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Platinum(II) and Palladium(II) Complexes with *N*-Aminoguanidine

David J. Aitken,*[a] Alberto Albinati,[b] Arnaud Gautier,[a] Henri-Philippe Husson,[c] Georges Morgant,[d] Dung Nguyen-Huy,[d] Jiří Kozelka,*[e] Pascale Lemoine,[f] Sandrine Ongeri,[c] Silvia Rizzato,[b] and Bernard Viossat[f]

Keywords: Platinum / Palladium / N ligands / Coordination modes

N-Aminoguanidine (Amgu) was examined for its behaviour as a ligand for platinum(II) and palladium(II). Protonated AmguH$^+$ can coordinate platinum as a monodentate ligand bound via the N4 amino group. Deprotonated, electrically neutral Amgu forms chelate complexes with both Pt^{II} and Pd^{II}; in these complexes Amgu is coordinated to the metal by the N4 amino group and the deprotonated N1 imino group, forming a five-membered ring. K[$PtCl_3$(dmso)] reacted with Amgu·HCl to yield a chelate complex with N1 bound *trans* to S, suggesting that an exchange between the N1 and N4 binding sites followed the primary nucleophilic attack of N4 on platinum. Whereas reactions between K_2PdCl_4 and Amgu·HCl were rapid and straightforward, K_2PtCl_4 was easily reduced to metallic platinum by Amgu·HCl, especially in stoichiometric conditions. Solution NMR and X-ray crystallographic characterization is presented for five new complexes: *trans*-[$PtCl_2$(AmguH-*N4*)$_2$]Cl_2·$2^1/_2H_2O$ (**3**), *trans*-[Pt(Amgu-*N1,N4*)$_2$]$(NO_3)_2$ (**4**), [PtCl(Amgu-*N1,N4*)(dmso)]Cl·$2H_2O$ (**5**), [$PdCl_2$(AmguH-*N1,N4*)] (**6**), and *trans*-[Pd(Amgu-*N1,N4*)$_2$]-Cl_2 (**7**).

Introduction

Cisplatin (*cis*-[$PtCl_2(NH_3)_2$]; cisplatyl®; platinol®; Figure 1) is one of the most successful drugs used currently in cancer chemotherapy.[1,2] Despite numerous efforts to synthesize analogues which would cause less severe side effects, have improved activity profiles, and/or allow the resistance to cisplatin to be circumvented, only three cisplatin analogues have been admitted for clinical use to date, carboplatin,[3] oxaliplatin,[4] and nedaplatin,[5] although none of them has brought about a real breakthrough in cancer chemotherapy. The particular features of the parent drug cisplatin, which distinguish it from its analogues, are its unique hydrogen-bonding capacity and its small size.[6] In this respect, aminoguanidine (Amgu; Figure 1) is an interesting potential bidentate ligand for replacement of the two NH_3 ligands, since it is only slightly bulkier and has six N–H bonds oriented in a manner different to those of cisplatin, thus offering a different pattern of strong hydrogen bonds. Amgu is in fact a molecule of considerable biological importance in its own right,[7–9] and its structure has been incorporated into a wide variety of organic compounds displaying diverse pharmacological activities.[10–15] Amgu is a

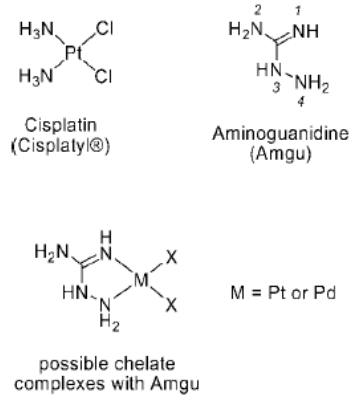


Figure 1. Structural formulae of cisplatin, aminoguanidine, and possible chelates of Pt^{II} or Pd^{II} analogous to cisplatin.

[a] Laboratoire SEESIB, UMR 6504 – CNRS, Département de Chimie, Université Blaise Pascal – Clermont-Ferrand II,
24 avenue des Landais, 63177 Aubière cedex, France
Fax: +33-4-73407717
E-mail: David.Aitken@univ-bpclermont.fr
[b] Dipartimento di Chimica Strutturale e Stereochimica Inorganica, Università di Milano,
Via G. Venezian 21, 20133 Milano, Italy
[c] Laboratoire de Chimie Thérapeutique, UMR 8638 – CNRS, Faculté des Sciences Pharmaceutiques et Biologiques, Université René Descartes – Paris V,
4 avenue de l'Observatoire, 75270 Paris cedex 06, France
[d] Laboratoire de Cristallochimie Bioinorganique, Faculté de Pharmacie, Université de Paris-Sud,
Rue Jean Baptiste Clément, 92296 Châtenay-Malabry cedex, France
[e] Laboratoire de Chimie et Biochimie Pharmacologiques et Toxicologiques, UMR 8601 – CNRS, Université René Descartes – Paris V,
45 rue des Saints-Pères, 75270 Paris cedex 06, France
Fax: +33-1-42868387
E-mail: jiri.kozelka@univ-paris5.fr
[f] Laboratoire de Cristallographie et RMN Biologiques, UMR 8015 – CNRS, Faculté des Sciences Pharmaceutiques et Biologiques, Université René Descartes – Paris V,
4 avenue de l'Observatoire, 75270 Paris cedex 06, France

dibasic compound, which is unstable in the free state; the guanidinium centre has the higher proton affinity (protonation on N1) but a dicationic species (second protonation on N4) is also known.[16–18]

