl), then it was filtered, washed with 300 mL H2O and recrystalised using excess alcohol.

The same procedure was used for the synthesis of 2-seleno-cobaldaxame (3b) compounds[hmseH].

hmtH: Yellow Solid Yield 83%, m.p.270-273 °C; IR (KBr): (N-OH) 3442 cm⁻¹, (C=N) 1650 cm⁻¹. ¹H NMR (DMSO-d6, 300 MHz): d (ppm) =11.55 (s, 1H, CHN), 13.92 (s,
Co6aCt(III) amf!Nkl{fl(II) complexes of new sidfur/seCeno carSaldoxime:

1H, OH), 7.22-8.8 (m, 5H). Mass, m/z: 205 (M+1), Elemental analysis (%): Calcd. For C_{10}H_{8}N_{2}O_{S}: C; 58.80, H; 3.95, N; 13.72 Found: C; 58.72, H; 3.80, N; 13.83.

6.2.2. Spectral data of 3-[(hydroxyimino)methyl]quinoline-2-selenol ligand [hmseH]

hmse: Brown Solid, Yield 83%, m.p. 286-289 °C; IR (KBr): (N-OH) 3435 cm\(^{-1}\), (C=N) at 1650 cm\(^{-1}\). \(^{1}\)H NMR (DMSO-d\(_{6}\), 300 MHz): d (ppm) =11.53 (s, 1H, CHN), 13.85 (s, 1H, OH), 7.22-8.8 (m, 5H). Mass, m/z: 205 (M+1), Elemental analysis (%): Calcd. For C_{10}H_{8}N_{2}O_{S}: C; 47.82, H; 3.21, N; 11.15 Found: C; 47.76, H; 3.16, N; 11.23.

6.2.3. Synthesis of [Co(hmt)\(_{2}\)(H\(_{2}\)O)\(_{2}\)]PF\(_{6}\) (1) and of [Co(hmse)\(_{2}\)(H\(_{2}\)O)\(_{2}\)]PF\(_{6}\) (2).

The respective ligands hmtH (2.04 g 0.01mol) or hmse-H (2.52 g 0.01mol) was dissolved in 50 ml ethanol. A solution of (0.02 mol of the metal salt [CoCl\(_{2}\)5H\(_{2}\)O (5.9g)] in ethanol was added drop wise under N\(_{2}\) atmosphere with constant stirring. The stirred mixtures were then heated to the reflux temperature for 2-3 hrs and was maintained at this temperature. The pH of the solution was ca. 1.5–3.0 and was adjusted to 4.5–5.5 by the addition of a 1% NaOH solution in ethanol. The complexes was precipeted by addition of NH\(_{4}\)PF\(_{6}\). After cooling to room temperature, the complexes was filtered, washed with H\(_{2}\)O and diethyl ether then dried in vacuum (Scheme 1).

6.2.4. Synthesis of [Ni(hmt)\(_{2}\)(H\(_{2}\)O)\(_{2}\)] (3) and [Ni(hmse)\(_{2}\)(H\(_{2}\)O)\(_{2}\)] (4)

A solution of NiCl\(_{2}\).6H\(_{2}\)O (11.87 mg, 0.05 mol) in ethanol (25 mL) was added to the respective ligands hmtH / hmseH solution of in ethanol (35 mL) in room temperature. The temperature of the mixture was raised to 55 °C, and 0.1N NH\(_{3}\) solution in ethanol was added to adjust the pH to 4.0. The precipitated complex was filtered, washed with cold ethanol, and dried under vacuum (Scheme 1).
Table 6.1. Elemental analysis data of Co(III) and Ni(II) complexes containing hmt and hmse ligands

