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Multiple Metal Binding to the 9-Methyladenine Model Nucleobase Involving N1, N6, and N7: Discrete Di- and Trinuclear Species with Different Combinations of Monofunctional Pd^{II} and Pt^{II} Entities

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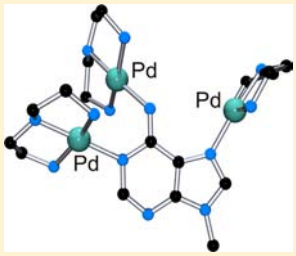
Supporting Information

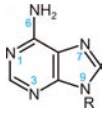
ABSTRACT: Several di- and trinuclear metal complexes consisting of the model nucleobase 9-methyladenine (9-MeA) or its mono-deprotonated form (9-MeA^-) and monofunctional $(dien)Pd^{II}$, $(dien)Pt^{II}$, $(NH_3)_3Pt^{II}$, or $(trpy)Pd^{II}$ in different combinations have been prepared and/or studied in solution by NMR spectroscopy: $[\{Pd(dien)\}_3(9\text{-MeA}^-\text{-}N1,N6,N7)]Cl_{3.5}(PF_6)_{1.5}\cdot 3H_2O$ (**1**), $[(dien)Pd(N1\text{-}9\text{-MeA-}N7)Pt(NH_3)_3](ClO_4)_4\cdot 9.33H_2O$ (**2**), $[(dien)Pt(N1\text{-}9\text{-MeA-}N7)Pt(NH_3)_3](ClO_4)_4\cdot H_2O$ (**3**), and $[\{(trpy)Pd\}_2(N1,N6\text{-}9\text{-MeA}^-\text{-}N7)Pt(NH_3)_3](ClO_4)_5\cdot 3H_2O$ (**4**). A migration product of **3**, $[(dien)Pt(N6\text{-}9\text{-MeA}^-\text{-}N7)Pt(NH_3)_3]^{3+}$ (**3a**), has been identified in solution. Unlike Pt-adenine bonds, Pd-adenine bonds are substantially labile, and consequently all Pd-containing complexes discussed here (**1**, **2**, **4**) exist in aqueous solution in equilibria of slowly interconverting species, which give rise to individual resonances in the ^1H NMR spectra. For example, **1** exists in an equilibrium of five adenine-containing species when dissolved in D_2O, **2** undergoes dissociation to $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ or forms the migration product $[(dien)Pd(N6\text{-}9\text{-MeA}^-\text{-}N7)Pt(NH_3)_3]^{3+}$ (**2a**), depending on pD, and **4** loses both $(trpy)Pd^{II}$ entities as the pD is increased. In no case is Pd binding to N3 of the adenine ring observed. A comparison of the solid-state structures of the two trinuclear complexes **1** and **4** reveals distinct differences between the Pd atoms bonded to N1 and N6 in that these are substantially out of the nucleobase plane in **1**, by ca. 0.6 Å and −1.0 Å, respectively, whereas they are coplanar with the 9-MeA^- plane in **4**. These out-of-plane movements of the two $(dien)Pd^{II}$ units in **1** are not accompanied by changes in hybridization states of the N1 and N6 atoms.



1. INTRODUCTION

N9-Blocked adenine nucleobases such as 9-methyladenine, 9-MeA (Chart 1), provide three endocyclic nitrogen atoms as potential metal coordination sites that are unprotonated at physiological pH, namely N1, N3, and N7. In addition, metal binding to the exocyclic N6 position is possible, following deprotonation of this site or a proton shift from the exocyclic amino group to an endocyclic ring nitrogen atom, hence tautomerization. Depending upon the specific conditions (pH, ratio of metal:nucleobase, nature of metal), binding to any of these positions, either *individually* or in *pairwise* combinations, is well documented.[1−5] A *3-fold* metal binding pattern, through N6,N7 in a chelating fashion as well as through N1 in a monodentate way, has been observed in a series of C_3-symmetrical cyclic trimer complexes of $M_3(A^-)_3$ stoichiometry (with A^- = N9-blocked adenine deprotonated at N6), with M being an octahedral metal ion.[6] Likewise *3-fold* metal binding, via N1, N3, and N7, is realized in a silver complex of 9-allyladenine[7] and in a helical mixed platinum/silver compound of 9-methyladenine.[8] Metal complexes containing unsubstituted adenine provide in addition the N9 site, thereby permitting even more combinations, but these shall not be further considered here.

Chart 1



Here we report on our findings on *3-fold* metal coordination of monodentate metal entities to N1, N6, and N7 of an adenine model nucleobase. Originally observed accidentally when reacting 9-MeA with an excess of $[Pd(dien)(OH)]^+$ at pH 11, we subsequently set out to better understand the way of formation of this product by partially replacing the labile $(dien)Pd^{II}$ units by more inert Pt^{II} entities, namely $(NH_3)_3Pt^{II}$ and $(dien)Pt^{II}$. As has previously been shown by us,[9] blockage of the N7 position of 9-MeA by $(NH_3)_3Pt^{II}$ permits a more detailed study of the coordination chemistry of pyrimidinic part

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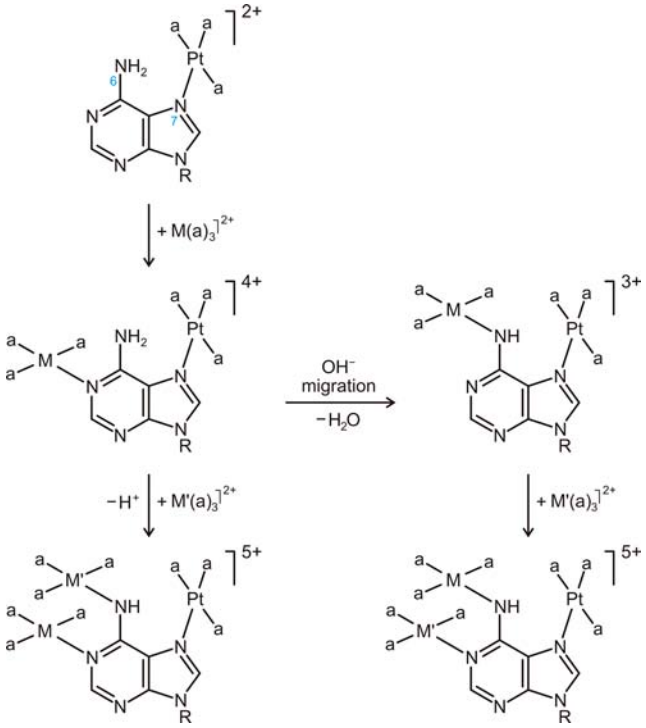
of the purine nucleobase and has led to mixed metal compounds with other cases of simultaneous metal coordination to N1, N6, and N7 sites.[9a] Specifically, we were interested in finding out whether metal binding to the exocyclic N6 site occurs directly from the N1,N7 dimetalated species or whether it takes place via the detour of initial metal migration from N1 to N6, and subsequent remetalation of N1 (Scheme 1).

Scheme 1. Feasible Pathways of Formation of Trinuclear 9-MeA Complexes Starting from $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$. With M ≠ M′, Two Different Isomers Can Be formed.



After all, as has been demonstrated before,[9b,10] metal migration from the kinetically favored N1 to the thermodynamically favored N6 is a common route to transition metal complexes carrying the metal ion at the deprotonated exocyclic amino group.

We have previously studied related mechanistic questions regarding the migration of a metal entity from N3 of 1-methylcytosine to the exocyclic amino group N4[11] and the way of formation of N3,N4 dimetalated 1-methylcytosinato complexes when starting from a compound with a single metal entity sitting at N3.[12] As to the former, it was found that metal migration from N3 to N4 via a chelate intermediate is possible, at least for Pt^{IV}.[11] Regarding the latter, there was circumstantial evidence from NMR spectroscopy that formation of dinuclear $(dien)Pt^{II}$ species proceeds via an initial metal migration step (from N3 to N4), followed by coordination of the second $(dien)Pt^{II}$ to N3, yet in a parallel way also via direct platination of N4.

2. EXPERIMENTAL SECTION

Materials and Methods. K_2PtCl_4, K_2PdCl_4, and adenine were of commercial origin. 9-Methyladenine (9-MeA),[13] $[Pt(9\text{-MeAH-}N7)Cl_3]$,[14] $[Pt(NH_3)_3(9\text{-MeA-}N7)](ClO_4)_2$,[15] $[(dien)Pd(N1\text{-9-MeA-}N7)Pt(NH_3)_3](ClO_4)_4\cdot 9.33H_2O$ (**2**),[16] [Pt(dien)I]I,[17] [Pd(dien)I]I,[18] and [Pd(trpy)Cl]Cl[19] were prepared as reported in the literature. C8-Deuterated 9-MeA (9-MeA-*d*8) was obtained by treating 9-MeA in D_2O at 80 °C.[20]

Instrumentation. Elemental analyses (C, H, N) were performed on a Leco Elemental Analyzer CHNS-932. ^1H NMR and ^{195}Pt NMR spectra were recorded on Varian FT-NMR Mercury 200, Bruker AC 300, and Bruker DRX 400 instruments in D_2O with sodium-3-(trimethysilyl)propanesulfonate (TSP, δ = 0.0 ppm) as the internal reference. The pD values of NMR samples were determined by use of a glass electrode and addition of 0.4 units to the uncorrected pH meter reading (pH*).[21] The pK_a values were determined by means of pD dependent ^1H NMR spectroscopy, and the changes in the chemical shifts of protons resulting from changes in pD were evaluated by a nonlinear least-squares fit according to the Newton−Gauss method.[22] The pK_a values for D_2O, obtained by this method, were then converted to H_2O.[23] The dissociation of **2** in dependence of the metal complex concentration was carried out by preparing NMR samples of defined concentrations of **2** and by integrating the methyl resonances of the two 9-MeA species and calculating the relevant concentrations of the two species. The pD values were checked and found to be in the range of 5−6.

*Preparation of $[\{Pd(dien)\}_3(9\text{-MeA}^-\text{-}N1,N6,N7)]Cl_{3.5}(PF_6)_{1.5}\cdot 3H_2O$ (**1**).* A suspension of [Pd(dien)I]I (83.3 mg, 0.18 mmol) and $AgPF_6$ (89 mg, 0.36 mmol) in water (10 mL) was stirred at 40 °C with daylight excluded for 24 h. After cooling (ice bath) and filtration of AgI, the solution was added to a solution of 9-MeA (13.8 mg, 0.09 mmol) in water (5 mL) and the pH raised to pH 11 by means of NaOH. After stirring for 1 h at 40 °C, another equivalent of $[Pd(dien)(H_2O)]^{2+}$ was added and the mixture stirred for 2 h at 40 °C and allowed to crystallize at 4 °C in the presence of a small amount of NaCl. Small yellow crystals were obtained in low yield after several days, which were characterized by X-ray crystallography. For ^1H NMR spectra of **1**, see Results and Discussion.

*Preparation of $[(dien)Pt(N1\text{-9-MeA-}N7)Pt(NH_3)_3](ClO_4)_4\cdot H_2O$ (**3**).* To a suspension of [Pt(dien)I]I (110 mg, 0.2 mmol) in water (3 mL), a solution of $AgClO_4$ (79 mg, 0.38 mmol, dissolved in 2 mL of H_2O) and a solution of $[Pt(NH_3)_3(9\text{-MeA-}N7)](ClO_4)_2$ (119 mg, 0.2 mmol dissolved in 5 mL of H_2O) were added. The mixture was stirred for 2 days at 40 °C with daylight excluded. After cooling (ice bath) for 30 min and filtration of AgI, the clear solution was allowed to crystallize at room temperature. The crude product (70 mg) was recrystallized from water (2 mL) with an excess of $NaClO_4$ added. Colorless crystals that appeared, proved to be **3**, according to X-ray crystallography. The yield was 50 mg (22%). Elemental analysis was in agreement with the presence of two water molecules per unit, but X-ray analysis revealed a lower water content. Calcd (%) for $C_{10}H_{33}N_{11}Cl_4O_{18}Pt_2$: C, 10.65; H, 2.95; N, 13.67. Found: C, 10.6; H, 2.9; N, 13.2. ^1H NMR (δ, D_2O, pD 7.5): 8.83 (superposition of H2 and H8, ca. 1.5H), 3.95 (s, 3H, CH_3), 3.32−2.88 (m, 8H, CH_2 dien). The ^1H NMR spectrum of a freshly prepared solution of **3** showed not even a trace of the Pt starting complex $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$. However, the same sample, kept at room temperature and daylight for six months showed a small amount (estimated 1−3%) of the starting compound and at the same time some changes around 8.8 ppm (isotopic exchange of H8). Complex **3** was obtained also by applying an excess of $[Pt(dien)(H_2O)](ClO_4)_2$ (molar ratio 1:2) to the starting compound $[Pt(NH_3)_3(9\text{-MeA-}N7)](ClO_4)_2$.

*Preparation of $[\{(trpy)Pd\}_2(N1,N6\text{-9-MeA}^-\text{-}N7)Pt(NH_3)_3](ClO_4)_5\cdot 3H_2O$ (**4**).* To a solution of [Pd(trpy)Cl]Cl (62.5 mg, 0.14 mmol) in water (3 mL), a solution of $AgClO_4$ (55.1 mg, 0.26 mmol in 1 mL of water) and a solution of $[Pt(NH_3)_3(9\text{-MeA-}N7)](ClO_4)_2$ (41.6 mg, 0.07 mmol, in 3 mL of water) were added. The mixture was stirred for 5 days at 65 °C with daylight excluded. After one day, the pH of the mixture was adjusted to 3.6. After five days the mixture was centrifuged, and the AgCl was removed by filtration. The clear yellow solution was then allowed to crystallize at room temperature. Orange crystals of **4** were isolated in 35% yield (40 mg). They contain three water molecules, as proved by X-ray crystallography. However, elemental analysis was in agreement with the presence of two water molecules per unit. Calcd (%) for $C_{36}H_{41}Cl_5N_{14}O_{22}Pd_2Pt$: C, 26.91; H, 2.57; N, 12.20. Found: C, 27.1; H, 2.7; N, 12.4. Compound **4** was

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obtained also by applying 1:1 and 1:3 molar ratios (Pt:Pd) of the precursor complexes. For ^{1}H NMR spectra of **4**, see Results and Discussion.

X-ray Data Collection. X-ray crystal data for **1**, **3**, and **4** were collected at 150 K on an Enraf-Nonius Kappa CCD (**1**) and on an Oxford Diffraction Xcalibur S (**3** and **4**) diffractometers, both equipped with monochromated Mo Kα radiation (0.71073 Å). Data reduction and cell refinement was done using the DENZO and SCALE-PACK (**1**) and CrysAlisPro (**3** and **4**) software.[24] All structures were solved by direct methods and refined by full-matrix least-squares methods based on F^2 using the SHELXL-97 and WinGX software.[25] All non-hydrogen atoms were refined anisotropically. All hydrogen atoms were positioned geometrically in idealized positions and refined with isotropic displacement parameters according to the riding model. Calculations were performed using the SHELXL-97 and WinGX software.[26] Refinement parameters for **1**, **3**, and **4** are as follows:

Crystal data for [{Pd(dien)}$_3$(9-MeA$^-$-*N*1,*N*6,*N*7)]-Cl$_{3.5}$(PF$_6$)$_{1.5}$·3H$_2$O (**1**): [C$_{36}$H$_{102}$Cl$_7$F$_{18}$N$_{28}$O$_6$P$_3$Pd$_6$], monoclinic, $P2_1/c$, a = 12.659(3) Å, b = 16.193(3) Å, c = 20.720(4) Å, β = 105.52(3)°, Z = 2, M_r = 2344.92 g mol^{-1}, V = 4092.5(14) Å^3, D_{calcd} = 1.903 g cm^{-3}, μ = 1.675 mm^{-1}, 17453 reflections collected, 8978 unique (R_{int} = 0.0529), $R1(F_o)$ = 0.0343 [$I > 2\sigma(I)$], $wR2$ (F_o^2) = 0.0552 (all data), GOF = 0.803. CCDC 878400.

Crystal data for [(dien)Pt(*N*1-9MeA-*N*7)Pt(NH$_3$)$_3$](ClO$_4$)$_4$·H$_2$O (**3**): [C$_{10}$H$_{31}$Cl$_4$N$_{11}$O$_{17}$Pt$_2$], triclinic, $P\bar{1}$, a = 8.0028(2) Å, b = 12.3780(4) Å, c = 16.3191(5) Å, α = 73.092(3)°, β = 82.199(3)°, γ = 79.405(3)°, Z = 2, M_r = 1109.44 g mol^{-1}, V = 1514.48(8) Å^3, D_{calcd} = 2.433 g cm^{-3}, μ = 9.669 mm^{-1}, 22753 reflections collected, 7179 unique (R_{int} = 0.0291), $R1(F_o)$ = 0.0265 [$I > 2\sigma(I)$], $wR2$ (F_o^2) = 0.0579 (all data), GOF = 1.055. CCDC 878401.

Crystal data for [{(trpy)Pd}$_2$(*N*1,*N*6-9MeA$^-$-*N*7)Pt(NH$_3$)$_3$]-(ClO$_4$)$_5$·3H$_2$O (**4**): [C$_{36}$H$_{43}$Cl$_5$N$_{14}$O$_{23}$Pd$_2$Pt], monoclinic, $P2_1/c$, a = 15.3957(5) Å, b = 18.5924(6) Å, c = 20.2973(11) Å, β = 114.318(3)°, Z = 4, M_r = 1624.98 g mol^{-1}, V = 5294.5(4) Å^3, D_{calcd} = 2.039 g cm^{-3}, μ = 3.655 mm^{-1}, 43329 reflections collected, 12714 unique (R_{int} = 0.0424), $R1(F_o)$ = 0.0351 [$I > 2\sigma(I)$], $wR2$ (F_o^2) = 0.0815 (all data), GOF = 0.955. CCDC 878402.

3. RESULTS AND DISCUSSION

X-ray Crystal Structure of [{Pd(dien)}$_3$(9-MeA$^-$-*N*1,*N*6,*N*7)]Cl$_{3.5}$(PF$_6$)$_{1.5}$·3H$_2$O (1). Yellow crystals of **1** were isolated in low yield when a reaction mixture containing 9-MeA and [Pd(dien)(H$_2$O)](PF$_6$)$_2$ (r = 1:2) was brought to pH 11 and crystallized in the presence of NaCl. Figure 1 gives two

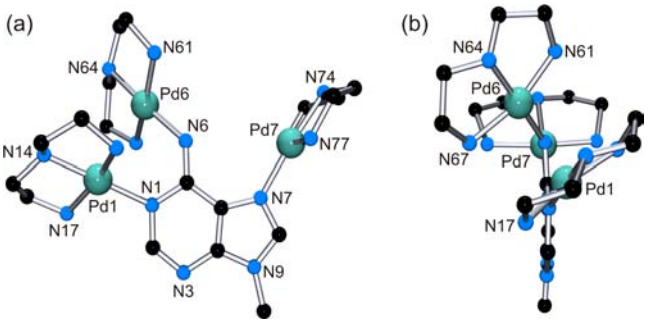

Figure 1. Front (a) and side (b) views of cation of Pd$_3$ complex **1**.

different views of the molecular cation of **1**, in which three (dien)Pd^{II} units are bonded to N1, N7, and the monodeprotonated N6 positions of the adenine nucleobase. The Pd atoms bonded to N1 (Pd1) and N6 (Pd6) are facing each other (Pd1–Pd6, 3.2354(8) Å, av. torsion angle 24.0°), a feature that appears to be further supported by hydrogen bonding interactions with three different chloride counteranions, which bridge NH-donor sites of the dien ligands: N11···Cl3···N61 (3.220(3) Å and 3.241(3) Å), N14···Cl2···N64 (3.120(4) Å and 3.152(3) Å), and N17···Cl4···N67 (3.206(3) Å and 3.364(3) Å). Tilt angles between the best adenine plane and the square-planar coordination planes of Pd1 and Pd6 are 48.97(10)° and 53.45(9)°, respectively. The coordination plane of Pd7 is roughly perpendicular to the adenine plane (84.40 (9)°). Pd–N bond lengths to the adenine donor atoms and to the dien-N atoms are not significantly different and are in the typical range for such bonds. Intramolecular Pd–Pd distances are as follows: Pd1···Pd6, 3.2354(8) Å; Pd6···Pd7, 5.2366(11) Å. Selected interatomic distances and angles are listed in Table 1. A view

Table 1. Selected Distances [Å] and Angles [deg] of Complex 1

Pd1–N1	2.060(3)	Pd7–N74	2.008(3)
Pd1–N11	2.040(3)	Pd7–N77	2.019(3)
Pd1–N14	2.002(3)	C6–N6	1.317(5)
Pd1–N17	2.049(3)	C6–N6–Pd6	129.0(3)
Pd6–N6	2.039(3)	C6–N6–H6	114(3)
Pd6–N61	2.039(3)	Pd6–N6–H6	112(3)
Pd6–N64	2.011(3)	N6–C6–N1	119.1(4)
Pd6–N67	2.045(3)	N6–C6–C5	126.3(4)
Pd7–N7	2.034(3)	N1–C6–C5	114.6(3)
Pd7–N71	2.048(3)	Pd1–Pd6	3.2354(8)

along the adenine plane of cation **1** as given in Figure 1b reveals marked differences between the positions of the three (dien)Pd^{II} units: While Pd7 is close to coplanar with the adenine plane (deviation −0.184(3) Å), Pd1 is significantly out of the nucleobase plane (0.577(3) Å), and Pd6 is even dramatically out of it (−0.989(4) Å), in opposite direction to Pd1. At first glance, the strong deviation of Pd6 might point to a change in N6 hybridization, from sp^2 in free 9-MeA to sp^3 in **1**, yet neither the size of the C6–N6–Pd6 angle of 129.0(3)° nor the shortness of the C6–N6 bond (1.317(5) Å), which compares with 1.329(2) Å in 9-MeA,[27] are consistent with this assumption. The angles about the H6 imido proton, which have been located in the difference Fourier map, have too high standard deviations to provide additional information. It is noted, however, that we have previously observed this feature—substantial out-of-plane movements of (en)Pd^{II} bonded to N6 and N1 sites of 9-MeA$^-$ in heteronuclear Pt$_2$Pd$_2$ complexes—although they were smaller than in the present case with **1** (max. 0.76(2) Å).[9a] As to Pd1 bonded to N1, the sum of the angles about N1 (Pd1–N1–C2, 115.0(3)°; Pd1–N1–C6, 124.0(2)°; C2–N1–C6, 119.6(3)°) suggest that despite some distortion and despite the deviation of Pd1 from the adenine plane, the N1 atom likewise remains sp^2 hybridized. A comparison with the situation in complex **4** (see below) tentatively suggests that steric constraints (repulsion of dien ligands: N11···N61, 3.815(5) Å; N17···N67, 3.751(4) Å) in conjunction with the softness of the (dien)Pd–N(adenine) bonds are mainly responsible for these structural features.

Solution Behavior of 1. The ^{1}H NMR spectrum of **1**, dissolved in D$_2$O (pD ca. 8.5), is complicated, giving rise to (at least) five sets of adenine resonances (A–E) (Figure 2). This multiplicity of resonances arises from rapid equilibration of different (dien)Pd^{II} complexes. By systematically varying the ratio r between [Pd(dien)(D$_2$O)]$^{2+}$ and 9-MeA as well as the

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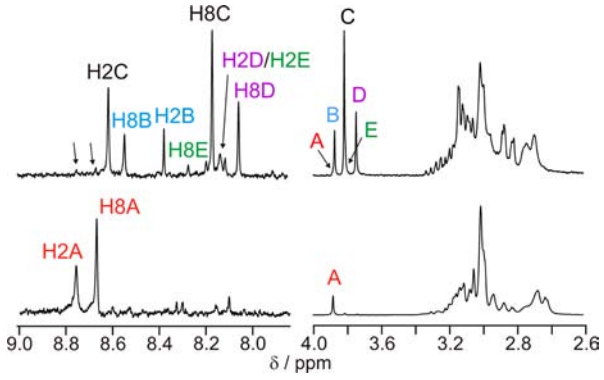

Figure 2. ^{1}H NMR spectrum of **1** in D_2O, pD 8.5 (top) and after addition of an excess of $[Pd(dien)(D_2O)]^{2+}$ at pD 6.7 (bottom). Note that aromatic and aliphatic resonances are drawn at different scales.

pD, several of the various species were assigned (Supporting Information). In most cases, a differentiation between H2 and H8 resonances of the adenine ligand was achieved by parallel experiments in which C8-deuterated 9-methyladenine (9-MeA-*d*8) was employed instead of regular 9-MeA, thereby allowing an unambiguous assignment of the H2 resonances.

Thus, with r = 1:1, pD 5.3, the solution contains the linkage isomer $[Pd(dien)(9\text{-MeA-}N1)]^{2+}$ (C) as the major product, followed by $[Pd(dien)(9\text{-MeA-}N7)]^{2+}$ (B), and free 9-MeA, with relative intensities of ca. 3:1:1 for C:B:9-MeA. The assignment of the two linkage isomers was achieved by comparison with the chemical shifts of the analogous $(dien)Pt^{II}$ species, which have been reported previously.[28] The preference of $(dien)Pd^{II}$ for N1 of 9-MeA is consistent with the higher basicity of this site over N7, as reported by Lim and Martin.[29] As the ratio r is increased to 2 (pD 5.8), free 9-MeA disappears, and a new species appears at lower field than (B) and (C), which is assigned to the dinuclear $[\{Pd(dien)\}_2(9\text{-MeA-}N1,N7)]^{4+}$ complex (A). Again, the situation with the dinuclear $(dien)Pt^{II}$ complex is similar.[30] An increase in pD (to 8.8 and 10.3; r = 2:1) causes a decrease in the intensity of (A) up to the point that its resonances are no longer seen (pD > 10). Instead the appearance of resonances due to two new sets of adenine resonances (D, E) is observed. The methyl resonances of these new species, which are also seen in low (E) to moderate abundance (D) when **1** is dissolved in D_2O, occur furthest upfield of all methyl resonances, at 3.75 and 3.80 ppm, respectively. Three of the four aromatic resonances are likewise at higher field than any of the other sets (A, B, C). Both species are therefore assigned to complexes with N6 being monodeprotonated and carrying a $(dien)Pd^{II}$ entity. However, a straightforward differentiation between N1,N6 or N6,N7 or N1,N6,N7 binding modes in D and E is not possible (see, however, discussion below on nature of **2a** and similarity with E). Relevant shifts of A–E are listed in the Supporting Information.

Observations with redissolved **1** thus demonstrated that the $(dien)Pd^{II}$ bonds with N atoms of 9-MeA are labile and that in neutral to moderately basic aqueous solution an equilibrium of five species occurs, which are in slow exchange on the NMR time scale. In order to get a deeper insight into this system, it was decided to substitute some of the $(dien)Pd^{II}$ entities by more robust $(NH_3)_3Pt^{II}$ and $(dien)Pt^{II}$ units. Specifically, the 9-MeA compound with $(NH_3)_3Pt^{II}$ coordinated to the N7 site, hence $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ was applied as a starting material.

Comparison of Cations of $[(dien)Pd(N1\text{-}9\text{-MeA-}N7)Pt(NH_3)_3](ClO_4)_4\cdot 9.33H_2O$ (2) and $[(dien)Pt(N1\text{-}9\text{-MeA-}N7)Pt(NH_3)_3](ClO_4)_4\cdot H_2O$ (3). These two compounds were prepared by reacting $[Pt(NH_3)_3(9\text{-MeA-}N7)](ClO_4)_2$ with $[Pd(dien)(H_2O)](ClO_4)_2$ and $[Pt(dien)(H_2O)](ClO_4)_2$, respectively, in water. Figure 3 gives views of the closely similar cations. Selected interatomic distances and angles of **3** are compiled in Table 2. Structural details of compound **2** and specifically its amazing arrangement of water molecules in the crystal structure have been recently reported by us.[16]

Table 2. Selected Distances [Å] and Angles [deg] of Complex 3

Pt1–N1	2.036(4)	Pt7–N7	2.016(4)
Pt1–N11	2.043(4)	Pt7–N71	2.050(4)
Pt1–N14	2.007(4)	Pt7–N72	2.036(4)
Pt1–N17	2.052(4)	Pt7–N73	2.039(4)
N11–Pt1–N17	168.66(17)	N71–Pt7–N73	178.71(17)
C6–N6	1.325(6)		

Both cations differ in water content (crystal packing), space groups of the unit cells, namely $R-3$ (**2**) and $P-1$ (**3**), and some additional aspects: The dien ligands of Pt^{II} (**2**) and Pd^{II} (**3**) ions display opposite $\delta\lambda$ and $\lambda\delta$ "sting ray" conformations of their dien ligands,[31] with the N14H protons *anti* (**2**) or *syn* (**3**) positioned with respect to the N6 exocyclic site. M–M distances are almost identical 6.3621(8) Å (**2**) and 6.3664(8) Å (**3**). Deviations of tilt angles between adenine and metal coordination planes and of metal–adenine distances are more pronounced in cation **2** (81.61(18)°, $Pd1N_4$; 84.87(19)°, $Pt7N_4$; 0.359(9) Å, Pd1; and 0.120(9) Å, Pt7) than in **3**

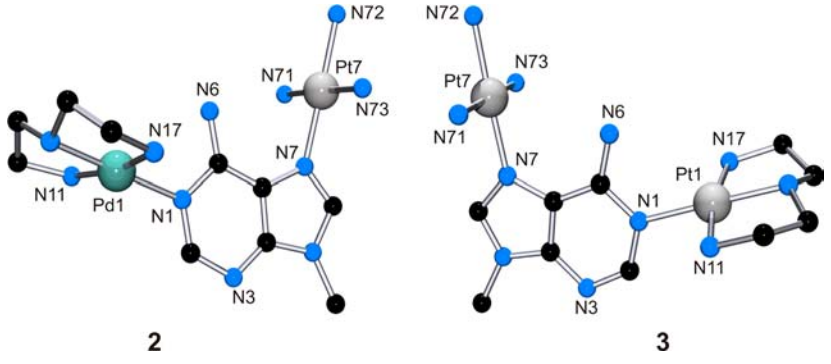

Figure 3. Views of cations of PdPt complex **2** and of Pt_2 complex **3**.

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(79.96(9)°, Pt1N$_4$; 89.38(9)°, Pt7N$_4$; 0.034(4) Å, Pt1; and 0.153(5) Å, Pt7). In the crystal, cations of **3** are surrounded by a water molecule and nine perchlorate anions. Two of them interact via 2-fold anion−π interactions with both adenine rings (Figure 4), while the remaining ones are engaged in hydrogen bonds with cation **3**. No significant interactions between cations are observed.

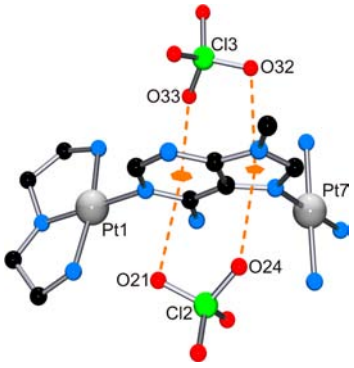
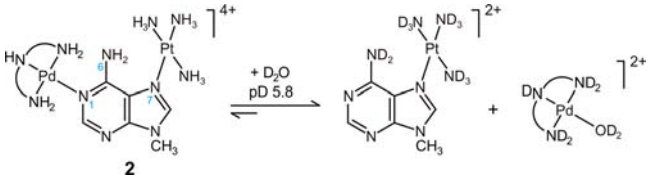


Figure 4. View of the two-fold anion−π interactions between cation **3** and two perchlorate anions.

Solution Behavior of 2. Complex **2**, when dissolved in D$_2$O (pD 5.8 at c ≃ 5 × 10^{-3} M; chemical shifts (ppm) of 9-MeA resonances: 8.80 (s, 1H, H8), 8.79 (s, 1H, H2), 3.93 (s, CH$_3$)), partially dissociates into the Pt starting complex [Pt(ND$_3$)$_3$(9-MeA-*N*7)]$^{2+}$ (chemical shifts (ppm): 8.67 (s, H8), 8.37 (s, H2), 3.92 (s, CH$_3$)) and [Pd(dien)(D$_2$O)]$^{2+}$ (superposition with dien resonances of **2**, (2.62−3.33 ppm), as evident from the ^{1}H NMR spectrum (Scheme 2 and Figure 5)).

Scheme 2. Partial Dissociation of PdPt Complex 2 in Aqueous Solution



2

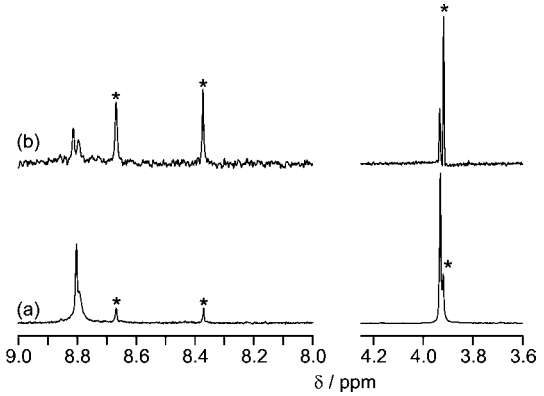


Figure 5. Sections of ^{1}H NMR spectra of **2** in D$_2$O. (a) Aromatic and CH$_3$ resonances of spectrum, c = 5 × 10^{-3} M, pD 5.75. (b) Sample of **2** diluted by a factor of 9. Asterisks denote resonances of the dissociation product [Pt(NH$_3$)$_3$(9-MeA-*N*7)]$^{2+}$ with H8 at 8.67, H2 at 8.37, and CH$_3$ at 3.92 ppm. Resonances of coordinated and free (dien)Pt^{II} occur between 2.6 and 3.2 ppm and are not shown.

Equilibrium is rapidly reached, and there is no spectral change with time at neutral pD. We originally considered the possibility that signals of the Pt starting compound might be due to an impurity, but dilution experiment unambiguously revealed that it is formed in a dissociative process. In fact, as solutions of **2** become more diluted, the relative amount of the Pt starting species increases. On the other hand, addition of (dien)Pd^{II} to a solution of **2** (1:1) at weakly acidic pD (5.2) reverses the dissociation and produces more of the PdPt complex **2**. The equilibrium depicted in Scheme 2 was evaluated by ^{1}H NMR spectroscopy in the pD range 5−6, hence, well outside the pK_a values of [Pd(dien)(H$_2$O)]$^{2+}$ (pK_a = 7.74)[29b] and that of [Pt(NH$_3$)$_3$(9-MeAH-*N*7)]$^{3+}$ (pK_a = 1.66 ± 0.04).[9a] The mean logK value for formation of **2** from [Pt(NH$_3$)$_3$(9-MeA-*N*7)]$^{2+}$ and [Pd(dien)(H$_2$O)]$^{2+}$ was found to be 2.9 ± 0.2 [L × mol^{-1}]. As compared to the logK of [Pd(dien)(Ado-*N*1)]$^{2+}$ (with Ado = adenosine), which is 4.5 [L × mol^{-1}][29b] and which should be reasonably close to the value of the corresponding 9-MeA complex, the decrease in stability by (4.5 − 2.9 =) 1.6 log unit presumably largely reflects the loss of N1 basicity as a consequence of (NH$_3$)$_3$Pt^{II} coordination at N7 (pK_a of 9-MeAH$^+$ ≃ 4.1;[32] pK_a of [Pt(NH$_3$)$_3$(9-MeAH-*N*7)]$^{3+}$ ≃ 1.7).

The pD of a solution of **2** in D$_2$O has an effect on the species distribution as well. At pD 2 (D$_2$O, DNO$_3$), **2** is largely dissociated, and [Pt(NH$_3$)$_3$(9-MeA-*N*7)]$^{2+}$ is already partially protonated at N1.

If the pD of an aqueous solution of **2** is raised above 8, the concentration of **2** likewise decreases at the expense of [Pt(NH$_3$)$_3$(9-MeA-*N*7)]$^{2+}$ (H8 at 8.67 ppm; H2 at 8.37 ppm; CH$_3$ at 3.92 ppm) and a new species **2a** displaying resonances at 8.30, 8.09, and 3.79 ppm (Figure 6).

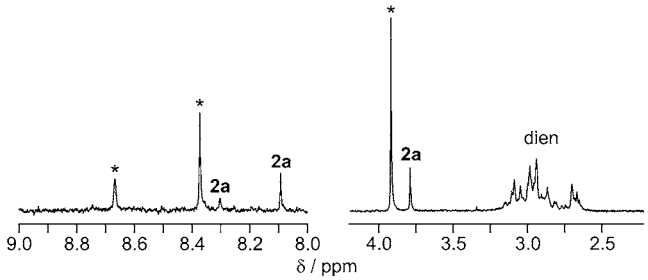


Figure 6. ^{1}H NMR spectrum of **2** in D$_2$O, pD 9.5. Lowfield region is enlarged for clarity. New resonances due to **2a** grow in at 8.30, 8.09, and 3.79 ppm. The H resonance at 8.30 ppm exchanges quickly against deuterium. Resonances of the Pt starting compound [Pt(NH$_3$)$_3$(9-MeA-*N*7)]$^{2+}$ are marked with asterisks. The furthest upfield multiplet centered at 2.7 ppm is assigned to a dien signal component of free [Pd(dien)(OH)]$^+$.

The aromatic protons of the adenine ligand(s) in the two compounds formed; yet in particular, the 8.67 and 8.30 ppm protons undergo fast isotopic H−D exchange under these pD conditions and are visible only in freshly prepared samples for a short period of time. Therefore, progress of the reaction could best be monitored by concentrating on the CH$_3$ resonances. With an excess of (dien)Pd^{II} (Pt:Pd = 1:2, 1:3, 1:4) and at pD 12, the species **2a** with its CH$_3$ resonance at 3.79 ppm dominates (Supporting Information). Concerning the nature of the species **2a** formed from **2** at high pH, two scenarios were considered: A Pd migration process from N1 to N6, as previously observed for Pt complexes,[9b,10b,c] combined with the

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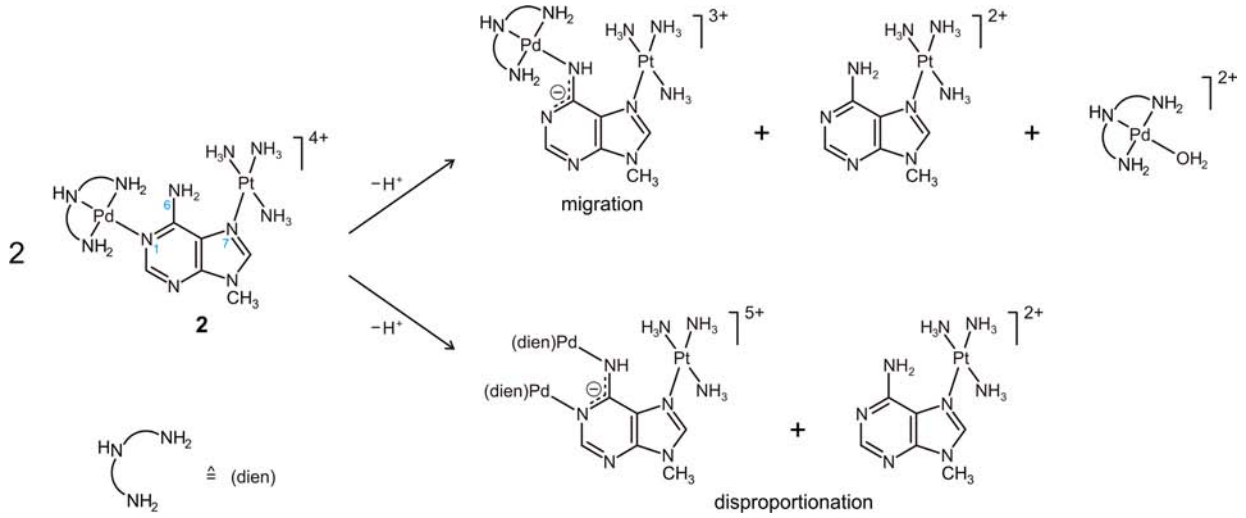
Scheme 3. Two Possible Reaction Pathways of 2 in Alkaline solution



dissociation process described above, or a disproportionation process, which in essence is the product of a reaction between **2** or the migration product with the available (dien)Pd^{II} (Scheme 3).

We favor the first option, hence **2a** being a migration product, namely $[(dien)Pd(N6\text{-}9\text{-}MeA^{-}\text{-}N7)Pt(NH_3)_3]^{3+}$, for the following reasons: First, spectra of **2** recorded at alkaline pD display signals due to free $[Pd(dien)(OH)]^{+}$. Second, the chemical shifts of the adenine resonances (H2, CH_3) are closely similar to those of the Pt analogue **3a** (see below), for which Pt migration from N1 to N6 is verified. Third, coordination of a $[Pd(dien)(OH)]^{+}$ entity to N1 of the migration product $[(dien)Pd(N6\text{-}9\text{-}MeA^{-}\text{-}N7)Pt(NH_3)_3]^{3+}$ is unlikely to occur, as $[Pd(OH)]^{+}$, unlike $[Pd(OH_2)]^{2+}$, does not readily bind to lone electron pairs of ligands. On the basis of the similarities in chemical shifts, we further propose that **2a** is the analogue of species "E" derived from **1** (see above).

Reaction of 2 with (dien)Pt^{II}. Mixing **2** with (dien)Pt^{II} in a 1:1 ratio and keeping the sample at room temperature (pD 6), indicates extensive (>70%) formation of the Pt_2 complex **3** (see below), with **2** (ca. 20%), the Pt starting compound $[Pt(NH_3)_3(9\text{-}MeA\text{-}N7)]^{2+}$ (<10%), as well as free (dien)Pd^{II} being the other components of the mixture. Although the CH_2 multiplets of the dien ligands are inherently difficult to interpret and to assign, in the present case a component of the proton resonances of free (dien)Pd^{II} (two doublets at ca. 2.62 and 2.67 ppm) is identified unambiguously, as it is well separated from the other components and those of coordinated (dien)Pt^{II}, which occur further downfield (ca. 2.8−3.3 ppm). Formally, reaction **2** + (dien)Pt^{II} thus represents a transmetalation which, of course, is facilitated by the lower thermodynamic stability of the Pd−N1 bond (see below). This difference in bond strength between analogous Pd^{II} and Pt^{II} species is a well-established feature in metal−nucleobase chemistry.[33]

Solution NMR Spectra of 3. The ^{1}H NMR spectrum of **3** in D_2O (pD 6.5) has its methyl resonance at 3.95 ppm as a sharp singlet, but the two aromatic protons are superimposed at 8.83 ppm, one of which, H8, is very much broadened and eventually disappears due to isotopic exchange. The remaining two signals (H2, CH_3) display a pD dependence expressed in highfield shifts above pD 9. The estimated pK_a for the exocyclic amino group of the 9-MeA ligand in **3** is ca. 10.0−10.5, consistent with previous findings with N1,N7 diplatinated 9-MeA complexes.[10c]

In contrast to **2**, complex **3** shows no immediate signs of dissociation in the pD range 4 to 9 at room temperature. However, upon prolonged standing (6 months, room temperature, daylight, pD 6), a new CH_3 resonance of low intensity (few % relative to 3.95 ppm resonance) is observed at 3.92 ppm, which is assigned to the starting compound $[Pt(NH_3)_3(9\text{-}MeA\text{-}N7)]^{2+}$. Samples kept above pD 9 reveal gradual (days at room temperature) formation of more starting compound and in addition of a major new species assigned to the migration product $[(dien)Pt(N6\text{-}9\text{-}MeA^{-}\text{-}N7)Pt(NH_3)_3]^{3+}$ (**3a**) (Figure 7). The latter has its resonances at 8.08 ppm (H2) and 3.80 ppm (CH_3), hence characteristically upfield shifted relative to those of **3** as a consequence of deprotonation of the 9-MeA ligand at N6.[9b,34] The assignment of **3a** as the N6 migration product of **3** is further verified by the pD dependence of its ^{1}H NMR resonances. Thus, lowering of the pD of samples containing **3a** causes downfield shifts of its resonances below pD 8, giving a pK_a of ca. 5.3 (converted to H_2O) for protonation of the N1 site. Again, this value is in good agreement with previous findings.[9b,10c]

There are additional resonances of very low intensities (close to 8.38 ppm signal; 3.85 ppm; see Figure 7), in aged, alkaline samples of **3**/**3a**, which cannot be assigned at present (Figure 7). The migration process is accompanied by a drop in pD as a consequence of the formation of the adeninato species **3a** from **3**, which has a neutral 9-MeA ligand. This drop in pD eventually causes the migration process to come to standstill, unless more base is added. The methylene resonances of the dien ligands become more complicated due to the presence of differently bonded (dien)Pt^{II} entities in **3** and **3a**, respectively (Figure 7). Concerning the migration process leading from **3** to **3a**, no conclusions on the mechanism can be made. Both an associative process (nucleophilic attack of deprotonated $N6H^{-}$ on Pt an N1) and/or a dissociative process involving a ring-opened or free $[Pt(dien)Pt(OD)]^{+}$ and subsequent reaction at $N6H_2$ are feasible. Observation of low amounts of free $[Pt(NH_3)_3(9\text{-}MeA\text{-}N7)]^{2+}$ in the ^{1}H NMR spectra of aged samples of **3** and in samples kept at alkaline pD support the notion that a dissociative process is at least one pathway to **3a**.