The coordination chemistry of Amgu has been described for a few transition metals. In one of the earliest studies, Thiele[19] described a complex salt of copper with the formula $[(CN_4H_5)_2Cu](HNO_3)_2$, which was later confirmed as the double chelate $[Cu(Amgu)_2](NO_3)_2$.[20,21] Similar square-planar chelate structures have been attributed to complexes of nickel(II).[21,22] Dirhodium(II) tetracarboxylate complexes of general formula $Rh_2(RCOO)_4(Amgu)(H_2O)$ where R = H, CH_3 or C_2H_5 have been described, in which the presence of a C=N→Rh bond was deduced; no evidence for the coordination of a second nitrogen function was found, although a bridging role for the Amgu ligand was not entirely ruled out.[23] In 1985, the preparation of a platinum(II) complex of Amgu having promising biological activity was reported in a patent.[24] Presumably on the basis of analogy with other diamino ligands, it was assumed that a chelate structure was obtained; no characterisation of the material was described, however.

In order to gain insight into the behaviour of Amgu as a ligand for Pt^{II}, particularly with a view to establishing a basis for new antitumour candidates, we undertook an investigation of the synthesis of several Pt^{II}-aminoguanidine complexes, and also of related Pd^{II} complexes for comparison.

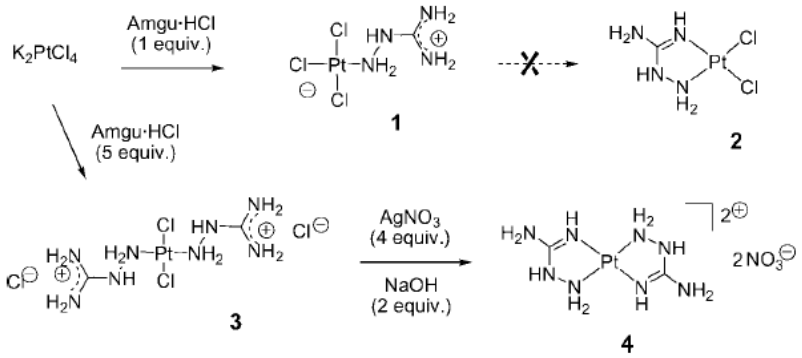
Results and Discussion

Platinum Complexes

In our first experiments, we reacted equimolar amounts of Amgu·HCl and K_2PtCl_4 in aqueous solution at ambient temperature for 15 h, according to the patent procedure.[24] In contrast to the literature report, no solid product appeared during this time; instead, small amounts of a black deposit (presumably reduced platinum) appeared on the walls of the reaction vessel. The remaining solution was evaporated and the residue was examined by NMR spectroscopy. Integration of ^1H NMR signals of a [D$_7$]dmf solution showed the presence of seven protons, which suggested that the Amgu ligand was protonated. The ^{195}Pt NMR spectrum showed one major signal at δ = –1997 ppm, corresponding to an NCl_3 ligand set for square planar platinum(II) species.[25] Minor peaks at δ = –1631, –2128 and –2218 ppm correspond to Cl_4 and two N_2Cl_2 ligand sets, respectively. We suspect that one of the latter two constituents was the anticipated chelate structure **2**, but the major species appeared to be a monodentate zwitterionic compound **1** (Scheme 1). N4 is the only nitrogen of Amgu having a lone-pair available to coordinate platinum when N1 of the guanidinium centre is protonated.

Attempts to adapt the reaction conditions in order to obtain chelate **2** met with failure. Neutralization of an aqueous Amgu·HCl solution with one equivalent of KOH immediately prior to addition of one equivalent of K_2PtCl_4 simply increased the production of the black deposit. Treatment of an aqueous Amgu·HCl solution with $AgNO_3$ immediately produced a white precipitate of AgCl which was removed by filtration, leaving a solution of Amgu·HNO_3. Addition of K_2PtCl_4 to Amgu·HNO_3 solution (or to Amgu·HNO_3 solution + one equivalent of KOH) produced an intractable solution containing the usual black deposit. Treating K_2PtCl_4 with two or four equivalents of $AgNO_3$ to replace chloride ions followed by addition of one equivalent of Amgu·HNO_3 solution (with or without one equivalent of KOH) gave similar results.

These unsuccessful attempts to isolate a single-chelate ligand complex such as **2** prompted us to investigate the possibility of forming a bis-chelate. In an initial effort, treatment of K_2PtCl_4 with two equivalents of Amgu·HCl lead once again to extensive black deposit formation over a 15 h reaction period. However, when an aqueous solution of K_2PtCl_4 was treated with 5 equiv. of Amgu·HCl and the solvent was evaporated under reduced pressure over a period of several hours, a yellow crystalline product was formed. Its NMR spectroscopic data in [D$_7$]dmf solution (8 identical N1 and N2 guanidinium protons at δ = 8.27 and a single ^{195}Pt signal at δ = –2277) and microanalytical data were consistent with the formula *trans*-$[PtCl_2(AmguH\text{-}N4)_2]Cl_2$ (**3**) (Scheme 1); the structure was confirmed by X-ray crystallographic analysis (Figure 2).



