

Cobalt(II) and copper(II) in selective coordination of armed ligands: $\{[(3,5\text{-dimethyl-}1H\text{-pyrazol-}1\text{-yl)methyl]amino\}$ acetic acid and $\{[bis\text{-}(3,5\text{-dimethyl-}1H\text{-pyrazol-}1\text{-yl)methyl]amino\}$ acetic acid

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Abstract

Two novel ligand pyrazole derivatives **AH** and **BH** (**AH** = [(3,5-dimethyl-1*H*-pyrazole-1-yl)methyl]amino acetic acid, **BH** = [bis-(3,5-dimethyl-1*H*-pyrazole-1-yl)methyl]amino acetic acid) formed simultaneously by the condensation of *N*-hydroxy methyl-3,5-pyrazole (**1**) with glycine (CH₃COOH) and their cobalt(II) or copper(II) mixed ligand complex, with 3,5-dimethyl-1*H*-pyrazole (Pz) have been synthesized and characterized by spectroscopic analysis and X-ray diffraction study. Distorted square pyramidal geometry is observed around copper(II) with two nitrogens (N₁, N₃ of **AH**) in the first plane and third nitrogen (N₄ of one pyrazolic ligand) and two oxygen atoms (O₄ and O₁) in the second plane. In contrast to Cu(II) cation which coordinates with ligand **AH**, the Co(II) cation prefers to coordinate with the second ligand **BH**.

Keywords: Polydentate N-ligands, copper and cobalt complexes, structures, selective coordination

Introduction

Copper is an important and much studied trace element. Quite apart from the biological^{1,2} or technological relevance²⁻⁴ of copper(II), the attractions of copper(II) to inorganic chemistry researchers can be understood easily, given the user friendliness of copper(II) complexes. These copper complexes are commonly air and moisture stable, having informative and easy-to-obtain UV-vis,⁵ E.S.R. spectroscopic^{6,7} signatures and also undergo reactions effectively in solution immediately after mixing. The stereochemical flexibility of copper(II) complexes means that they adopt a wider range of coordination geometries than any other transition ions.⁷ Copper(II)

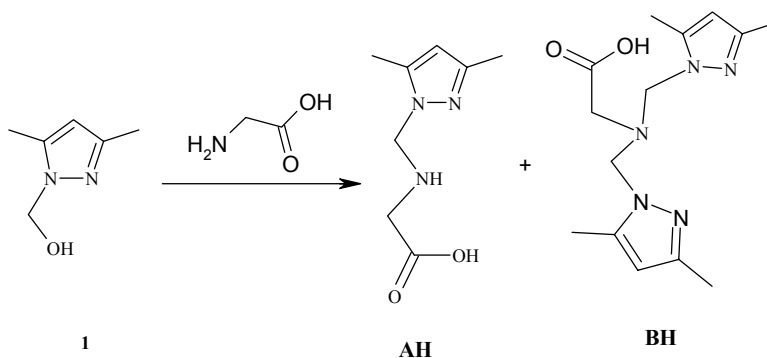
complexes have found possible medical uses in the treatment of many diseases including cancer.^{8,9} For copper(II) d^9 electronic configuration penta- or hexa- coordination is usually found.¹⁰ Thus, one of the prevailing observations is that upon oxidation of copper(I) to copper(II), a large structural change occurs which often is accomplished by solvent coordination. System for which this process does not occur are very rare.¹⁰ Several such type of copper complexes reported by taking the substituted 1,10-phenanthroline.¹¹⁻¹⁴ The first example of four coordinate copper(II) having a CuN_4 chromophore was investigated by Hathaway.¹⁵ Recently examples of four-coordinated copper(II) bearing 1,10-phenanthroline/2,9-dimethyl phenanthroline was investigated.^{16,17} In these structures the CuN_4 chromophores generally involves a trigonal or tetrahedral distortion from planar.

