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9-Methyladenine complexes of platinum(II) stabilized by trimethylphosphine: Use of ^{15}N nuclear magnetic resonance spectroscopy to assign the co-ordination site

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The new 9-methyladenine (made) complexes *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ and *cis*-$[\{Pt(PMe_3)_2(made - H)\}_2][NO_3]_2$ have been prepared and characterized. They are formed by treating stoichiometric amounts of the nucleobase with an aqueous solution of *cis*-$[Pt(PMe_3)_2(NO_3)_2]$ at autogenous and neutral pH, respectively. A detailed multinuclear (^1H, ^{31}P, ^{195}Pt, ^{13}C and ^{15}N at natural abundance) NMR investigation in $(CD_3)_2SO$ indicated that in the mononuclear complex the adenine ligands are N(1)-co-ordinated and that rotation around the metal–nitrogen bonds is slow on the NMR time-scale leading to the presence of two conformers with a relative abundance of *ca.* 2:1. In the dinuclear complex the NH_2-deprotonated adenine acts as a bridging ligand through the N(1) and N(6) atoms. The sites of metal binding are clearly evidenced in the ^{15}N NMR spectra by the remarkable shifts shown by the co-ordinated nitrogens (60 ppm upfield for the endocyclic atom and 25 ppm downfield for the exocyclic one, with respect to the unco-ordinated nucleobase) and their coupling with the ^{31}P nucleus of the ligand in mutual *trans* position ($^2J_{NP}$ *ca.* 60 Hz).

In spite of the low receptivity of the ^{15}N nucleus (3.85×10^{-6} with respect to the proton),[1] an increasing number of NMR techniques such as heteronuclear multiple quantum coherence (HMQC), heteronuclear multiple-bond correlation (HMBC), insensitive nuclei enhancement *via* polarization transfer (INEPT), *etc.*, allow the attribution of the ^{15}N chemical shifts of nitrogen-containing compounds, even for moderately concentrated solutions. We have recently applied this spectroscopy to some mono- and poly-nuclear platinum(II) cytosine complexes of which the structure was known.[2] The metal co-ordination causes remarkable changes in the electronic properties of the pyrimidine ring which result in diagnostic shifts of the resonances of the platinated nitrogens.

As an extension of our work on the synthesis and characterization of platinum(II) complexes of model nucleobases with tertiary phosphines as ancillary ligands, we have now investigated the reaction of *cis*-$[Pt(PMe_3)_2(NO_3)_2]$ with 9-methyladenine (made). The neutral 9-substituted adenine contains three endocyclic nitrogen atoms of which only N(7) and N(1) are important sites for metal binding.[3] Most of these adenine complexes of platinum(II) are N(7) co-ordinated.[4] However, examples of the involvement of the N(1) atom are also known, in dinuclear derivatives in which the simultaneous co-ordination of two metal centres to the N(1) and N(7) sites is observed,[5] as well as in mononuclear complexes.[6]

We have recently described a new binding mode of adenine in platinum chemistry showing that the hydroxo complex *cis*-$[\{Pt(PMe_3)_2(\mu\text{-}OH)\}_2][NO_3]_2$, the species present in solutions of *cis*-$[Pt(PMe_3)_2(NO_3)_2]$ at neutral pH,[7] deprotonates the exocyclic NH_2 group of 9-ethyladenine giving the dinuclear derivative *cis*-$[\{Pt(PMe_3)_2(eade - H)\}_2][NO_3]_2$ (eade − H = NH_2-deprotonated 9-ethyladenine) in which the nucleobase acts as a bridging ligand through the N(1) and N(6) atoms.[8]

In this paper we describe the synthesis and characterization of the new complexes *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ and *cis*-$[\{Pt(PMe_3)_2(made - H)\}_2][NO_3]_2$ (made − H = NH_2-deprotonated 9-methyladenine) formed when the reaction

made

between *cis*-$[Pt(PMe_3)_2(NO_3)_2]$ and the nucleobase is carried out at autogenous and neutral pH, respectively. The compounds have been characterized by multinuclear NMR spectroscopy (^1H, ^{31}P, ^{195}Pt, ^{13}C and ^{15}N at natural abundance) showing that the ^{15}N data are particularly useful in determining the metal co-ordination sites in this class of complexes stabilized by trimethylphosphine.

