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Reactivity of *trans*-$[PtCl_2(NCMe)_2]$ with cycloaliphatic amines: An ESI and NMR study. X-ray structure of *trans*-$[PtCl_2\{Z\text{-}N(H)=C(CH_3)NHCHCH_2CH_2\}_2]$

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ABSTRACT

The reactivity of the cyclic primary aliphatic amines cyclopropyl-, cyclopentyl- and cyclohexylamine with *cis*- and *trans*-$[PtCl_2(NCMe)_2]$, under the same experimental conditions, is compared. Whereas *cis*-$[PtCl_2(NCMe)_2]$ yields the neutral diamidine compounds, the reactions with *trans*-$[PtCl_2(NCMe)_2]$ take place either with addition or substitution processes yielding the neutral diamidine complexes *trans*-$[PtCl_2(Amidine)_2]$, the monocationic *trans*-$[PtCl(Amine)(Amidine)_2]Cl$ and the dicationic *trans*-$[Pt(Amine)_2(Amidine)_2]Cl_2$ salts. An NMR and ESI study indicate that the main species formed is the monocationic *trans*-$[PtCl(Amine)(Amidine)_2]Cl$ complex.

The X-ray structure of *trans*-$[PtCl_2\{N(H)=C(CH_3)NHCHCH_2CH_2\}_2]$ is reported and its supramolecular arrangement is described.

1. Introduction

The reactivity of coordinated nitrile ligands activated towards nucleophilic attack by protic H–OR and H–NRR′ nucleophiles, such as alcohols and amines, to afford iminoethers and amidine derivatives, respectively, has been extensively reviewed [1].

Recently, the addition to *cis*- and *trans*-$[PtCl_2(NCR)_2]$ (R = Me, Et, Ph) of dialkyl- and dibenzylhydroxylamines R_2NOH (R = Me, Et, CH_2Ph, CH_2-C_6H_4-*p*-Cl) [2] and of the guanidine derivatives $HN{=}C(NMe_2)_2$ [3] has been reported to give the corresponding new diimino species of the type $[PtCl_2\{NH{=}C(R)ONR_2\}_2]$ and $[PtCl_2\{NH{=}C(R)N{=}C(NMe_2)_2\}_2]$, respectively, the latter containing two N-bound monodentate 1,3-diaza-1,3-diene ligands. On the other hand, a completely different reactivity has been observed when $HN{=}C(NHPh)_2$ is the reacting guanidine [4], giving rise to platinum(II) 1,3,5-triazapentadiene complexes. The addition of amidine derivatives of the type PhC(=NH)NHPh to *trans*-$[PtCl_2(NCR)_2]$ (R = CH_2Ph, Ph, C_6H_4-*p*-Cl) has been also shown to achieve the imidoylamidinate platinum(II) complexes $[Pt\{NH{=}C(R)NC(Ph{=}NPh\}_2]$, representing a new family of Pt(II)-based luminescent compounds emissive at room temperature both in solution and in the solid state [5].

It is noteworthy that the nature of the products of all these reactions appears to depend strongly on the geometry of the platinum complex (*cis* or *trans*), on the nitrile ligand, on the reacting nucleophile and on the experimental conditions (stoichiometry, temperature, time), affording neutral, monocationic or dicationic derivatives, where the entering nucleophile can substitute (even partially) or not the coordinated nitrile ligands. In particular, primary and secondary aliphatic amines have been reported to react with *cis*- and *trans*-$[PtCl_2(NCR)_2]$ giving rise to neutral and cationic diamidine derivatives depending on the nitrile, the amine and the reaction conditions as summarized in Scheme 1 [6].

A similar behavior, summarized in Scheme 2, has been observed for the reaction of *cis*- and *trans*-$[PtCl_2(NCR)_2]$ with ammonia [7].

The interest for amidine complexes arises from the possibility to prepare new cytotoxic platinum compounds [8] whose antitumor activity can be examined. In these derivatives the lipophilicity can be tuned by changing R substituents. The presence of the $NH{=}C(sp^2)$ moiety bonded to the platinum center together with additional NH groups allows further interactions with the DNA to potentially form new types of lesions with respect to the quite active iminoether derivatives *cis*-$[PtCl_2\{N(H){=}C(OMe)CH_2Ph\}_2]$ [9] and *trans*-$[PtCl_2\{N(H){=}C(OR)Me\}_2]$ (R = Me, Et) [10].

In this frame, the introduction of cyclic aliphatic amines may be of interest by taking into account that platinum derivatives bearing the cyclohexylamine moiety are known to exhibit antitumor activ-

