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Structure of a Methylmercury Complex with 4-Nitroimidazole

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Abstract

(4-Nitroimidazolato)methylmercury(II) belongs to the rhombohedral space group $R3c$, with $a = 11.434$ Å, $\alpha = 111.40°$ and $Z = 6$. The structure was refined on 558 unique non-zero reflections to $R = 0.037$. The CH_3Hg^+ group is linearly bonded to the heterocyclic nitrogen atom more remote from the nitro substituent. The metal forms secondary bonds in its equatorial plane with available donor atoms in adjacent molecules: (2 + 3) coordination around Hg is completed by contacts with a nitro oxygen and the free nitrogen atom of one molecule, and another nitro oxygen in a different molecule. Six molecules are linked into a closed loop around the three-fold axis by means of these secondary bonds.

Introduction

Nitroimidazoles have important medical applications as chemotherapeutic agents and potential radiosensitizers [1, 2]. A variety of metal complexes with imidazole and many derivatives have been described and structurally characterized [3], but very few with nitrosubstituted ligands [2, 4]. In the case of the 4-nitro compound (4-NO_2ImH), the question of the relative affinity of the two available nitrogens has not been clearly answered. The only complex studied so far by X-ray diffraction is $[Co(NH_3)_5(4\text{-}NO_2Im)]Cl_2$ [5], in which the ligand was found to be coordinated via N(1). However, this compound does not really settle the question, since it was prepared by *in situ* nitration of coordinated imidazole in the $[Co(NH_3)_5(Im)]^+$ cation. As part of our research programs on mercury complexation with biologically important molecules [6, 7], the uniligating CH_3Hg^+ cation was used to determine the first binding site in nitroimidazole for a typical heavy atom.

Experimental

Crystal Data

Formula: $C_4H_5N_3O_2Hg$, formula weight = 327.69, trigonal, space group $R3c$, a (rhombohedral cell) = 11.434(9) Å, $\alpha = 111.40(9)°$, $V = 1060.6$ Å^3, $Z = 6$, $D_c = 3.077$ g cm^{-3}. λ(Cu K$\bar{\alpha}$) = 1.54178 Å (graphite monochromator), $T = 23$ °C, μ(Cu Kα) = 415.3 cm^{-1}. Crystal size: needle (0.61 mm) with multiple lateral faces (described as a cylinder of mean radius 0.047 mm).

Data Collection and Structure Resolution

The crystals were prepared as described elsewhere [8]. Trigonal symmetry was detected from a set of precession and cone-axis photographs. Space groups $R\bar{3}c$ and $R3c$ were consistent with the systematic absences (hhl, $l \neq 2n$) noted on the films.

The data were collected with an Enraf-Nonius CAD4 diffractometer following the procedure described elsewhere [9]. The mean fluctuation of the three standard reflections was ±1.5%. A set of 589 unique reflections was collected ($2\theta_{max} = 120°$), of which 558 had $I > 3\sigma(I)$. The data were corrected for the effects of Lorentz, polarization and absorption (transmission coefficient = 0.13–0.39).

The structure was solved by the heavy-atom method and refined by full-matrix least-squares. In space group $R\bar{3}c$ (twelve-fold general equipoint), the six molecules in the unit cell would have to occupy a special position. This space group could be ruled out by inspection of the Patterson map. Structure resolution was straightforward in space group $R3c$. Mercury was located from the Patterson map, and the remaining non-hydrogen atoms were positioned from a difference Fourier map. Isotropic refinement of all non-hydrogen atoms converged to $R = \Sigma||F_o| - |F_c||/\Sigma|F_o| = 0.112$. The hydrogen atoms attached to C(2) and C(5) were fixed at idealized positions (C–H = 0.95 Å, sp^2 hybridization, $B = 5.0$ Å^2). Their positions were recalculated after each cycle of refinement. Those of the CH_3Hg^+ group were not located. Anisotropic refinement of all non-hydrogen atoms

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TABLE 1. Fractional coordinates ($\times 10^3$, Hg $\times 10^5$)