<table>
<thead>
<tr>
<th>Compounds (Molecular formulae)</th>
<th>Colour</th>
<th>Calculated (Found)</th>
<th>Magnetic Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>H</td>
</tr>
<tr>
<td>[Co(hmt)₂(H₂O)₂]PF₆</td>
<td>Blue green</td>
<td>47.71</td>
<td>4.00</td>
</tr>
<tr>
<td>[Co(hmt)₂(H₂O)₂]PF₆</td>
<td>Blue green</td>
<td>(47.70)</td>
<td>(4.02)</td>
</tr>
<tr>
<td>[Co(hmt)₂(H₂O)₂]PF₆</td>
<td>Blue green</td>
<td>40.22</td>
<td>3.38</td>
</tr>
<tr>
<td>[Co(hmt)₂(H₂O)₂]PF₆</td>
<td>Blue green</td>
<td>(40.21)</td>
<td>(3.37)</td>
</tr>
<tr>
<td>[Co(hmse)₂(H₂O)₂]PF₆</td>
<td>Dark green</td>
<td>47.74</td>
<td>4.01</td>
</tr>
<tr>
<td>[Co(hmse)₂(H₂O)₂]PF₆</td>
<td>Dark green</td>
<td>(47.71)</td>
<td>(4.13)</td>
</tr>
<tr>
<td>[Ni(hmt)₂(H₂O)₂]PF₆</td>
<td>Green</td>
<td>40.24</td>
<td>3.38</td>
</tr>
<tr>
<td>[Ni(hmse)₂(H₂O)₂]PF₆</td>
<td>Green</td>
<td>(40.21)</td>
<td>(3.35)</td>
</tr>
<tr>
<td>[Ni(hmt)₂(H₂O)₂]PF₆</td>
<td>Light green</td>
<td>47.74</td>
<td>4.01</td>
</tr>
<tr>
<td>[Ni(hmse)₂(H₂O)₂]PF₆</td>
<td>Light green</td>
<td>(47.71)</td>
<td>(4.13)</td>
</tr>
</tbody>
</table>

Scheme 1: Synthetic route for the synthesis of sulfur/seleno carbaldoxime ligands (hmtH/hmseH) and their Co(III) and Ni(II) complexes.
6.3. Result and discussion

Attempts to crystallize the ligands and their complexes in different solvents failed. The authenticities of the ligands and their complexes have been established by IR, $^1$H NMR elemental analysis and UV–Vis spectral data. In general, reactions of the ligands with a metal salt and gave a good yield of mononuclear complexes corresponding to the general formula \([M(hmt)_2(H_2O)_2]^n\) and \([M(hmse)_2(H_2O)_2]\) (where \(M=\text{Co(III)}\) or \(\text{Ni(II)}\), \(hmt=3-[(\text{hydroxyimino})\text{methyl}]\text{quinoline-2-thiol}, \ hmse=3[(\text{hydroxyimino})\text{methyl}]\text{quinolines-2-selenol, n= 1 for Co(III) and 0 for Ni(II)}\)). They are soluble in DMF, DMSO and buffer solution and are stable at room temperature.

IR Spectra

In the IR, spectrum of the ligands, the O-H stretching vibrations were observed at ca. 3480–3359 cm$^{-1}$. The stretching vibrations belonging to the C=N and N-O groups occur at ca. 1635–1648, and 1425–1430 cm$^{-1}$, respectively. These values are in harmony with the previously reported aminoglyoxime derivatives [35-42]. The ligands show band in the 976-980 cm$^{-1}$ for C=S/SeH vibration.

Figure 6.2. IR spectra of seleno carbaldoxime (HMSe)
Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carbaldoxime:

In the $^1$H-NMR spectrum of ligands, a broad signal associated with primary amine groups, disappeared and new chemical shifts at 14.02 and 11.55 ppm were observed which could be assigned to SH and OH protons [43,44]. The deuterium exchange properties of these protons also appeared during the formation of the desired compound.

![Figure 6.3. $^1$H NMR spectrum of Seleno Carbaldoxime](image)

The mononuclear cobalt(III) sulfur/seleno carbaldoxime complexes were prepared in 68-71% yields by treating CoCl$_2$. 6H$_2$O in an absolute ethanol mixture with the ligands in the presence of a base such as NaOH. The new cobalt(III) complexes have a metal:ligand ratio of 1:2 on the bases of the elemental analysis.

