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One cationic dinuclear silver(I) complex of dppatc formed in situ by replacing ethylenediamine units of dppeda through aminothiocarbamide

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ARTICLE INFO

Article history: Received 25 May 2011 Accepted 5 July 2011 Available online 13 July 2011

Keywords: Silver(I) N,N-bis(diphenylphosphanylmethyl) aminothiocarbamide Crystal structure Aminothiocarbamide In situ formation

ABSTRACT

Reaction of silver nitrate with N,N,N',N'-tetra(diphenylphosphanylmethyl)ethylenediamine (dppeda) in the presence of aminothiocarbamide in $CH_2Cl_2/MeOH$ afforded an unexpected and low-yield binuclear complex $[Ag_2(dppatc)_2](NO_3)_2 \cdot 2MeOH$ (dppatc = N,N-bis(diphenylphosphanylmethyl)aminothiocarbamide) (1). An X-ray analysis revealed that the $[Ag_2(dppatc)_2]^{2+}$ dication of 1 contains a centrosymmetric double half-open cage structure in which two Ag centers are bridged by a pair of the heteroscopionate dppatc ligands via four Ag- μ -S and four Ag – P bonds. The in situ-formed dppatc ligand in 1 could be readily generated by one-pot and high-yield reaction of diphenylphosphine with formaldehyde and aminothiocarbamide. Further reaction of AgNO₃ with dppatc could produce 1 in a relatively high yield. The results provided an efficient route to the synthesis of dppatc and also an interesting insight into its coordination chemistry.

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In the past decades, synthesis of polynuclear silver(I) coordination compounds of P,S-mixed ligands received much attention due to their rich structural chemistry and their potential applications in advanced materials including sulfide-based glasses and solid electrolytes [1,2]. Among them, many compounds have separate phosphine and thiolate ligands coordinate at silver(I) centers [3]. Only few examples have been reported to hold the P and S donor atoms in the same ligand [4]. On the other hand, the chemistry of coordination compounds with multiphosphine ligands has been extensively investigated because of their interesting structures and their abundant applications in catalysis. medicine and optical materials [5–7]. For instance, reaction of AgNO₃ and AgCl with one tetraphosphine ligand, N,N,N',N'-tetra(diphenylphosphanylmethyl)ethylene diamine (dppeda), gave rise to a cationic binuclear basket-shaped complex [Ag₂(dppeda)Cl](NO₃) [8]. It is noted that the presence of chloride was critical in the formation of this complex. Then two questions come out. Is it possible to introduce a sulfide or a sulfur-containing species in such a system? What other structures could be anticipated? Within these questions in mind, we selected aminothiocarbamide, which could be a sulfide reagent, to introduce into reactions of AgNO₃ with dppeda. Unexpectedly, another cationic binuclear complex containing an in situ-formed ligand N,N-bis (diphenylphosphanylmethyl)aminothiocarbamide (dppatc), [Ag₂ $(dppatc)_2 | (NO_3)_2 (1)$ was isolated in a low yield. The ligand dppatc contains one S and two P donor atoms and its coordination chemistry has never been reported before. In this communication we report the rational synthesis and structural characterization of dppatc and complex **1**.

Sulfide urea is known to give an inorganic sulfide through the cleaving its C=S bond by heating or binding to metals [9]. Therefore we expected that aminothiocarbamide may work in a similar way to create sulfides for aggregating Ag⁺ ions. Treatment of AgNO₃ with equimolar dppeda in the presence of equimolar aminothiocarbamide in CH₂Cl₂/ MeOH led to the formation of **1** in 9% vield [10] (Scheme 1). According to its X-ray structure described later, no inorganic sulfide was generated from the cleavage of the C=S bond of aminothiocarbamide. On the contrary, aminothiocarbamide replaced the ethylenediamine unit of dppeda to form two equiv of dppatc. In this process, the four C - N bonds of dppeda were cleaved to four Ph₂PCH₂⁺ species while two C – N bonds for each dppatc were generated by aminothiocarbamide to link two $Ph_2PCH_2^+$ species. The C-N cleavage and regeneration and the coordination of S and P atoms to silver(I) centers may be completed in situ in a cooperative way. Intriguingly, direct reactions of dppeda with one or two equiv. of aminothiocarbamide without Ag⁺ failed to produce this ligand. After numerous attempts, we found that one-pot reaction of aminothiocarbamide with 2 equiv. of diphenylphosphine and excess formaldehyde could readily produce dppatc in 97% yield (Scheme 2) [11]. With pure and large scale of dppatc in hands, reactions of dppatc with silver(I) salts were quite straightforward. Treatment of dppatc with equimolar AgNO₃ in CH₂Cl₂/MeOH gave rise to **1** in 72% yield [10]. Thus we supposed that the presence of Ag⁺ was quite critical in the formation of dppatc during the reactions of dppeda with aminothiocarbamide. The

