Complexes of Palladium(II) with Nucleosides. Preparation and Properties of Complexes of the type Potassium Trichloro(nucleoside)palladate(II)

By **Nick Hadjiliadis*** and **George Pneumatikakis**, Inorganic Chemistry Laboratory, University of Athens, Navarinou 13A, Athens, Greece

The preparation of the monobase complexes $K[PdLCl_3]$ (L = nucleoside or pyridine) is described for the first time, in dimethylformamide solutions. The complexes are characterized by elemental analyses, conductivity measurements, i.r. spectra, and chemical reactions. They are unstable in aqueous or acidic solutions. At pH *ca.* 9—10 the inosine and guanosine derivatives are transformed into dimeric O(6)N(7) chelates. The reactions of $K[PdLCl_3]$ with other nucleosides in water have also been studied and produce 1 : 4 and 1 : 2 complexes of the type $[PdLL'_3]Cl_2$, *cis*- or *trans*-$[PdL(L')]Cl_2$, and *cis*- or *trans*-$[Pd(L - H)(L' - H)]$, where L' = the same or a different nucleoside to L. The binding sites of these complexes are N(7) of the purine rings, as is revealed by their ^1H n.m.r. spectra.

THE discovery of the antitumour properties of *cis*-$[Pt(NH_3)_2Cl_2]$ and related complexes [1-3] has been followed by extensive investigations of the reactions of these complexes with purine and pyrimidine bases,[4-8] the constituents of DNA. Based on the assumption that the activity of the complexes is due to their ability to react with DNA, several studies of their interactions have also been carried out *in vitro*.[9-12] Proposals on the mechanism of the antitumour action of *cis*-$[Pt(NH_3)_2Cl_2]$ reacting with DNA have been made,[9,12-14] including the formation of O(6)N(7) chelates with the guanine bases [9,12] and the formation of cross links between adjacent or opposite bases.[10,11,13,14]

Recently, Martin and his co-workers [15,16] have studied the interactions of Pd^{II} with nucleosides, as models for the intracellular action of platinum(II) antitumour complexes. The advantages for such studies *in vitro* as compared to Pt^{II} are the faster (10^5—10^6 times) ligand-exchange reactions and the easy formation of aqua-derivatives of Pd^{II}.[15,16] Studies on the interactions of Pd^{II} with nucleosides are only recent and relatively sparse.[15-23] Recently [22,23] we reported the reactions of $K_2[PdCl_4]$ with guanosine (guo), inosine (ino), and cytidine (cyd). The binding sites of the bases were determined as being primarily the N(7) of guo and ino and the N(3) of cyd. In addition, N(7)O(6) chelation was found in these studies for some of the isolated complexes with guo and ino.

In continuation of our studies on interactions of Pd^{II} with nucleosides, we present here a general procedure for the preparation of the mononucleoside complexes of the type $K[PdLCl_3]$, which we believe are reported for the first time. The general reactivity behaviour of the complexes under study, the binding sites of the metal to nucleosides, and the possibility of the existence of N(7)O(6) chelates are also examined and discussed.

RESULTS AND DISCUSSION

Reactions of the salts $K_2[MCl_4]$ (M = Pd^{II} or Pt^{II}) with nitrogenous bases (*i.e.* L = NH_3 or py) in aqueous solutions generally produce uncharged complexes of the type *cis*-$[ML_2Cl_2]$, due to the lower *trans* effect of the bases as compared to chloride ion.[24,25] Although complexes of the type $K[PtLCl_3]$ are known,[26-29] to our knowledge the analogous palladium(II) complexes have not as yet been reported. There are only few 1 : 1 complexes of Pd^{II} with nitrogenous bases,[30] *e.g.*

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$[Pt(NH_3)_4][Pd(NH_3)Cl_3]_2$ and $K[Pd(alaO)Cl_2]$ (alaO = alaninate). However, they are numerous when L = PR_3 or AsR_3.[31,32] Dimeric complexes of the type $[\{PdLX_2\}_2]$ are also known.[33] Recently, Kong and Rochon [34] reported a new synthesis of the complexes $K[PtLCl_3]$ in dimethylformamide (dmf) at 60—70 °C, where L = a nucleoside, which can be applied to nitrogenous bases in general.