The present compounds [(3,5-dimethyl-1*H*-pyrazol-1-yl)methyl]amino acetic acid (**AH**) and [bis-(3,5-dimethyl-1*H*-pyrazol-1-yl)methyl]amino acetic acid (**BH**) are respectively tridentate N,N,O- and tetradentate N,N,N,O-ligands with donor groups suitably placed for forming two or three 5-membered chelate rings. In continuation of Patel group's work on copper(II) mixed ligand complexes,^{18,19} we previously described synthesis and characterization of mixed ligand complex of copper(II) using tridentate [(3,5-dimethyl-1*H*-pyrazol-1-yl)methyl] amino acetic acid (**AH**) and monodentate *N*-hydroxy methyl-3,5-pyrazole (Py) ligand.²⁰ Surprisingly when we tried to obtain the analogous Co(II) complex, we discovered the existence of a second new N,N,N,O-ligand **BH**. Here we will correct and clarify this ambiguous situation.

Results and Discussion

Synthesis

For a preparative scale reaction, commercially available glycine was reacted with hydroxymethylated pyrolic precursor **1** leading to a mixture of two compounds **AH** and **BH**, the products shown by TLC after a 2-4 days mixing in acetonitrile, as one point. Precipitation in water, filtration of compounds **AH** and **BH**, followed by washing with cold water to eliminate solvent and unreacted starting materials (Scheme 1).



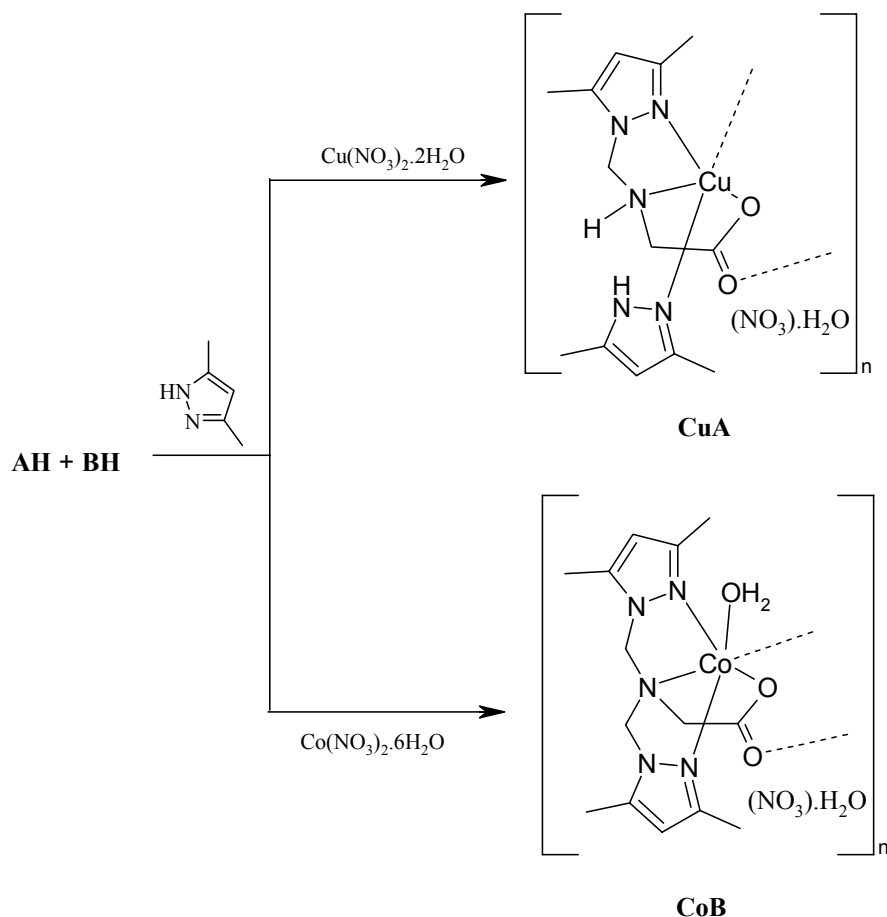
Scheme 1. Synthesis of the ligands **AH** and **BH**.

Although it has been reported by our group that the ligand **AH** was purified and well characterised with its Cu(II) complex [20], It is too difficult to see on TLC or to separate the ligands **AH** and **BH** before their coordination to Cu(II) or Co(II) cations. So no ligands **AH** and **BH** gave satisfactory individual spectroscopic analysis.