Results and Discussion

Characterization of *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$

Aqueous solutions of the nitrato complex cis-$[Pt(PMe_3)_2(NO_3)_2]$ at autogenous pH react quantitatively at room temperature with 2 equivalents of made to form the bis adduct *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ which has been isolated as a white microcrystalline solid. In Tables 1–3 the ^1H, ^{13}C and ^{15}N NMR data for this compound, obtained in $(CD_3)_2SO$ solution, along with those of the unco-ordinated nucleobase, are collected; for the ^{31}P and ^{195}Pt data see the Experimental section.

For all the nuclei investigated the corresponding spectrum exhibits two sets of resonances having an intensity ratio of *ca.* 2:1. Thus, in the ^1H NMR spectrum at 400 MHz each proton of the adenine is observed as a couple of singlets, the only exception being the NH_2 hydrogens which are seen as a single very broad resonance at δ *ca.* 8.8. The phosphine protons also occur as two overlapped doublets ($^2J_{PH}$ 11.5 Hz, with unresolved ^{195}Pt satellites), the relative intensities (2:1) of which compare well with those of the ^{31}P signals in the corresponding $^{31}P\text{-}\{^1H\}$ NMR spectrum. The latter is

Table 1 Proton NMR data for the isolated complexes (L = PMe_3) and the free base in $(CD_3)_2SO$ at 298 K. The coupling constant $^1J_{PH}$ values (in Hz) are in parentheses

Compound	H(2)	H(8)	NH_2/NH	NCH_3	$P(CH_3)_3$
made	8.13	8.06	7.13	3.69	—
cis-$[PtL_2(made)_2][NO_3]_2$	8.62	8.27	8.8	3.69	1.58 (11.5)*
	8.75	8.28	8.8	3.70	1.59 (11.5)
cis-$[\{PtL_2(made\text{-}H)\}_2][NO_3]_2$	8.11	8.02	6.58	3.58	1.86 (11.7)
					1.41 (10.6)

* More abundant species.

Table 2 Carbon-13 NMR data for the isolated complexes (L = PMe_3) and the free N(9)-substituted adenine in $(CD_3)_2SO$ at 298 K. Coupling constant values (Hz) $^1J_{CH}$ in parentheses, $^3J_{CH}$ in square brackets

Compound	C(2)	C(4)	C(5)	C(6)	C(8)	N(9)CH_3	$P(CH_3)_3$
made	152.4	149.8	118.3	155.8	141.3	29.3	
	(198.1)	[12.1, 4.8][a]	[10.9][b]	[11.3]	(210.8)	(140.8)	
cis-$[PtL_2(made)_2][NO_3]_2$[c]	151.4	147.9	119.3[d]	153.6	143.8	29.82	13.8[e]
	(208.8)	[11.9, 4.6][a]	[11.2]	[8.3]	(214.5)	(141.3)	
	150.8	148.1	119.0[f]	154.1	144.1	29.77	13.4[e]
	(208.5)	[11.8,4.2][a]	[11.8]	[8.3]	(215)	(141.6)	
cis-$[\{PtL_2(made\text{-}H)\}_2][NO_3]_2$	151.3	144.9	123.1[g]	162.5	141.4	29.6	14.9;[h] 14.0[i]
	(203)	[12, <4][a]	[11]	[7]	(213)	(141)	

[a] The first value refers to $^3J_{[C(4)\text{–}H(2)]}$, the second to $^3J_{[C(4)\text{–}H(8)]}$. [b] Atom C(5) shows, in addition, a long-range correlation with the amino protons. [c] First row gives values for the most abundant conformer. [d] 1:2:1 Triplet, $^4J_{CP}$ = 1.4 Hz. [e] Second-order multiplet (see text). [f] 1:2:1 Triplet, $^4J_{CP}$ = 1.6 Hz. [g] 1:2:1 Triplet, $^4J_{CP}$ = 4.6 Hz. [h] Doublet of doublets, $^1J_{CP}$ = 41.9 and $^3J_{CP}$ = 1.3 Hz. [i] Doublet, $^1J_{CP}$ = 39.4 Hz.