It was found that the latter reaction can be extended to the preparation of the analogous palladium(II) complexes [equation (1)]. The duration (3—4 h) and

$$K_2[PdCl_4] + L \xrightarrow[25\ °C]{dmf} K[PdLCl_3] + KCl \quad (1)$$

the temperature (25 °C) are the main differences from the reactions of the analogous platinum(II) complexes [34] (overnight and 60—70 °C). The analytical results and the conductivity data are given in Table 1, i.r. spectra of the complexes in the solid state in Table 2.

The complexes $K[Pd(aguo)Cl_3]$ and $K[Pd(aino)Cl_3]$ (aguo = triacetylguanosine, aino = triacetylinosine) show two bands in the region of 1 700 cm^{-1}, at 1 737 and 1 705 cm^{-1} for the former and at 1 744 and 1 707 cm^{-1} for the latter. The bands at 1 737 and 1 744 cm^{-1} are due to the C=O stretching vibrations of the acetyl groups of the sugar moiety, while those at 1 705 and 1 707 cm^{-1} are due to the C=O stretching vibrations of the carbonyl groups at the position 6 of the purine skeleton, for the two complexes respectively. The same motions [ν(C=O)] give bands at 1 697, 1 706, and 1 709 cm^{-1} for the complexes $K[Pd(guo)Cl_3]$, $K[Pd(ino)Cl_3]$, and $K[Pd(xao)Cl_3]$ (xao = xanthosine) and indicate that the bonding site of the bases to the metal is other than the carbonyl oxygen at position 6.[22,23] The same is true for the complex $K[Pd(cyd)Cl_3]$ which shows ν(C=O) at almost the same frequency as free cytidine, 1 658 and 1 660 cm^{-1} respectively. The ν(Pd–Cl) modes give rise to two medium-strong bands in the 320—340 cm^{-1} region. Assignments of other characteristic bands of the above complexes as well as of $K[Pd(py)Cl_3]$ (py = pyridine) are given in Table 2.

All the $K[PdCl_3]$ complexes decomposed in aqueous solutions giving very high conductivities (see Table 1) and they were also unstable in acid solutions. We were therefore unable to record their ^1H n.m.r. spectra. In particular, the complexes in which the ligand has a C=O group at position 6 and an imine proton at N(1) of the purine ring precipitated instantaneously in aqueous solutions, with a subsequent decrease in pH. The precipitates give indications of a Pd–O(6) interaction (shift of the carbonyl band at 1 700 cm^{-1} to lower frequencies) and most probably are mixtures of N(7)O(6) chelated and non-chelated complexes.[22,23] Complete chelation is better achieved when the pH of the solutions is kept at 9—10 for 30 min at room temperature. In this way, the precipitates obtained show only one band at *ca.* 1 625 cm^{-1} due to the co-ordinated carbonyl group.[22,23] In alkaline solutions the reaction may proceed as in (2). The chemical analyses are satisfactory for the dimeric products (Table 1) which are insoluble in organic solvents. The dimers also exhibit a weak absorption at *ca.* 330 cm^{-1} in the far-i.r. spectrum, due to Pd–Cl–Pd stretchings.[24]

Although the bonding sites in the complexes $K[PdLCl_3]$ cannot be determined directly from their i.r. or n.m.r. spectra, a few characteristic reactions of the complexes with other nucleosides provide indirect evidence for the

$$2K[PdLCl_3] \xrightarrow{pH\simeq 9\text{-}10} \left[\begin{array}{c} N(7) \quad Cl \quad O(6) \\ \diagdown\ Pd \quad Pd\ \diagup \\ O(6) \quad Cl \quad N(7) \end{array}\right] + 2KCl + 2HCl \quad (2)$$

bonding sites.[22,23] Mixing stoicheiometric amounts of the complexes with nucleosides (1 : 3) reaction (3) takes place, where L′ is the same or a different nucleoside to L.

$$K[PdLCl_3] + 3L' \xrightarrow{H_2O} [PdLL'_3]Cl_2 + KCl \quad (3)$$

In this way complexes of the type $[PdL_4]Cl_2$,[22,23] such as those with L = ino or guo, were isolated, as well as the new mixed complexes $[Pd(xao)(ino)_3]Cl_2$, $[Pd(xao)(guo)_3]Cl_2$, $[Pd(guo)(ino)_3]Cl_2$, and $[Pd(ino)(guo)_3]Cl_2$. These complexes are 1 : 2 electrolytes in aqueous solutions (see Table 1).

From the ^1H n.m.r. spectra of these complexes (Table 3) we conclude that the binding sites of all the purine bases with Pd^{II} is N(7). The H(8) protons nearest to the bonding site are shifted downfield by 0.5—0.6 p.p.m. as in similar palladium(II) complexes.[16,18,21-23] The complex $[Pd(ino)(guo)_3]Cl_2$ shows H(8) at 8.86 p.p.m. and H(2) at 8.16 p.p.m. for inosine, while H(8) of guanosine is at 8.47 p.p.m. For free inosine these resonances are at 8.82 and 8.11 p.p.m., while the resonance for free guanosine is at 7.80 p.p.m. In the complex $[Pd(guo)(ino)_3]Cl_2$ inosine exhibits the H(8) resonance at 8.83 p.p.m. and H(2) at 8.15 p.p.m., while for guanosine H(8) is at 8.45 p.p.m. For $[Pd(xao)(ino)_3]Cl_2$ we have resonances at 8.77 and 8.11 p.p.m. assigned to H(8) and H(2) of inosine, and at 8.61 p.p.m. assigned to H(8) of xanthosine. Finally, the complex $[Pd(xao)(guo)_3]Cl_2$ gives one band at 8.49 p.p.m. and one at 8.33 p.p.m. assigned to H(8) of guanosine and xanthosine respectively. The relative intensities of the bands depend on the amounts of nucleosides present. Mixed complexes of nucleosides in solution have been reported with Zn^{II} but they were not

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[34] P. C. Kong and F. D. Rochon, *J.C.S. Chem. Comm.*, 1975, 599.

isolated.[35] In these complexes the nucleosides were believed to act as bidentate ligands. The analogous platinum(II) complexes, with four nucleosides bonded through N(7), are also known.[4c] Recently, the 1 : 4 complexes of Pd^{II} and Pt^{II} with cytidine and adenosine were reported.[21]

Mixed complexes of the type $[PdL(L')]Cl_2$ were also prepared from $K[PdLCl_3]$ [equations (4) and (5)]. The *cis* geometry seems more likely for the products of these reactions as indicated by Kurnakoff tests.[36] This result is in agreement with the *trans* effect of nucleosides being smaller than that of halogens.[4c,22,23] A *trans* product was also isolated from aqueous solutions as a

$$K[Pd(ino)Cl_3] + xao \xrightarrow{0.5N\ HCl} cis\text{-}[Pd(ino)(xao)]Cl_2 + KCl \quad (4)$$

$$K[Pd(guo)Cl_3] + xao \xrightarrow{0.5N\ HCl} cis\text{-}[Pd(guo)(xao)]Cl_2 + KCl \quad (5)$$

