Metal Complexes of Benzodiazepines. Part 3.[1] Synthesis and Characterization of Organometallic Complexes of Platinum(II)

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The complexes *cis*-$[PtMe_2(Me_2SO)L^1]$ and $[PtR_2L^2]$ (R = Me or Ph) are easily obtained by reaction in CH_2Cl_2 of the complexes $[PtMe_2(Me_2SO)_2]$ or $[\{PtPh_2(Et_2S)\}_2]$ with L^1 = 2,3-dihydro-2,2,4-trimethyl-1*H*-1,5-benzodiazepine or L^2 = bromazepam = 7-bromo-1,3-dihydro-5-(2-pyridyl)-2*H*-1,4-benzodiazepin-2-one. They are the first examples of simple organometallic adducts of benzodiazepines with platinum(II). Their ^1H and ^{13}C NMR spectra suggest the co-ordination of L^1 through N^5, while L^2 acts as a bidentate ligand by means of the imine and pyridine nitrogen atoms. The co-ordinated heterocyclic rings show a notable increase in their inversion barrier.

Despite the considerable number of organometallic complexes containing Pt–C σ bonds,[2] few examples of compounds of this type with biologically relevant molecules have been reported.[3] Benzodiazepines, a class of psychotherapeutic agents widely used for their tranquilizing and sedative hypnotic properties, have attracted an increasing interest as ligands toward metal ions.[1,4] Recently some of us reported the synthesis, crystal structure, and characterization in the solid and solution of the compound *trans*-dichloro(7,8-dichloro-2,3-dihydro-2,2,4-trimethyl-1*H*-1,5-benzodiazepine)(tri-*n*-propylphosphine)palladium(II),[1b] and investigated the thermodynamics and kinetics of the reactions between the complex *trans*-$[Pd_2I_4(PPr^n_3)_2]$ and a variety of typical 1,4-benzodiazepines.[1a]

In this paper we report the synthesis and characterization of some organometallic complexes of platinum(II) of formula *cis*-$[PtMe_2(Me_2SO)L^1]$ (L^1 = 2,3-dihydro-2,2,4-trimethyl-1*H*-1,5-benzodiazepine) and $[PtR_2L^2]$[R = Me or Ph; L^2 = bromazepam = 7-bromo-1,3-dihydro-5-(2-pyridyl)-2*H*-1,4-benzodiazepin-2-one]. Cyclometallated derivatives [PtCl(L − H)L] and $[PtCl_2(L - H)]$ (L = diazepam = 7-chloro-1,3-dihydro-1-methyl-5-phenyl-2*H*-1,4-benzodiazepin-2-one) have been briefly described,[4d] but, to the best of our knowledge, our complexes represent the first examples of simple organometallic adducts of benzodiazepines with platinum(II).

Experimental

The ligand L^2, commercially available, was used without further purification; L^1 was prepared by the published procedure.[5] Infrared spectra were recorded as Nujol mulls between CsI plates on a Perkin-Elmer FT-IR 1720X instrument, NMR spectra on a Bruker 80Q (^1H at 80 MHz) or a Varian Gemini 300 instrument (^1H at 300 MHz, ^{13}C at 75 MHz) from freshly prepared solutions in $CDCl_3$, [$^2H_7$]dimethylformamide or $(CD_3)_2SO$ and the chemical shifts are relative to internal tetramethylsilane.

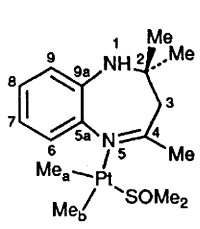
Preparation of the Complexes.—The complexes *cis*-$[PtCl_2(Me_2SO)_2]$, *cis*-$[PtMe_2(Me_2SO)_2]$, and $[\{PtPh_2(Et_2S)\}_2]$ were prepared according to literature procedures.[6] A synthesis of the complex $[PtCl_2L^2]$ was previously reported,[4b] but the procedure described here was found more convenient.

cis-(*Dimethyl sulphoxide*)(2,3-*dihydro*-2,2,4-*trimethyl*-1H-1,5-*benzodiazepine*)*dimethylplatinum*(II) **1**. To a solution of *cis*-$[PtMe_2(Me_2SO_2)_2]$ (0.200 g, 0.52 mmol) in CH_2Cl_2 (5 cm^3), L^1 (0.101 g, 0.54 mmol) dissolved in the same solvent (5 cm^3) was added dropwise. The reaction mixture was stirred at room temperature for 4 h, and diethyl ether was added until precipitation started. After cooling the mixture overnight at −20 °C, complex **1** was isolated as a white solid (0.180 g, 70%) (Found: C, 38.9; H, 5.65; N, 5.7. $C_{16}H_{28}N_2OPtS$ requires C, 39.1; H, 5.7; N, 5.7%).