Table 3 Nitrogen-15 NMR data for the isolated complexes (L = PMe_3) and the free N(9)-substituted adenine in $(CD_3)_2SO$ at 298 K. Coupling constant values (Hz) are $^1J_{NH}$ in parentheses; $^2J_{NP}$ in square brackets and $^2J_{NH}$ in braces

Compound	N(1)	N(3)	N(6)	N(7)	N(9)
made	−141.1[a]	−151.0	−296.9	−137.1	−225.9
	{15.2}	{15.2}	(−89.0)	{10.6}	{8.2}
cis-$[PtL_2(made)_2][NO_3]_2$[b]	−201.2[a]	−144.2	−284.1[c]	−132.8	−217.7
	[57 ± 10]	{13.9}		{11.3}	{7.8}
	{11.4}				
	−199.7[a]	−142.2	−294.8[c]	−133.1	−217.7
	[60 ± 10]	{13.7}		{12.1}	{7.8}
	{10.9}				
cis-$[\{PtL_2(made - H)\}_2][NO_3]_2$	−201.2	−152.0	−268.4	−133.5	−219.9
	[60 ± 10]	{13}	(−77)	{11}	{7}
	{11}		[48 ± 10]		

[a] The N(1) nucleus shows also a long-range correlation with the amino-group protons. [b] The first row gives value for the most abundant conformer. [c] The amino nitrogen resonances were obtained through a refocused INEPT experiment, with proton decoupling, by using a standard pulse sequence.

characterized by two singlets, symmetrically flanked by ^{195}Pt satellites with $^1J_{PtP}$ values typical for phosphorus *trans* to nitrogen donors.[9] Two sets of signals are also seen in the ^{195}Pt-$\{^1H\}$ NMR spectrum, each being a 1:2:1 triplet due to coupling with the ^{31}P nuclei. These data indicate the presence in solution of two species, both containing chemically equivalent phosphine ligands (*i.e. trans* to the same donor atom) which might be due to different sites of metal complexation on the adenine ligands. It is known that selective co-ordination of adenine at the N(7) site is observed only in strongly acidic media whereas in moderately acidic or neutral solutions the N(7) and N(1) atoms have comparable affinity toward platinum(II) electrophiles.[6,10] In addition to X-ray analysis, the binding sites have been differentiated with a variety of studies such as pH-dependent ^1H NMR, facilitated by the use of adenine selectively deuteriated at the C(8) position, IR and Raman spectroscopy.

In order to define the site of metal complexation in *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ we have undertaken a ^{15}N NMR investigation because the ^1H spectra recorded both at 400 and 90 MHz were not diagnostic. The aromatic protons of the adenine under high-field conditions did not exhibit coupling with ^{195}Pt and at low field the resolution was insufficient. The unambiguous assignment of the H(8) and H(2) resonances was achieved through a full analysis of the ^{13}C NMR spectrum.

^{13}C NMR spectra. Fig. 1 reports the inverse-detected ^1H–^{13}C shift-correlated spectrum of the isolated complex in the low-field region. Each purine carbon is observed as a couple of resonances with an intensity ratio of 2:1. The carbon resonances at δ 143.8 and 144.1, attributable to the C(8) atom in comparison with the free adenine (Table 2), correlate with the proton resonances at δ 8.27 and 8.28, respectively, through a $^1J_{CH}$ of 215 Hz, which are straightforwardly assigned to H(8). The resonances at δ 151.4 and 150.8 are both correlated with the proton resonances centred at δ 8.62 and 8.75, respectively, through a $^1J_{CH}$ of 209 Hz, which are in turn assigned to the C(2) and to H(2) atoms.

The remaining carbon resonances were assigned through the detection of long-range correlation ($^3J_{CH}$) with the H(2), H(8) and NCH_3 protons. The conventional ^{13}C-$\{^1H\}$ spectrum, obtained at 100.61 MHz for a 0.1 mol dm^{-3} solution, indicates that none of the purine carbons exhibits coupling with the ^{195}Pt nucleus, probably as a consequence of the large contribution of the chemical shift anisotropy.[11] Only C(5) appears coupled with the ^{31}P nuclei as indicated by the occurrence of apparent 1:2:1 triplets ($^4J_{CP}$ = 1.5 Hz, average). The phosphine carbons are characterized by two partially overlapped multiplets, with relative intensity 2:1, each interpretable as an A_3XX' spin system[12] centred at δ 13.8 and 13.4, for which $|^1J_{CP} + {}^3J_{CP}|$ = 44 Hz.