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^{1387-7003/\$ –} see front matter 0 2011 Elsevier B.V. All rights reserved. doi:10.1016/j.inoche.2011.07.002



Ag⁺ ion was assumed to induce the in situ replacement of ethylenediamine unit of dppeda via aminothiocarbamide and facilitate the formation of dppatc via its binding to the P and S atoms.

The ligand dppatc is soluble in CHCl₃, CH₂Cl₂, DMF, and DMSO, and insoluble in MeOH, MeCN and Et₂O. Compound **1** is soluble in DMSO, and insoluble in common solvents. The elemental analyses were consistent with their formulas. In the IR spectrum of **1**, the strong bands at 1483, 1435, 843, 741, and 694 cm^{-1} were assigned to the phosphino groups of dppatc. The ¹H NMR spectrum of dppatc showed signals related to protons of the methylene groups, the amido groups and the phenyl groups at 3.69-3.89, 5.57-5.90 and 7.26-7.33 ppm, respectively. A single broad doublet resonance at 8.40 ppm was observed for the phosphino groups of dppatc in the ³¹P{¹H}NMR of **1** (Fig. S1). The chemical shift from 8.40 ppm (1) to dppatc (-26.4 ppm) may be due to the coupling between the ³¹P and ¹⁰⁷Ag(¹⁰⁸Ag) nuclei [8,12]. In order to gain more insight into the stability of 1 in solution, we measured its positive electrospray ionization mass spectrum (ESI-MS) in DMSO. It exhibited a set of peaks assignable to $[Ag_2(dppatc)_2]^{2+}$ (*m*/*z*=596.0) and $[Ag_2(dppatc-H)_2]^+$ (*m*/*z*=1189.1) (Fig. S2). The existence of these two cationic fragments suggested that the dication of **1** was guite stable in solution, which also confirmed why dppatc was preferably formed from the reaction of dppeda with aminothiocarbamide in the presence of Ag^+ ion.

Compound $1 \cdot 2$ MeOH crystallizes in the triclinic space group $P_{\overline{1}}$ and the asymmetric unit consists of half a $[Ag_2(dppatc)_2]^{2+}$ dication, one NO_3^- anion and one MeOH solvent molecule [13]. The structure of the dication of **1** was presented in Fig. 1. Each dppatc ligand shows a scorpion-like structure, which may resemble the so-called monoanionic "scorpionate" ligand [15]. Each of its two P atoms binds one Ag^+ and one S bridges two Ag centers to form an half-open $[Ag_2S_2P_2C_2N_2]$ cage. Two cages share the $[Ag_2S_2]$ rhomb to form a double half-open cage with a crystallographic center of symmetry located at the middle of $Ag(1) \cdots Ag(1A)$ contact. Such a structure is uncommon in the metal complexes of monoanionic "scorpionate" ligand. Each Ag(1) atom in **1** is coordinated by two P atoms from the PPh₂ groups of two different dppatc ligands and two S atoms from C=S of two different dppatc ligands, forming a distorted tetrahedral geometry. The mean Ag–P bond length (2.4378(9) Å) in **1** is close to that of $[Ag_2(dppm)_2(L)_2]$ (2.432(3) Å, dppm = bis(diphenylphosphino) methane, L=N,N'-diethyldithiocarbamate) [16], but slightly shorter than that of $[Ag(PPh_3)_2 L]$ (2.474(2) Å, L=pyrazolecarbodithiolate) [15]. The average Ag–S bond length (2.7069(11) Å) is longer than those of $[Ag(PPh_3)_2 L]$ (2.670(2) Å, L=pyrazolecarbodithiolate) and $[Ag_2(dppm)_2(L)_2]$ (2.662(3) Å, L=N,N'-diethyldithiocarbamate). The Ag(1)···Ag(1A) contact of 3.3956(11) Å is slightly shorter than the sum of the van der Waals radii of two Ag atoms (3.44 Å), and may suggest they are related by so-called agentophilicity [17].