Scheme 1.

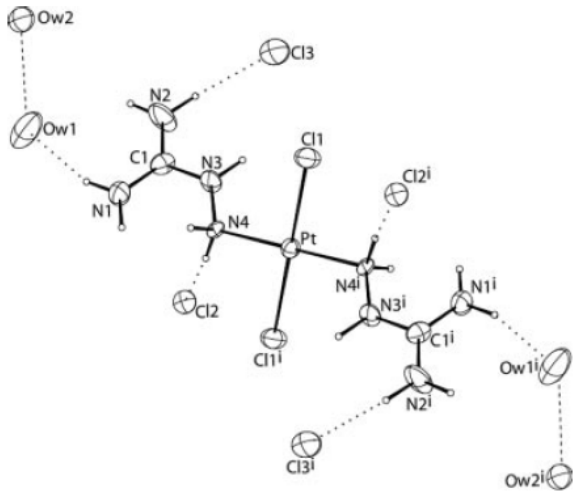


Figure 2. CAMERON plot (50% thermal probability ellipsoids) of the crystal structure of **3**. Selected bond lengths [Å] and angles [°]: Pt–Cl1 2.295(3), Pt–N4 2.064(7), C1–N1 1.295(13), C1–N2 1.283(13), C1–N3 1.350(13), N4–N3 1.389(11), Cl1–Pt–N4 90.8(2), Cl1–Pt–N4i 89.2(2), N1–C1–N2 121.9(10), N1–C1–N3 121.6(9), N2–C1–N3 116.4(10).

In the crystal, the structure is centrosymmetric, so that only half of the molecule is independent, with two Amgu molecules acting as monodentate ligands, coordinating to platinum through the hydrazine-type nitrogen N4, whose geometry and hydrogen atom count clearly indicate sp^3 hybridization. Two chlorine atoms complete the inner ligand sphere with a *trans*-geometry, and two chloride ions and 2.5 water molecules per unit cell are located in the crystal. The Pt atom lies on a centre of symmetry. The N1 and N2 atoms of Amgu each bear two hydrogens; one of the N1 hydrogens participates in a hydrogen bond with a water molecule. Hydrogen bonds with chloride counterions are also observed for one hydrogen on each atom N2 and N4. Distances and angles at the platinum centre have usual values, while distances and angles of the Amgu moiety are comparable to those observed for uncomplexed Amgu cations in the solid state.[16,26–28] Distances C1–N1, C1–N2 and C1–N3 have approximately equal values, as should be expected for a delocalized guanidinium system. The Amgu ligand is approximately planar (maximum deviation from the least-squares-plane defined by the atoms C1, N1, N2, N3, and N4 is 0.039(2) Å for N3), confirming that nitrogen N3 is sp^2 hybridized. On the other hand, the overall structure of **3** is not planar; the angle between the platinum coordination plane and the mean ligand plane (N1–C1–N2–N3–N4) is 147.4°.

In an effort to make the Amgu ligands of complex **3** behave as chelates, a sample of **3** was treated with 4 equiv. of silver nitrate to precipitate all halide, then with 2 equiv. of base. This induced the slow appearance of colourless crystals, which were identified as *trans*-$[Pt(Amgu)_2](NO_3)_2$ (**4**; Scheme 1) by X-ray diffraction analysis, as shown in Figure 3.

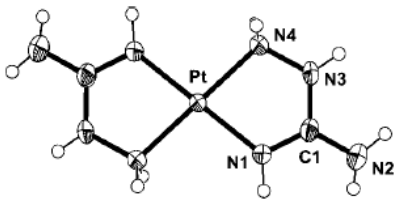


Figure 3. ORTEP plot (50% thermal probability ellipsoids) of the crystal structure of **4**; nitrate counterions are omitted. Selected bond lengths [Å] and angles [°]: Pt–N1 1.996(6), Pt–N4 2.031(6), N1–C1 1.305(10), C1–N2 1.331(10), C1–N3 1.348(10), N4–N3 1.434(9), N1–Pt–N4 80.0(2), C1–N1–Pt 116.2(5), N1–C1–N2 125.8(8), N1–C1–N3 117.0(6), C1–N3–N4 116.6(5), N3–N4–Pt 110.1(4), N2–C1–N3 116.8(7).

The structure consists of centrosymmetric square planar $[Pt(Amgu)_2]^{2+}$ cations and nitrate counterions; the Pt atom lies on a centre of symmetry. The coordination sphere of the Pt atom is formed by two *trans*-oriented bidentate Amgu ligands coordinated through the terminal hydrazine N4 atom and the imine N1 atom, each of which forms a planar five-membered chelate ring with the metal centre (maximum deviation from the PtN_4 least-squares plane: 0.04 Å). The small bite angle of Amgu constrains the endocyclic N1–Pt–N4 angle to 80.0(2)° which is slightly less than the angle of 83.1(1)° found for the bis(ethylenediamine) complex $[Pt(en)_2]^{2+}$.[29] The Amgu moiety of **4** is nearly planar (torsion angle N2–C1–N3–N4 4.6°). Distances C1–N1, C1–N2 and C1–N3 are again of approximately equal values, and are comparable with those for protonated uncomplexed ligand.[16,26–28] There is no localised double bond, and the positions of the H atoms and the planarity of the ligand suggest an sp^2 hybridisation for all atoms except N4, which remains sp^3-hybridised.