The IR spectrum of ligand **AH** (containing **BH**) shows one large, medium absorption band around 3260 cm^{-1} , which may be due to a hydrogen bonded $\nu(\text{NH})$ in the end structure or $\nu(\text{OH})$ in the carboxymethylated/ amine form. Both C=N imine groups are visible at 1580 and 1520 cm^{-1} for compound **AH** and **BH**. These bands correlate with carboxylated secondary or tertiary amine compounds **AH** and **BH**, which usually exhibit a variable band in the region $1690\text{-}1640\text{ cm}^{-1}$. This compound also shows one strong $\nu(\text{CO})$ stretching frequency at ca. 1670 cm^{-1} . From this we cannot conclude closely that the resulting product of Scheme 1 exists in the all one principal form **AH** as shown by crystallographic study of **CuA** complex.²⁰

In the $^1\text{H-NMR}$ spectrum of **AH**, the chemical shift for C(4) proton appears at 5.87 ppm, with no coupling to any adjacent atoms. Furthermore, the chemical shift for methylene protons ($\text{NH-CH}_2\text{-Pyrazol}$) appear as doublet at 5.03 ppm, with coupling to proton of adjacent amine group. The second methylene protons ($\text{NH-CH}_2\text{-COOH}$) appear at 2.93 ppm, with coupling to proton of adjacent amine group.

The IR spectrum of the Cu(II) complex **CuA** shows one large, medium absorption band around $3523/3340/3238\text{ cm}^{-1}$ which may be due to a hydrogen bonded $\nu(\text{NH})$ in the end structure of **A** or $\nu(\text{NH})$ in the monodentate ligand Pz. Both C=N imine groups are visible at 1587 and 1566 cm^{-1} for compound **AH**. These bands correlate with carboxylated secondary amine compound **AH**, which usually exhibit a variable band in the region $1690\text{-}1640\text{ cm}^{-1}$. This compound also shows one strong $\nu(\text{CO})$ stretching frequency at ca. 1613 cm^{-1} . From this we have concluded that the dissymmetric ligand **AH** exists in the alone principal form **AH** as shown in Scheme 1.



Scheme 2. Selective coordination of ligands **AH** and **BH**. Selected data for **AH**: IR (KBr, ν cm^{-1}): 3260 (m, NH), 2900 (m, -CH), 1670 (s, C=O), 1580 (s, C=C), 1520 (m, C-N), 1310 (w), 1230 (s), 1120 (w), 810 (w). ^1H NMR (250 MHz, CDCl_3) δ ppm: 5.87 (s, 1H, Pz); 5.03 (d, 2H, N- CH_2 -N, $J = 3.42$ Hz); 2.20 (s, 3H, CH_3); 2.13 (s, 3H, CH_3).

The correspondent polymeric complex **CuA** was prepared by reacting the copper nitrate dihydrate salt, $\{[(3,5\text{-dimethyl-1}H\text{-pyrazol-1-yl)methyl]amino\}$ acetic acid **LH**, and 3,5-dimethyl-1*H*-pyrazole in water. This complex is stable at ambient conditions.²⁰

X-Ray crystallography

A blue irregular prismatic crystal of $\{[\text{Cu}(\text{A})(\text{Pz})](\text{NO}_3)\cdot\text{H}_2\text{O}\}_n$ was mounted on a glass fiber and used for data collection. Cell constants and an orientation matrix for data collection were obtained by least-squares refinement of the diffraction data from 23 reflections in the range of $1.04 < \theta < 24.93^\circ$ on an Enraf Nonius MACH3 automatic diffractometer.²¹ Data were collected at 293 K using $\text{CuK}(\alpha)$ radiation ($\lambda = 0.70930 \text{ \AA}$) and the $\omega/2\theta$ -scan technique, and corrected for Lorentz and polarization effects.²² A semi-empirical absorption correction (Psi-scans) was made.²³

Complexes **CuA** and **CoB** have been structurally characterized by single crystal X-ray crystallography. The first complex **CuA** crystallizes in the monoclinic with the space group of $C2/c$, $a = 24.440(2) \text{ \AA}$, $b = 6.9711(6) \text{ \AA}$, $c = 23.924(2) \text{ \AA}$, $\alpha = 90^\circ$, $\beta = 119.728(6)^\circ$ and $\gamma = 90^\circ$ as it has been reported previously by Bolte et al.²⁰ An ORTEP view of the cationic complex is shown in Figure 1.

The crystal structure analysis of the title compound, $\{[\text{Cu}(\text{II})(\text{C}_5\text{H}_8\text{N}_2)(\text{Pz})](\text{NO}_3)\cdot\text{H}_2\text{O}\}_2$, reveals that the copper(II) ion lies in a distorted square pyramidal with N_3O_2 copper(II) environment. It is possible that the O atoms of the nitrate group are involved in intra- and intermolecular hydrogen bonding. The continuity of the present complex structure (Fig. 2) shows dimer consisting of two copper atoms and two (**A**) anions. The two halves of the dimer are related by a crystallographic twofold axis. Each L- anion binds one copper atom at its two nitrogen and one oxygen atoms, and the second copper of the dimer at one of its carboxyl oxygen atoms. The copper atoms are 5-coordinated distorted square pyramidal. The atom Cu forms bonds to the nitrogen atoms N(1), N(3) of LH, N(4) of one pyrazolic ligands and to a carboxyl oxygen atom O(4) and O(1) of the other **AH** molecule of the dimer. There is also a weaker bond between the copper and oxygen O(6) of the NO_3 anion (Fig. 3). In the five coordinate structures, the **AH** molecules occupy the basal plane. The pyrazolic ligands display axial coordination. The base of each distorted square pyramidal unit is occupied by N(1), N(3) and O(4) atoms, with a optical position is occupied by the O(1) atom of the second LH ligand. Similar geometry is suggested in $[\text{Cu}(\text{PMDT})(\text{bipy})](\text{ClO}_4)_2$ and $[\text{Cu}(\text{PMDT})(\text{phen})](\text{ClO}_4)_2$ complexes.¹⁸

In contrast to the dissymmetric tridentate N,N,O-ligand **AH**, the new tetradentate N,N,N,O-ligand **BH** would have a symmetric charge distribution. Therefore, the most probable complexed form for **BH** contains a hemilabile bond (Co-OCO). These results prompt several pertinent observations: (i) This new type of armed tetradentate ligand can furnish an interesting model for preparing large series of organometallic catalysors with various metals because the hemilabile character of metal-carboxylate bond is generally present in large catalytic reactions; (ii) The unsaturated electronic configuration of both Cu(II) and Co(II) enables us to prepare various complexes for organic catalysis, redox and magnetic materials; and (iii) Functionalised polydentate ligands can easily be prepared from glycine and other amino-acid precursors.

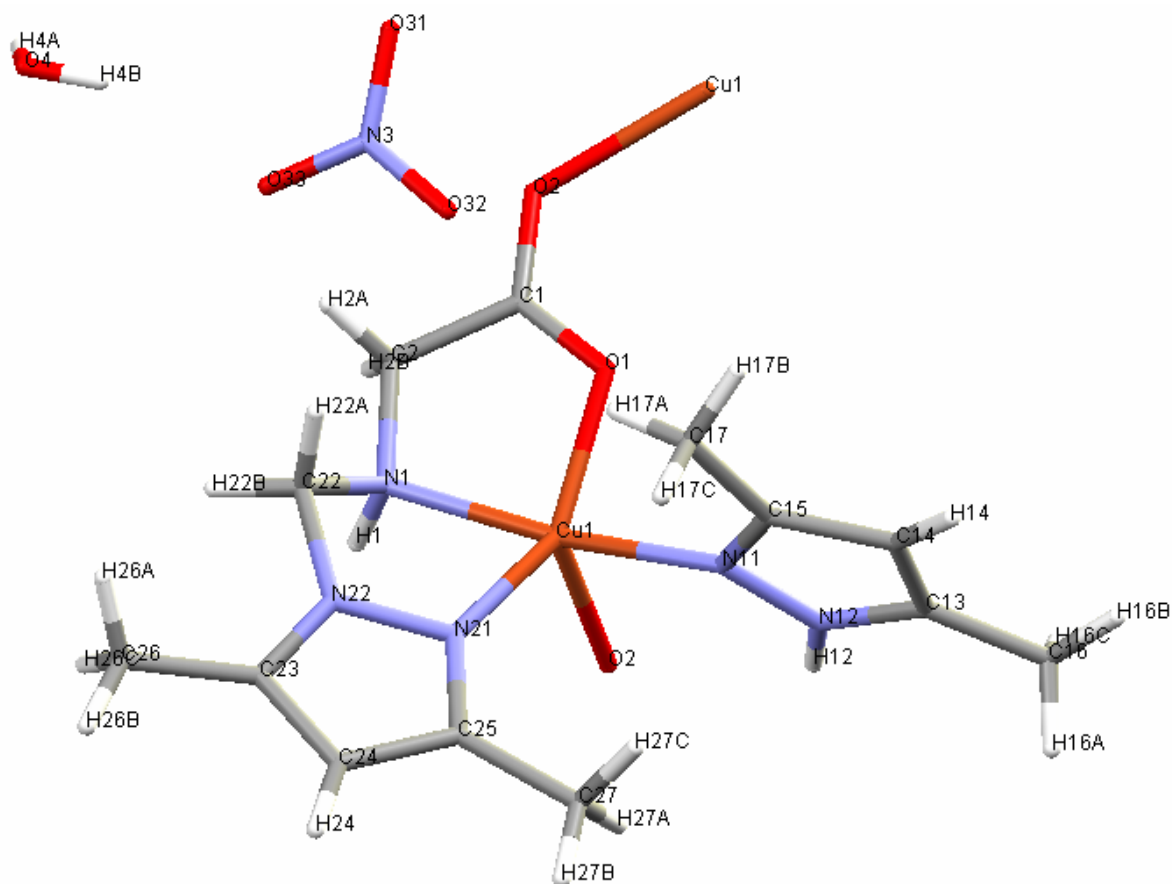


Figure 1. ORTEP view for the complex cation of $[\text{Cu}(\text{A})(\text{Pz})]^+$.²⁰

The equatorial plane of the distorted tetrahedron contains two N atoms, viz. N(1) and N(21). The other positions are occupied by atom O(1) and N(11) of the carboxylate group and nitrogen atom O(5) of the pyrazolic ligand. A possible intermolecular interaction could occur between atoms N(3) of NO_3^- with O(2) of carboxylate group, also other intermolecular interaction is possible between methylene protons (CH_2) and nitrate atom O(32). This weakly bound atom O(6) lies at the apex of a pyramid of which the corners of the approximately square base are occupied by the strongly bound ligand atoms N(1), N(3), N(4) and O(4). The copper atom Cu(I) lies near the centre of the square. The complex ion as a whole carries a double negative charge. This must be distributed mainly over the peripheral oxygen atoms O(1), O(4), O(6) and their symmetry-related equivalents. In fact, the Cu centre ion is surrounded by an octahedron of oxygen and nitrogen atoms, of which two O(1) and O(6) are in axial positions. If one of the nitrate oxygen O(6) is included, the environment of the cuprate ion becomes a very irregular octahedron with O(6) much displaced in the direction of O(1).

Several papers on copper(II) complexes with tetradentate ligand L containing one arm on central N atom ($L = N,N$ -bis(3,5-dimethylpyrazol-1-ylmethyl)-1-functionalized-2-aminoethane; N,N -bis(2-pyridyl-1-ylmethyl)-1-functionalized-2-aminoethane) have been published to date.

They describe the synthesis and X-ray crystal structure of di-1-chloro- bis{[*N,N*-bis(3,5-dimethyl-pyrazol-1-ylmethyl)-1-hydroxyethanamine]-copper(II)} dichloride dihydrate,²⁴ [Cu(L)(Pz)(ClO₄)₂],²⁵ and [Cu(L)(Pz)-(NO₃)₂],²⁶ where Pz is 3,5-dimethyl-pyrazole. In the chloride compound, the Cu(II) atom displays a distorted octahedral coordination, while in the perchlorate and nitrate compounds, the Cu(II) coordination geometry is described as distorted square-pyramidal.²⁷