The IR spectra of the cobalt(III) complexes have been compared with those for similar compounds in order to establish the coordination modes of the oxime ligands in
these complexes [46]. The cobalt(III) complexes have IR spectra very similar to those of
the free ligands, except for the absence of the OH stretching vibrations. A weak and low
intensity band at ca. 1547–1640 cm\(^{-1}\) indicates the formation of a hydrogen bridge during
complexation with the ligands, since the hydrogen bridge reduces the strength of the OH
bond. The occurrence of hydrogen bridges by the loss of one oxime proton per oxime
molecule during the complexation of these ligands accounts for the one non-identical
\(-\text{N}-\text{O}\) linkages, \(\text{C}=\text{N}-\text{O-H}\) in the complexes [47]. The stretching vibrations of the
azomethine and (C-SH)/C-Se groups appearing at 1640 - 1650 cm\(^{-1}\) in the free ligands are
shifted to 1610-1615 cm\(^{-1}\) in the mononuclear cobalt(III) complexes suggested the
involvement of oxime nitrogen and sulfur/selenium group of quinolines in bonding with
Co(III) ion. In addition to these new bands of the complexes also showe broad bands in the
reigain of 3263-3197 cm\(^{-1}\) due to the presence of coordinated water molecules.

\[\text{Figure 6.4} \quad \text{IR spectrum of Co(III) complex of sulfur carbaldoxime}\]
The mononuclear complexes of nickel(II), were synthesized by a standard procedure and it gave 60-70% yields. The elemental analysis results shows that these mononuclear complexes have 1:2 metal:ligand ratio. In the IR spectrum of the mononuclear nickel(II) complexes, the weak deformation bands at 750 and 756 cm\(^{-1}\) for the characteristic stretching vibrations belonging to C-S and C-Se, respectively. The shift of bands observed for C=N and N-O groups were observed at 1597-1605 and 1617-1630 cm\(^{-1}\), respectively indicate that the nitrogen oxime and S/Se group take part in Complexation with the nickel(II) ion[45]. Together the complexes having two coordinated water molecules. In the case of the nickel(II) complexes, the coordinated H\(_2\)O groups are identified by a broad OH absorption at 3197 cm\(^{-1}\) due to water molecule.

![Figure 6.5. IR spectrum of Ni(II) complex of seleno carbaldoxime](image)

6.4. **UV-Visible spectra**

The electronic spectrum of the ligands and their complexes were recorded in DMF at 10\(^{-3}\)M concentration. The electronic spectra of the complexes were dominated by
charge-transfer transitions in the UV-Visible regions. The peaks corresponding to the \( \pi \to \pi^* \) transitions in the ligands were observed at 250–270 nm. The peaks belonging to the \( \pi \to \pi^* \) transitions are shifted to a longer wavelength as a consequence of coordination when binding with the metal, confirming the involvement of formation ligands in metal complex formation.

Figure 6.6. Absorption spectra of hmtH ligand and its Co(III) and Ni(II) complexes

The electronic spectrum of the cobalt(III) complexes shows strong absorption bands at 420 nm, which may be assigned to the \( ^4T_{1g} \to ^4A_{2g}(F) \) transition. Absorptions exist at 510 nm, which are ascribed to metal-to ligand charge transfer transitions in the octahedral complexes [34]. The electronic spectra of the nickel(II) complex show absorption band at 650–660 attributed to the \( ^1A_{1g} \to ^1B_{1g} \) transitions which are compatible with the complexes having a octahedral structure [48]. The cobalt(III) complex are diamagnetic [49], whereas the Nickel(II) complexes are paramagnetic, as expected for d^8 and their magnetic susceptibilities are 3.91–4.12 and 1.72–1.80 B.M. respectively [50].
6.5. $^1$H NMR spectra

The chemical shifts belonging to the OH protons in oxime disappeared from the $^1$H NMR spectrum of cobalt(III) complexes after complexation with cobalt(III) chloride hexahydrate, and the presence of a new resonance at lower field was assigned by formation of the hydrogen bridge which could easily be identified by deuterium exchange [51]. The geometric isomers of cobalt(III) complexes can be inferred from the proton n.m.r. spectra, since the alternative chemical environments will show O---H-O bridge protons in the cis-form, but only one $^1$H NMR resonance in the trans structure. The observed spectrum has only one $^1$H NMR resonance suggesting the trans-form of the complexes [52-54].