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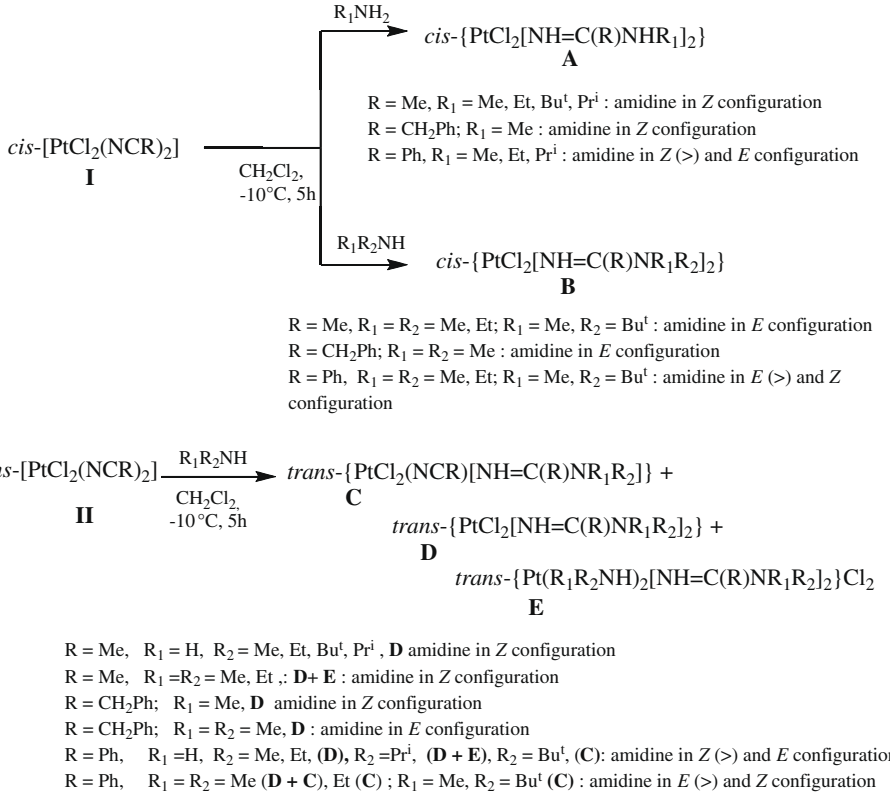
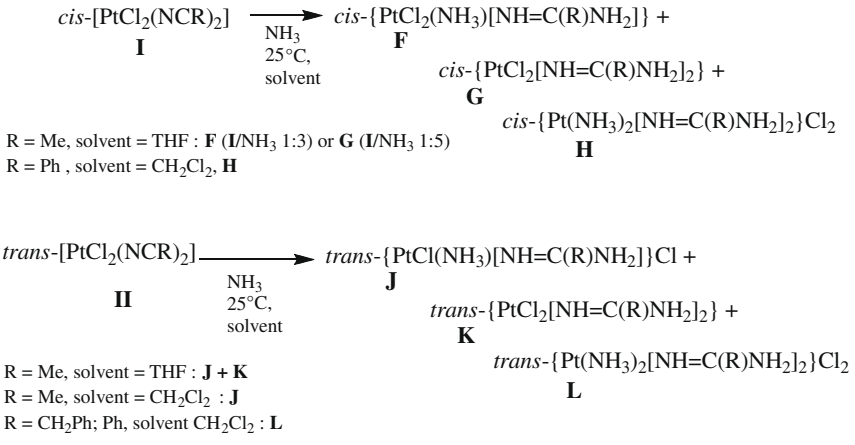


Scheme 1.



Scheme 2.

ity in vitro, in vivo and *cis*, *trans*, *cis*-$[PtCl_2(NH_3)(C_6H_{11}NH_2)(O\text{-}COCH_3)_2]$ (JM216), is the first orally active platinum compound to enter clinical trials. [11].

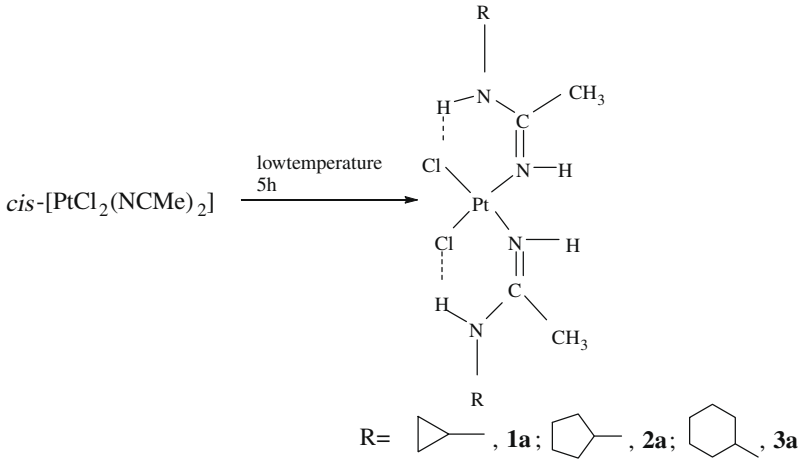
Recently, we reported that the reaction of *cis*-$[PtCl_2(NCMe)_2]$ with cyclopropyl-, cyclopentyl- and cyclohexylamine afforded the diamidine derivatives **1a–3a**, according to Scheme 3. Compound **3a,** bearing the cyclohexyl ring, showed to be significantly more cytotoxic in vitro than the cyclopropyl and the cyclopentyl analogs with a marked activity against *cis*-platin resistant cell lines [12].

Herein we describe the reactions of *trans*-$[PtCl_2(NCMe)_2]$ with cyclopropyl-, cyclopentyl- and cyclohexylamine which yield mixtures of neutral and cationic amidine derivatives, whose formation has been detected through ESI and NMR determinations.

2. Results and discussion

2.1. The reactions of trans-[PtCl$_2$(NCMe)$_2$] with cycloaliphatic primary amines

The reactions of cyclopropyl-, cyclopentyl- and cyclohexylamine under the same experimental conditions afford different products when performed with *cis*-$[PtCl_2(NCMe)_2]$ and *trans*-$[PtCl_2(NCMe)_2]$. The addition of a 5-fold excess of RNH_2 (R = cyclopropyl, cyclopentyl, cyclohexyl) to *cis*-$[PtCl_2(NCMe)_2]$ at −20 °C in CH_2Cl_2 leads after 5 h to the formation of the corresponding bis amidine complexes *cis*-$[PtCl_2\{Z\text{-}NH{=}(NHR)Me\}_2]$ (R = cyclopropyl, **1a**; cyclopentyl, **2a**, cyclohexyl, **3a**) in high yield [12]. In the



Scheme 3.

complexes **1a**, **2a** and **3a** both amidine ligands are in the *Z* configuration with the formation of strong intramolecular hydrogen bonds between each chlorine and the imino-proton of the NHR moiety giving rise to six-membered rings, according to Scheme 3, in agreement with what observed for the products of the addition of other primary aliphatic amines to coordinated acetonitrile [6a,c].

The reactivity of the cyclic aliphatic amines with *trans*-$[PtCl_2(NCMe)_2]$, under the same experimental conditions above reported for the *cis* complexes, takes place either with addition or substitution processes. Spectroscopic data indicate that mixtures of products are formed which contain the neutral diamidine complexes *trans*-$[PtCl_2(Amidine)_2]$, the monocationic *trans*-$[PtCl(Amine)(Amidine)_2]Cl$ and the dicationic *trans*-$[Pt(Amine)_2(Amidine)_2]Cl_2$ salts (Scheme 4), as the major products.

As for the reaction with cyclopropylamine, the formation of the neutral diamidine complex was confirmed by the X-ray structure of complex **1b** (Fig. 1).