[7-*Bromo*-1,3-*dihydro*-5-(2-*pyridyl*)-2H-1,4-*benzodiazepin*-2-*one*]*dichloroplatinum*(II) **3**. The complex *cis*-$[PtCl_2(Me_2SO)_2]$ (0.210 g, 0.5 mmol) was dissolved in Me_2SO (5 cm^3) by gently warming. A methanolic solution of L^2 (0.160 g, 0.5 mmol) was added with stirring. Compound **3** precipitated spontaneously. After *ca.* 4. h the deep red crystals were separated by filtration and washed with diethyl ether (0.260 g, 90%) {Found: C, 29.0; H, 3.1; N, 5.7. Calc. for $C_{18}H_{22}BrCl_2N_3O_3PtS_2$, $[PtCl_2L^2]\cdot 2Me_2SO$:[4b] C, 29.3; H, 3.0; N, 5.7%}.

[7-*Bromo*-1,3-*dihydro*-5-(2-*pyridyl*)-2H-1,4-*benzodiazepin*-2-*one*]*dimethylplatinum*(II) **4**. A solution of L^2 (0.228 g, 0.72 mmol) in CH_2Cl_2 was added dropwise to a stirred solution of *cis*-$[PtMe_2(Me_2SO)_2]$ (0.275 g, 0.72 mmol) in the same solvent. The solution became deep red and after *ca.* 30 min a deep red microcrystalline solid began to separate. The reaction mixture was stirred for 3 h and then the precipitate was filtered off. The solution was concentrated to small volume *in vacuo* to give a second crop of $[PtMe_2L^2]$ (total 0.290 g, 74%) (Found: C, 35.8; H, 2.9; N, 7.9. $C_{16}H_{16}BrN_3OPt$ requires C, 35.5; H, 3.0; N, 7.8%).

[7-*Bromo*-1,3-*dihydro*-5-(2-*pyridyl*)-2H-1,4-*benzodiazepin*-2-*one*]*diphenylplatinum*(II) **5**. This complex was prepared in a similar way to **4**, using $[\{PtPh_2(Et_2S)\}_2]$ (0.284 g, 0.32 mmol) and L^2 in the metal to ligand molar ratio 1:1. The reaction mixture was stirred for 24 h and the deep red product **5** was recrystallized from CH_2Cl_2–light petroleum (0.320 g, 74%) (Found: C, 46.6; H, 3.2; N, 6.3. $C_{26}H_{20}BrN_3OPt$ requires C, 46.9; H, 3.0; N, 6.3%).



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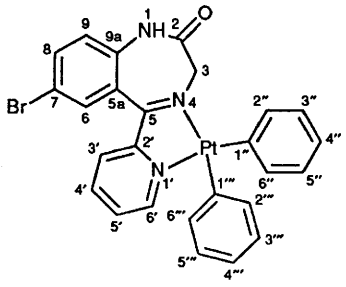

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Results and Discussion

The complexes *cis*-$[PtR_2(Me_2SO)_2]$ and $[\{PtR_2(Et_2S)\}_2]$ provide a convenient route to the synthesis of organometallic complexes of platinum(II) with benzodiazepines, because sulphoxides and thioethers are readily displaced by nitrogen-donor ligands.[6b,c,7]

Complexes with L^1.—By treating L^1 in dichloromethane with the platinum complex in stoichiometric ratio at room temperature the 1:1 adduct is obtained [equation (1)]. The

$$cis\text{-}[PtMe_2(Me_2SO)_2] + L^1 \longrightarrow cis\text{-}[PtMe_2(Me_2SO)L^1] + Me_2SO \quad (1)$$

same product is obtained even when an excess of ligand is employed (metal to ligand molar ratio 1:2.5).

The infrared spectrum of complex **1** shows a strong absorption at 1100 cm^{-1}, which can be assigned to ν(S=O) of the co-ordinated Me_2SO and is consistent with platinum–sulphur bonding.[8] The band attributed to the stretching mode ν(N–H) appears at 3281 cm^{-1} (3295 cm^{-1} for the free ligand); these data rule out the possibility of co-ordination through N^1,[9] and strongly suggest co-ordination through N^5. On the other hand, a single-crystal analysis of the complex *trans*-dichloro(7,8-dichloro-2,3-dihydro-2,2,4-trimethyl-1*H*-1,5-benzodiazepine)(tri-*n*-propylphosphine)palladium(II) shows that the co-ordination of this 1,5-benzodiazepine, strictly related to L^1, occurs through N^5.[1b]