The packing of the Pt units gives rise to infinite stacks of square-planar complexes (correlated by a *c* glide plane) with a Pt–Pt separation of 3.332(1) Å. The molecular packing is stabilized by hydrogen-bonding interactions between the cationic complex and the oxygen atoms of nitrate (N–O in the range 2.90–3.28 Å), generating a complex supramolecular three-dimensional network in which all the nitrate oxygens and the N-bonded hydrogens of the ligands are involved (Figure 4). This network demonstrates the hydrogen-bond forming potential of platinum-chelated Amgu.

The unsuccessful attempts to prepare a mono-Amgu complex from K_2PtCl_4 prompted us to investigate alternative platinum(II) starting materials. We have previously found $K[PtCl_3(dmso)]$[30] to be more convenient than K_2PtCl_4 for the formation of binuclear platinum(II) complexes with rigid diamine ligands.[31,32] Furthermore, $K[PtCl_3(dmso)]$ successfully provided a chelate complex with Gly-His where reaction of this ligand with K_2PtCl_4 failed.[33] In the event, when a slight molar excess of Amgu·HCl was added to a solution of $K[PtCl_3(dmso)]$ in water, a solid product began forming after only 90 min. A satisfactory 73% yield of a single chelate complex was obtained; its composition was suggested as [PtCl(Amgu)(dmso)]Cl (**5**) from analytical and spectro-

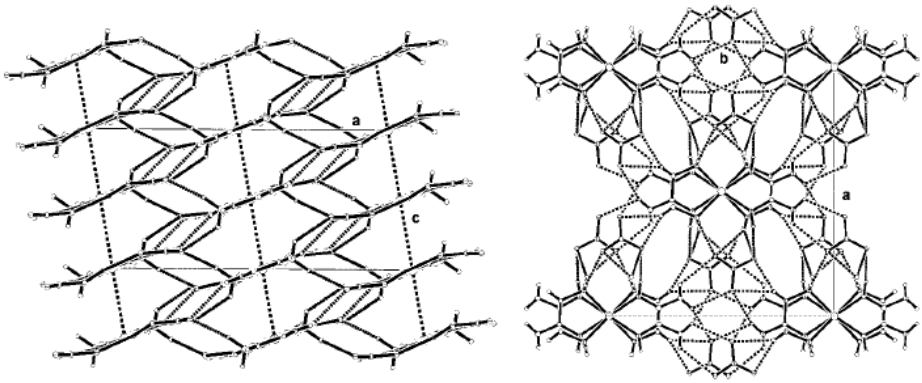


Figure 4. Views along the b (left) and c (right) crystallographic axes of the molecular packing of **4**. The selection criteria for hydrogen bonds (depicted as thin dotted lines) were: d(N···O) < R(N) + R(O) + 0.50, d(H···O) < R(H) + R(O) –0.12, N–H···O > 100.0°.

scopic data (in particular ^{1}H NMR signal integrations and a single ^{195}Pt NMR signal at δ = –3134 ppm) and was confirmed by X-ray diffraction (Figure 5).

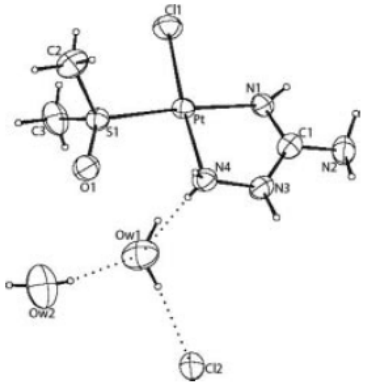
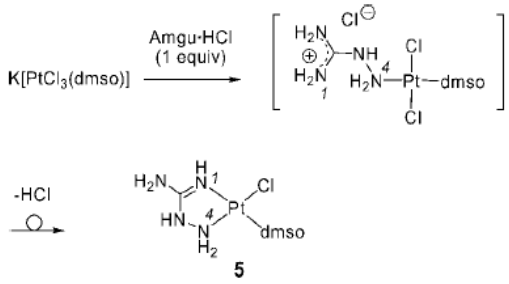


Figure 5. CAMERON plot (50% thermal probability ellipsoids) of the crystal structure of **5**. Selected bond lengths [Å] and angles [°]: Pt–Cl1 2.298(1), Pt–S1 2.208(1), Pt–N1 1.990(4), Pt–N4 2.034(4), C1–N1 1.312(6), C1–N2 1.340(6), C1–N3 1.338(7), N3–N4 1.443(6), N1–Pt–N4 80.6(2), Pt–N1–C1 115.2(3), N1–C1–N2 124.5(5), N1–C1–N3 117.4(4). N2–C1–N3 118.0(5), C1–N3–N4 117.0(4), N3–N4–Pt 109.1(3), Cl1–Pt–N1 93.9(1), Cl1–Pt–S1 92.81(6), S1–Pt–N4 92.8(1).

Distances and angles at the platinum centre have typical values. Comparison of the Pt–N1 and Pt–N4 bond lengths for **4** with those observed for **5** reveals no indication for any significahe least-squares-plane of 0.050(2) Å for N4. The crystal packing of this complex involves several hydrogen bonds, in particular N4–H4B···Ow1 [2.996(7) Å, 167°].