TABLE 1

Analytical and physical data of the complexes

Complex	Analysis (%) [a] C	H	N	Pd	Cl	M.p. [b] (θ_c/°C)	Λ_M (20 °C)/ S cm² mol⁻¹
$K[Pd(ino)Cl_3]$	23.35 (23.05)	2.65 (2.30)		19.9 (20.45)	20.35 (20.5)	210	60 (dmf) *ca.* 600 (H_2O)
$K[Pd(guo)Cl_3]$	21.95 (22.4)	2.70 (2.40)		19.25 (19.85)	19.55 (19.9)	230	69 (dmf) *ca.* 550 (H_2O)
$K[Pd(xao)Cl_3]$	22.8 (22.35)	2.55 (2.25)			20.1 (19.85)	245	79 (dmf) *ca.* 645 (H_2O)
$K[Pd(cyd)Cl_3]$	22.0 (21.95)	2.40 (2.60)			21.25 (21.5)		65 (dmf)
$K[Pd(py)Cl_3]$	17.75 (18.1)	1.80 (1.50)			32.0 (32.15)	150	79 (dmf)
$K[Pd(aino)Cl_3]$	29.1 (29.4)	3.00 (2.45)			15.5 (14.95)	215	70 (dmf)
$K[Pd(aguo)Cl_3]$	28.7 (29.05)	2.25 (2.85)			16.5 (16.1)	250	80 (dmf)
$[Pd_2(guo - H)_2Cl_2]\cdot 4H_2O$	25.9 (26.05)	3.30 (3.45)	15.1 (15.2)	23.45 (23.1)	7.50 (7.70)	200	3.9 (dmso)
$[Pd_2(ino - H)_2Cl_2]$	28.95 (29.35)	3.25 (2.70)		26.6 (26.0)		150	2.8 (dmso)
cis-$[Pd(ino)(xao)]Cl_2$	32.1 (32.9)	3.80 (3.30)		14.25 (14.55)		185	8 (dmf)
$[Pd(xao)(guo)_3]Cl_2$	36.2 (36.6)	4.00 (3.75)		8.30 (8.90)		200	210 (H_2O)
trans-$[Pd(ino)(guo)]Cl_2$	32.6 (32.9)	3.85 (3.40)		14.1 (14.6)		235	15 (dmf)
$[Pd(guo)(ino)_3]Cl_2$	37.6 (37.95)	4.15 (3.85)		8.80 (9.30)		190	239 (H_2O)
cis-$[Pd(guo)(xao)]Cl_2$	32.45 (32.2)	3.35 (3.35)		14.3 (14.1)		190	12 (dmf)
$[Pd(ino)(guo)_3]Cl_2$	36.8 (37.05)	4.00 (3.95)		8.50 (9.00)		185	233 (H_2O)
$[Pd(xao)(ino)_3]Cl_2$	37.35 (37.9)	4.20 (3.80)		8.90 (9.25)		210	197 (H_2O)
trans-$[Pd(ino - H)(guo - H)]$	36.45 (36.6)	3.55 (3.50)		16.75 (17.0)		200	

[a] Calculated values are given in parentheses. [b] The decomposition points are reported.

TABLE 2

Characteristic i.r. bands (cm^{-1}) of the complexes

Complex	ν(C=O) skeletal	ν(C=O) acetyls	ν(C=C,C=N) rings	ν(Pd–Cl)
$K[Pd(ino)Cl_3]$	1 706		1 595, 1 559, 1 520	333, 323
$K[Pd(guo)Cl_3]$	1 697		1 574	335, 330
$K[Pd(xao)Cl_3]$	1 709		1 621, 1 579	337, 331
$K[Pd(cyd)Cl_3]$	1 658		1 522, 1 497	
$K[Pd(py)Cl_3]$			1 638, 1 612, 1 540	332, 327
$K[Pd(aino)Cl_3]$	1 707	1 744	1 591, 1 556, 1 517	337, 331
$K[Pd(aguo)Cl_3]$	1 705	1 737	1 629, 1 588	337, 331
$[Pd(ino)(guo)_3]Cl_2$	*ca.* 1 700		1 583, 1 537	
$[Pd(guo)(ino)_3]Cl_2$	*ca.* 1 700		1 585, 1 552	
trans-$[Pd(guo)(ino)]Cl_2$	*ca.* 1 700		1 592, 1 560	333
trans-$[Pd(guo - H)(ino - H)]$	*ca.* 1 630		1 598, 1 535	
cis-$[Pd(ino)(xao)]Cl_2$	*ca.* 1 700		1 620, 1 582, 1 512	330, 344
cis-$[Pd(guo)(xao)]Cl_2$	*ca.* 1 700		1 585, 1 540	342, 362 (?)
$[Pd(xao)(guo)_3]Cl_2$	*ca.* 1 700		1 585, 1 542	
$[Pd(xao)(ino)_3]Cl_2$	*ca.* 1 700		1 585, 1 553	
$[Pd_2(ino - H)_2Cl_2]$	*ca.* 1 625		1 540, 1 497	330
$[Pd_2(guo - H)_2Cl_2]$	*ca.* 1 625		1 530, 1 492	330

[35] S. M. Wang and N. L. Li, *J. Amer. Chem. Soc.*, 1966, **88**, 4592; 1968, **90**, 5069; L. S. Kan and N. L. Li, *ibid.*, 1970, **92**, 281.