Figure. 6.7. Mass spectra of hmt ligand
6.6. DNA binding studies

Hypochromism as well as bathochromic shift (red shift) in the interligand charge transfer maximum of complexes (1), (2), (3) and (4) were observed in the presence of increasing amounts of CT-DNA in the absorption titration experiment (Fig. 6.8.). For complex (1) there two three well resolved bands at 225 and 354 nm, for complex (2) also exists three well resolved bands at 230, 285 and 369 nm with increasing DNA concentration. The hypochromism increased upto 34.14\% at 225 nm at 405 nm for complex (1) and 28.1\% at 230 nm and 28.5\% at 285 nm for complex (2) respectively. The hypochromism observed for all the four complexes are accompanied with a small red shift. The change in the absorbance values with increasing amounts of CT-DNA were used to evaluate the intrinsic binding constants ($K_b$) for the complexes. The values of $K_b$ evaluated for (1), (2) (3) and (4) are almost equal to the reported Ru(II) complexes which are classical intercalators[ 55]. The intrinsic binding constants $K_b$ of these complexes with DNA follows the order (3) [$K_b=3.4\times10^5$ M$^{-1}$] > (1) [$K_b=2.5\times10^5$ M$^{-1}$] > (2) [$K_b=2.4\times10^5$ M$^{-1}$] > (4) [$K_b=2.3\times10^5$ M$^{-1}$]. On the basis of the similarities in structure, absorption titration characteristics, and apparent binding constants, it can be suggested that the complexes are bound to DNA through intercalation. This suggestion was further supported by viscosity and thermal denaturation experiments.
Figure 6.8: Absorption spectra of complex (3) in Tris-HCl buffer upon addition of DNA. [Complex (3)] = 0.5 μM, [DNA] = 0-100 μM. Showing variation in absorption with increase in conc. of [DNA]. Inner plot of [DNA]/(ε_r-ε_i) versus [DNA] for titration of DNA with both extracts.

6.7. Viscosity measurements

Intercalation of a ligand to DNA is known to cause a significant increase in the viscosity of a DNA solution due to an increase in the separation of the base pairs at the intercalation site and, hence, an increase in the overall DNA molecular length. In contrast, a ligand that binds in the DNA groove causes a less pronounced change (positive/negative) or no change in the viscosity of a DNA solution[56]. In the present study, the effect of (1), (2), (3) and (4) on the viscosity of CT-DNA solution were investigated. The values of relative viscosity (η/η_o), (where η and η_o are the specific viscosities of DNA in the presence and absence of the complexes, respectively) are plotted against [Co]/[DNA] and [Ni]/[DNA]. As seen in Fig.6.7, there is a positive change of viscosity of DNA with increasing the concentration of the complexes to DNA.
This experimental result suggested that, all the complexes intercalated between two adjacent base pairs of DNA through a classical intercalation mode [57].

![Figure 6.7. Effect of increasing amounts of (1) [- - - - - -], (2) [-----], (3) [-----] and (4) [-----] on the relative viscosities of CT-DNA at 25 (±0.1)°C.](image)