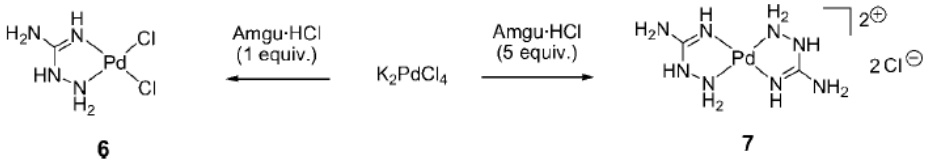
When $[PtCl_3(dmso)]^-$ reacts with $AmguH^+$, the first nucleophilic substitution is expected to occur *trans* to the dmso ligand,[30,34] yielding *trans*-$[PtCl_2$(AmguH-*N4*)-(dmso)$]^+$. Deprotonation (aided by the acidifying effect that N4-coordination to platinum is expected to exert on the N3 imonium group) and chelation would produce the isomer of $[PtCl$(Amgu-*N1*,*N4*)(dmso)$]^+$ with N4 bound *trans* to dmso. The fact that in crystals of complex **5** the N4 atom is coordinated *trans* to Cl^- suggests that a rearrangement has occurred following the first N4 attack, producing the thermodynamically more stable isomer (Scheme 2).



Scheme 2.

Palladium Complexes

The stoichiometric reaction between K_2PdCl_4 and Amgu·HCl proceeded smoothly, in contrast to that with K_2PtCl_4, yielding $[PdCl_2$(AmguH-*N1*,*N4*)] (**6**), without any sign of reduction of Pd^{II} (Scheme 3). This difference can be attributed to the standard oxidation potentials for the M^0/M^{II} couples which are more negative for platinum than for palladium[35] and to the 10^3 times faster substitution reaction rates of Pd^{II} compared to Pt^{II}.[36] The structure of **6** (Figure 6), indicated by solution state NMR spectroscopic data, was confirmed by X-ray crystallographic analysis. The



Scheme 3.

square planar palladium(II) centre presents usual bond lengths and angles, while the chelating ligand, coordinated through N1 and N4, is virtually planar (torsion angle N1–C1–N3–N4 2°). It is noteworthy that there was no need to liberate the Amgu ligand in its free base form in order to obtain complex **6**; indeed, repeating the reaction in the presence of 1 equiv. of NaOH led to a lower isolated yield (72%) of compound **6**.

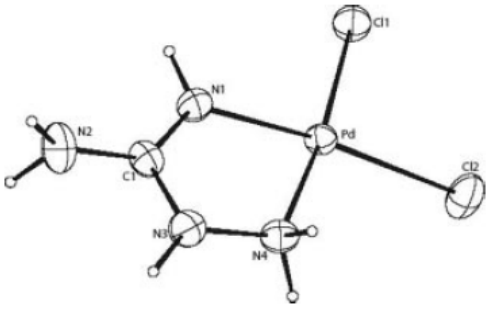


Figure 6. CAMERON plot (50% thermal probability ellipsoids) of the crystal structure of **6**; selected bond lengths [Å] and angles [°]: Pd–Cl1 2.303(2), Pd–Cl2 2.322(2), Pd–N1 1.968(6), Pd–N4 2.019(5), C1–N1 1.307(8), C1–N2 1.339(9), C1–N3 1.347(9), N3–N4 1.407(8), Cl1–Pd–Cl2 93.86(6), Cl1–Pd–N1 92.7(2), Cl2–Pd–N4 92.5(2), N1–Pd–N4 81.0(2), N1–C1–N2 123.7(7), N1–C1–N3 117.9(6), N3–C1–N2 118.3(6).

Treatment of K_2PdCl_4 with 5 equiv. of Amgu·HCl in aqueous solution followed by evaporation of the solvent over a period of several hours gave a good yield of *trans*-[Pd(Amgu-*N1*,*N4*)$_2$]Cl_2 (**7**) (Scheme 3). Once again, the prerequisite loss of one proton for coordination of N1 proceeded even in the acidic solution; the final pH of the reaction mixture was 1.5. The bis-chelate structure of **7** was confirmed by X-ray crystallographic analysis (Figure 7). The planar palladium(II) centre is centrosymmetric, bearing two Amgu ligands chelated through N1 and N4 in a *trans* fashion. The ligand is again almost planar (torsion angle N1–C1–N3–N4 5°) and the overall structure of the metal complex is very similar to that of **4**. Two chloride ions are located in the crystal packing and are involved in two hydrogen bonds with the complex.

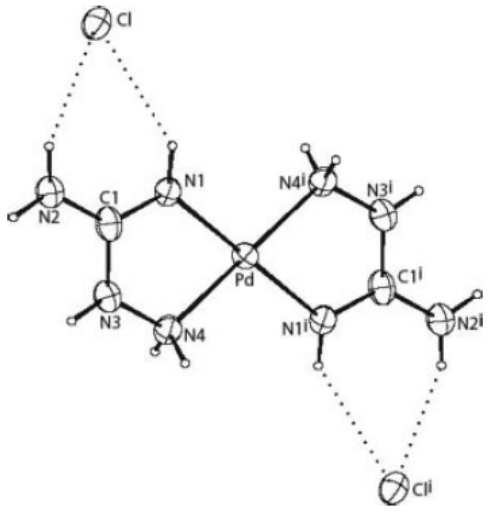


Figure 7. CAMERON plot (50% thermal probability ellipsoids) of the crystal structure of **7**. Selected bond lengths [Å] and angles [°]: Pd–N1 1.977(7), Pd–N4 2.029(7), C1–N1 1.303(11), C1–N2 1.341(12), C1–N3 1.358(11), N3–N4 1.401(9), H1···Cl 3.436(8), H21···Cl 3.288(9), N1–Pd–N4 80.6(3), Pd–N1–C1 115.2(6), N1–C1–N3 117.2(8), N2–C1–N3 116.8(9). N1–C1–N2 125.9(9), C1–N3–N4 116.9(7), N3–N4–Pd 109.7(5), N1–H1···Cl 142, N2–H21···Cl 151.