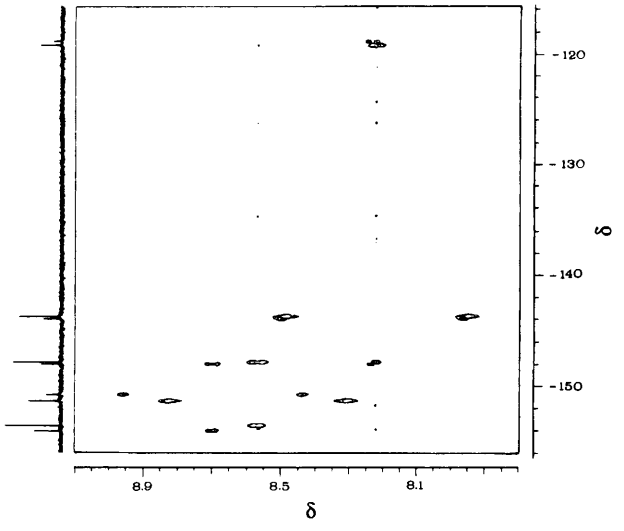

Fig. 1 Inverse-detected ^{1}H–^{13}C shift-correlated spectrum (aromatic region) of *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ in $(CD_3)_2SO$ obtained in a HMBC experiment without the low-pass J filter and no decoupling during acquisition

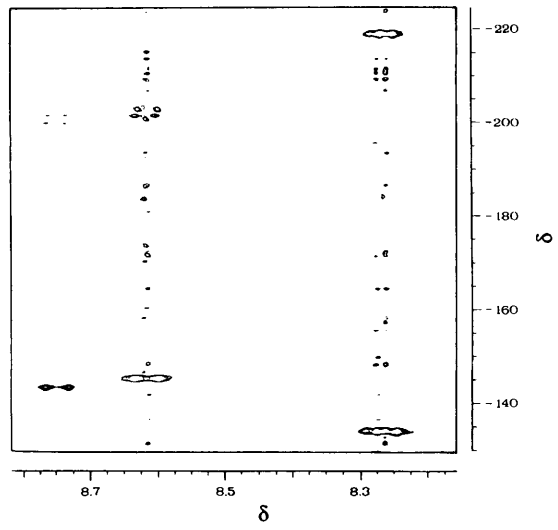

Fig. 2 Inverse-detected ^{1}H–^{15}N shift-correlated spectrum of *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ in $(CD_3)_2SO$ obtained in a HMBC experiment without decoupling during acquisition

In Table 2 the ^{13}C NMR parameters of the free nucleobase are also reported which agree well with those found in the literature.[13] The comparison of these data with those of the co-ordinated adenine in *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ shows a shielding of the C(2), C(4) and C(6) atoms and a deshielding of C(8) and C(5). The lack of ^{13}C–^{195}Pt coupling of the carbon atoms adjacent to the site of platination and the small variations of the ^{13}C parameters of the nucleobase upon co-ordination prevent the unambiguous determination of the site of metal binding. However, the inverse-detected ^{1}H–^{13}C NMR spectrum enables the correct assignment of the proton resonances which are the basis of the subsequent assignment of those at nitrogen.