The photoluminescent properties of dppatc and **1** in the solid state at room temperature were investigated. Upon excitation at 243 nm, dppatc exhibited photoluminescence with emission maxima at 390 nm (Fig. S3). However **1** exhibited no photoluminescence which may be ascribed to the fact that binding of Ag⁺ to dppatc caused its fluorescence to be quenched. The thermogravimetric analyses revealed that **1** was stable in room temperature (Fig. S4). The first weight loss of 4.79% in the region of 20 °C – 160 °C roughly corresponds to the weight loss of all the methanol molecules (calculated 4.65%). The second loss of 77.57% (160 °C–800 °C) is ascribed to the loss of nitrate and the dppatc ligands (calculated 77.70%). The decomposition residual species was assumed to be silver oxide.

In summary, we demonstrated that reaction of $AgNO_3$ with dppeda and aminothiocarbamide produced one unique Ag/dppatc complex **1**. Compound **1** holds a cationic double half-open cage structure in which two Ag centers are linked by a pair of the heteroscopionate dppatc ligands through four Ag-µ-S and four Ag – P bonds. The in situ-formed dppatc ligand could be readily generated by one-pot and high-yield reaction of diphenylphosphine with formaldehyde and aminothiocarbamide. We are currently extending this work by studies on the assembly of other novel dppatc-based arrays from its reactions of other metals such as Cu(I), Au(I) and Pd(II).



Scheme 2. Synthesis of the ligand dppatc.



Fig. 1. View of the structure of the dication of **1** with 30% thermal ellipsoids. All hydrogen atoms are omitted for clarity. Selected bond lengths (Å) and angles (°): Ag(1) – P(1) 2.4374 (10), Ag(1) – P(2A) 2.4385(9), Ag(1) – S(1) 2.6762(12), Ag(1) – S(1A) 2.7376(11), Ag(1) – Ag(1) – 3956(11); P(1) – Ag(1) – P(2A) 134.14(3), P(1) – Ag(1) – S(1A) 113.21(4), P(2A) – Ag(1) – S(1A) 100.02(4), P(1) – Ag(1) – S(1) 96.05(4), P(2A) – Ag(1) – S(1) 100.02(4), P(1) – Ag(1) – S(1) – Ag(1) – Ag(1) – S(1) 107.09 (4), S(1A) – Ag(1) – S(1) 102.32(3), Ag(1A) – S(1) – Ag(1) 77.68(3). Symmetry code: (A) 0.5 – *x*, -0.5 + y, 0.5 - z.

Acknowledgments

This work was financially supported by the National Natural Science Foundation of China (20871088, 20901054, and 90922018), the Nature Science Key Basic Research of Jiangsu Province for Higher Education (09KJA150002), the Specialized Research Fund for the Doctoral Program of higher Education of Ministry of Education (20093201110017), the State Key Laboratory of Coordination Chemistry of Nanjing University, the Qin-Lan and the "333" Projects of Jiangsu Province, and the "Soochow Scholar" Program and the Program for Innovative Research Team of Suzhou University. We also thanked the helpful suggestions from the reviewers and the editor.

Appendix A. Supplementary data

CCDC 826192 contains the supplementary crystallographic data for **1**. These data can be obtained free of charge via http://www.ccdc. cam.ac.uk/conts/retrieving.html, or from the Cambridge Crystallographic data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or e-mail: deposit@ccdc.cam.ac.uk. Supplementary materials related to this article can be found online at doi:10.1016/j.inoche.2011.07.002.