### 6.8. Thermal denaturation study

The melting temperature ($T_m$) of double-stranded DNA changes with different binding modes. Generally, the melting temperature increases when metal complexes bind to DNA by intercalation, as intercalation of the complexes into DNA base pairs causes stabilization of base stacking and hence raises the melting temperature of the double-stranded DNA; DNA melting experiments are useful in establishing the extent of intercalation [58]. A large change in the $T_m$ of DNA is indicative of a strong interaction with DNA. The effect of Co(III) and Ni(II) complexes on the melting temperature of calf thymus DNA in buffer is shown in Figure 6.8. At the melting temperature range of 75-80 °C, the double helix denatures into single-stranded DNA. The thermal denaturation experiment carried out for DNA in the absence of any added complex gave a $T_m$ of 67-70 °C. The observed melting temperatures in the presence of complex at different
concentrations were 75-78 °C respectively. The large increases in \( Tm \) in the presence of the complex are comparable to those observed for classical intercalators [59-61], and suggest that the complex have a large DNA-binding affinity.

![Melting curves of CT-DNA](image)

**Figure 6.8.** Melting curves of CT-DNA in the absence and presence of complexes (1), (2), (3) and (4)

### 6.9. Oxidative cleavage

The oxidative DNA cleavage activity of the complexes was studied by gel electrophoresis using super coiled (SC) pUC19 DNA (0.5 μg) in Tris–HCl buffer (pH, 7.2). The cleavage activity results show that at different concentrations the complexes were exhibit nuclease activity. The oxidative cleavage results in Fig. 6.9. indicates that, the concentrations of 20 μM, 30 μM and 40 μM the complex (2) was able to convert 52%, 65% and 71% of the initial super coiled (SC) form (Form I) to nicked circular (NC) form (Form II) respectively (Lane 2-4), whereas complex (1) at the same concentration was able to convert only 34%, 49% and 62% respectively (Lane 5-7). From these results,
we infer that cobalt(III) complex (2) containing selenium atom act as a potent cleaving agent.

Figure 6.9. Effects of complexes (1) & (2) at various concentrations (20-60 μM) on the pUC 19 supercoiled DNA against OH generated by oxidative pattern in presence of H2O2. Lane 1, untreated DNA (control); lane 2, DNA + 20 μM (1); lane 3, DNA + 40 μM (1); lane 4, DNA + 60 μM (1); lane 5, DNA + 20 μM (2); lane 6, DNA 40 μM (2); lane 7, DNA + 60 μM (2).

These qualitative findings could be quantified by densitometric analysis of the bands originating from SC and NC plasmids. Bands from the linear form, although clearly visible on the gels, were difficult to quantify. Large errors arise on weaker bands because the definition of the background is somewhat arbitrary in those cases. Therefore, parameters for quantification were chosen such that only the SC and NC bands were included in the procedure. The sum of intensity of both bands was standardized to 100% in all lanes. A plot of relative intensities is presented in Fig.6.10. (for complex (1) and (2)).
Conclusion

The synthesis of DNA binding and nuclease activity of four complexes of carbaldoxime ligands is described. The new mononuclear complexes corresponding to the general formula $[\text{M}(\text{L}_2(\text{H}_2\text{O}))]^n^+$, where $\text{M}=\text{Co(III)}$ or $\text{Ni(II)}$; $\text{L}=3-[(\text{hydroxyimino})$ methyl]quinoline-2-thiol/Seleno ligands[hmth/hmseH]; $n=1$ for Co(III) and $n=0$ for Ni(II) were well characterized by elemental analysis, FT-IR, $^1$H-NMR and electronic spectra. The DNA binding activity of the complexes were studied by using absorption, viscosity and thermal denaturation methods. The result shows that the complexes bound to DNA with intrinsic binding constant $k_b$ of $3.4\times10^5$ M$^{-1}$ (1); $[K_b=2.5\times10^5$ M$^{-1}$] (2); $[K_b=2.3\times10^5$ M$^{-1}$] (3) and $[K_b=2.4\times10^5$ M$^{-1}$] (4), respectively. The complexes exhibit enhance cleavage activity when the concentration of the complexes increases (60 $\mu$M).
Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carbaldoxime:

References


Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carbodioxide:


Cobalt(III) and Nickel(I) complexes of new sulfur/seleno carboxylate:


Cobalt(III) and Nickel(II) complexes of new sulfur/seleno carbadoxime:


