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INVESTIGATION OF THE AQUEOUS BINARY SYSTEM Al(III)-ORGANOPHOSPHATE LIGAND. RELEVANCE TO Al(III) BIOTOXICITY

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Abstract

A new Al(III)-organophosphate species was synthesized in aqueous solution at the optimum pH 4. The reacted organophosphate ligand is N-(phosphonomethyl)iminodiacetic acid. The isolated crystalline material was characterized by elemental analysis, spectroscopic techniques (FT-IR, NMR) and X-ray crystallography. The new species contain aluminum ions in an octahedral environment.

Keywords: *Aluminum(III), N-(phosphonomethyl)iminodiacetic acid*

Introduction

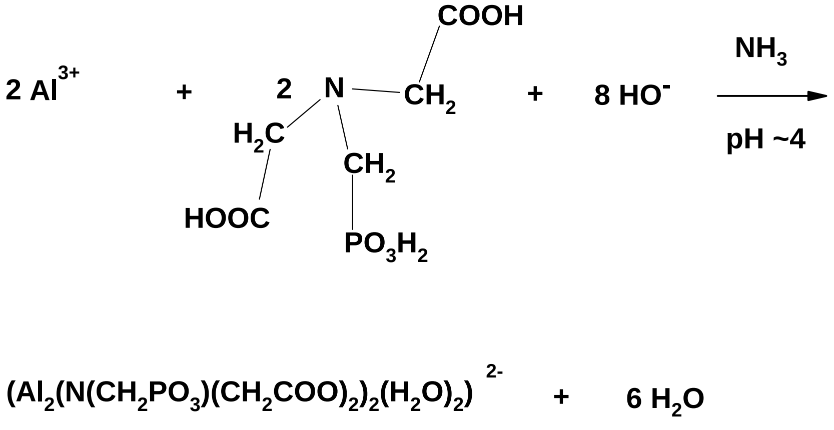
Aluminum has been known to exert biotoxic effects in humans. The recent interest in aluminum chemistry has been closely linked to its neurotoxic effects and pathogenetic processes that lead to a number of biological disorders. Common examples include Alzheimer's disease (AD) (Crapper, 1976), dialysis related osteomalacia (Van der Voet, 1989), microcytic anemia (Kerr, 1988), etc. Even though the biotoxic role of Al(III) (especially in the case of Alzheimer's Disease) is being perused, no conclusions for its role can yet be drawn. It has been found that amyloid plaques present in patients, who have reached a late stage of the disease, are linked to the presence of elevated amounts of Al(III) (McLachan, 1986; Perl, 1985). It is, therefore, important to investigate the aqueous chemistry of Al(III) in the presence of functional groups that reflect the chemical environment naturally occurring in proteins or peptides of sensitive areas of the brain associated with memory, cognition and motor functions of a human being.

One such representative Al(III) binder is the low molecular mass ligand N-(phosphonomethyl)iminodiacetic acid (NTAP). It possesses the appropriate structural and chemical attributes ordinarily encountered in the hyperphosphorylated forms of the tau (τ) protein and the neurofibrillary tangles in Alzheimer's disease.

Experimental

The aqueous synthetic chemistry of the binary system Al(III)-NTAP was investigated. Under specific reaction stoichiometric and pH conditions, the arisen reactivity led to the isolation of a new species of Al(III) with NTAP, $(NH_4)_2[Al_2(N(CH_2PO_3)(CH_2COO)_2)_2(H_2O)_2]$ (**1**).

The synthesis of **1** was carried out in aqueous media (nanopure water was used). The pH was adjusted to 4 with ammonia for complex **1**. The addition of the base was crucial for the isolation of the species. The resulting reaction mixture was placed in the refrigerator at 4 ^{0}C. The stoichiometric reaction for the synthesis of complex 1 is given below:



The FT-IR spectra of complex **1** (figure 1) was recorded in KBr and reflected the presence of vibrationally active carboxylate groups. The antisymmetric stretching vibrations $\nu_{as}(COO^-)$ appear in the range 1642 cm^{-1}, whereas the symmetric stretches $\nu_s(COO^-)$ appear in the range 1433-1405 cm^{-1} for complex **1**.

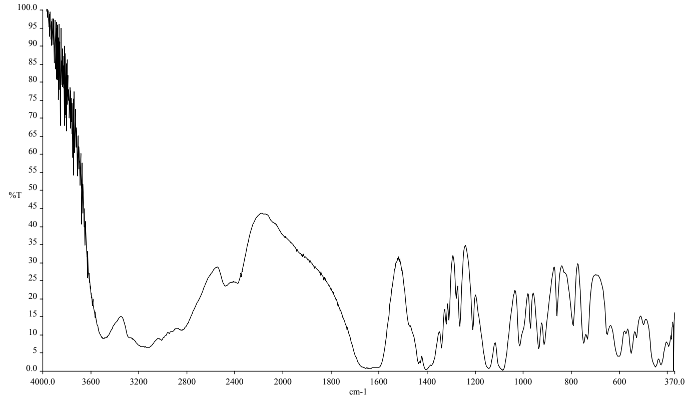


Figure 1. The FT-IR spectra of the $(NH_4)_2[Al_2(N(CH_2PO_3)(CH_2COO)_2)_2(H_2O)_2]$

X-Ray crystallography was instrumental in revealing the three dimensional structure of the investigated molecules. The structure of the isolated species is presented in Figure 2.

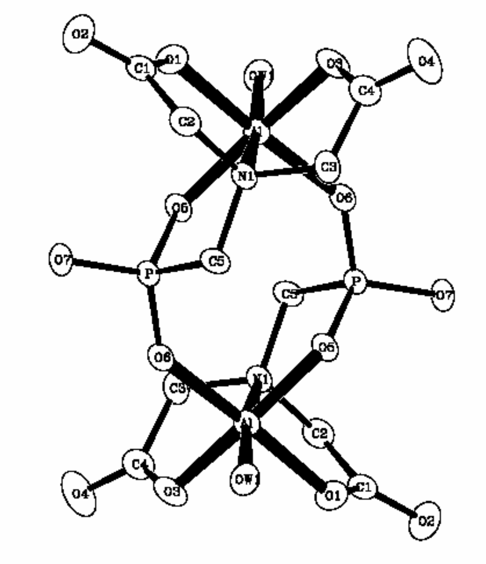


Figure 2. ORTEB diagram of the anionic complex $[Al_2(N(CH_2PO_3)(CH_2COO)_2)_2(H_2O)_2]^{2-}$

Each Al(III) ion coordinates to one N-(phosphonomethyl) iminodiacetic acid in a distorted octahedral environment. Each N-(phosphonomethyl)iminodiacetic acid is fully deprotonated. The addition of ammonia, was crucial in the investigated reaction, because it initially helps to adjust the pH of the reaction mixture, and it concurrently provides the ligand for Al(III) with the appropriate counter ions needed to balance the arisen charge in the assembled complex.

The isolated complex **1** was characterized in detail by ^{13}C-NMR solid state, ^{1}H-NMR solution spectroscopy.

Conclusions

The aqueous chemistry of the binary system Al(III)-organophosphonate ligand was investigated. The collective physicochemical and spectroscopic data suggest potential modes of coordination of aluminum to protein sites and furthermore to phosphorylated anchors. Beyond that, the chemistry emerging from the examination of aluminum interacting with low molecular mass targets sheds light into the speciation of that metal ion and its relevant consequent biotoxic effects extending to the formation of senile plaques and the Alzheimer's disease.

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