2,2)], only for the (4,0) and (trans 2,2) isomers. These deviations are not surprising, since the (4,0) isomer is the most sterically hindered of the four, while the (trans 2,2) is the least hindered isomer.

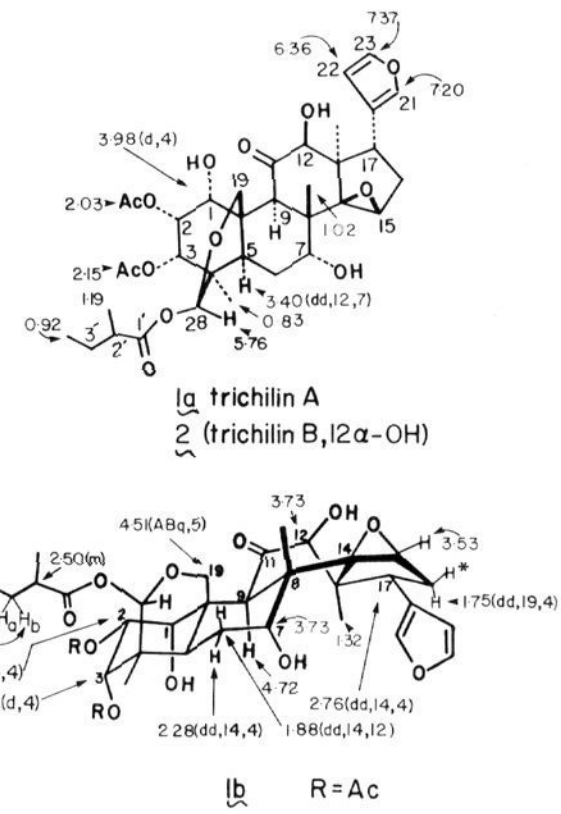
Time-dependent irradiations of each of the atropisomers of H_2PF,THA were carried out and monitored by HPLC. Since there are four potential sites for isomerization, there are several feasible mechanisms ranging from one-bond-only isomerization to simultaneous four-bond isomerization. It appears that for H_2PF,THA, photointerconversion of the atropisomers occurs neither by a step-by-step one bond process in which only one bond rotates (or is labilized) upon excitation nor by a random process in which all phenyl rings can rotate simultaneously in the excited state. Irradiation of (4,0) H_2PF,THA yields (3,1) H_2PF,THA and (trans 2,2) H_2PF,THA as initial photoproducts. Appearance of the (cis 2,2) isomer occurs only after a substantial buildup of the (3,1) isomer is achieved. Thus, it is evident that, due to either the geometry or the electron distribution of the porphyrin excited state, two trans porphine–phenyl bonds have lowered barriers to rotation. Studies of the initial photoproducts from the other isomers give results consistent with this picture. Although additional study is necessary to provide additional support, these results could be consistent with a picture of the free-base porphyrin triplet as a nonplanar structure warped or ruffled in such a way as to permit enhanced rotation of opposite bridge substituted groups.

Interestingly, in contrast to our findings with the free base, irradiation of (4,0) ZnPF,THA initially yields only (3,1) ZnPF,THA. Thus the presence of the metal apparently affects the excited state structure such that only a step-by-step one-bond isomerization process applies.[16,17] Studies with other picket-fence-type porphyrins and a variety of metal complexes are in progress to determine the effect of group size, excited state lifetime, and metal–ligand coordination on the rate and mechanism of the photoatropisomerization process.

Acknowledgment. We thank the U.S Army Research Office (Grant DAA629-77-6-0063) and National Institutes of Health (Grant GM 15,238) for support of this work.

(17) Initial product studies of PdPF,THA, as well as of H_2 PF,TPiv and its metal complexes have so far been hindered by incomplete resolution of isomers by HPLC.

Scheme I



[a] ^{1}H NMR data ($CDCl_3$), 300 MHz, in ppm (multiplicity and J values); the data are shown in both **1a** and **1b**. The 16β-H (*) is obscured by the acetate peaks.

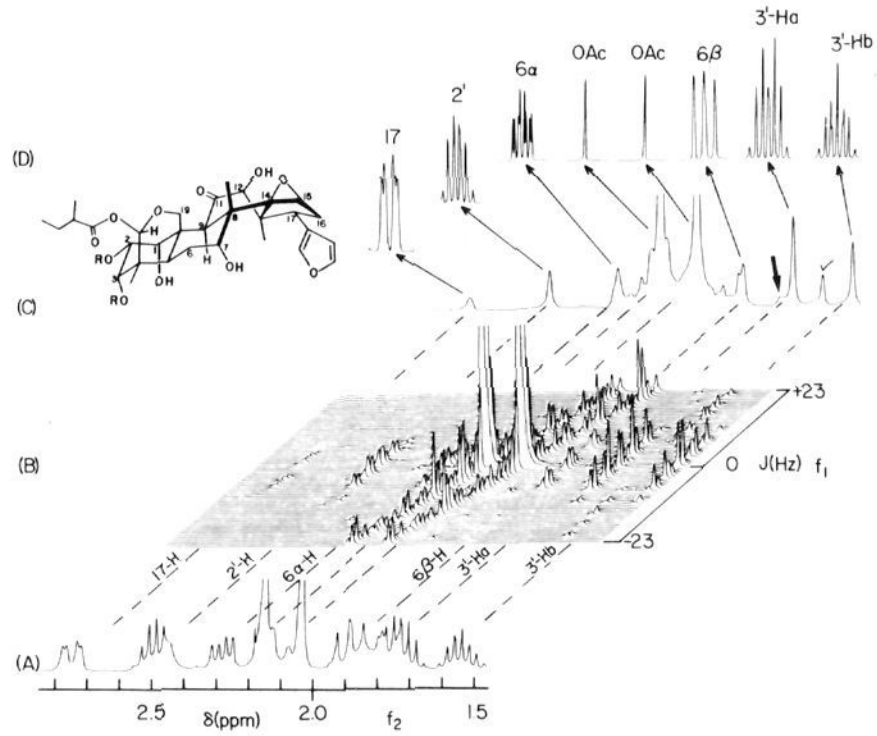


Figure 1. Partial spectra of **1** measured in $CDCl_3$ at 300 MHz. (A) Conventional NMR spectrum, (B) two-dimensional J spectrum (absolute value stacked plot, 64 traces are shown), (C) "proton-decoupled-proton" spectrum from a projection of (B) onto the horizontal (f_2) axis, and (D) J spectra (cross sections of the stacked plot). The short thick arrow in trace C is the 16α-H signal (see test).

Isolation and Structures of Trichilins, Antifeedants against the Southern Army Worm

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The root bark of the East African plant *Trichilia roka* (Meliaceae) has yielded a series of new limonoids, "trichilins", which are antifeedants[1] against the North American pest insects, the Southern army worm (*Spodoptera eridania*), and the Mexican bean beetle (*Epilachna varivestis*). They are one of the few antifeedants active against the voracious *S. eridania* caterpillar.[2] The isolation of the various congeners A–F, which was monitored by army worm assay, was a tedious process requiring very careful use of high-performance LC. The root bark (365 g)[3] was defatted with petroleum ether and extracted with ether to yield 2.9 g of an extract. The extract was flash chromatographed[4] with Et_2O/hexane, and the active fraction was rechromoatographed on a flash column with 1.5% MeOH/CH_2Cl_2. Repeated passage through a high-performance LC, Whatman Partisil M9 semiprep column, by using 0.4–1% MeOH in CH_2Cl_2 as the solvent finally gave the following trichilins: (A) 100 mg; mp 191–192 °C (dec); UV(MeOH) 213 nm (ϵ 4050); CD (MeOH) $\Delta\epsilon_{213}$ +2.6, $\Delta\epsilon_{304}$ −3.7. (B) 40 mg; UV 209 (ϵ 4600); CD $\Delta\epsilon_{217}$ +1.2, $\Delta\epsilon_{306}$ −1.9. (C) 2.8 mg; UV 214(ϵ 4400); CD $\Delta\epsilon_{212}$ +3.2, $\Delta\epsilon_{291}$ −1.0. (D) 7 mg; UV 212(ϵ 2800); CD $\Delta\epsilon_{288}$ +0.4, $\Delta\epsilon_{205}$ −1.1, $\Delta\epsilon_{298}$ − 3.1. (E) 2 mg.