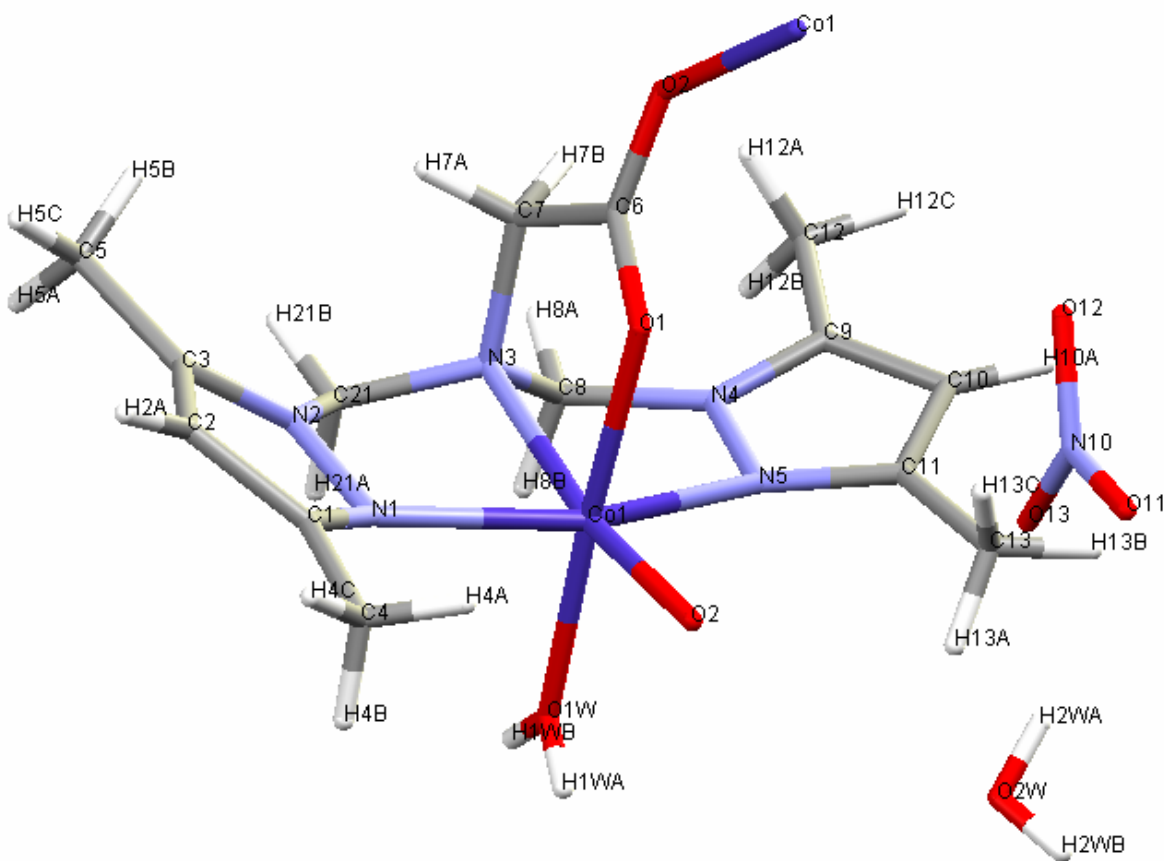


Figure 2. ORTEP view for the complex cation of [Co(B)(OH₂)]⁺.

Supplementary Information

Crystallographic data for the structural analysis have been deposited with the Cambridge crystallographic Data Centre, CCDC No. 602491 for complex {[Co(B)(OH₂)]⁺(NO₃⁻)·H₂O}_n. Copies of this information can be obtained free of charge from The Director, CCDC, 12 Union Road, Cambridge, CB2 1EZ, UK (fax: +44-1223-336033; e-mail: deposit@ccdc.cam.ac.uk or <http://www.ccdc.cam.ac.uk>).

Since the properties of the two compounds **AH** and **BH** were different, it was difficult to separate the two compounds simultaneously. To have a clear idea about the polymeric aspect of complex **Co(B)**, the ORTEP view for the continuity of the complex cation of $[\text{Co}(\text{B})(\text{OH}_2)]^+$ has been added here as shown in Figure 3.

