Note

1,2,4-triazolo[4,3-a]pyrimidines: a new kind of ligands. Structure of the silver(I) dimer with the 7-oxo derivative

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Abstract

This paper describes the silver dinuclear complex [Ag₂L₂(NO₃)₂]·2H₂O, where L represents the bridging ligand 7,8-dihydro-7-oxo-1,2,4-triazolo[4,3-a]pyrimidine, this being the first example of a coordination compound of a 1,2,4-triazolo[4,3-a]pyrimidine derivative. As a difference with the most studied 1,2,4-triazolo[1,5-a]pyrimidine derivatives, the coordination takes place through the contiguous nitrogen atoms of the triazole ring, closing a six member Ag₂N₄ core with a higher intermetallic distance, 3.4791(3) Å. Linear coordination of silver is not possible in this geometry, so flat trigonal coordination involving also the nitrate counteranion is found instead.

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1. Introduction

The condensation of a ring of 1,2,4-triazole and another one of pyrimidine gives rise to the formation of bicyclic heterocycles known as 1,2,4-triazolopyrimidines. Four different possibilities exist for the relative orientation of both rings, so four different isomeric families of compounds are defined (see Fig. 1). Among these, 1,2,4-triazolo[1,5-a]pyrimidine derivatives are thermodynamically more stable and, thus, the most studied ones [1], a few of them being commercially available. Revisions surveying the synthesis, reactivity, spectroscopic characterization and crystallographic studies of 1,2,4-triazolo[1,5-c]pyrimidines [2], 1,2,4-triazolo[4,3-a]pyrimidines [3] and 1,2,4-triazolo[4,3-c]pyrimidines [4] have also been published.

The studies about the coordination chemistry of triazolopyrimidines have been exclusively focused till now in the 1,5-a series. These compounds, which are structurally similar and may be regarded as mimic of isomeric purines, have displayed a rich coordination chemistry, a considerable number of new compounds with interesting structural features having been characterized [5], including simple mononuclear compounds with monodentately coordinated ligands [6,7] and di or polynuclear compounds in which either the triazolopyrimidine ligand [8] or other auxiliary ligands [9] bridge the metal atoms.

On the other hand, we have not found in the bibliography any reference for a coordination compound of any of the other arrangements (1,5-c, 4,3-a or 4,3-c), despite the fact that the different relative orientation of the nitrogen atoms inside the heterocycles could generate a wide number of new structural motifs, specially if di
or polynuclear species are formed with bridging heterocycles. A difficulty that has to be taken into account in a study of this type is the lowest stability of these compounds if compared with the 1,5-a derivatives, isomerization processes (Dimroth rearrangement) may take place on heating, possibly catalysed by acidic or basic pH [10].

This note is a first exploration in the coordination chemistry of 1,2,4-triazolo[4,3-a]pyrimidines. These compounds present, comparing with the corresponding 1,5-a isomers, the change in the position of one of the nitrogen atoms in the triazole ring which is now placed as separated as possible from the pyrimidine ring, with less steric hindrance and contiguous to the other external imidazole nitrogen. They are analogous and may be regarded as mimics of pyrazolo[3,4-d]pyrimidines, a family of biologically relevant compounds related to purines, the most outstanding of which is allopurinol.

Silver(I) is one of the cations that has shown a higher number of different structural motifs when reacting with 1,2,4-triazolo[1,5-a]pyrimidines [5] and this is why we have chosen it for this first study with a member of the 4,3-a family, namely that with an exocyclic oxygen atom at position 7. A dinuclear complex has been obtained, its structure being described here. The bridging mode of the ligand and the arrangement of the compound are different from those found for 1,2,4-triazolo[4,3-a]pyrimidines.

2. Experimental

Reagents were obtained from standard commercial sources, organic reagents were of synthetic grade and inorganic reagents of analytical grade.

2.1. Synthesis of 7,8-dihydro-7-oxo-1,2,4-triazolo[4,3-a]pyrimidine hemihydrate

7,8-Dihydro-7-oxo-1,2,4-triazolo[4,3-a]pyrimidine (L) was synthesized according to the procedure described by Reimlinger et al. [11]. 4.2 g of 3-amino-1,2,4-triazole and 5 g of methyl propiolate and 0.1 g of hydroquinone (as catalyst) are refluxed in absolute ethanol for 24 h. A white microcrystalline solid appears as the reaction proceeds, which is filtered off without cooling and recrystallized in water. The yield is 2.5 g. The compound is obtained as the hemihydrate. Elemental analysis: C, 41.7; H, 3.6; N, 39.0. Calc. for C₇H₅N₄O₁.₅: C, 41.38; H, 3.45; N, 38.62.

2.2. Synthesis of the silver complex

The silver complex [Ag₂(L₂(NO₃)₂)].2H₂O was prepared by mixing two solutions, 10 ml each, containing 1mmol de AgNO₃ and 1 mmol of L, respectively, in 5 M HNO₃. After standing at room temperature for 24 h, colourless crystals, suitable for X-ray work, are obtained. Elemental analysis: C, 18.5; H, 1.8; N, 21.6. Calc. for C₁₀H₁₂Ag₂N₁₀O₁₀: C, 18.53; H, 1.85; N, 21.61.

2.3. Instrumentation

Microanalysis of C, H and N was performed in a Fisons Instruments EA-1008 analyser. Thermal behaviour was studied under an air flow in a Shimadzu TGA-50 and a Shimadzu DSC-50 equipment. ¹H and ¹³C NMR spectra were recorded for dmso-d₆ solutions of the compounds on a Bruker AM-300 spectrometer (all these equipments were sited at the Centre of Scientific Instrumentation of the University of Granada). IR spectra were obtained using a FT MIDAC Prospect 1 spectrophotometer with samples dispersed in KBr pellets.

2.4. Crystallography

Data for a single crystal of the silver complex (dimensions, 0.49 × 0.19 × 0.18 mm) were collected at room temperature in a Bruker SMART APEX CCD system with Mo Kα radiation (λ = 0.7107 Å). Data were corrected for absorption (multi-scan, transmission range, 0.4965–0.6930). The structure was solved by the heavy atom method and anisotropically refined in F³ using SHELXL-97 [12]. Hydrogen atoms of the heterocycle were placed in ideal positions and those of the water molecule were refined with fixed O–H distance. Isotropic thermal parameters of all H atoms fixed to 1.2 times the equivalent isotropic thermal parameter of their parent atoms.

Crystal data for [Ag₂(C₅H₄N₄O)₂(NO₃)₂].2H₂O, monoclinic, space group P2₁/c, a = 10.5297(6) Å, b = 12.6897(9) Å, c = 6.9432(4) Å, β = 94.782(1)°,
\( V = 924.51(9) \ \text{Å}^3, \ Z = 2, \ D_{\text{calc}} = 2.328 \ \text{Mg/m}^3, \ \mu = 2.199 \ \text{mm}^{-1}, \ 5595 \ \text{reflections} (2080 \ \text{unique}) \ \text{collected} \) (\( \theta \) range 1.94–28.14°), \( wR_2 = 0.0592, \ R \) (for 1912 data with \( I > 2\sigma(I) \)) = 0.0232.

The supplementary crystallographic data for this paper have been deposited in the CCDC (Deposition number CCDC 239420). These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033; e-mail: deposit@ccdc.cam.ac.uk).

3. Results and discussion

3.1. Characterization of the ligand

Virtually nothing is said in the bibliography about the characterization of 7,8-dihydro-7-oxo-1,2,4-triazolo[4,3-a]pyrimidine, so some data are indicated here for possible future reference. Most intense infrared peaks appear at 1713, 1578, 1507, 1274, 840 and 520 cm\(^{-1}\), the first one (carbonyl) being splitted; the presence of the acidic hydrogen atom is shown in the characteristic set of peaks in the 2700–3100 cm\(^{-1}\) region.