References

- (a) I.G. Dance, L.J. Fitzpatrick, M.L. Scudder, Synthesis and molecular structure of pentakis(triphenylphosphine) hexakis(4-chlorobenzenethiolato) hexasilver (I), derived from a new Ag₅(SR)₆ cage structure, Inorg. Chem. 23 (1984) 2276–2681;
- (b) E. Bembenek, O. Crespo, M.C. Gimeno, P.G. Jones, A. Laguna, Synthesis of silver (1) complexes with the bis(diphenylphosphany1)-o-carborane ligand. Crystal structures of [Ag(phen){(PPh₂)₂C₂B₁₀H₁₀]ClO₄ and [Ag{(SPPh₂)₂-CH₂){(PPh₂)₂C₂B₁₀H₁₀]ClO₄·CH₂Cl₂, Chem. Ber. 127 (1994) 835–840.
 [2] (a) D. Fenske, C. Persau, S. Dehnen, C.E. Anson, Ag₇₀S₂₀(SPh)₂₈(dppm)₁₀]
- [a] D. Fenske, C. Persau, S. Dehnen, C.E. Anson, Ag₇₀S₂₀(SPh)₂₈(dppm)₁₀] (CF₃CO₂)₂ and [Ag₂₆₂S₁₀₀(StBu)₆₂(dppb)₆, Angew. Chem. Int. Ed. 43 (2004) 305–309;
 - (b) Z. Zhang, J.H. Kennedy, H. Eckert, Glass formation and structure in non-oxide chalcogenide systems. The short range order of Ag₂S–P₂S₅ glasses studied by ³¹P MAS-NMR and dipolar NMR techniques, J. Am. Chem. Soc. 114 (1992) 5715–5784.
- [3] (a) D.D. Heinrich, J.P. Fackler Jr., P. Lahuerta, The structure of a dinuclear silver(I) complex: Ag₂[S₂C₂(CN)₂][P(C₆H₅)₃]₄, Inorg. Chim. Acta 116 (1986) 15–19;