Mixing 3 with (dien)Pd^{II}. In order to understand the mechanism of formation of N1,N6,N7-trimetalated 9-MeA^{-}

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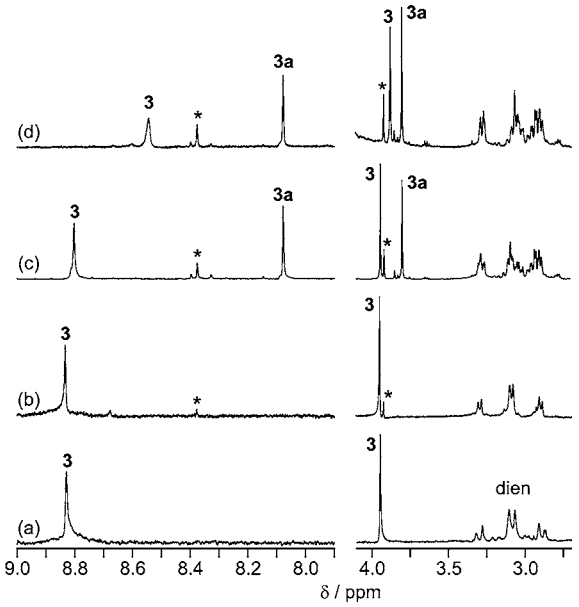

Figure 7. ^{1}H NMR spectra of **3** in D_2O. (a) Freshly prepared sample, pD 6.5 (200 MHz). (b) Aged sample kept for 6 months in D_2O at 22 °C, in daylight, pD 6 (500 MHz). Aging has produced small amounts of $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ (signals with asterisks). (c) Aged sample brought to pD 9 with pD dropped to 8.1 within 5 d at 22 °C (500 MHz). Clearly visible is the migration product **3a**, as well as unidentified minor products of low intensities in the range of the methyl signals. (d) Aged sample brought to pD 11 with pD dropped to 10.2 within 18 d at 22 °C (500 MHz). Of the two aromatic adenine protons, only H2 resonances are seen, as H8 protons have exchanged for deuterium.

species, complex **3** was also mixed with $[Pd(dien)(D_2O)](ClO_4)_2$ (r = 1). While no change in the ^{1}H NMR spectra was observed at pD 5.4, at higher pD values (9, 12) the two observable 9-MeA resonances undergo smooth upfield shifts, with no indication of rapid formation of any additional species inert on the NMR time scale, however (Supporting Information). With time (weeks to months), there are spectroscopic changes, which are accompanied by a drop in pD and formation of an unidentified fine black (metallic?) precipitate. For example, a sample initially brought to pD 9 shows a pD of 7.5 after five months, with the main CH_3 resonance at 3.94 ppm and a second one of lower intensity at 3.81 ppm, with aromatic protons exchanged. These resonances could possibly be assigned to **3** and **3a**, respectively. A sample brought initially to pD 12 lowers its pD to 9.0 over the same time period, with the two CH_3 signal intensities then reversed. Two additional resonances of very low intensities are seen at 3.92 and 3.84 ppm. The drop in pD can be rationalized either by a metal migration from N1 to N6 or by binding of a third metal entity to N6 of a N1,N7-dimetalated species. Given the similar chemical shifts of **2a** and **3a**, it is difficult to differentiate these cases.

^{195}Pt NMR Spetra of 2 and 3. $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ exhibits its ^{195}Pt NMR resonance in D_2O solution at −2547 ppm, fully consistent with expectations for a Pt nucleus coordinated to four N donor atoms.[35] Very much to our surprise, **2** has its ^{195}Pt resonances (D_2O, pD 5.1) at virtually the same chemical shift, irrespective of sample concentration, and clearly even under conditions of high sample concentration when **2** is the dominant species (see above). Specifically, no two separate resonances for **2** and the starting complex are observed (Supporting Information). This implies that (dien)-Pd^{II} coordination to N1 of $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ has no measurable effect on Pt at N7.

This tentative conclusion was subsequently supported by the ^{195}Pt NMR spectrum of complex **3** (Figure 8). In D_2O, **3**

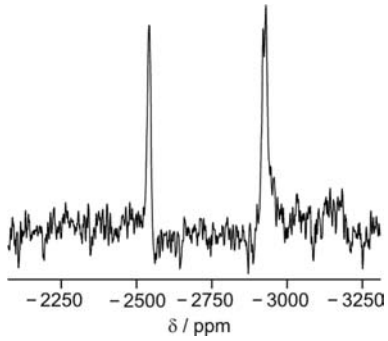

Figure 8. ^{195}Pt NMR spectrum of **3** (D_2O, pD 5).

displays two sets of Pt resonances in 1:1 ratio at −2548 ppm and a second one centered at −2935 ppm. The latter resonance is split in two components, separated by 10 ppm. As **3**, unlike **2**, does not readily dissociate in solution, the two sets are assigned to the $(NH_3)_3Pt^{II}$ at N7 (−2548 ppm) and the $(dien)Pt^{II}$ at N1 (−2930 and −2940 ppm). Splitting of Pt resonances are common in complexes of adenine-N1 (and also adenine-N7)[36] and cytosine-N3,[12] possibly as a consequence of slow rotation of the $(dien)Pt^{II}$ about the Pt−N(nucleobase) bonds. Thus, very much like $(dien)Pd^{II}$ in **2**, $(dien)Pt^{II}$ coordinated to N1 of 9-MeA has practically no influence on the chemical shift of the $(NH_3)_3Pt^{II}$ entity at N7. This situation contrasts that in ^{1}H NMR spectra, where binding of the second metal to N1 has a distinct effect on the proton resonances of the 9-MeA ligand.

We presently do not have a straightforward explanation of this observation but point out conclusions drawn by R. B. Martin et al.,[37] who on the basis of an extensive analysis of pK_a values of purine nucleobases and stability constants of their $(dien)Pd^{II}$ complexes, had come to the conclusion that compared to two protons or a proton and a metal bonded to N1 and N7 sites of a purine base (here: 9-MeA) two metal ions coordinated to these sites have the lowest "interaction".

X-ray Crystal Structure of $[\{Pd(trpy)\}_2(N1,N6\text{-}9MeA^{-}\text{-}N7)Pt(NH_3)_3](ClO_4)_5\cdot 3H_2O$ (4). Complex **4** was prepared by reacting $[Pt(NH_3)_3(9\text{-MeA-}N7)](ClO_4)_2$ with excess $[Pd(trpy)(H_2O)](ClO_4)_2$ in water at pH 3.6. Figure 9 gives two views of the molecular cation of **4**. Selected interatomic distances and angles are listed in Table 3.

Cation **4** displays an analogous binding pattern as **1**, with $(NH_3)_3Pt^{II}$ at N7 (Pt7) and two $(trpy)Pd^{II}$ units at N1 (Pd1) and N6 (Pd6), in place of the three $(dien)Pd^{II}$ units of cation **1**. This modification permits an instructive comparison between cations **1** and **4**, in particular with regard to the drastic differences between the positions of the metals bonded to N1 and N6. The following features are observed with **4**: First, both Pd1 and Pd6 are essentially coplanar with the adenine best plane. Deviations are −0.003(4) Å for Pd1 and 0.029(6) Å for Pd6. Second, there is efficient stacking between the two trpy ligands (3.3−3.5 Å), thereby leading to a shorter Pd1···Pd6 distance in **4** (3.0698(5) Å) as compared to **1** (3.2354(8) Å). Dihedral angles between the trpy ligands and the adenine ring are virtually identical in **4** (74.72(8)° and 74.53(8)°), unlike with the N_3 planes of the dien ligands in **1**. Third, the C6−N6

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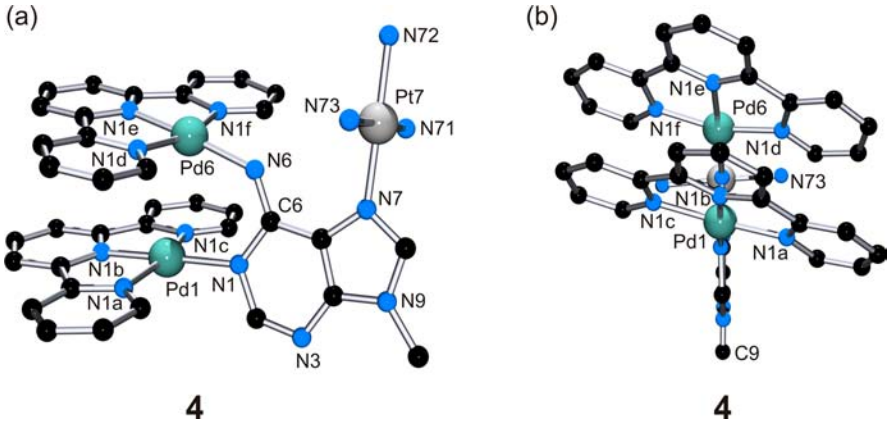

Figure 9. Front (a) and side (b) views of the molecular cation of **4**.