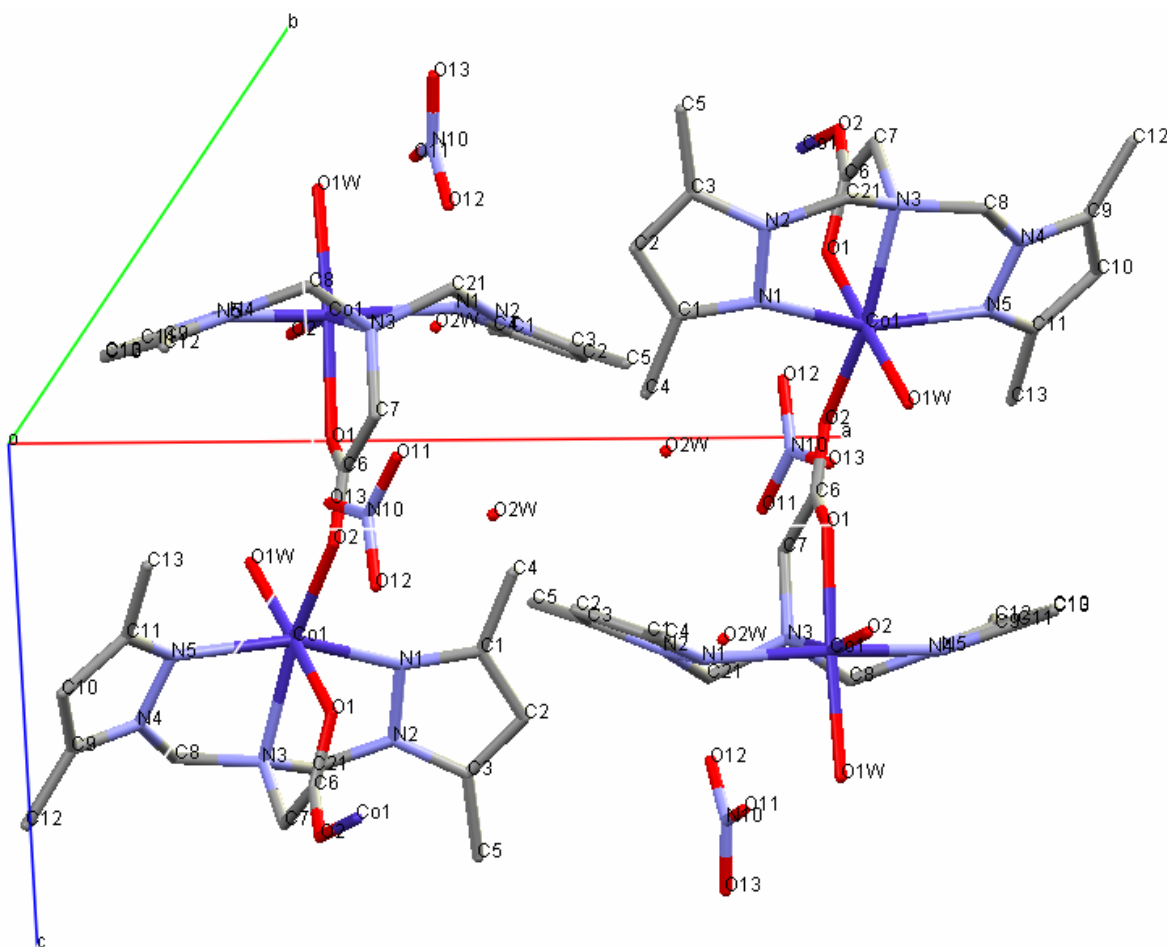


Figure 3. ORTEP view for the continuity of the complex cation of $[\text{Co}(\text{B})(\text{OH}_2)]^+$. The hydrogen atoms have been omitted for clarity.

Conclusions

Using the standard TLC technique with a single of solvent system and a silicate gel or alumina of the solid phase, but the separation of them could be achieved by selective coordination of Cu(II) with **AH** or Co(II) with **BH**. The present results of our studies indicate that the coordination technique by varying metallic cation is a powerful and selective technique for the separation of armed ligands **AH** and **BH**.

As a perspective, the use of the ligands **AH** and **BH** represents a new selective way for the synthesis of polymeric copper(II) or Co(II) complex containing hemilabile bond Cu-O or Co-O. Moreover, they are soluble in the reaction mixture and could catalyse reactions which are impossible to perform with the M(II)Cl-L complexes. The metal could also be changed and act as a template and allow the notoriously difficult catalysis suggested previously. We will try to relate the redox potentials of the analogous complexes to their possible biocatalytic activity.

The synthetic methodology adopted for the preparation of these present complexes may be useful in fine tuning the structural features to get more accurate Cu₂Cu₂ SOD and Co₂Co₂ superoxidase dismutase (SOD) models for the active site. The SOD like activity evaluation will reveal modes with this important enzymatic activity.

In conclusion, a combined crystallographic and spectroscopy approach is useful not only to give the complete characterization of the new complexes, but also it will help to correlate their structural features with possible biological activation.

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