When the reactions proceed for longer times or are carried out at room temperature the dicationic complexes **1c, 2c** and **3c** are formed as the only isolated products [13]. The chloride substitution by an entering amine was previously described for the reaction of *trans*-$[PtCl_2(NCMe)_2]$ with ammonia [7] and was reported by us in the case of the reaction of *trans*-$[PtCl_2(NCMe)_2]$ with iso-

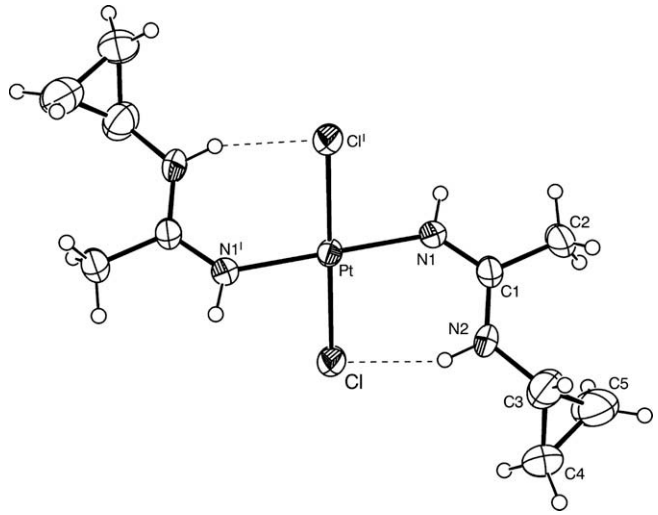
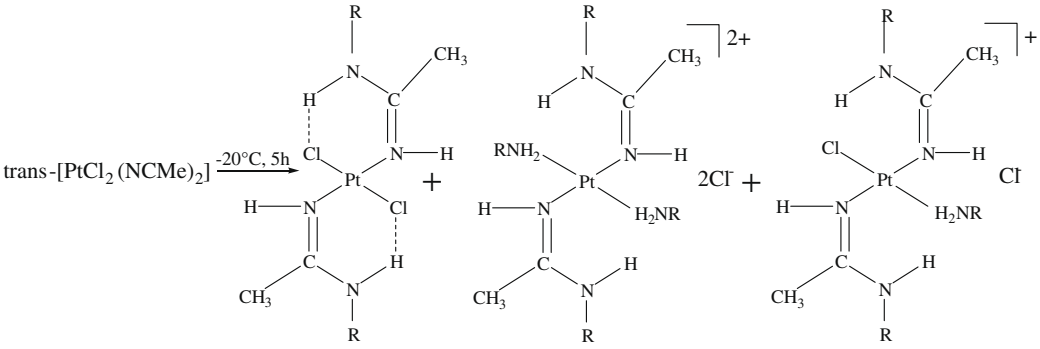


Fig. 1. Perspective ORTEP drawing of *trans*-$[PtCl_2\{N(H)=C(CH_3)NHCHCH_2CH_2\}_2]$ (**1b**) with the atom-labeling scheme.



R =						
	, **1b**	15%	**1c**	40%	**1d**	40%
	, **2b**	10%	**2c**	40%	**2d**	45%
	, **3b**	5%	**3c**	45%	**3d**	45%

Scheme 4.

Table 1
Selected 1H and ^{13}C (in parentheses) NMR data (ppm).

Compound	Amidine				Amine
	PtN*H*	CH_3	N*H*CH (doublet)	*C*=N	NH_2
1a	6.61	2.24 (20.5)	7.15($^3J_{HH}$ = 7.2 Hz)	168.1	
1b	7.50	2.32 (20.6)	7.42 ($^3J_{HH}$ = 8.0 Hz)	169.9	
1c	7.07	2.30 (20.7)	8.98 ($^3J_{HH}$ = 7.5 Hz)	168.8	5.11 br ($^2J_{PtH}$ = 48 Hz)
1d	7.29	2.31 (20.9)	7.51 ($^3J_{HH}$ = 8.0 Hz)	169.7	6.00 br ($^2J_{PtH}$ = 70 Hz)
2a	6.60	2.17 (20.9)	7.01 ($^3J_{HH}$ = 7.5 Hz)	165.8	
2b	7.50	2.27 (20.8)	7.33 ($^3J_{HH}$ = 8.5 Hz)	[a]	
2c	7.06	2.26 (20.6)	8.80 ($^3J_{HH}$ = 9.0 Hz)	166.3	5.16 br ($^2J_{PtH}$ = 50 Hz)
2d	7.69	2.25 (21.5)	7.13 ($^3J_{HHv}$ = 8.5 Hz)	166.8	5.88 d ($^2J_{PtH}$ = 70 Hz)
3a	6.52	2.11 (19.8)	6.88 ($^3J_{HH}$ = 9.0 Hz)	164.2	
3b	7.60	2.22 (20.2)	7.37 ($^3J_{HH}$ = 9.0 Hz)	[a]	
3c	6.91	2.23 (20.6)	8.71 ($^3J_{HH}$ = 9.6 Hz)	165.4	4.86 ($^2J_{PtH}$ = 54 Hz)
3d	7.01	2.20 (20.3)	7.14 ($^3J_{HH}$ = 8.8 Hz)	165.4	5.84 ($^2J_{PtH}$ = 65 Hz)

[a] Too low to be observed.

propylamine [6c]. It also was used to achieve symmetric and asymmetric *trans*-platinum(II) complexes, *trans*-[$PtCl_2(Amine_1)_2$] and *trans*-[$PtCl_2(Amine_1)(Amine_2)$] [14] starting from K_2PtCl_4.

In Table 1 selected NMR data of compounds **1a–3a**, **1b–3b, 1c–3c** and **1d–3d** are reported. The ^1H NMR spectra show the presence of a unique set of signals due to both amidine ligands in each compound having a *Z* configuration. This feature is also confirmed by the signals of the CH_3 protons which fall in the range 2.1–2.4 ppm, whereas in the case of *E* configuration, the CH_3 resonance is observed at values shifted about 0.5 ppm downfield [6].

The reaction of *trans*-[$PtCl_2(NCMe)_2$] with cyclopropylamine at −10 °C was followed by ^1H NMR in $CDCl_3$: in a few minutes from the addition of 2.2 equiv. of amine to *trans*-[$PtCl_2(NCMe)_2$] the formation of the monocationic species *trans*-[$PtCl(H_2N\overbrace{CHCH_2CH_2}\{N(H)=C(CH_3)NH\overbrace{CHCH_2CH_2}\}]Cl$ (**1d**), was observed. The ^1H NMR spectrum of **1d** is characterized by the signals at 6.0 ppm ($^2J_{PtH}$ 70 Hz) indicating the presence of a coordinated amine and together with a signal at 7.29 ppm (PtNH) and a doublet at 7.55 ppm of the NH moiety. The cyclopropyl ring gives rise to multiplets in the range 0.6–0.9 ppm and also at 2.6 ppm due to the CH proton. The methyl group of the amidine ligand gives rise to a singlet at 2.31 ppm (*C*H_3, 20.90 ppm in the $^{13}C\{^1H\}$ spectrum). The signals of **1d** increase within the first hour as well as those of **1b** and **1c** (the latter in a significant higher extent). After 24 h, only the signals of **1c** are present. Similar results are obtained in the case of the reaction of *trans*-[$PtCl_2(NCMe)_2$] with cyclopentylamine and cyclohexylamine.

As for the reaction with cyclopropylamine, **1b** can be obtained in a higher yield (ca. 50%) by performing the reaction with *trans*-[$PtCl_2(NCMe)_2$] at 0 °C in THF for 1 h, where **1b** is less soluble and its precipitation prevents the displacement of the chlorides by the amine. The role of solubility has been underlined by Natile and coworkers [7a] for the reaction of *cis*-[$PtCl_2(NCMe)_2$] with NH_3, which yields the corresponding neutral amidine complexes *cis*-[$PtCl_2L\{NH=C(Me)NH_2\}$] (L = NH_3 or $NH=C(Me)NH_2$), which are also insoluble in THF. Conversely, the analogous reactions of *trans*-[$PtCl_2(NCMe)_2$] with NH_3 leads to products soluble in THF which can react further to form the cationic complex [$PtCl(NH_3)\{Z\text{-}NH=C(Me)NH_2\}$]Cl by chloride displacement with NH_3.

Also the reactions of cyclopentylamine and cyclohexylamine with *trans*-[$PtCl_2(NCMe)_2$] performed in THF at 0 °C for 1 h afford mixtures of neutral and cationic diamidine complexes. If the reaction time is reduced or Pt/amine molar ratio is increased, unreacted *trans*-[$PtCl_2(NCMe)_2$] can be recovered. The reactions have been carried out also in CH_3CN, obtaining quite similar results. Due to their similar solubilities, attempts to separate compounds **1c–3c** from **1d–3d** failed.

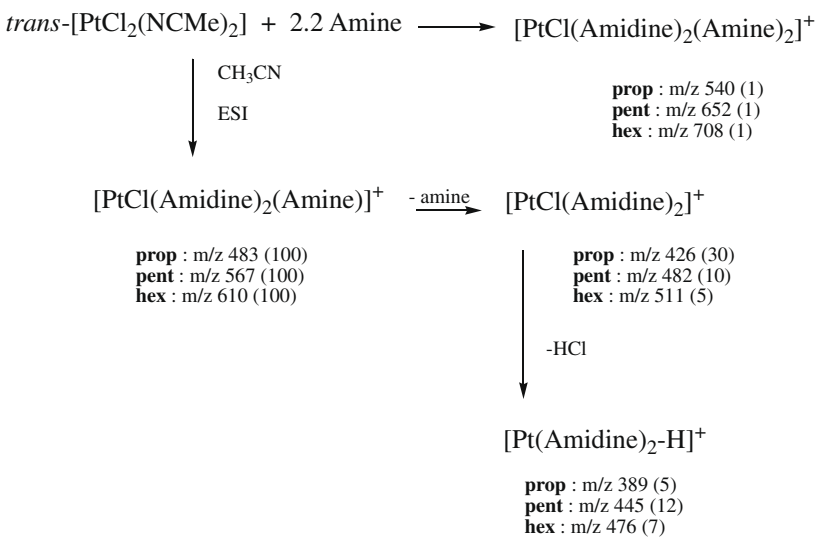
2.2. The reactions of trans-[$PtCl_2(NCMe)_2$] with cycloaliphatic primary amines under ESI conditions

The reactions of cyclopropyl-, cyclopentyl- and cyclohexylamine have been carried out also in CH_3CN at room temperature and the yellow solutions obtained by addition of 2.2-fold excess of the amines have been immediately analyzed by ESI MS. In all cases it was observed the formation of only the cationic species $[PtCl(Amine)(Amidine)_2]^+$, which represents the base peak and its isotopic distribution is in very good agreement with that calculated. The ESI data are summarized in Scheme 5.

The formation of the ionic species has been confirmed by MS/MS experiments and isotope pattern analysis. The parent peaks show the loss of the corresponding amine and subsequently the loss of 37 Da, corresponding to HCl. Very low abundance peaks (about 1%) corresponding to the pentacoordinate species $[PtCl(Amidine)_2(Amine)_2]Cl$ are present in all cases, which do not increase with the time. It is noteworthy that peaks corresponding to $[Pt(Amidine)_2(Amine)_2]^{2+}$, which are characteristic of the ESI MS spectra of species **1c–3c** [13], are completely absent. Further reactions occur in the ESI source involving dinuclear species, doubling in abundance during the time of analysis (about 15 min), which can be summarized as follows: $[Pt_2(Amidine)_4(CH_3CN)_3]^+$, *m/z* 905 (2); $[Pt_2(Amidine)_4(CH_3CN)_4]^+$, *m/z* 946 (5); $[Pt_2(Amidine)_4(CH_3CN)_4(Amine)]^+$, *m/z* 1003 (10) and $[Pt_2(Amidine)_4(CH_3CN)_4(Amine)_2]^+$, *m/z* 1060 (6) in the case of reaction with cyclopropylamine; $[Pt_2Cl_2(Amidine)_4(CH_3CN)_2]^+$, *m/z* 1047 (3); $[Pt_2Cl_2(Amidine)_4(CH_3CN)_3]^+$, *m/z* 1088 (7); $[Pt_2Cl_2(Amidine)_4(CH_3CN)_3(Amine)]^+$, *m/z* 1173 (12) and $[Pt_2Cl_2(Amidine)_4(CH_3CN)_3(Amine)_2]^+$, *m/z* 1258 (4) for cyclopentylamine; $[Pt_2(Amidine)_4(CH_3CN)_4]^+$, *m/z* 1114 (3); $[Pt_2(Amidine)_4(CH_3CN)_5]+$, *m/z* 1155 (5); $[Pt_2(Amidine)_4(CH_3CN)_5(Amine)]^+$, *m/z* 1254 (12) and $[Pt_2(Amidine)_4(CH_3CN)_5(Amine)_2]^+$, *m/z* 1353 (2) in the case of cyclohexylamine.

These results confirm that ESI MS technique can be useful to follow reaction processes and detect intermediate species [15], even if further reactions induced by ESI conditions can occur, in particular involving the formation of oligonuclear species [16].

In our case the ESI MS analysis of the reaction mixture indicates that the first product formed by reacting *trans*-[$PtCl_2(NCMe)_2$] with cycloaliphatic amines is the monocationic species $[PtCl(Amine)(Amidine)_2]^+$, in agreement with the NMR results. It is also to note that the system *trans*-$Pt(Amidine)_2$ appears to be



Scheme 5.

particularly stable, with exchange processes occurring on the ancillary ligands without amidine loss [17] and in agreement with NMR indications [18].

2.3. X-ray crystal structure of *trans*-[$PtCl_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$}$_2$] (**1b**)

Summaries of the refinement results and other crystallographic information are provided in Table 2.

The molecular structure of **1b** shows a perfect *trans* orientation of the ligands, lying the metal ion in an inversion center. A view of the molecule with the atom-labeling scheme is shown in Fig. 1 and significant bond lengths and angles are reported in Table 3.

The square planar coordination geometry around Pt is characterized by the values of the Pt–N and Pt–Cl bond distances of 2.014(5) and 2.309(2) Å, respectively, as well as by the N(1)–Pt(1)–Cl angles (85.5(2)–94.5(2)°), in agreement with literature data [6a,19,20] for similar Pt(II) derivatives with coordinated amidine ligands. Both amidine ligands are shown to be in the *Z* configuration. The molecular structure presents two intramolecular hydrogen bonds N(2)–H···Cl of 2.364(2) Å with N(2)–H···Cl angle of 151.4(5)°, and its centrosymmetrically related part of the molecule, that stabilize the *Z* configuration of the ligands as already observed in other amidine Pt(II) complexes [6a,19,20]. The intramolecular interactions, together with the steric hindrance of the ciclopyrolamine, determine the opening of the Pt–N(1)–C(1) angle (133.4(5)°) as already observed in the complexes *trans*-[$PtCl_2${*Z*-N(H)=C(NHMe)CH_2Ph}$_2$ [6a] (136.1(5)°) and *trans*-[$PtCl_2${*Z*-N(H)=C(NHBu^t)Ph}$_2$] [19] (138.7(3)°) showing intramolecular H-bond of 2.55(9) and 2.61 Å, respectively. The N(1)–C(1) and C(1)–N(2) bond distances of 1.298(8) and 1.333(9) Å, respectively, and the angles N(1)–C(1)–N(2) and C(1)–N(2)–C(3) of 120.4(6)° and 127.6(6)° suggest an electronic delocalization along the N–C–N moiety with an sp^2 hybridization of both the nitrogen atoms. These features were found in similar amidine Pt(II) complexes such as *trans*-[$PtCl_2${*Z*-N(H)=C(NHBu^t)Me}$_2$] [6a] (with N(1)–C(1) and the N(2)–C(1) bond distances of 1.304(4) and 1.321(5) Å, respectively) and *trans*-[$PtCl_2${*Z*-N(H)=C(NHMe)CH_2Ph}$_2$] (with N(1)–C(1) and N(2)–C(1) bond distances of 1.278(8) and 1.324(9) Å, respectively) [6a]. The results reported here seem to suggest that the electronic delocalization is peculiar of this type of ligands, where the N–C(R)–N system is almost planar in analogy with the same evidence reported for uncoordinated imino ether moieties [21]. It is observed also that the C(1)–C(2) (1.492(8) Å) and N(2)–C(3) (1.461(9) Å) bond distances are well comparable with those already found in the *trans*-[$PtCl_2${*Z*-N(H=C(NHMe)Me}$_2$] derivative [6a]. The N=C–N planes of the amidine ligands form each other a

Table 2
Crystal data and structure refinement parameters for *trans*-[$PtCl_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$}$_2$] (**1b**).

Empirical formula	$C_{10}H_{20}N_4Cl_2Pt$
fw	462.29
T (K)	293(2)
λ (Å)	0.71073
Crystal system	monoclinic
Space group	*C*2/*c*
a (Å)	14.524(3)
b (Å)	8.583(2)
c (Å)	12.458(3)
β (°)	105.36(3)
V (Å^3)	1497.5(6)
Z	4
ρ_{calc} (g cm^{-3})	2.050
F (0 0 0)	880
θ range (°)	3–28
μ (Mo Kα) (mm^{-1})	7.192
No. of reflections collected	1874
No. of observed [$I \geqslant 2\sigma(I)$]	1585
R (F^2)[a]	0.031
Rw (F^2)[b]	0.076
GOF	1.232

[a] $R = \sum(|F_o| - |F_c|)/\sum|F_o|$.
[b] $R_w = [\sum\{w(|F_o|^2 - |F_c|^2)^2\}/\sum\{w(|F_o|^2)^2\}]^{1/2}$.

Table 3
Selected bond lengths (Å) and angles (°) for *trans*-[$PtCl_2${*Z*-NH=C(N(H)C_3H_5)CH_3}$_2$] (**1b**).

Pt–N(1)	2.014(5)	N(1)–Pt–Cl	94.5(2)
Pt–Cl	2.309(2)	N(1)–Pt–Cl[a]	85.5(2)
N(1)–C(1)	1.298(8)	C(1)–N(1)–Pt	133.4(5)
N(2)–C(1)	1.333(9)	C(1)–N(2)–C(3)	127.6(7)
N(2)–C(3)	1.461(9)	N(1)–C(1)–N(2)	120.4(6)
C(1)–C(2)	1.492(8)	N(1)–C(1)–C(2)	121.4(6)
C(3)–C(4)	1.476(9)	N(2)–C(1)–C(2)	118.2(6)
C(3)–C(5)	1.439(9)	N(2)–C(3)–C(5)	119.5(9)
C(4)–C(5)	1.488(9)	N(2)–C(3)–C(4)	116.4(9)

[a] At –*x*, –*y*, –*z*.

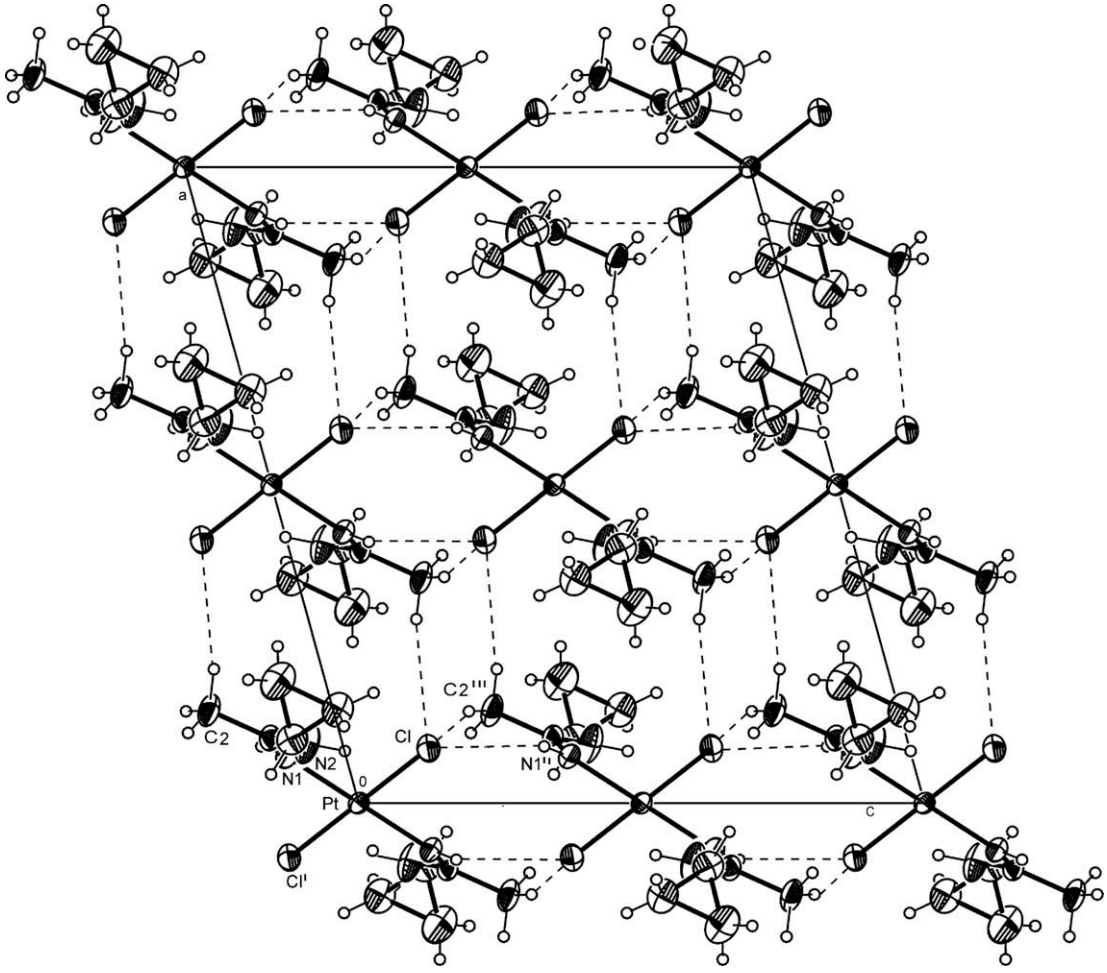


Fig. 2. Packing diagram for *trans*-[$PtCl_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$}$_2$] (**1b**) viewed down the *b*-axis. Dotted line shown the interaction between the chlorine atom and the hydrogen of the amino group of the adjacent molecules (″ at *x*, −*y*, *z* + 0.5) and with hydrogen atoms of the CH_3 amidine moiety (‴ at 0.5 − *x*, 0.5 − *y*, −*z*) giving rise a supramolecular arrangement based only on hydrogen short contacts.

dihedral angle of 7.5(4)° and with the platinum square planar a dihedral angle of 44°. Similarly to that previously observed in the case of *trans*-[$PtCl_2${*Z*-N(H)=C(NHBu^t)Me}$_2$] [6a] intermolecular hydrogen bonding interactions between the chlorine atom and the hydrogen of the amino group of the adjacent molecule (Cl···H(1)–N(1)″ 2.858(2) Å with angle of 153.8(4)°, ″ at *x*, −*y*, *z* + 1/2), determine the molecular packing with the formation of polymeric chains developing along the *c* axis (Fig. 2).

Each chlorine atom is also involved into two short contacts with hydrogen atoms of the CH_3 groups thus giving rise to a supramolecular arrangement. The shortest contact is found with the CH_3 of the same amidine moiety with which the intermolecular hydrogen bond is formed (Cl···H–C(2)″ 2.788(3) Å with angle of 160.0(5)°) in a fashion of the type depicted in Fig. 2. The last short contact is with a CH_3 group of an adjacent molecule with Cl···H–C(2)‴ bond distance of 2.938(2) Å and angle of 167.6(6)° (‴ at 0.5 − *x*, 0.5 − *y*, −*z*). In the crystal packing the shortest distance between chlorine atoms is 3.973(3) Å and between platinum atoms of 6.229(2) Å.