The signals in the \(^1\)H and \(^13\)C NMR spectra (in dmso) and their assignments are: 6.09 (H6), 8.32 (H5) with \( J(H5-H6) = 7.7 \ \text{Hz}, \ 8.66 \ \text{(H3)}, \ 12.7 \ \text{(very broad, H8), 109.7 \ (C6), 134.1 \ (C3), 136.5 \ (C5), 148.8 \ (C8a) and 161.4 \ (C7) ppm. The values for the pyrimidine ring are very similar to those in the analogous derivative of the 1,5-a family, namely 4,5-dihydro-5-oxo-1,2,4-triazolo[1,5-a]pyrimidine (taking into account the change in the numbering scheme, see Fig. 1) [13], while the C and the H atoms of the triazole ring appear considerably shielded and unshielded, respectively.

Dehydration appears in the TG and DSC diagrams as very well defined weight loss and endothermical effects, respectively, with peak at 98.3 °C and \( \Delta H = 25.8 \ \text{kJ per mole of H}_2\text{O}. \) The anhydrous compound does not melt but it starts its pyrolytic decomposition at 250 °C, which finishes at 740 °C.

The compound is poorly soluble in water but its solubility increases greatly by adding either an acid or a base. It is insoluble in ethanol and very soluble in DMSO.

3.2. Characterization and crystal structure of \([\text{Ag}_2\text{L}_2(\text{NO}_3)_2] \cdot 2\text{H}_2\text{O}\)

The infrared spectrum of this compound is almost identical to that of the free ligand, the only noticeable difference being the presence of a very intense new band at 1384 cm\(^{-1}\) (\( \nu(\text{NO}_3^-) \)). This agrees with the fact that the ligand is coordinated in neutral form without changing its tautomeric form. Water is very tightly retained in this compound according to its TG and DSC diagrams, since it is not eliminated until 160 °C; this dehydration overlapping with another process, since the weight loss is much higher than expected and the endothermical effect is immediately followed by an exothermical one.

Fig. 2. Molecular structure of \([\text{Ag}_2\text{L}_2(\text{NO}_3)_2] \cdot 2\text{H}_2\text{O}\) according to X-ray analysis. Both halves are related by a crystallographic inversion centre. Non-hydrogen atoms are represented by ellipsoids at the 50% probability level.
The crystal structure is built by dinuclear centrosymmetric units (Fig. 2) in which both silver atoms are bridged by two heterocycles, which are linked to the metal atoms through both external nitrogen atoms (N1 and N2) of the triazole ring. This defines a hexagonal Ag2N4 core for which there are a number of other examples in the bibliography, involving pyrazole [14], 1,2,4-triazole [15] and tetrazole [16] derivatives as well as pyridazines [17], but we have not found any for a 5 + 6 bicyclic ligand. This behaviour is very different to that of 1,2,4-triazolo[1,5-a]pyrimidines, which also form with Ag(I) dinuclear compounds but with a N3–N4 (N1–N8 translated to the [4,3-a] numbering scheme) bridging mode that leads to an eight member Ag2C2N4 core [18]. As a consequence, the intermetallic distance (Table 1) is much higher in the compound described here.

The geometry of the cluster makes it impossible for the silver atom to adopt its usual linear coordination; instead, a flat trigonal geometry is observed, the third coordination position being occupied by a nitrate anion and the distortion of the triangle not being too severe (see bond distances and angles in Table 1). A weak interaction with a second oxygen of nitrate is also indicated in Table 1. The Ag2L2 moiety is planar within 0.025 Å with O1N clearly displaced from this plane (0.983(3) Å) and the water oxygen close to it (0.223(4) Å); the nitrate plane is rotated at an angle of 60.2(8)° with respect to the Ag2L2 plane.

The ligand is clearly in its amido tautomeric form and N8–H forms a rather strong hydrogen bond towards the water molecule which, in turn, forms another hydrogen bond with the nitrate anion defining in this way an eight member pseudochelate ring. Again, the behaviour is different from that observed for the most similar member of the [1,5-α] series, for which the stability of the N4–Ag bond is able to displace the acidic proton to the exocyclic oxygen atom, giving rise to the formation of the unusual iminophenolic tautomer [19]. The strongly acidic media prevent deprotonation of N8, avoiding the formation of colloidal (likely polymeric) species that takes place at higher pH, difficult to filter and with uncertain stoichiometry.

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References