^{15}N NMR spectra. Unequivocal evidence about the site of platination in this adenine complex stems from its ^{15}N NMR spectrum (data in Table 3 together with those of the uncoordinated nucleobase obtained in our laboratory). In Fig. 2 the inverse-detected ^{1}H–^{15}N shift-correlated spectrum of a $(CD_3)_2SO$ solution (*ca.* 0.1 mol dm^{-3}) of *cis*-$[Pt(PMe_3)_2(made)_2][NO_3]_2$ is reported. All but one adenine nitrogen show two sets of resonances and those centred at δ −201.2 and −199.7 exhibit coupling with one ^{31}P nucleus. The more intense proton resonance at δ 8.62, assigned to H(2) on the basis of the ^{1}H–^{13}C correlation, shows two long-range correlations with the nitrogen signals at δ −144.2 and −201.2. The H(2) resonance of the less-abundant species correlates with the nitrogens at δ −142.2 and −199.7. The resonances at δ −201.2 and −199.7 are attributable to the N(1) atom owing to their long-range correlations with the amino-group protons, not visible in Fig. 2 because of their low intensities. Consequently the assignment of the N(3) resonance was straightforward. The N(7) and N(9) resonances, detected through the long-range correlation with the H(8) proton, were assigned on the basis of their different values of the ^{2}J[NH(8)] coupling constant.[14] Although the ^{15}N–^{195}Pt interaction was not detectable, owing to the high field utilized,[11] the presence of a two-bond ^{15}N–^{31}P coupling for the N(1) resonance provides unequivocal evidence of the involvement of this atom in the metal binding. The observed value of $^{2}J_{NP}$ is in the range found in other square-planar complexes having the coupled nuclei in mutual *trans* positions.[2,15] The N(1) resonances show a remarkable shielding (60 ppm) upon metallation, according to the change in the nitrogen screening constant;[16] the remaining nitrogens undergo minor variations of their chemical shifts, and in particular the N(7) resonance is deshielded by 4 ppm with respect to the free base.

We conclude that, since both the species present in the solution of *cis*-$[Pt(PMe_3)_2(made)_2]^{2+}$ contain the adenine ligands platinated at the N(1) site, the two sets of resonances seen in the ^{15}N NMR spectra must be due to hindered rotation of the purine ring around the platinum–nitrogen bond. The different chemical environments of the nucleobases when they are oriented in the same (head-to-head) or in the opposite (head-to-tail) direction with respect to the platinum co-ordination plane account for the differences of the spectroscopic parameters of all the nuclei investigated. Moreover, since the N(1) resonance of the relatively more abundant species is identical to that found for *cis*-$[\{Pt(PMe_3)_2(made - H)\}_2]^{2+}$ (see later), it is likely that the head-to-tail arrangement of the two adenines corresponds to the more stable conformation.

Attempts to study the activation energy for the interconversion of the two species were prevented by the relative instability of the complex. At temperatures higher than 110 °C, a single resonance in the ^{31}P NMR spectrum (at 36.23 MHz) is detectable. However, the appearance of a yellow colour after heating the solution, initially colourless, indicates that some irreversible changes have occurred.

Characterization of *cis*-$[\{Pt(PMe_3)_2(made - H)\}_2][NO_3]_2$

The complex *cis*-$[\{Pt(PMe_3)_2(made - H)\}_2]^{2+}$ has been obtained by treating the nucleobase with an aqueous solution of *cis*-$[Pt(PMe_3)_2(NO_3)_2]$ at neutral pH or with the hydroxo complex *cis*-$[\{Pt(PMe_3)_2(\mu\text{-}OH)\}_2]^{2+}$, according to reaction (1). The isolated compound exhibits ^{1}H and ^{31}P NMR data

$$cis\text{-}[\{Pt(PMe_3)_2(\mu\text{-}OH)\}_2]^{2+} + 2\,made \longrightarrow cis\text{-}[\{Pt(PMe_3)_2(made - H)\}_2]^{2+} + 2\,H_2O \quad (1)$$

very similar to those of the 9-ethyladenine analogue, *cis*-$[\{Pt(PMe_3)_2(eade - H)\}_2][NO_3]_2$ recently characterized by single-crystal X-ray analysis.[8] The latter contains two NH_2-deprotonated 9-ethyladenine anions bridging two *cis*-$Pt(PMe_3)_2$ units through the N(1) and N(6) atoms, arranged in a head-to-tail fashion. Accordingly, the ^{1}H NMR spectrum of *cis*-$[\{Pt(PMe_3)_2(made - H)\}_2][NO_3]_2$, obtained at 89.55 MHz, shows the resonance attributable to H(2) (Table 1) flanked by a shoulder due to poorly resolved platinum satellites ($^{3}J_{PtH}$ = 15 Hz), the right part of which is hidden by the H(8) resonance. The N(6)H resonance is characterized by a broad singlet with non-detectable ^{195}Pt–^{1}H coupling; the two chemically non-