It is noteworthy that this supramolecular packing is achieved through the occurrence of hydrogen bonds an other short hydrogen contacts, without unsaturated moieties involvement (cooperative hydrogen bonds, electrostatic and π–π interaction are the most relevant synthons in supramolecurar metal–organic arrangements [22]).

3. Experimental

3.1. General procedures and materials

The infrared spectra were taken on a Perkin–Elmer Spectrum 100 FT IR Spectrophotometer (CsI films); the wavenumbers (ν) are given in cm^{-1}. ^1H and ^{13}C NMR solution spectra were obtained at 25 °C using a Bruker Avance-400 spectrometer (9.4-T field) operating at 400.13 and 100.61 MHz, respectively, and using a Bruker 200 AC spectrometer operating at 200.12 and 50.32 MHz, respectively; δ values (parts per million, ppm) are relative to Me_4Si. Suitable integral values for the proton spectra were obtained with a prescan delay of 10 s. The assignments of the proton resonances were performed by standard chemical shift correlation spectroscopy (COSY), total COSY (TOCSY) and Nuclear Overhauser Enhancement Spectroscopy (NOESY) experiments. In the phase-sensitive NOESY measurements the presence of intense cross-peaks, in phase with the diagonal, indicates a chemical exchange between the correlated nuclei (exchange spectroscopy spectra) [23]. The ^{13}C resonances were attributed through 2D-heterocorrelated COSY experiments: heteronuclear multiple quantum correlation (HMQC) with bilinear rotation decoupling [24] and quadrature along F1 achieved using the time proportional phase increment method [25] for the hydrogen-bonded carbon atoms, heteronuclear multiple bond correlation (HMBC) [26] for the quaternary ones. ESI MS

analyses were performed using a Finningan LCQ-Duo ion-trap instrument, operating in positive ion mode (sheathgas flow N_2 30 au, source voltage 4.0 kV, capillary voltage 21 V, capillary temperature 200 °C). The He pressure inside the trap was kept constant. The pressure directly read by an ion gauge (in the absence of the N_2 stream) was 1.33×10^{-5} Torr. The collision-induced dissociation experiments were performed by applying a supplementary RF voltage (tickle voltage) to the end caps of the ion-trap in the range 0–80% of its maximum value (5 V peak to peak). Sample solutions were prepared by reacting *trans*-[$PtCl_2(NCCH_3)_2$] (3 mg) in CH_3CN (5 ml) with 2.2 equiv. of the amine and immediately analyzed.

All work was carried out under a N_2 atmosphere using standard Schlenck techniques. All solvents were reagent grade and were distilled prior to use. Deuterated solvents were purchased from Cambridge Isotope Laboratories (CIL) and stored under molecular sieves. *Trans*-[$PtCl_2(NCMe)_2$] was synthesized as described in the literature [27].

3.2. Reactions of trans-[$PtCl_2(NCMe)_2$] with cycloaliphatic primary amines

3.2.1. Reaction of trans-[$PtCl_2(NCMe)_2$] with cyclopropylamine

A suspension of *trans*-[$PtCl_2(NCMe)_2$] (300 mg, 0.86 mmol) in CH_2Cl_2 (30 ml) at −20 °C was treated with a 5-fold excess of cyclopropylamine 300 μl (4.3 mmol; $\rho = 0.824$ g/ml). The reaction mixture was stirred at the low temperature for 5 h and then the volume was concentrated to ca. 10 ml under reduced pressure. *n*-Hexane (40 ml) was added and the suspension was stirred at −10 °C for 1 h. The precipitate was then filtered off at room temperature and washed with Et_2O (3 × 15 ml). By ^{1}H NMR spectroscopy, the reaction product revealed to be a mixture of products where the most abundant were the neutral diamidine complex *trans*-[$PtCl_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$}$_2$] (**1b**), the dicationic diamine–diamidine complex *trans*-[Pt(NHCHCH$_2$CH$_2$)$_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$}$_2$]Cl_2 (**1c**) and the monocationic amine- diamidine complex *trans*-[PtCl(NHCHCH$_2$CH$_2$){N(H)=C(CH_3)NHCHCH$_2$CH$_2$}$_2$]Cl (**1d**). Complex **1c** was obtained as a pure product by performing the reaction at room temperature for 24 h [13]. Complex **1b** has been obtained in higher yield (50%) by reacting *trans*-[$PtCl_2(NCMe)_2$] (100 mg, 0.29 mmol) in THF (10 ml) at 0 °C with a 2.2-fold excess of cyclopropylamine 44 μl (0.63 mmol; $\rho = 0.824$ g/ml) and crystallized from CH_2Cl_2/Et_2O. *Anal.* Calc. for $C_{10}H_{20}N_4Cl_2Pt$ (MW 462.28): C, 25.98; H, 4.36; N, 12.12. Found: C, 26.11; H, 4.40; N, 12.24%. IR: ν_{N-H} 3439, 3227, 3219 cm^{-1} (m), $\nu_{C=N}$ 1628 cm^{-1} (s), ν_{PtCl_2} 322 cm^{-1} (w). ^{1}HNMR ($CDCl_3$) : $\delta = 0.67$ and 0.81 (m, C*H*$_2$, 4H), 2.32 (s, NCC*H*$_3$, 3H), 2.60 (m, N(H)C*H*, 1H), 7.50 (s, Pt*NH*, 1H), 7.42 (d, N*H*, $^3J_{HH} = 8.0$ Hz,1H). ^{13}C {^{1}H} NMR ($CDCl_3$): $\delta = 21.2$ (s, *C*H$_3$), 7.3 (s, *C*H$_2$), 24.8 (s, *C*H), 169.9 (s, *C*=N). Complex **1d**: IR: $\nu_{C=N}$ 1630 cm^{-1} (s). ^{1}HNMR ($CDCl_3$) : $\delta = 0.65$ and 0.80 (m, C*H*$_2$, 4H), 2.31 (s, NCC*H*$_3$, 3H), 2.60 (m, N(H)C*H*, 1H), 7.29 (s, Pt*NH*, 1H), 7.51 (d, N*H*, $^3J_{HH} = 8.0$ Hz,1H); 6.00 (d, NH_2(amine) $^3J_{HH} = 8.2$ Hz, 2H). ^{13}C {^{1}H} NMR ($CDCl_3$): $\delta = 20.9$ (s, *C*H$_3$), 7.2 (s, *C*H$_2$), 24.1 (s, *C*H), 169.7 (s, *C*=N).