- (b) W.P. Su, M.C. Hong, R. Cao, J.T. Chen, D.X. Wu, H.Q. Liu, J.X. Lu, A tetranuclear silver complex with dppm and i-mnt ligands. Synthesis and structural characterization of [Ag₄ (μ-dppm)₄(μ₄-i-mnt)₂]·0.5DMF (i-mnt=2,2-dicyano-1,1-ethylenedithiolate; dppm=bis(diphenylphosphino)methane), Inorg. Chim. Acta 267 (1998) 313–317;
- (c) C.W. Liu, B.J. Liaw, J.C. Wang, T.C. Keng, Solid state structures of [Ag₅(dppm)₄ (S₂CC(CN)P(O)(OEt)₂)₂][PF₆] and Ag₄(dppm)₄(S₂CC(CN)P(O)(OEt)₂)₂: variable coordination modes of 1,1-dithiolate to silver(I), Inorg. Chem. 39 (2000) 1329–1332;
- (d) T.C. Deivaraj, J.J. Vittal, Synthesis, structures and ³¹P NMR studies of bis (diphenylphosphino)methane adducts of copper and silver thiocarboxylates, J. Chem. Soc. Dalton Trans. (2001) 322–328;
- (e) G.A. Ardizzoia, G. La Monica, A. Maspero, M. Moret, N. Masciocchi, Silver(I) pyrazolates. Synthesis and X-ray and ³¹P-NMR characterization of triphenyl-phosphine complexes and their reactivity toward heterocumulenes, Inorg. Chem. 36 (1997) 2321–2328;
- (f) P. Aslanidis, P. Karagiannidis, P.D. Akrivos, B. Krebs, M. Lage, Silver(1) complexes with heterocyclic thiones and tertiary phosphines as ligands, Inorg. Chim. Acta 254 (1997) 277–284;
- (g) J. Vicente, P. Gonzalez-Herrero, Y. Garcia-Sanchez, P.G. Jones, Novel types of tetra-, hexa-, octa-, and dodecanuclear silver clusters containing (2,7-di-tertbutylfluoren-9-ylidene)methanedithiolate, Inorg. Chem. 48 (2009) 2060–2071;
- (h) C.W. Liu, B.J. Liaw, L.S. Liou, J.C. Wang, A 2D honeycomb-shaped network based on a starburst cluster: [Ag₄(µ₃-Cl)(PPh₂(CH₂)₂PPh₂)1.5{S₂P(OR)₂}₃] (R = Et, Prⁱ), Chem. Commun. (2005) 1983–1985;
- P. Aslanidis, P.J. Cox, S. Divanidis, P. Karagiannidis, Diphosphines as bridging ligands in polymeric and dimeric thione-S-ligated Ag(1) nitrate complexes, Inorg. Chim. Acta 357 (2004) 2677–2686;
- (j) D. Fenske, A. Rothenberger, M.S. Fallah, Ag₁₂(PhS₂P-PS₂Ph)₆(dppeS)₆, Eur. J. Inorg. Chem. (2005) 59–62;
- (k) O. Crespo, V.V. Brusko, M.C. Gimeno, M.L. Tornil, A. Laguna, N.G. Zabirov, Gold and silver complexes with the ligands N-[bis(isopropoxy)-thiophosphoryl] thiobenzamide and N-[bis(isopropoxy)thiophosphoryl]-N'-phenylthiourea, Eur. J. Inorg. Chem. (2004) 423–430.
- [4] (a) P. Di Bernardo, M. Tolazzi, P. Zanonato, The crystal structure of a chelate silver(I) complex: {Ag [Ph₂P(CH₂)₂SCH₂CH₃]₂}ClO₄, Inorg. Chim. Acta 215 (1994) 199–201;
 - (b) S.M. Kuang, Z.Z. Zhang, T.C.W. Mak, Synthesis and characterization of group 11 and 12 complexes containing a new thioether-functionalized and pyridine-based bis(phosphine) ligand, 2,6-bis[2-(diphenylphosphino)ethylsulfanylmethyl]pyridine, J. Chem. Soc. Dalton Trans. (1998) 317–320.
- [5] (a) M. Lemhadri, A. Battace, T. Zair, H. Doucet, M. Santelli, Heck arylations of pent-4-enoates or allylmalonate using a palladium/tetraphosphine catalyst, J. Organomet. Chem. 692 (2007) 2270–2281;
 - (b) M. Lemhadri, H. Doucet, M. Santelli, Sonogashira reaction of aryl halides with propiolaldehyde diethyl acetal catalyzed by a tetraphosphine/palladium complex, Tetrahedron 61 (2005) 9839–9847;
 - (c) I. Kondolff, M. Feuerstein, H. Doucet, M. Santelli, Synthesis of all-cis-3-(2diphenylphosphinoethyl)-1,2,4-tris(diphenylphosphinomethyl)cyclopentane (ditricyp) from dicyclopentadiene, Tetrahedron 63 (2007) 9514–9521.
- [6] (a) J.D. Kelly, A. Forster, M.B. Higley, Technetium-99 m-tetrofosmin as a new radiopharmaceutical for myocardial perfusion imaging, J. Nucl. Med. 34 (1993) 222-227.
 (b). J.D. Kelly, K.W. Chin, I.A. Latham, Ligands and cationic complexes thereof
 - (b). J.D. Kelly, K.W. Chin, I.A. Latham, Ligands and cationic complexes thereof with technetium-99 m, U S. Patent. (1991) 5045302.
- [7] (a) E.J. Fernández, A. Laguna, M. Monge, M. Montiel, M.E. Olmos, J. Péreza, E. Sánchez-Forcadaa, Dendritic(phosphine)gold(1)thiolate complexes: assessment of the molecular size through PGSE NMR studies, Dalton Trans. (2009) 474–480;
 - (b) Y. Takemura, H. Takenaka, T. Nakajima, T. Tanase, Hexa- and octagold chains from flexible tetragold molecular units supported by linear tetraphosphine ligands, Angew. Chem. 121 (2009) 2191–2195.
- [8] L. Li, Z.G. Ren, N.Y. Li, Y. Zhang, J.P. Lang, Syntheses, crystal structures and luminescent properties of two silver complexes of N, N, N, N'. Artera (diphenylphosphanylmethyl)ethylene diamine, Inorg. Chim. Acta 362 (2009) 3910–3914.
- [9] (a) R.M. Wang, W. Xu, J. Zhang, LJ. Li, A new hexanuclear iron-selenium nitrosyl cluster: primary exploration of the preparation methods, structure, and spectroscopic and electrochemical properties, Inorg. Chem. 49 (2010) 4814–4819;
 - (b) Q.L. Huang, H. Chen, Y.C. Zhang, C.L. Wu, CuS nanostructures prepared by a hydrothermal method, J. Alloys Compd. 509 (2011) 6382–6387.