Proton and ^{13}C NMR data for the free ligand L^1[5d,e,10] and *cis*-$[PtMe_2(Me_2SO)(L^1)]$ **1** are reported in Table 1. Only the resonances of the 4-Me protons, H^6 and C^4 are significantly shifted to lower fields by complexation. In addition the 4-Me proton signal of **1** shows a ^{195}Pt satellite doublet in $CDCl_3$ solution (δ 2.87, $^4J_{HPt}$ 6.0 Hz). These results show that only the N^5 electronic environment is substantially affected by co-ordination, as observed for *trans*-dichloro(7,8-dichloro-2,3-dihydro-2,2,4-trimethyl-1*H*-1,5-benzodiazepine)(tri-*n*-propylphosphine)palladium(II).[1b] In the ^1H NMR spectrum ($CDCl_3$) of free L^1 the 2-Me_2 protons resonate as a single sharp peak at δ 1.34, while two distinct singlets of equal intensity at δ 1.28 and 1.42 are observed for the same nuclei in compound **1**. These data are indicative of the influence of platinum co-ordination on the conformational mobility of the heptaatomic ring: in complex **1**, heterocyclic ring inversion occurs slowly on the NMR time-scale and the geminal methyl groups become diastereotopic. The same phenomenon involves the 3-protons: they resonate as a singlet at δ 2.22 ($CDCl_3$) for L^1, are deceptively coincident for **1** dissolved in $CDCl_3$ [δ 2.29 (br s)], but the ^1H NMR spectrum of **1** in $[^2H_7]$dimethylformamide shows the $2H^3$ resonating as a typical AB system (δ_A 2.44, δ_B 2.27, J_{gem} 12.64 Hz). Similarly the two methyl groups bonded to sulphur are equivalent in the NMR spectra of *cis*-$[PtMe_2(Me_2SO)_2]$,[6c] but give different peaks for the ^1H and ^{13}C resonances of complex **1** both in $CDCl_3$ and $[^2H_7]$dimethylformamide.[11] All these ^1H and ^{13}C signals present platinum satellites, so confirming the bonding through S.

The observed raising of the ring-inversion barrier because of the metal co-ordination can be compared to the analogous conformational influence caused by fusion of further heterocyclic rings onto benzodiazepine systems.[10c,d] The ^1H NMR spectrum of complex **1** in $[^2H_7]$dimethylformamide was measured at a series of temperatures up to 95 °C and, although some line broadening occurred, no changes were observed consistent with inversion of the heterocyclic ring, while an appreciable amount of free L^1 was present at the end of the experiment.

Finally, the proton resonances of methyl groups bonded to platinum are observed as two singlets of equal intensity. This implies their *cis* geometry in complex **1**, and the coupling constant 78.6 Hz in $CDCl_3$ agrees well with $^2J_{HPt}$ (79.2 Hz in $CDCl_3$) measured for methyl protons *trans* to Me_2SO in *cis*-$[PtMe_2(Me_2SO)_2]$,[6c] while $^2J_{HPt}$ for the methyl group *trans* to N^5 in **1** is 87.1 Hz in $CDCl_3$. The unambiguous assignment of all aromatic resonances was achieved by means of two-dimensional ^1H–^{13}C shift correlation experiments and analysis of the ABCD resonance pattern of the benzene protons, carried out by iterative computer fitting with the LAOCN3 program.[12] From the contour plot of the two-dimensional heteronuclear shift correlated NMR spectrum of L^1 in $CDCl_3$, even the resonances at δ 122.16 and 125.59, whose related proton resonances occur very close to each other (δ 6.99 and 6.98), can be unambiguously assigned to C^7 and C^8 respectively.[10b]

When L^1 was added to a solution of the bridged complex $[\{PtPh_2(Et_2S)\}_2]$ in CH_2Cl_2 (molar ratio metal to ligand 1:1) with the aim of obtaining *cis*-$[PtPh_2(Et_2S)L^1]$, the reaction product was a mixture of the starting complex and *cis*-$[PtPh_2L^1]$ **2**. This reaction was not further investigated, but the NMR parameters of **2** (Table 1) show L^1 ligands again co-ordinated through N^5 and equivalent, since only one set of signals is observed for the benzodiazepine moieties (and phenyl groups). The inequivalence of the 2-Me_2 protons and AB pattern observed for the $2H^3$ (δ_A 2.02, δ_B 1.87, J_{gem} 12.50 Hz) show once more the influence of metal co-ordination on the inversion barrier of the heptaatomic rings. The *cis* geometry of the complex is assigned from $^3J_{CPt}$ 77.0 Hz measured for $C^{3'(5')}$, since a value of *ca.* 40 Hz is expected for a *trans*-diaryl complex.[13]

Complexes with Bromazepam (L^2).—The organometallic complexes $[PtR_2L^2]$ have been prepared by reaction (2) or (3), carried out at room temperature (molar ratio metal to ligand 1:1). Bromazepam is potentially a bidentate ligand and, in its

$$cis\text{-}[PtR_2(Me_2SO)_2] + L^2 \longrightarrow [PtR_2L^2] + 2\,Me_2SO \quad (2)$$

(R = Cl or Me)

$$[\{PtPh_2(Et_2S)\}_2] + 2\,L^2 \longrightarrow 2\,[PtPh_2L^2] + 2\,Et_2S \quad (3)$$

co-ordination complexes so far reported, chelation always occurs through the imino N^4 and pyridyl nitrogen $N^{1'}$.[4a–c]

The infrared spectra of the compounds $[PtMe_2L^2]$ **4** and $[PtPh_2L^2]$ **5** show distinctive features of chelated bromazepam. The strong band due to ν(C=O) at 1680 cm^{-1} is practically unchanged upon complexation, while characteristic modifications of the absorptions of the aliphatic and pyridine imine groups are observed, in comparison to free L^2.

We collect in Table 2 proton and ^{13}C NMR parameters of free bromazepam[14] and its new organometallic complexes **4** and **5**, together with the not yet reported NMR data for the dichloro complex **3** whose crystal structure has recently been described.[4b] Analytical and spectral data for **3** fully agree with those reported for the same compound previously synthesised in a different way.[4b]

The NMR study of compounds **3**–**5**, sparingly soluble in $CDCl_3$, was carried out in $(CD_3)_2SO$ or $[^2H_7]$dimethyl-

Table 1 Proton (300 MHz) and ^{13}C (75 MHz) NMR spectroscopic data for L^1 and its complexes **1** and **2**

Compound	δ(^{1}H) (*J* in Hz)	δ(^{13}C) (*J* in Hz)
L^1 ($CDCl_3$)	1.34 (6 H, s, 2-Me_2), 2.22 (2 H, s, 2 H^3), 2.36 (3 H, s, 4-Me), 2.95 (1 H, br s, H^1), 6.74 [1 H, m, $J(H^7H^9)$ 1.39, $J(H^8H^9)$ 7.89, H^9], 6.98 [1 H, m, $J(H^6H^8)$ 1.39, $J(H^7H^8)$ 9.06, H^8], 6.99 [1 H, m, $J(H^6H^7)$ 7.89, H^7], 7.14 (1 H, m, H^6)	29.62 (4-Me), 30.24 (2-Me_2), 44.89 (C^3), 68.28 (C^2), 121.83 (C^9), 122.16 (C^7), 125.59 (C^8), 126.93 (C^6), 138.06 (C^{9a}), 140.92 (C^{5a}), 172.67 (C^4)
[$DCON(CD_3)_2$]	1.29 (6 H, s, 2-Me_2), 2.24 (2 H, s, 2 H^3), 2.26 (3 H, s, 4-Me), 3.53 (1 H, br s, H^1), 6.8–7.0 (4 H, m, aryl H)	
1 ($CDCl_3$)	0.55 (3 H, s, $^2J_{HPt}$ 87.1, Me_b), 0.61 (3 H, s, $^2J_{HPt}$ 78.6, Me_a), 1.28 and 1.42 (6 H, two s, 2-Me_2), 2.29 (2 H, br s, 2 H^3), 2.68 ($^3J_{HPt}$ 12.1) and 2.71 ($^3J_{HPt}$ 11.0) (6 H, two s, SMe_2), 2.87 (3 H, s, $^3J_{HPt}$ 6.0, 4-Me), 3.10 (1 H, br s, H^1), 6.82 [1 H, m, $J(H^6H^9)$ 0.37, $J(H^7H^9)$ 1.74, $J(H^8H^9)$ 7.32, H^9], 7.11 [1 H, m, $J(H^6H^8)$ 1.91, $J(H^7H^8)$ 8.63, H^8], 7.13 [1 H, m, $J(H^6H^7)$ 7.52, H^7], 8.02 (1 H, m, H^6)	−20.51 ($^1J_{CPt}$ 771.2, Me_b), −5.44 ($^1J_{CPt}$ 754.6, Me_a), 29.89 (2-Me_2), 30.43 (4-Me), 43.27 ($^2J_{CPt}$ 39.2) and 44.46 ($^2J_{CPt}$ 26.4) (SMe_2), 46.78 (C^3), 69.28 (C^2), 123.62 (C^9), 123.72 (C^7), 127.95 (C^8), 128.08 (C^6), 138.85 (C^{9a}), 142.52 (C^{5a}), 179.66 (C^4)
[$DCON(CD_3)_2$]	0.43 (3 H, s, $^2J_{HPt}$ 79.1, Me_a), 0.48 (3 H, s, $^2J_{HPt}$ 88.6, Me_b), 1.27 and 1.40 (6 H, two s, 2-Me_2), 2.27 and 2.44 (2 H, two d, J_{gem} 12.64, 2 H^3), 2.52 ($^3J_{HPt}$ 11.8) and 2.86 ($^3J_{HPt}$ 11.2) (6 H, two s, SMe_2), 2.87 (3 H, s, 4-Me), 4.85 (1 H, br s, H^1), 7.0–7.2 (3 H, m, H^{7-9}), 8.05 (1 H, m, H^6)	
2 ($CDCl_3$)	0.86 and 1.02 (12 H, two s, 2-Me_2), 1.87 and 2.02 (4 H, two d, J_{gem} 12.50, 2 H^3), 2.23 (6 H, s, 4-Me), 2.54 (2 H, br s, H^1), 6.76 (2 H, d, J_{ortho} 7.13, H^9), 6.8–6.9 (10 H, m, C_6H_5), 7.10 (2 H, t, H^7), 7.21 (2 H, t, H^8), 8.88 (2 H, d, H^6)	29.07 and 29.27 (2-Me_2 and 4-Me), 46.62 (C^3), 67.87 (C^2), 120.77 (C^9), 123.11 ($C^{4'}$), 124.44 (C^7), 125.40 ($^3J_{CPt}$ 77.0, $C^{3',5'}$), 127.19 (C^8), 129.26 (C^6), 138.87 (C^{9a}), 139.54 ($^2J_{CPt}$ 36.7, $C^{2',6'}$), 141.55 (C^{5a}), 143.73 ($C^{1'}$), 179.60 (C^4)*

* Carbon atoms belonging to the phenyl groups are labelled with a prime.

Table 2 Proton (300 MHz) and ^{13}C (75 MHz) NMR spectroscopic data for L^2 and its complexes **3**–**5**

Compound	δ(^{1}H) (*J* in Hz)	δ(^{13}C) (*J* in Hz)
L^2 [$(CD_3)_2SO$]	4.22 (2 H, br s, 2 H^3), 7.18 [^{1} H, d, $J(H^8H^9)$ 8.70, H^9], 7.42 [1 H, d, $J(H^6H^8)$ 2.35, H^6], 7.51 [1 H, m, $J(H^{3'}H^{5'})$ 0.90, $J(H^{4'}H^{5'})$ 7.70, $J(H^{5'}H^{6'})$ 4.76, $H^{5'}$], 7.71 (1 H, dd, H^8), 7.96 [1 H, td, $J(H^{3'}H^{4'})$ 7.70, $J(H^{4'}H^{6'})$ 1.34, $H^{4'}$], 8.05 (1 H, dd, $H^{3'}$), 8.57 (1 H, dd, $H^{6'}$), 10.65 (1 H, br s, H^1)	57.36 (C^3), 114.53 (C^7), 123.62 (C^9), 123.88 ($C^{3'}$), 125.48 ($C^{5'}$), 128.00 (C^{5a}), 134.24 (C^6), 134.52 (C^8), 137.71 ($C^{4'}$), 139.39 (C^{9a}), 149.00 ($C^{6'}$), 156.46 ($C^{2'}$), 168.36 (C^5)
[$DCON(CD_3)_2$]	4.35 (2 H, br s, 2 H^3), 7.34 [1 H, d, $J(H^8H^9)$ 8.69, H^9], 7.54 [1 H, m, $J(H^{3'}H^{5'})$ 0.98, $J(H^{4'}H^{5'})$ 7.61, $J(H^{5'}H^{6'})$ 4.95, $H^{5'}$], 7.60 [1 H, d, $J(H^6H^8)$ 2.43, H^6], 7.78 (1 H, dd, H^8), 8.01 [1 H, td, $J(H^{3'}H^{4'})$ 7.80, $J(H^{4'}H^{6'})$ 1.72, $H^{4'}$], 8.15 [1 H, dt, $J(H^{3'}H^{6'})$ 0.80, $H^{3'}$], 8.59 (1 H, m, $H^{6'}$), 10.58 (1 H, br s, H^1)	
3 [$(CD_3)_2SO$]	4.22 and 5.65 (2 H, two d, J_{gem} 12.08, 2 H^3), 7.23 [1 H, d, $J(H^8H^9)$ 8.85, H^9], 7.78 [1 H, dd, $J(H^{3'}H^{4'})$ 7.93, $J(H^{3'}H^{5'})$ 0.89, $H^{3'}$], 7.93 [1 H, m, $J(H^{4'}H^{5'})$ 7.93, $J(H^{5'}H^{6'})$ 4.76, $H^{5'}$], 7.94 [1 H, dd, $J(H^6H^8)$ 2.26, H^8], 8.05 (1 H, d, H^6), 8.32 [1 H, td, $J(H^{4'}H^{6'})$ 1.40, $H^{4'}$], 9.54 (1 H, dd, $H^{6'}$), 11.11 (1 H, br s, H^1)	56.16 (C^3), 116.28 (C^7), 123.58 (C^{5a}), 124.71 (C^9), 129.90 ($C^{5'}$), 130.98 ($C^{3'}$), 132.82 (C^6), 136.90 (C^8), 139.03 (C^{9a}), 141.36 ($C^{4'}$), 150.09 ($C^{6'}$), 156.84 ($C^{2'}$), 168.98 (C^2), 174.20 (C^5)
[$DCON(CD_3)_2$]	4.46 and 5.99 (2 H, two d, J_{gem} 12.08, 2 H^3), 7.46 [1 H, d, $J(H^8H^9)$, 8.79, H^9], 8.0–8.1 [3 H, m, $J(H^{3'}H^{4'})$ 8.03, $J(H^{3'}H^{6'})$ 0.62, $J(H^{4'}H^{5'})$ 8.02, $J(H^{5'}H^{6'})$ 5.55, $J(H^6H^8)$ 2.26, $H^{3'}H^{5'}H^8$], 8.26 (1 H, d, H^6), 8.48 [1 H, td, $J(H^{4'}H^{6'})$ 1.35, $H^{4'}$] 9.75 (1 H, dd, $H^{6'}$), 11.07 (1 H, br s, H^1)	