Atom	x	y	z
Hg(1)	50000	− 19866(10)	45429(9)
O(41)	818(3)	535(3)	806(3)
O(42)	691(3)	423(3)	873(2)
N(1)	613(3)	33(3)	543(3)
N(3)	780(2)	273(2)	615(2)
N(4)	739(3)	417(3)	791(3)
C(1)	382(4)	− 421(3)	377(4)
C(2)	715(4)	120(4)	528(3)
C(4)	718(3)	286(3)	697(3)
C(5)	612(3)	137(3)	651(3)
H(2)*	740	77	461
H(5)*	551	114	689

Starred items not refined.

converged to $R = 0.037$, whereas the weighted residual $R_w = [\Sigma w(|F_o| - |F_c|)^2/\Sigma w|F_o|^2]^{1/2}$ was 0.047. The goodness-of-fit ratio was 2.03. The general background in the final difference Fourier map was lower than ±0.7 e/Å^3, except for four peaks of $\pm|1.3$–$1.6|$ e/Å^3 near mercury. The final coordinates are listed in Table 1.

The scattering curves were taken from standard sources [10]. The anomalous dispersion terms f' and f'' for Hg were included [11].

Results and Discussion

The structure consists of monomeric $CH_3Hg(C_3H_2N_3O_2)$ molecules, as represented schematically in Fig. 1 with the interatomic distances and bond angles.

Unsubstituted imidazole in its anionic form has two symmetry-equivalent nitrogen donors. In the presence of the 4-nitro substituent, these nitrogens are no longer equivalent. The CH_3Hg^+ cation is found to coordinate to N(1), that is, the site more distant from the electron-withdrawing nitro group. The coordination of mercury is roughly linear (C(1)–Hg(1)–N(1) = 175(1)°) as expected. The Hg–N (2.07(3) Å) and Hg–C distances (2.01(4) Å) are similar to the values observed in analogous compounds [6, 7, 12].

Comparisons with $[Co(NH_3)_5(NO_2Im)]^+$ [5] reveal no significant differences in ring geometry. The distances involving the nitro group are also normal [13]. However, the errors on the organic portion of this molecule are large because the scattering power of mercury outweighs those of the light atoms. The five-membered ring is planar within 0.01 Å (0.3 σ), but the CH_3Hg^+ group deviates appreciably from the plane: the distances are −0.2036(8) Å for Hg(1) and −0.39(4) Å for C(1). Some distortion is also noted for the nitro group (N(4), 0.11(3); O(41), 0.26(3); O(42), −0.05(3) Å), which clearly results from intermolecular contacts with CH_3Hg^+ groups. Nevertheless, in contrast with the case of $PtCl_2(misonidazole)_2$ [2], the nitro group remains coplanar with the ring.

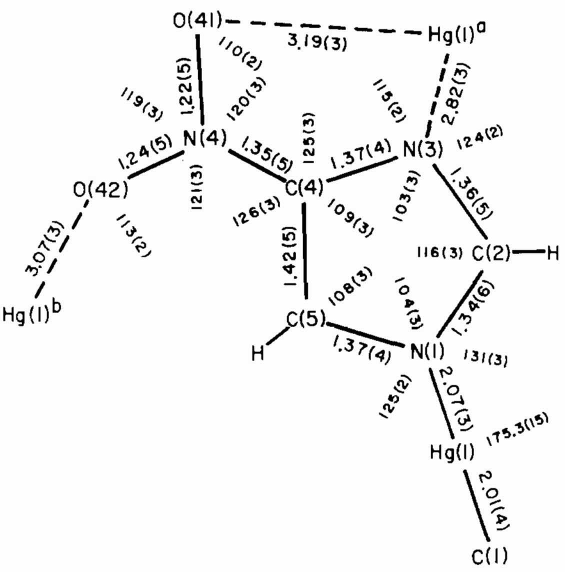

Fig. 1. Numbering scheme, interatomic distances and bond angles. a = 1 + y, z, x; b = z, x, 1 + y.