Table 3. Selected Distances [Å] and Angles [deg] of Complex 4

Pd1–N1	2.040(4)	Pt7–N72	2.033(4)
Pd1–N1a	2.036(4)	Pt7–N73	2.034(4)
Pd1–N1b	1.928(4)	C6–N6	1.305(6)
Pd1–N1c	2.027(4)	C6–N6–Pd6	132.4(3)
Pd6–N6	2.019(4)	C6–N6–H6	114(3)
Pd6–N1d	2.014(4)	Pd6–N6–H6	113(3)
Pd6–N1e	1.930(4)	N6–C6–N1	121.6(4)
Pd6–N1f	2.032(4)	N6–C6–C5	124.6(4)
Pt7–N7	2.012(4)	N1–C6–C5	113.7(4)
Pt7–N71	2.026(4)	Pd1–Pd6	3.0698(5)

bond length in **4** (1.305(6) Å) is comparable to that observed in **1** (see above), thus proving that the partial double bond character of this bond is retained also in **4**. However, the C6–N6–Pd6 angle in **4** has further increased to 132.4(3)° in **4**. Fourth, Pd1–N1 and Pd6–N6 bonds are slightly shorter in **4**, with the difference being 0.020 Å (corresponding to 4σ). We are aware of the substantially different electronic properties of (dien)Pd^{II} on one hand and of (trpy)Pd^{II} on the other but find it difficult to attribute the differences of Pd1 and Pd6 positions in **1** and **4** to a single reason, e.g., sterical ones, electronic ones of the metal entities, softness of N6, etc. We plan to study this aspect further applying computational methods.

The $(NH_3)_3Pt^{II}$ unit at N7 displays normal structural features. The Pt ion is almost coplanar with the nucleobase plane (deviation 0.038(5) Å), and the Pt coordination plane is at an angle of 86.0(1)° with respect to the adenine.

In the crystal, cations of **4** are interacting with perchlorate anions and water molecules. There are no stacking interactions involving bpy rings of different cations.

Solution Behavior of 4. Similar to the situation with **1** (see above), complex **4** undergoes a dissociation process when dissolved in D_2O (pD 7.4) (Figure 10). Two methyl resonances suggest the presence of two different adenine species: One set of resonances, observed at 3.93 ppm (CH_3) and 8.68 ppm (H8), agrees with chemical shifts of $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$. The second aromatic 9-MeA resonance (H2) of this species, expected at 8.37 ppm, is not observed because it is buried under trpy resonances. Formation of this compound implies that there is partial loss of *both* (trpy)Pd^{II} entities from **4**.

At pD 12 the dissociation of **4** is practically complete, and essentially only the methyl resonance of the Pt starting compound $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ at 3.92 ppm is left, as

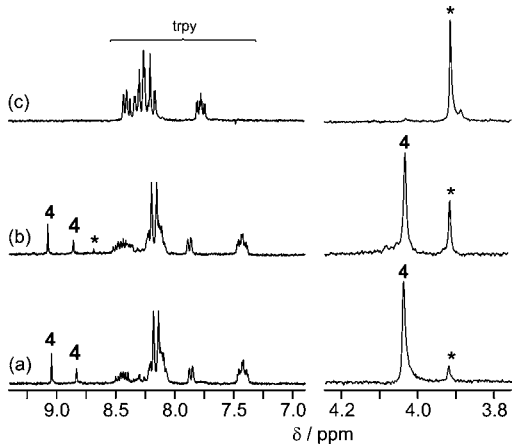

Figure 10. ^1H NMR spectra (D_2O) of **4**. (a) Immediately after dissolving **4**, pD 7.4. (b) Spectrum (a) after addition of NaOD to give pD 9. (c) Spectrum (a) after addition of NaOD to give pD 12. Signals due to $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ are indicated by asterisks. There is complete isotopic exchange of H2 and H8 resonances of 9-MeA at the most alkaline pD.

both H2 and H8 adenine protons have undergone isotopic exchange. In the aromatic region of the spectrum, only resonances of $[Pd(trpy)(OD)]^+$ are seen, as identified by comparison with a spectrum of this compound at identical pD and in the absence of any 9-MeA species.

4. CONCLUSIONS

Reactions between Pd^{II} species and nucleobases in general lead to a multitude of products, the equilibria of which depend on variables such as pH, concentration, and metal:ligand ratio.[29,34,38] Unlike with the corresponding Pt^{II} analogs, which usually are kinetically "inert", a separation and rational isolation of a particular Pd nucleobase complex from mixtures of compounds is therefore more difficult and frequently subject to serendipity. For example, reaction of the model nucleobase 9-MeA with $[Pd(dien)(D_2O)]^{2+}$ in D_2O leads to (at least) five different products, which are in slow equilibrium. We were able to isolate one component, complex **1**, from a concentrated solution, which proved to be trinuclear, with (dien)Pd^{II} entities bonded simultaneously to N1, N6, and N7. When redissolved in water, **1** rearranges in solution to give again a mixture of complexes. In order to better understand this process and to assign at least some of the compounds formed, we decided to

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apply an adenine complex containing an "inert", yet closely similar analog of (dien)Pd^{II}, namely $(NH_3)_3Pt^{II}$, bonded to the N7 position of 9-MeA, and to probe reactivity patterns with (dien)Pd^{II} (**2**) and (trpy)Pd^{II} (**3**), similar to the situation we had previously reported for reactions of $[Pt(NH_3)_3(9\text{-MeA-}N7)]^{2+}$ with (en)Pd^{II}.[9a] The assumption that Pt^{II} at N7 retains its bond to the adenine ring throughout the reactions with Pd^{II} proved correct, at least within the sensitivity possible in ^{1}H NMR spectroscopy. Complex **2** was found to lose (dien)Pd^{II} from the N1 site in neutral to acidic medium and to form the Pd−N6 migration product **2a** at alkaline pD. This latter conclusion was drawn essentially from the behavior of complex **3**, which has a (dien)Pt^{II} at N1 and which undergoes a slow migration to N6 under similar conditions. There was no evidence for a disproportionation reaction of **2** with formation of a trinuclear complex with (dien)Pd^{II} entities at N1, N6, and the $(NH_3)_3Pt^{II}$ at N7 under the experimental conditions (concentration, pD), but given the existence of some minor, unassigned ^{1}H NMR resonances in the case of **3**, such a possibility cannot be excluded with the analogous dinuclear Pt complex **3**. Nevertheless, migration of the Pt entity from N1 to N6 is the preferred reaction. The two (trpy)Pd^{II} entities in **4** likewise are prone to dissociation at alkaline pH. In no cases were there signs from ^{1}H NMR spectroscopy for any measurable metal (Pd^{II} or Pt^{II}) binding to N3, as such a binding pattern should have caused a large and highly characteristic downfield shift of the methyl resonance at N9.[2,38,39] The easy dissociation of metal entities from the N1 site of N9-platinated adenine seems to be facilitated by the loss of basicity of this position as a consequence of Pt coordination to N7. Migration of the N1 bound metal to N6 is due to the increased acidity of the exocyclic amino group, which likewise is caused by the Pt at N7. The intriguing differences in Pd positions in the trinuclear complexes **1** and **4** is awaiting further clarification.

■ ASSOCIATED CONTENT

Supporting Information

Additional spectroscopic (NMR, ESI-MS) and X-ray information. This material is available free of charge via the Internet at http://pubs.acs.org

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Notes

The authors declare no competing financial interest.

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■ DEDICATION

The authors dedicate this paper to Prof. Dr. Ionel Haiduc, Cluj Napoca on the occasion of his 75th birthday.

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