[36] N. S. Kurnakoff, *J. prakt. Chem.*, 1894, **50**, 483.

bis(chelate) complex [equation (6)]. The pH of the solution decreased during the reaction. The complexes

$$K[Pd(guo)Cl_3] + ino \xrightarrow{H_2O} trans\text{-}[Pd(guo - H)(ino - H)] + KCl + 2\ HCl \quad (6)$$

trans-[Pd(ino − H)$_2$] and -[Pd(guo − H)$_2$] were prepared analogously from aqueous solutions.[23] The complex *trans*-[Pd(guo − H)(ino − H)] is soluble in 0.5—1N HCl, where the Pd–O(6) bonds break by the addition of 2 HCl molecules.[4c,23] The *trans* geometry of

$$trans\text{-}[Pd(ino - H)(guo - H)] \xrightarrow{0.5N\ HCl} trans\text{-}[Pd(ino)(guo)]Cl_2 \quad (7)$$

this last complex was again confirmed by a Kurnakoff test.[23,26]

absence of direct Pd–Cl bonds. Free carbonyl groups are also evident in the spectra of the complexes *cis*-[Pd(ino)(xao)]Cl$_2$, *cis*-[Pd(guo)(xao)]Cl$_2$, and *trans*-[Pd(ino)(guo)]Cl$_2$ as well as ν(Pd–Cl) sttetchings at *ca.* 330 cm^{-1} (Table 2). However, the complex *trans*-[Pd(ino − H)(guo − H)] shows carbonyl stretchings at *ca.* 1 630 cm^{-1} in accordance with the existence of O(6)N(7) chelates [4,22,23,37] (Table 2 and Figure).

In conclusion the results of the present study provide a new synthetic route to the preparation of palladium(II) complexes of the type K[PdLCl$_3$] which are reported for the first time. The quite unstable complexes of this type, tending to be hydrolyzed and form N(7)O(6) chelates, are stabilized when mixed with stoicheiometric amounts of other nucleosides and form complexes of the type

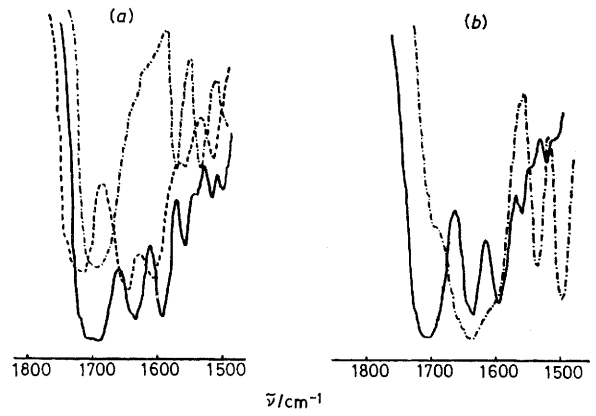
TABLE 3

Hydrogen-1 n.m.r. chemical shifts (δ/p.p.m.) of the complexes in D_2O [a]

	Inosine			Guanosine		Xanthosine	
Compound	H(8)	H(2)	H(1′)	H(8)	H(1′)	H(8)	H(1′)
ino	8.22	8.11	5.93 [b]				
			6.03				
guo				7.80	5.68 [b]		
					5.74		
xao						7.80	
[Pd(ino)(guo)$_3$]Cl$_2$	8.86	8.16	5.95 [b]	8.47	5.75 [b]		
			6.01		5.82		
[Pd(guo)(ino)$_3$]Cl$_2$	8.83	8.15	6.00 [b]	8.45	5.93 [b]		
			6.05		5.99		
[Pd(xao)(ino)$_3$]Cl$_2$	8.77	8.12	5.88 [b]			8.61	5.78 [b]
			5.94				5.84
[Pd(xao)(guo)$_3$]Cl$_2$				8.49	5.85 [b]	8.33	5.73
					5.79		

[a] The solvent for guo and xao was S(CD$_3$)$_2$O. [b] Doublet.