equivalent phosphines give two well separated doublets with distinct $^2J_{HP}$ values and scarcely resolved platinum satellites. The dimeric nature of the cation *cis*-[{Pt(PMe$_3$)$_2$(made − H)}$_2$]$^{2+}$ is evidenced in the ^{31}P-{^{1}H} NMR spectrum (obtained at 36.23 MHz) by the presence of resonances attributable to long-range platinum–phosphorus couplings ($^5J_{PtP}$ = 17 Hz), symmetrically flanking the main AB multiplet. Similar effects were detected for the analogous *cis*-[{Pt(PMe$_3$)$_2$(eade − H)}$_2$]$^{2+}$ and the structurally related 1-methylcytosine derivative *cis*-[{Pt(PMe$_3$)$_2$(mcyt − H)}$_2$]$^{2+}$.[7,8]

The ^{13}C NMR data, obtained through a conventional ^{13}C-{^{1}H} spectrum, and assigned through an inverse-detected ^{1}H–^{13}C NMR spectrum, are collected in Table 2. With the exception of C(5), all the purine carbons occur as singlets, and no coupling with the platinum was detected. The C(5) resonance is observed as an apparent 1:2:1 triplet due to coupling with the ^{31}P nuclei. From Table 2 it is clear that it is the replacement of one amino proton in the adenine by the *cis*-Pt(PMe$_3$)$_2^{2+}$ electrophile that is responsible for the more remarkable shifts of the purine carbons: 6.7 ppm for C(6), 4.8 ppm for C(5) and −4.9 ppm for C(4), while C(8) is only slightly affected. As observed in the case of *cis*-[Pt(PMe$_3$)$_2$(made)$_2$]$^{2+}$, the ^{13}C NMR data do not appear particularly useful in solving the N(1), N(7) site dichotomy of platination of the nucleobase.

More informative are the ^{15}N NMR spectra obtained through inverse-detection experiments. Fig. 3(*a*) reports the inverse-detected ^{1}H–^{15}N shift-correlated HMQC spectrum of *cis*-[{Pt(PMe$_3$)$_2$(made − H)}$_2$][NO$_3$]$_2$, in the region of the exocyclic nitrogen, from which it is clear that N(6) correlates with the directly bonded hydrogen ($^1J_{NH}$ = −77 Hz) and exhibits coupling with one ^{31}P nucleus ($^2J_{NP}$ *ca.* 50 Hz). In Fig. 3(*b*) the HMBC spectrum of the endocyclic nitrogen atoms is depicted. As appears from the F$_1$ axis, the resonance at δ −201.2, which correlates with the H(2) proton, exhibits coupling with one ^{31}P nucleus ($^2J_{NP}$ = *ca.* 60 Hz) and therefore it is attributable to the N(1) atom. The resonance at δ −152, which also correlates with the H(2) proton, is attributable to N(3), while those centred at δ −219.9 and −133.5 which are correlated with H(8) proton are assignable to N(9) and N(7), respectively. Thus, the replacement of one amino proton of the adenine by *cis*-Pt(PMe$_3$)$_2^{2+}$ results in a downfield shift for the N(6) resonance as a result of the opposite effects due to deprotonation and metallation.[16] On the other hand the metallation of the N(1) atom causes the expected upfield shift of its resonance, the value of which is identical to that observed for the more abundant conformer of *cis*-[Pt(PMe$_3$)$_2$(made)$_2$]$^{2+}$.