It is well established that substitution of the imidazole N–H proton by a metal makes the other nitrogen atom significantly more basic [5]. Molecular packing reflects the basicity of N(3), which forms a strong Hg···N intermolecular contact. The view along the diagonal of the rhombohedral unit cell (Fig. 2) shows around the three-fold axis, an interesting pattern optimizing secondary bond formation between mercury and adjacent molecules. Beside the above Hg···N contact of 2.82(3) Å, the O(41) atom of the nitro group interacts weakly (Hg···O = 3.19(3) Å) and closes a 'chelate ring' on the same metal atom (Table 2). The environment of mercury is completed by another Hg···O contact of 3.07(3) Å with O(42), stronger than the previous one, but still above the 3.0 Å limit often considered for appreciable bonding. These secondary bonds create closed loops involving six molecules around the cell three-fold axes (Fig. 2).

Coordination to N(1) undoubtedly identified this site as the intrinsically most basic in this ligand. The lower basicity of N(3) can be ascribed to the electron-withdrawing effect of the adjacent nitro substituent. This statement applies well to the CH_3Hg^+ ion, which shows a strong preference for linear two-coordination and imposes no severe requirements on the number and geometry of the secondary bonds forming in the 'equatorial' plane. Other metals could take greater advantage of the possible chelate effect on the N(3)–nitro side, and balance with chelate stabilization the lower stability of a metal–N(3) bond. The low basicity of the nitro oxygens and the 125(3)° angle at

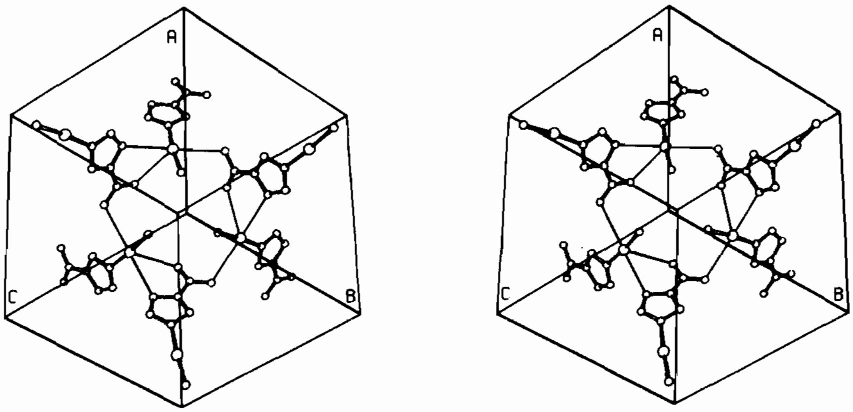

Fig. 2. Stereoview showing the arrangement of six molecules about the three-fold axis of the rhombohedral unit cell. The atoms, which can be identified by reference to Fig. 1, are represented by spheres of arbitrary size, the largest spheres corresponding to mercury. The thin lines correspond to Hg···N or Hg···O secondary bonds.

TABLE 2. Environment of mercury

Distances (Å)			
Hg(1)–N(1)	2.07(3)	Hg(1)–N(3)^{b}	2.82(3)
Hg(1)–C(1)	2.01(4)	Hg(1)–O(41)^{b}	3.19(3)
		Hg(1)–O(42)^{a}	3.07(3)
Angles (°)			
N(1)–Hg(1)–C(1)	175.3(15)	C(1)–Hg(1)–O(41)^{b}	91.6(13)
N(1)–Hg(1)–O(42)^{a}	86.6(10)	C(1)–Hg(1)–N(3)^{b}	98.3(13)
N(1)–Hg(1)–O(41)^{b}	91.8(10)	N(3)^{b}–Hg(1)–O(41)^{b}	53.9(8)
N(1)–Hg(1)–N(3)^{b}	86.3(10)	N(3)^{b}–Hg(1)–O(42)^{a}	171.1(8)
C(1)–Hg(1)–O(42)^{a}	88.9(13)	O(41)^{b}–Hg(1)–O(42)^{a}	121.0(8)

$^{a}y, z-1, x$. $^{b}z, x-1, y$.

C(4) would disfavor ring closure. Nevertheless, for metals with higher coordination numbers and greater affinity for hard donors, coordination on either site could become not very different.

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