Finally, the i.r. spectra of all the complexes of the type [PdL$_4$]Cl$_2$ (Table 2 and Figure) show free carbonyl



Infared spectra in the 1 500—1 800 cm^{-1} region of the compounds: (*a*) [Pd(guo)(ino)$_3$]Cl$_2$ (——), guo (– – – –), ino (— · — · —); and (*b*) *trans*-[Pd(guo)(ino)]Cl$_2$ (——) and *trans*-[Pd(guo − H)-(ino − H)] (— · — · —)

stretchings at *ca.* 1 700 cm^{-1} and do not show bands at 330 cm^{-1} attributable to Pd–Cl, a good indication for the [PdL$_4$]Cl$_2$. The bonding sites of the purine nucleosides with Pd^{II} are once again confirmed, primarily, as the N(7) atoms.[15,16,18,20-23] These sites are also preferred with platinum(II) [4-8,13,14,34] and other metals.[35] The preparation of *cis* or *trans* mixed complexes [PdL(L′)]Cl$_2$ has been achieved, based on the *trans* influence of the nucleosides.[4b,4c,23]

The existence of O(6)N(7) metal chelates [4c,22,23,37] is once again found to be possible in the present study, although it has been rejected by other workers.[38,39] Sletten [40] excluded O(6)N(7) chelation with Cu^{II}, on the basis of a crystal-structure determination of bis(9-methyl-6-oxopurine)copper(II) trihydrate, due to steric effects. However, a direct Cu^{II}–N(7)O(6) chelate has recently been observed [41] in the crystal structure of a theophyllinato-complex where the conformational changes following the formation of the theophylline chelate were significant. It seems that such a chelate may exist when the ligand undergoes distortion to accommodate the metal ion [42] and depends primarily on the donor properties of the substituent at position 6.[4c,23] The formation of such chelates *in vitro* support

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the mechanism of the antitumour action of *cis*-[Pt(NH_3)$_2$$Cl_2$] and related complexes proposed by Maquet and Theophanides [9] and Goodgame *et al.*[12]

EXPERIMENTAL

Materials.—The nucleosides were purchased from Raylo Chemicals Ltd. and used without further purification. Potassium tetrachloropalladate(II) was obtained from Fluka A.G. The acetyl derivatives of inosine and guanosine were prepared according to the method of Bredereck.[43]

The i.r. spectra were recorded on a Beckman model 2050 spectrophotometer in KBr pellets or Nujol mulls. The positions of the bands are given to within ±2 cm. Hydrogen-1 n.m.r. spectra were obtained on a Varian T60 high-resolution spectrometer. Tetramethylsilane was used as external reference for spectra recorded in D_2O. Conductivity measurements were performed using an E 365 B conductoskope (Metrohm Ltd., Herisau, Switzerland). Melting points were determined on a Fischer–John's apparatus and are uncorrected. Microanalyses were made in the laboratories of the National Hellenic Research Foundation (N.H.R.F.) in Athens.

Preparation of the Complexes.—(*a*) *General procedure for the monobase complexes of type* K[PdLCl_3] (L = *a nucleoside or pyridine*). The salt K_2[$PdCl_4$] (1 mmol, 0.3266 g) and the corresponding nucleoside or pyridine (1 mmol) were suspended in dmf (25—30 cm^3) and stirred at room temperature for 3—4 h. During this time complete dissolution of the starting materials was achieved, while insoluble KCl appeared. The mixtures were kept in a refrigerator for *ca.* 2 h to complete deposition of KCl. They were then filtered and the complexes precipitated with Pr^iOH–OEt_2 (1 : 2, 300 cm^3). The precipitates were filtered off, washed with small portions of acetone and diethyl ether, and dried first at room temperature *in vacuo* ($CaCl_2$) and then at 110 °C *in vacuo* (P_4O_{10}), yields 70—90%. Recrystallization of the complexes from dilute HCl was not essential as in the case of the corresponding platinum(II) complexes.[34] Indeed, recrystallization caused decomposition of the complexes in many cases. The analytical results are satisfactory without recrystallization.