4 [$(CD_3)_2SO$]	1.07 ($^2J_{HPt}$ 86.3) and 1.18 ($^2J_{HPt}$ 82.4) (6 H, two s, Me), 4.33 and 5.04 (2 H, two d, J_{gem} 11.29, 2 H^3), 7.25 [1 H, d, $J(H^8H^9)$ 8.74, H^9], 7.75 [1 H, dd, $J(H^{3'}H^{4'})$ 7.59, $J(H^{3'}H^{5'})$ 0.90, $H^{3'}$], 7.90 [1 H, td, $J(H^{4'}H^{5'})$ 7.59, $J(H^{5'}H^{6'})$ 5.37, $H^{5'}$], 7.95 [1 H, dd, $J(H^6H^8)$ 2.28, H^8], 8.02 (1 H, d H^6), 8.30 [1 H, td, $J(H^{4'}H^{6'})$ 1.47, $H^{4'}$], 9.26 (1 H, dd, $H^{6'}$), 10.87 (1 H, br s, H^1)	−13.94 ($^1J_{CPt}$ 802.6) and −13.74 ($^1J_{CPt}$ 819.2) (Me), 56.08 (C^3), 116.07 (C^7), 124.61 (C^9), 126.86 (C^{5a}), 129.23 ($C^{5'}$), 129.44 ($C^{3'}$), 131.86 (C^6), 135.13 (C^8), 137.68 (C^{9a}), 138.14 ($C^{4'}$), 147.52 ($C^{6'}$), 155.84 ($C^{2'}$), 168.22 (C^5), 170.63 (C^2)
5 [$(CD_3)_2SO$]	4.13 and 4.54 (2 H, two d, J_{gem} 11.42, 2 H^3), 6.71 and 6.76 (2 H, two t, J_{ortho} 7.32, $H^{4'',4'''}$), 6.87 and 6.90 (4 H, two t, $H^{3'',3''',5'',5'''}$), 7.23 [1 H, d, $J(H^8H^9)$ 8.75, H^9], 7.28 and 7.34 (4 H, two d, $H^{2'',2''',6'',6'''}$), 7.76 [1 H, br d, $J(H^{3'}H^{4'})$ 7.75, $J(H^{3'}H^{5'})$ 0.90, $H^{3'}$], 7.78 [1 H, m, $J(H^{4'}H^{5'})$ 7.71, $J(H^{5'}H^{6'})$ 4.83, $H^{5'}$], 7.91 [1 H, dd, $J(H^6H^8)$ 2.24, H^8], 8.07 (1 H, d, H^6), 8.26 [1 H, td, $J(H^{4'}H^{6'})$ 1.38, $H^{4'}$], 8.33 (1 H, br d, $H^{6'}$), 10.87 (1 H, br s, H^1)	57.07 (C^3), 115.65 (C^7), 121.48 and 121.65 ($C^{4'',4'''}$), 124.15 (C^9), 125.46 (C^{5a}), 126.78 ($^3J_{CPt}$ 67.4, $C^{3'',3''',5'',5'''}$), 129.10 ($C^{5'}$), 129.65 ($C^{3'}$), 132.32 (C^6), 135.50 (C^8), 138.08 and 138.39 ($C^{2'',2''',6'',6'''}$), 138.18 (C^{9a}), 138.97 ($C^{4'}$), 146.19 and 146.27 ($C^{1'',1'''}$), 149.37 ($C^{6'}$), 155.14 ($C^{2'}$), 169.53 (C^2), 170.55 (C^5)
($CDCl_3$)	3.91 and 5.10 (2 H, two d, J_{gem} 11.75, 2 H^3), 6.9 (2 H, m, J_{ortho} 6.47, $H^{4'',4'''}$), 7.06 and 7.08 (4 H, two t, $H^{3'',3''',5'',5'''}$), 7.13 [1 H, d, $J(H^8H^9)$ 8.74, H^9], 7.3–7.5 (4 H, m, $H^{2'',2''',6'',6'''}$), 7.58 [1 H, m, $J(H^{3'}H^{5'})$ 0.65, $J(H^{4'}H^{5'})$ 7.97, $J(H^{5'}H^{6'})$ 5.35, $H^{5'}$], 7.66 [1 H, br d, $J(H^{3'}H^{4'})$ 7.92, $H^{3'}$], 7.70 [1 H, d, $J(H^6H^8)$ 2.20, H^6], 7.81 (1 H, dd, H^8), 8.07 [1 H, td, $J(H^{4'}H^{6'})$ 1.45, $H^{4'}$], 8.6 (1 H, br s, H^1), 8.73 (1 H, br d, $H^{6'}$)	