300 MHz, ppm); δ 3.69 (d, 2H, -CH₂-), 3.89 (d, 2H, -CH₂-), 5.57 (s, 2H, -NH₂), 5.90 (s, 2H, - NH-), 7.26–7.33 (m, 20H, - Ph). ³¹P{¹H} NMR (300 MHz, ppm): δ 8.40 (d, *I* = 3.39 Hz).

- [11] Synthesis of dppatc: To a solution of aminothiocarbamide (228 mg, 2.5 mmol) in MeOH (20 mL) was added formaldehyde (527 mg, 6.5 mmol) and diphenylphosphine (930 mg, 5 mmol). The mixture was heated at reflux for 1.5 h to vield a colorless solution. After all the volatile species was removed in vacuo, the resulting solid was purified by recrystallization in $CH_2Cl_2/MeOH$ (v/v=1:5). Yield: 1184 mg (97% based on diphenylphosphine). Anal. Calcd. for $C_{27}H_{27}N_3P_2S$: C, 66.52; H, 5.58; N,8.62; found. C, 65.98; H, 5.49; N, 8.42; IR (KBr disk): 3403 (w), 3144 (w), 2811 (w), 2362 (w), 1589 (m), 1522 (m), 1481 (m), 1434 (s), 1384 (w), 1184 (w), 1096 (w), 1027 (w), 999 (w), 852 (w), 741 (s), 695 (s), 505 (m), 431 (w). ¹H NMR (CDCl₃-d₆, 300 MHz, ppm): δ 3.69(d, 2H, – CH₂-), 3.89 (d, 2H, – CH₂-), 5.57 (s, 2H, -NH2), 5.90 (s, 2H, -NH-), 7.26-7.33 (m, 20H, -Ph). 31P{1H} NMR (300 MHz, ppm): $\delta - 26.4$ (s).
- [12] D.J. Eisler, C.W. Kirby, R.J. Puddephatt, Tetraphosphinitoresorcinarene complexes: dynamic clusters with silver(I) and copper(I) halides, Inorg. Chem. 42 (2003) 7626-7634
- [13] Crystal data for 1: C56H62Ag2O8N8P4S2, Mr=1378.9, colorless crystal, triclinic, space group *P*₁, *a*=10.680(2) Å, *b*=11.703(2) Å, *c*=12.951(3) Å, *α*=74.33(3)°, β=76.16(3)°, γ=75.99(3)°, *V*=1485.8(5) Å³, *Z*=1, *D_c*=1.541 g/cm³, *F*(000)=410

and $\mu = 0.897 \text{ mm}^{-1}$. T = 223(2) K. 13426 reflections collected. 5130 unique $(R_{int} = 0.0398), R_1 = 0.0426, wR_2 = 0.1026 and S = 1.029. Data collections of$ **1**wereperformed with Mo K α radiation ($\lambda = 0.71073$ Å) on a Rigaku Mercury CCD X-ray diffractometer. The structures were solved by direct methods and refined with fullmatrix least-squares technique using SHELXTL-97 software package [14]. All nonhydrogen atoms were refined anisotropically while all hydrogen atoms were placed in geometrically idealized positions and constrained to ride on their parent atoms with $U_{iso}(H) = 1.2U_{eq}$. [14] (a) G.M. Sheldrick, SHELXS-97, Program for Solution of Crystal Structures,

- University of Göttingen, Germany, 1997;
 - (b) G.M. Sheldrick, SHELXL-97, Program for Refinement of Crystal Structures, University of Göttingen, Germany, 1997.
- [15] G.A. Ardizzoia, G. La Monica, A. Maspero, M. Moret, N. Masciocchi, Silver(I) pyrazolates. Synthesis and X-ray and ³¹P-NMR characterization of triphenylphosphine complexes and their reactivity toward heterocumulenes, Inorg. Chem. 36 (1997) 2321 - 2328
- [16] C. Dinicola, J.N. Effendy, C. Pettinari, B.W. Skelton, A.A. White, Synthesis and structural characterization of adducts of silver(I) diethyldithiocarbamate with Pdonor ligands, Inorg. Chim. Acta 360 (2007) 2935-2943.
- N. Kaltsoyannis, Relativistic effects in inorganic and organometallic chemistry, J. [17] Chem. Soc. Dalton Trans. (1997) 1-12.