(*b*) *General procedure for the dimeric complexes* [Pd_2(L − H)$_2$$Cl_2$] (L = *inosine or guanosine*). The salts K[Pd(ino)Cl_3] or K[Pd(guo)Cl_3] (1 mmol) were dissolved into water (40 cm^3). Yellow precipitates appeared immediately for both complexes and the pH of the solutions decreased to *ca.* 2. The pH was adjusted to *ca.* 9—10 and the solution was stirred for *ca.* 30 min keeping the pH constant. The pH was then adjusted to 6.5 and the precipitates were filtered off, washed with small quantities of water, acetone, and diethyl ether, and dried *in vacuo* in the presence of $CaCl_2$. The yields were quantitative.

(*c*) *General procedure for the mixed nucleoside complexes* [PdL(L′)$_3$]Cl_2. Each nucleoside (inosine or guanosine) (0.6 mmol) was dissolved or suspended in water (100 cm^3) and the complexes K[PdLCl_3] (0.2 mmol) were added in small portions with vigorous stirring. The mixtures were stirred at room temperature for 3—4 h until complete dissolution was achieved. The solutions were then filtered free from any insoluble particles and the filtrates evaporated to dryness. The residues were taken up with D_2O (1.5 cm^3) to record their ^1H n.m.r. spectra. The spectra indicated the presence of one complex in solution, which was precipitated with excess of acetone, filtered off, washed with acetone and diethyl ether, and dried. The complexes isolated in this way were washed with small quantities of ethanol–water (8 : 2) at 0 °C by decantation to remove KCl. The yields were in the range 50—60%.

(*d*) cis-(*Inosine*)(*xanthosine*)*palladium*(II) *dichloride*, *cis*-[Pd(ino)(xao)]Cl_2. The salt K[Pd(ino)Cl_3] (1 mmol, 0.5202 g) and xanthosine (1 mmol, 0.2842 g) were dissolved in 0.5N HCl (15 cm^3) and stirred for *ca.* 2 h. The precipitate which formed was filtered off, washed with small quantities of 0.5N HCl, acetone, and diethyl ether, and dried at 110 °C *in vacuo*, yield 60%.

(*e*) cis-(*Guanosine*)(*xanthosine*)*palladium*(II) *dichloride*, *cis*-[Pd(guo)(xao)]Cl_2. The salt K[Pd(guo)Cl_3] (1 mmol, 0.5352 g) and xanthosine (1 mmol, 0.2843 g) were suspended in 0.5N HCl (15 cm^3) and stirred for 2 h at room temperature. The yellow precipitate which formed was filtered off, washed with small quantities of 0.5N HCl, acetone, and diethyl ether, and dried at 110 °C *in vacuo*, yield 65%.

(*f*) trans-(*Guanosinato*)(*inosinato*)*palladium*(II), *trans*-[Pd(ino − H)(guo − H)]. Guanosine (1 mmol, 0.2833 g) was suspended in water (25 cm^3) and K[Pd(ino)Cl_3] (1 mmol, 0.5202 g) was added in small portions with vigorous stirring. The pH of the mixture adjusted to *ca.* 7 with 0.1N K[OH] and maintained for 2 h. The yellow precipitate which formed was filtered off, washed with hot water, acetone, and diethyl ether, and dried at 60 °C *in vacuo* for 2 h and then at 110 °C *in vacuo* for another 2 h, yield 85%.

(*g*) trans-(*Guanosine*)(*inosine*)*palladium*(II) *dichloride*, *trans*-Pd(ino)(guo)]Cl_2. The complex *trans*-[Pd(ino − H)-(guo − H)] (1 mmol, 0.6559 g) was suspended in 0.5N HCl (10 cm^3) and stirred until complete dissolution was achieved. The resulting yellow solution was filtered into Pr^iOH–OEt_2 (1 : 2, 200 cm^3). The yellow precipitate which formed was filtered off, washed with acetone and diethyl ether, and dried at 60 and 110 °C *in vacuo*, yield 90%.

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[43] H. Bredereck, *Ber.*, 1947, **80**, 401.