Conclusions

N-Aminoguanidine has been shown to be a chelator of platinum(II) and palladium(II), coordinating the metal through the hydrazine-type amino N4 group and the imino groupN1. Reaction between K[$PtCl_3$(dmso)] and Amgu·HCl yielded the mono-chelate [PtCl(Amgu-*N1*,*N4*)(dmso)]$^+$ (**5**) in which the N4 atom of Amgu is bound *trans* to Cl^-, whereas the initial coordination is expected to place N4 *trans* to dmso. Thus, the activation barrier for breakage of the Pt–N4 bond *trans* to Pt–S does not seem to be high, and the thermodynamically more stable isomer is obtained. For the Pd^{II} complexes, kinetic lability and formation of the thermodynamically more stable isomers was expected in any case.

Amgu is also a reducing agent, and in some cases reactions with Pt^{II} complexes led to reduction to Pt^0, whereas the analogous Pd^{II} complex underwent a clean ligand-substitution reaction under the same conditions. K[$PtCl_3$(dmso)] proved to be a starting material less susceptible to reduction by Amgu than K_2PtCl_4. Protonated AmguH$^+$ has a single coordination site, the hydrazine-type amino group N4, and we have characterized one platinum complex with two AmguH$^+$ ligands bound in a *trans*-configuration (complex **3**).

The solid-state structures of the compounds studied here show a variety of hydrogen bonding networks. All four nitrogens of the Amgu ligand are able to behave as hydrogen atom donors, suggesting that platinum complexes of this ligand may warrant further investigation for their interactions with DNA. Hydrogen bonding between platinum spectator ligands and DNA are thought to play a role in stabilizing particular conformers in guanine···guanine crosslinks[37] and it has been hypothesized that they may be important for antitumour activity.[38,39]

Experimental Section

General Remarks: Melting points were determined on a Thermovar apparatus and are uncorrected. Electrospray mass spectra were obtained using a Thomson quadrupole instrument equipped with an Analytica atmospheric pressure source. IR spectra were recorded from samples dispersed as nujol mulls between KBr plates on a Perkin–Elmer 1600 Fourier Transform instrument. NMR spectra were recorded on a Bruker AC-300 instrument (^{1}H: 300.13 MHz; ^{13}C{^{1}H}: 75.43 MHz) and a Bruker ARX-250 instrument (^{195}Pt: 53.63 MHz) using standard pulse sequences. Chemical shifts (δ) are given in ppm and are quoted relative to TMS or Na_2PtCl_6. Elemental analyses were carried out by Laboratoire de Microanalyse, Insti-

tut de Chimie des Substances Naturelles du CNRS, Gif-sur-Yvette, France. Water was doubly distilled and organic solvents were purified by standard procedures before use. Aminoguanidine hydrochloride, potassium tetrachloroplatinate and potassium tetrachloropalladate were obtained commercially and used without further purification. The salt K[$PtCl_3$(dmso)] was prepared via the literature procedure.[30]

K[$PtCl_3$(AmguH)] (1): Amgu·HCl (55 mg, 0.5 mmol) was added to a solution of K_2PtCl_4 (207 mg, 0.5 mmol) in water (1 mL), and the mixture was stirred at room temp. for 12 h. A dark deposit was removed by filtration and the filtrate was evaporated to leave an amorphous brown residue (220 mg). This sample showed: ^{1}H NMR ([D_7]dmf): δ = 7.44 (s, 2 H), 7.95 (s, 2 H), 8.45 (s, 1 H), 8.99 (s, 2 H) ppm. $^{13}C\{^1H\}$ NMR ([D_7]dmf): δ = 157.9 ppm. ^{195}Pt NMR ([D_7]dmf): δ = –1631 (minor), –1997 (major), –2128 (minor), –2218 (minor) ppm.