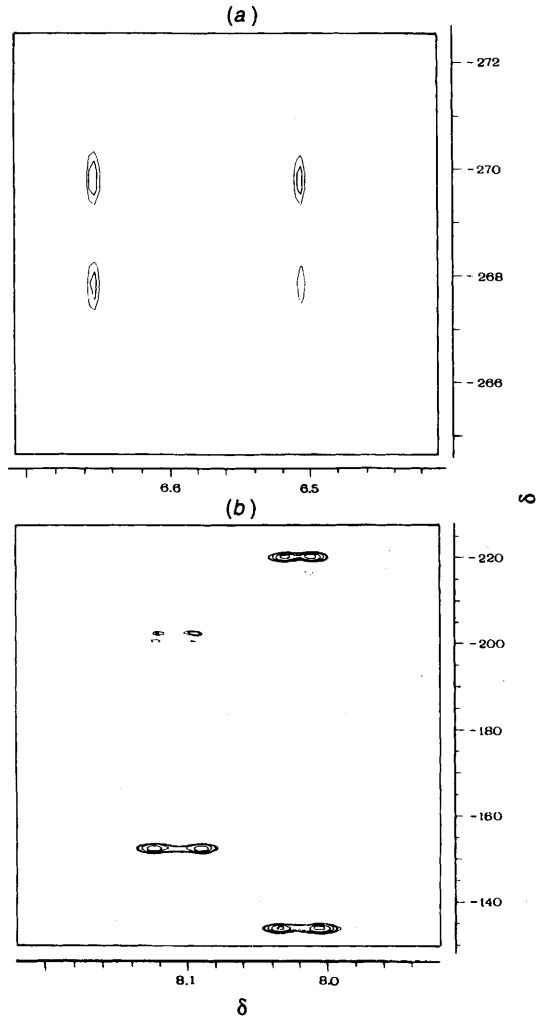

Fig. 3 Inverse-detected ^{1}H–^{15}N shift-correlated spectra of *cis*-[{Pt(PMe$_3$)$_2$(made − H)}$_2$][NO$_3$]$_2$ obtained in (*a*) a HMQC experiment in the NH region without decoupling during acquisition, and (*b*) a HMBC experiment (aromatic region) without decoupling during acquisition

Conclusion

In the reaction of the aqua complex *cis*-[Pt(PMe$_3$)$_2$(OH$_2$)$_2$]$^{2+}$ with made, the nucleobase is selectively platinated at the N(1) position, a result in line with the higher basicity of this donor atom but in contrast with other findings for related amine complexes in which the preference for the N(7) site was observed.[6]

Unlike the 1-methylcytosine[8] and 9-methylguanine[17] analogues, for which a single conformer was detected in solution, in the bis adduct *cis*-[Pt(PMe$_3$)$_2$(made)$_2$]$^{2+}$ the two conformations arising from hindered rotation around the Pt–N(1) bonds have comparable stability. Moreover, the binding mode of the NH$_2$-deprotonated 9-substituted adenines, previously characterized in the solid state for the ethyl derivative,[8] has been confirmed in solution for *cis*-[{Pt(PMe$_3$)$_2$(made − H)}$_2$]-[NO$_3$]$_2$, showing that N(1), N(6) are the only atoms involved in the metal co-ordination.

The detection of ^{15}N chemical shifts, at natural abundance, through modern inverse-detected ^{1}H–^{15}N NMR spectroscopy, allows the assignment of the complexation sites in these adenine complexes stabilized by trimethylphosphine. This approach requires the independent assignment of the H(2) and H(8) resonances which can be, in turn, obtained through their long-range correlations with the carbons; it overcomes the lack of J_{HPt} and J_{CPt} at high magnetic field and the difficulties in rationalizing the changes in ^{1}H chemical shifts of the complexed with respect to the free nucleobase.

Experimental

Materials and methods

The complexes *cis*-[Pt(PMe$_3$)$_2$(NO$_3$)$_2$] and *cis*-[{Pt(PMe$_3$)$_2$(μ-OH)}$_2$][NO$_3$]$_2$ were synthesized as previously reported.[6] The nucleobase 9-methyladenine prepared according to the literature method.[18] The ^{1}H, ^{13}C, ^{31}P, ^{195}Pt and ^{15}N NMR spectra were obtained in (CD$_3$)$_2$SO at 298 K in 5 mm sample tubes on a Bruker AMX 400-WB spectrometer operating at 400.13, 100.61, 161.98, 85.88 and 40.56 MHz, respectively. The ^{1}H and ^{13}C spectra were referenced by assigning the ^{1}H impurity in the solvent at δ 2.49 and the ^{13}C multiplet at δ 39.5, respectively. The external references were H$_3$PO$_4$ (85% w/w in D$_2$O) for ^{31}P, Na$_2$PtCl$_4$ in D$_2$O (adjusted to δ −1628 from Na$_2$PtCl$_6$) for ^{195}Pt and MeNO$_2$ (in CDCl$_3$ at 50% v/v) for ^{15}N.