formamide solutions. However, the good agreement between the ^1H NMR data collected for **5** in $CDCl_3$ and $(CD_3)_2SO$ solutions (Table 2) rules out possible substitution processes of L^2 from Me_2SO. The aromatic NMR data in Table 2 were obtained by LAOCN3 calculation[12] of proton chemical shifts and coupling constants. Chelation of L^2, as occurs in **3**–**5**, heavily influences the NMR spectra. Protons H^3, resonating as only one signal for the free ligand, appear as a typical AB quartet for the complexes studied, showing that the co-ordinated ligand is frozen in one limiting conformation, as observed for L^1 in **1** and **2**. Downfield shifts of L^2 proton resonances are generally observed upon co-ordination, roughly related to the distances from platinum, apart from the $H^{3'}$ signal, which shifts to high field. Actually all pyridine resonances

are distinctively affected by co-ordination: free L^2 shows a conformational preference for the $C^{2'}/C^5$ rotamer characterized by *anti* orientation of two centres of high electron density (namely $N^{1'}$ and N^4) both in the solid and solution state,[14c,15] while in complexes **3**–**5** the α-diimine system is constrained in the *syn* conformation because L^2 acts as bidentate ligand towards the metal.[4b] In this latter situation the upfield shift of $H^{3'}$ comes from two opposite phenomena, a downfield shift produced by the metal inductive effect and a prevalent upfield shift produced by disappearance of the N^4 paramagnetic effect upon complexation, when L^2 takes the $N^{1'}/N^4$ *syn* conformation. The same two effects may also be expected to influence the $H^{6'}$ signal. However this resonance shifts to a much lower field upon co-ordination,[16] because of its closer proximity to the metal, apart from complex **5**, where the upfield shift of $H^{6'}$ can be reasonably explained in terms of the aromatic shielding effect by the phenyl groups bonded to platinum. The crystal structure of *cis*-$[PtPh_2(Me_2SO)_2]$ shows its phenyl groups almost perpendicular to the co-ordination plane,[17] and this arrangement can also be adopted in complex **5**.

As regards spin–spin coupling with ^{195}Pt, ^{13}C NMR spectra of the L^2 complexes studied (Table 2) allow only the measurement of $^1J_{CPt}$ for the two methyl groups in **4** and $^3J_{CPt}$ for $C^{3''',3'''',5''',5''''}$ in **5**, while the C^3 and $C^{6'}$ resonances appear widened by ^{195}Pt satellites too weak to be observed or unresolved. Moreover the ^1H NMR spectra at 300 MHz of the same complexes show only the $^2J_{HPt}$ for the methyl protons in **4**, but when in $(CD_3)_2SO$ at 80 MHz we were able to measure $^2J_{HPt}$ 20.8 Hz for $H^{6'}$ and $^3J_{HPt}$ 20.3 and 22.3 Hz for the 2 H^3 doublets at δ 5.04 and 4.33 respectively. This is in line with the noteworthy phenomenon concerning the increased broadening (or even the absence) of ^{195}Pt satellites when the ^1H NMR spectra of platinum complexes are recorded on a higher-field spectrometer.[18]

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References

1 (*a*) Part 2, M. Cusumano, A. Giannetto, P. Ficarra, R. Ficarra and S. Tommasini, *J. Chem. Soc., Dalton Trans.*, 1991, 1581; (*b*) Part 1, M. C. Aversa, P. Giannetto, G. Bruno, M. Cusumano, A. Giannetto and S. Geremia, *J. Chem. Soc., Dalton Trans.*, 1990, 2433.

2 F. R. Hartley, in *Comprehensive Organometallic Chemistry*, eds. G. Wilkinson, F. G. A. Stone and E. W. Abel, Pergamon, Oxford, 1982, vol. 6, pp. 471–762.

3 Y. T. Fanching, W. P. Ridley and J. M. Wood, *J. Am. Chem. Soc.*, 1979, **101**, 1442; L. S. Hollis, A. R. Amundsen and E. W. Stern, *J. Am. Chem. Soc.*, 1985, **107**, 274; H. Schöllhorn, U. Thewalt and B. Lippert, *J. Chem. Soc., Chem. Commun.*, 1986, 258.