***trans*-[$PtCl_2$(AmguH-*N4*)$_2$]Cl_2·2$^1/_2H_2O$ (3):** Amgu·HCl (220 mg, 2.0 mmol) was added to a solution of K_2PtCl_4 (166 mg, 0.4 mmol) in water (2 mL). The mixture was stirred at room temp. for 15 min, during which time the pH dropped to 2.7, and was then placed in a vacuum desiccator (10 Torr) in the presence of active silica gel and left at room temp. for 15 h. The slow evaporation of water left yellow crystals which were washed successively with water, ethanol, ether, then dried under vacuum (0.5 Torr) to give a first crop of compound **3** (39 mg). The combined washings were evaporated to leave more yellow crystals which were washed with water, ethanol and ether, as before, to give a second crop of compound **3** (62 mg). Combined yield: 52%. M.p. 140 °C. ESMS: *m*/*z* = 208 $[M]^{2+}$. IR: $\tilde{\nu}$ = 3379 (NH), 3329 (NH), 3134 (NH), 1674 (C=N), 1607 (NH) cm^{-1}. ^{1}H NMR ([D_7]dmf): δ = 8.27 (s, 8 H), 8.54 (s, 4 H), 9.31 (s, 2 H) ppm. $^{13}C\{^1H\}$ NMR ([D_7]dmf): δ = 158.7 ppm. ^{195}Pt NMR ([D_7]dmf): δ = –2277 ppm. $C_2H_{14}Cl_4N_8Pt·2^1/_2H_2O$ (532.2): calcd. C 4.51, H 3.60, N 21.06, Cl 26.64; found C 4.86, H 3.31, N 20.66, Cl 26.66.

***trans*-[Pt(Amgu-*N1*,*N4*)$_2$]$(NO_3)_2$ (4):** Complex **3** (15 mg; 0.029 mmol) and 4 equiv. $AgNO_3$ (19.7 mg) in 0.5 mL D_2O were stirred at ambient temperature for 3 d. The precipitate was filtered off, the filtrate was treated with 6 µL of 1 N NaOH (ca. 2 equiv.), and the solution placed in an NMR tube. A ^{195}Pt NMR spectrum recorded overnight did not show any peaks but it the tube colorless crystals appeared. The crystals were identified as [Pt(Amgu)$_2$]$(NO_3)_2$ by means of a structure analysis using X-ray diffractometry.

PtCl(Amgu-*N1*,*N4*)(dmso)]Cl·2H_2O (5): Amgu·HCl (46 mg, 0.42 mmol) was added to a solution of K[$PtCl_3$(dmso)] (160 mg, 0.38 mmol) in water (1.2 mL). The mixture was stirred at room temp. for 90 min, during which time few crystals started to precipitate. The mixture was then placed in a vacuum desiccator (10 Torr) over $CaCl_2$ and left until one third of the volume remained. The solid residue was filtered, washed with water, then dried under vacuum (0.5 Torr). Compound **5** was thus obtained as yellow-white crystals. Yield: 117 mg, 73%. M.p. 192 °C (dec.). ESMS: *m*/*z* = 383 [M – Cl]. IR: $\tilde{\nu}$ = 1635 (C=N), 1553 (NH), 1126 (S=O), 1023 (S=O) cm^{-1}. ^{1}H NMR ([D_7]dmf): δ = 3.62 (s, 6 H), 6.68 (s, 1 H), 7.16 (s, 2 H), 9.38 (s, 2 H), 10.00 (s, 2 H) ppm. $^{13}C\{^1H\}$ NMR ([D_7]dmf): δ = 43.3, 167.8 ppm. ^{195}Pt NMR ([D_7]dmf): δ = –3134 ppm. $C_3H_{12}Cl_2N_4OPtS·2H_2O$: calcd. C 7.93, H 3.55, N 12.33, S 7.06; found C 7.62, H 3.29, N 11.89, S 7.48.

[$PdCl_2$(AmguH-*N1*,*N4*)] (6): Amgu·HCl (55 mg, 0.5 mmol) was added to a solution of K_2PdCl_4 (163 mg, 0.5 mmol) in water (2.5 mL). The mixture was stirred at room temp. for 15 min, during which time a precipitate formed. This solid was isolated by filtration and washed with ethanol then ether, and dried under vacuum (0.5 Torr). Compound **6** was thus obtained as brownish-red crystals. Yield: 102 mg, 82%. M.p. 188–190 °C (dec.). IR: $\tilde{\nu}$ = 3423 (NH), 3338 (NH), 3186 (NH), 3106 (NH), 1620 (C=N), 1580 (NH) cm^{-1}. ^{1}H NMR ([D_7]dmf): δ = 5.06 (s, 1 H), 6.44 (s, 2 H), 7.77 (s, 2 H), 8.59 (s, 1 H) ppm. $^{13}C\{^1H\}$ NMR ([D_7]dmf): δ = 166.1 ppm. $CH_6Cl_2N_4Pd$ (251.4): calcd. C 4.78, H 2.41, N 22.28, Cl 28.20; found C 4.51, H 2.51, N 22.32, Cl 28.16.

***trans*-[Pd(Amgu-*N1*,*N4*)$_2$]Cl_2 (7):** Amgu·HCl (276 mg, 2.5 mmol) was added to a solution of K_2PdCl_4 (163 mg, 0.5 mmol) in water (2.5 mL). The mixture was stirred at room temp. for 15 min, during which time the pH dropped to 1.5 and a precipitate formed. The mixture was then placed in a vacuum desiccator (10 Torr) in the presence of active silica gel and left at room temp. for 5 h. The solid residue was washed with a methanol/water mixture (9:1), then dried under vacuum (0.5 Torr). Compound **7** was thus obtained as yellow crystals. Yield: 146 mg, 89%. M.p. 200 °C (dec.). ESMS: *m*/*z* = 127 $[M]^{2+}$. IR: $\tilde{\nu}$ = 3392 (NH), 3332 (NH), 3106 (NH), 1639 (C=N), 1560 (NH) cm^{-1}. ^{1}H NMR ([D_6]dmso): δ = 5.20 (s, 2 H), 6.51 (s, 4 H), 7.93 (s, 4 H), 8.66 (s, 2 H) ppm. $^{13}C\{^1H\}$ NMR ([D_6]-dmso): δ = 165.5 ppm. $C_2H_{12}Cl_2N_8Pd$ (325.5): calcd. C 7.38, H 3.72, N 34.43, Cl 21.78; found C 7.89, H 3.38, N 33.82, Cl 22.86.