For proton-decoupled ^{13}C, ^{31}P and ^{195}Pt NMR spectra typical conditions were: 0.8–1 s for relaxation delay, 60° pulse angle, spectral widths of 18, 12 and 50 kHz respectively, with 16 or 32k data points. Natural-abundance ^{15}N chemical shifts

were obtained through ^{1}H-detected heteronuclear multiple-quantum or multiple-bond correlation (HMQC or HMBC) experiments without decoupling during acquisition.[19,20] The acquisition parameters were as follows: in F2, spectral width in the range 1–2 ppm with FID resolution 0.6–1.2 Hz and 128 scans; in F1, spectral width 200 ppm with a FID resolution 15–63 Hz and 512–128 increments. Relaxation and evolution delays for one-bond and long-range coupling constants were 1 s, 5.5 ms and 50 ms, respectively. Zero filling in F1 and F2, a sine function in F1 and sensitivity function in F2 (line-broadening = 1) were applied before Fourier transformation. The refocused INEPT spectrum for the mononuclear complex was obtained using a standard pulse sequence with proton decoupling. Typical acquisition parameters were: spectral width 20 kHz, 32k data points, relaxation delay 1 s, delay for the coherence transfer corresponding to a $^1J_{NH}$ of 90 Hz and 5000 scans. The HMBC spectra were also recorded for the ^{13}C nuclei. The experimental conditions were similar to those reported for ^{15}N with the following differences: 64 scans, 256 increments and evolution delay 62 ms. Proton, ^{31}P, ^{13}C and ^{195}Pt NMR spectra were also obtained on a JEOL 90Q spectrometer.

Preparations

***cis*-[Pt(PMe$_3$)$_2$(made)$_2$][NO$_3$]$_2$.** To a solution of *cis*-[Pt(PMe$_3$)$_2$(NO$_3$)$_2$] (252 mg, 0.536 mmol) in water (25 cm^3) a 2:1 ratio of 9-methyladenine (160 mg) was added and the resulting solution was stirred at room temperature for 16 h. The solvent was evaporated under vacuum and the residue dissolved in methanol (3.5 cm^3). Addition of diethyl ether afforded a microcrystalline precipitate which was filtered off and dried under vacuum [*ca.* 10^{-3} Torr (*ca.* 0.133 Pa), 24 h], yield 303 mg (73%) (Found: C, 27.8; H, 4.25; N, 20.65. $C_{18}H_{32}N_{12}O_6P_2Pt$ requires C, 28.1; H, 4.15; N, 21.9%). NMR [at 27 °C in $(CD_3)_2SO$]; ^{31}P, δ −26.76 (s, relative intensity 2, $^1J_{PtP}$ 3250 ± 1) and −27.11 (s, 1, $^1J_{PtP}$ = 3238 ± 1), ^{195}Pt, δ −4380.1 (1:2:1 t, 2, $^1J_{PtP}$ 3250 ± 3) and −4391.4 (1:2:1 tr, 1, $^1J_{PtP}$ 3238 ± 3 Hz).

***cis*-[{Pt(PMe$_3$)$_2$(made − H)}$_2$][NO$_3$]$_2$.** 9-Methyladenine (37.8 mg, 0.254 mmol) was added to a solution of *cis*-[{Pt(PMe$_3$)$_2$(μ-OH)}$_2$(NO$_3$)$_2$] (108 mg, 0.127 mmol) in water (10 cm^3). The resulting solution was stirred at room temperature for 48 h, then treated with charcoal at 50 °C for a few minutes, filtered and the solvent removed *in vacuo*. The solid residue was dissolved in MeOH–EtOH (1:1, 3.5 cm^3). Addition of Et$_2$O (10 cm^3) afforded a white powdery solid which was filtered off and dried *in vacuo* (85 mg, 60%) (Found: C, 24.45; H, 4.40; N, 13.65. $C_{12}H_{24}N_6O_3P_2Pt$ requires C, 25.85; H, 4.35; N, 15.10%). NMR [at 27 °C in $(CD_3)_2SO$]: ^{31}P, δ (AB multiplet) −30.33 ($^1J_{PtP}$ 3004 ± 1) and −30.98 ($^1J_{PtP}$ 3236 ± 1) with $^2J_{PP}$ 26.1 Hz; ^{195}Pt, δ −4207 (dd).

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