4 (*a*) J. A. Real and J. Borrás, *Synth. React. Inorg. Metal-Org. Chem.*, 1984, **14**, 843, 857; (*b*) A. Benedetti, A. C. Fabretti, C. Preti, G. Tosi and P. Zannini, *J. Cryst. Spectrosc. Res.*, 1987, **17**, 771; (*c*) J. A. Real, J. Borrás, X. Solans and M. Font-Altaba, *Transition Met. Chem.*, 1987, **12**, 79; (*d*) S. Stoccoro, M. A. Cinellu and G. Minghetti, CISCI89, Congresso Interdivisionale della Societa' Chimica Italiana, Perugia, 1989; (*e*) M. A. Cinellu, S. Gladiali, G. Minghetti, S. Stoccoro and F. Demartin, *J. Organomet. Chem.*, 1991, **401**, 371 and refs. therein.

5 (*a*) W. Ried and P. Stahlhofen, *Chem. Ber.*, 1957, **90**, 815; (*b*) L. K. Mushkalo and V. A. Chuiguk, *Ukr. Khim. Zh.*, 1969, **35**, 740; (*c*) A. N. Kost, Z. F. Solomko, L. N. Polovina and L. G. Gergel, *Khim. Geterosikl. Soedin.*, 1971, **7**, 553; (*d*) Dang Quoc Quan, R. Caujolle and Thi Bang Tam Dang, *C. R. Acad. Sci., Ser. C*, 1971, **272**, 1518; (*e*) J. Werner and R. Radeglia, *J. Prakt. Chem.*, 1975, **317**, 1035; (*f*) Z. Szeverényi and L. I. Simándi, *J. Mol. Catal.*, 1989, **51**, 155.

6 (*a*) J. H. Price, A. N. Williamson, R. F. Schraum and B. B. Wayland, *Inorg. Chem.*, 1972, **11**, 1280; (*b*) B. R. Steele and K. Vrieze, *Transition Met. Chem.*, 1977, **2**, 140; (*c*) C. Eaborn, K. Kundu and A. Pidcock, *J. Chem. Soc., Dalton Trans.*, 1981, **933**.

7 D. Minniti, G. Alibrandi, M. L. Tobe and R. Romeo, *Inorg. Chem.*, 1987, **26**, 3956; G. Alibrandi, D. Minniti, L. Monsu' Scolaro and R. Romeo, *Inorg. Chem.*, 1989, **28**, 1939.

8 F. A. Cotton, R. Francis and W. D. Horrocks, *J. Phys. Chem.*, 1960, **64**, 1534.

9 P. W. W. Hunter and G. A. Webb, *J. Chem. Soc., Dalton Trans.*, 1973, 26.

10 (*a*) W. W. Hunter and G. A. Webb, *Tetrahedron*, 1973, **29**, 147; (*b*) R. Radeglia and W. Jehn, *J. Prakt. Chem.*, 1976, **318**, 1049; (*c*) M. C. Aversa, P. Giannetto, A. Ferlazzo and G. Bruno, *J. Chem. Soc., Perkin Trans. 2*, 1986, 1533; (*d*) M. C. Aversa, A. Ferlazzo, P. Giannetto and F. H. Kohnke, *Synthesis*, 1986, 230; (*e*) M. C. Aversa, P. Bonaccorsi, A. Ferlazzo and P. Giannetto, *J. Chem. Res.*, 1991, (*S*) 86, (*M*) 730.

11 E. L. M. Lempers, M. J. Bloemink and J. Reedijk, *Inorg. Chem.*, 1991, **30**, 201.

12 D. F. DeTar, *Computer Programs for Chemistry*, Benjamin, New York, 1968, vol. 1, pp. 10–53.

13 D. R. Coulson, *J. Am. Chem. Soc.*, 1976, **98**, 3111.

14 (*a*) P. Ficarra, M. G. Vigorita and A. Tommasini, *Boll. Chim. Farm.*, 1977, **116**, 720; (*b*) K. Kovar, D. Linden and E. Breitmaier, *Arch. Pharm.*, 1981, **314**, 186; (*c*) E. Finner, H. Zeugner and W. Milkowski, *Arch. Pharm.*, 1984, **317**, 79.

15 H. Butcher, T. A. Hamor and I. L. Martin, *Acta Crystallogr., Sect. C*, 1983, **39**, 1469.

16 G. Matsubayashi, M. Okunaka and T. Tanaka, *J. Organomet. Chem.*, 1973, **56**, 215.

17 R. Bardi, A. Del Pra, A. M. Piazzesi and M. Trozzi, *Cryst. Struct. Commun.*, 1981, **10**, 301.

18 H. van der Poel and G. van Koten, *Inorg. Chem.*, 1981, **20**, 2950.

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