X-ray Crystallographic Studies: For compounds **3**, **5**, **6** and **7**, diffraction intensity data were collected at T = 292 K using CAD4 Express Enraf–Nonius software[40] with a CAD4 diffractometer equipped with a graphite monochromator [Mo-K_α radiation (λ = 0.7107 Å)], and data reduction using RC93.[41] All data were corrected for Lorentz-polarisation effects and empirical absorption correction using DIFABS[42] was applied. The structure was solved by direct methods using SIR-92[43] and refined by least-squares methods on F using CRYSTALS,[44] except in the case of compound **5**, for which the structure was refined by least-squares methods on F^2 using SHELXL-97[45] incorporated in the WinGX package.[46] Hydrogen atoms were placed geometrically after each cycle with isotropic parameters constrained to be 1.2 times the U_{eq} of the carrier atoms. Molecules were drawn using CAMERON.[47]

For compound **4**, despite the screening of a large number of crystals, we were unable to find crystals for which the conventional auto-indexing routine of the SMART programme[48] could find a plausible unit cell. Nonetheless, data collection was performed at T = 293 K on a SMART-CCD Bruker diffractometer [Mo-K_α radiation (λ = 0.7107 Å)] using the ω-scan method, in the range $2° < \theta < 25°$. Many reflections showed a splitting typical of twin crystals; therefore a twin analysis with the program GEMINI[49] was attempted using about 800 of the collected reflections. This analysis revealed a multiple twinning with at least two different crystal components. It was possible to obtain a substantial number of pure reflections, from the larger of the two identified domains, which allowed the resolution of the structure by traditional Patterson methods. Data from the second component were also integrated, but due to the much worse internal agreement, were neglected. The space group was determined from the systematic absences, while the cell constants were refined with the data reduction software SAINT.[50] The collected intensities were corrected for Lorentz and polarization factors and empirically for absorption using the SADABS program.[51] The structure was refined by full-matrix least-squares on F^2 using SHELX-97[52] using anisotropic thermal parameters for all atoms except hydrogens. The hydrogen atoms were located, during the last stage of refinement, in the difference Fourier maps. The molecule was drawn using ORTEP.[53] The search for hydrogen bonds in the packing was carried out using PLATON.[54]

Crystal data, data collection parameters and convergence results are listed in Table 1.

Table 1. Crystal data and structure refinement for **3**, **4**, **5**, **6** and **7**.

	3	**4**	**5**	**6**	**7**
Empirical formula	$C_2H_{14}Cl_4N_8Pt \cdot 2^1/_2H_2O$	$C_2H_{12}N_{10}O_6Pt$	$C_3H_{12}Cl_2N_4OPtS \cdot 2H_2O$	$CH_6Cl_2N_4Pd$	$C_2H_{12}Cl_2N_8Pd$
M_w	532.2	467.3	454.3	251.4	325.5
Crystal system	monoclinic	monoclinic	monoclinic	monoclinic	monoclinic
Space group	*I2/a*	*C2/c*	$P2_1/n$	$P2_1/n$	$P2_1/n$
a [Å]	7.316(1)	14.154(3)	8.520(4)	5.866(1)	5.991(2)
b [Å]	24.659(1)	12.633(2)	8.950(6)	11.644(2)	10.939(3)
c [Å]	8.494(1)	6.664(1)	16.586(8)	9.401(2)	7.786(2)
α [°]	90	90	90	90	90
β [°]	96.87(1)	100.40(1)	90.45(1)	90.45(2)	102.24(2)
γ [°]	90	90	90	90	90
V [Å^3]	1521.3(6)	1172.0(4)	1265(1)	642.0(2)	498.7(3)
Z	4	4	4	4	2
$\rho_{calcd.}$ [g·cm^{-3}]	2.33	2.65	2.39	2.60	2.17
$F(000)$	992	880	856	480	320
μ [mm^{-1}]	9.93	12.02	11.67	3.62	2.37
θ range [°]	2.55–27.96	2–25	2.46–29.98	2.79–27.96	3.26–27.96
Measured reflections	4026	4707	7328	1768	1376
Independent reflections	1837	1027	3672	1550	1205
Observed reflections	1082	762	2866	997	697
Selection criterion	$I > 3\sigma(I)$	$I \geq 4\sigma(I)$	$I > 2\sigma(I)$	$I > 3\sigma(I)$	$I > 2\sigma(I)$
R_1	0.037	0.0313	0.030	0.030	0.043
wR_2	0.040	0.0741	0.071	0.076	0.045
GOF	0.91	1.06	1.02	0.97	0.96
Residual electron density [e·Å^{-3}]	–2.16/1.03	–0.94/5.07	–1.38/1.74	–0.69/0.63	–1.33/0.84

CCDC-279695 (for **3**), -623191 (for **4**), -296006 (for **5**), -279568 (for **6**), and -279569 (for **7**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

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