3.2.2. Reaction of trans-[$PtCl_2(NCMe)_2$] with cyclopentylamine

A suspension of *trans*-[$PtCl_2(NCMe)_2$] (300 mg, 0.86 mmol) in CH_2Cl_2 (30 ml) at −20 °C was treated with a 5-fold excess of cyclopentylamine 424 μl (4.3 mmol; $\rho = 0.863$ g/ml). The reaction mixture was stirred at the low temperature for 5 h and then the volume was concentrated to ca. 10 ml under reduced pressure. *n*-Hexane (40 ml) was added and the suspension was stirred at −10 °C for 1 h. The precipitate was then filtered off at room temperature and washed with Et_2O (3 × 15 ml). By ^{1}H NMR spectroscopy, the reaction product revealed to be a mixture of products where the most abundant were the complexes *trans*-[PtCl(NHCHCH$_2$CH$_2$CH$_2$CH$_2$){N(H)=C(CH_3)NHCHCH$_2$CH$_2$CH$_2$CH$_2$}$_2$]Cl (**2d**) and *trans*-[Pt(NHCHCH$_2$CH$_2$CH$_2$CH$_2$)$_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$CH$_2$CH$_2$}$_2$]Cl_2 (**2c**). Complex **2c** was obtained as a pure product by performing the reaction at room temperature for 24 h [13]. Complex **2d**: IR: $\nu_{C=N}$ 1640 cm^{-1} (s). ^{1}H NMR ($CDCl_3$): $\delta = 1.57$ and 1.94 (m, N(H)CHCH$_2$C*H*$_2$, 4H), 1.69 and 1.80 (m, N(H)CHC*H*$_2$, 4H), 3.75 (m, N(H)C*H*, 1H), 2.25 (s, NCC*H*$_3$), 7.69 (br, Pt*NH*), 7.13 (s, $^3J_{HH} = 8.5$ Hz, N*H*); 5.88 (d, NH_2(amine) $^3J_{HH} = 8.2$ Hz, 2H). ^{13}C {^{1}H} NMR ($CDCl_3$): $\delta = 21.5$ (s, NCCH_3), 23.5 (s, N(H)CHCH$_2$C*H*$_2$), 33.9 (s, N(H)CHC*H*$_2$), 54.7 (s, N(H)*C*H), 165.2 (s, *C*=N).

3.2.3. Reaction of trans-[$PtCl_2(NCMe)_2$] with cyclohexylamine

A suspension of *trans*-[$PtCl_2(NCMe)_2$] (300 mg, 0.86 mmol) in CH_2Cl_2 (30 ml) at −20 °C was treated with a 5-fold excess of cyclopentylamine 492 μl (4.3 mmol; $\rho = 0.867$ g/ml). The reaction mixture was stirred at the low temperature for 5 h and then the volume was concentrated to ca. 10 ml under reduced pressure. *n*-Hexane (40 ml) was added and the suspension was stirred at −10 °C for 1 h. The precipitate was then filtered off at room temperature and washed with Et_2O (3 × 15 ml). By ^{1}H NMR spectroscopy, the reaction product revealed to be a mixture of products where the most abundant were the complexes *trans*-[PtCl(NHCHCH$_2$CH$_2$CH$_2$ CH$_2$CH$_2$){N(H)=C(CH_3)NHCHCH$_2$CH$_2$CH$_2$CH$_2$CH$_2$}$_2$]Cl (**3d**) and *trans*-[Pt(NHCHCH$_2$CH$_2$CH$_2$ CH$_2$CH$_2$)$_2${N(H)=C(CH_3)NHCHCH$_2$CH$_2$CH$_2$CH$_2$CH$_2$}$_2$]Cl_2 (**3c**). Complex **3c** was obtained as a pure product by performing the reaction at room temperature for 24 h [13]. Complex **3d**: IR: ν_{N-H} 3439, 3227, 3219 cm^{-1} (m), $\nu_{C=N}$ 1635 cm^{-1} (s). ^{1}H NMR ($CDCl_3$): $\delta = 1.17$ and 1.99 (m, N(H)CHC*H*$_2$, 4H), 1.22 and 1.82 (m, N(H)CHCH$_2$C*H*$_2$, 4H), 1.64 and 1.20 (m, N(H)CHCH$_2$CH$_2$C*H*$_2$, 2H), 3.10 (m, N(H)C*H*, 1H), 2.20 (m, NCC*H*$_3$, 3H), 7.01 (br, Pt*NH*, 1H), 7.14 (d, $^3J_{HH} = 8.8$ Hz, N*H*, 1H), 5.84 (d, NH_2(amine) $^3J_{HH} = 8.3$ Hz, 2H). ^{13}C {^{1}H} NMR ($CDCl_3$): $\delta = 20.3$ (s, NCCH_3), 24.7 (s, N(H)CHCH$_2$CH$_2$C*H*$_2$), 34.3 (s, N(H)CHC*H*$_2$), 25.3 (s, N(H)CHCH$_2$C*H*$_2$), 54.1 (s, N(H)*C*H), 165.4 (s, *C*=N).

3.3. X-ray measurements and structure determination

Crystal was lodged in Lindemann glass capillary and centered on a four circle Philips PW1100 diffractometer using graphite monochromated Mo Kα radiation (0.71073 Å), following the standard procedures, at room temperature. All intensities were corrected for Lorentz polarization and absorption [28]. The structure was solved by standard direct methods [29]. Refinement was carried out by full-matrix least-squares procedures (based on F_o^2) using anisotropic temperature factors for all non-hydrogen atoms. Hydrogen atoms were placed in calculated position with fixed isotropic thermal parameters (1.2 $\boldsymbol{U}_{equiv}$) of the parent carbon atom. Structure refinement and final geometrical calculations were carried out with SHELXL-97 [30] program, implemented in the WINGX package [31].

4. Supplementary material

CCDC 742479 contains 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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