(1) (a) Nakanishi, K. *Pontif. Accad. Sci. Scr. Varia* **1977**, *41*, 185. (b) Kubo, I.; Nakanishi, K. *ACS Symp. Ser.* **1977**, *62*, 165.

(2) Of the antifeedants that we have isolated so far, the trichilins are the only compounds besides azadirachtin (see ref 16) which are active against *S. eridania*. Electrophysiological studies are in progress to clarify the mode of action of antifeedants: Zack, C., unpublished data.

(3) Collected by the authors in June 1979 at Simba Hill near Mombasa, Kenya.

(4) Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923. This rapid chromatography method is well suited for compounds which decompose from being in contact with SiO_2 over an extended period. The trichilins could not be isolated when treated with $CHCl_3$ and conventional SiO_2 columns.

0002-7863/81/1503-1228$01.25/0

Table I. ^{13}C NMR Spectra of 1 Measured at 62.89 MHz in Deuteriochloroform[a]

C-1	72.4 d	C-18	22.4 q
C-2	68.7 d	C-19	64.9 t
C-3	73.3 d	C-20	123.5 s
C-4	41.0 s	C-21	143.0 d
C-5	41.2 d	C-22	111.4 d
C-6	26.4 t	C-23	140.2 d
C-7	71.3 d	C-28	93.4 d
C-8	45.6 s	C-29	18.2 q
C-9	46.7 d	C-30	21.2 q
C-10	41.9 s	CH_3CO (2)	20.5 q
C-11	213.7 s	CH_3CO (2)	168.7 s
C-12	78.7 d	CH_3CO (3)	20.7 q
C-13	48.9 s	CH_3CO (3)	169.9 s
C-14	71.1 s		
C-15	54.8 d	C-1′	175.2 s
C-16	31.3 t	C-2′	28.4 d
C-17	32.7 d	C-3′	26.4 t
		CH_3 (2′)	16.2 q
		CH_3 (3′)	11.2 q

[a] Numbers in parentheses denote the carbon number (see **1a** for numbering).

Extensive ^1H and ^{13}C NMR studies[5] of trichilins A (**1**) and B (**2**), both $C_{35}H_{46}O_{13}$, CI-MS *m/e* 675 $(M + 1)^+$, including two-dimensional *J* spectroscopy,[6] allowed us to assign all of the peaks in the complex spectra as well as to derive structures **1** and **2**, respectively (Scheme I). The structures were then confirmed through chemical correlations. Some pertinent points related to our structural studies are listed as follows:

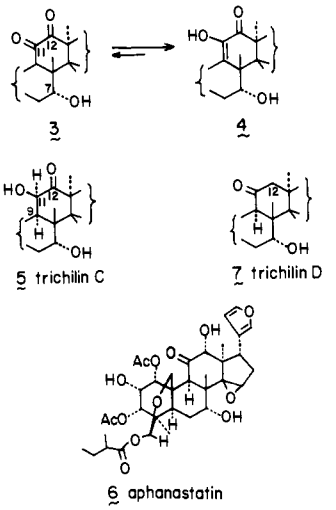
(i) The partial 300-MHz 2-D *J* spectrum of trichilin A is shown in Figure 1. Additional information which is not readily obtainable from conventional one-dimensional spectra can be gained by this technique because of the inherent enhanced resolution and peak separation.[6] For example, the 6α-H/7-H coupling is apparent in the *J* spectrum (Figure 1D) but not in the 1-D spectrum (Figure 1A). The 16β proton (H* in **1b**) could not be measured due to the overlap of the acetate signals. The 16α-H at 1.75 ppm (heavy arrow in Figure 1C, see also **1b**) was obscured by the more intense 3′-H_a peak of the side chain at 1.72 ppm (see **1b**); however, it was possible to estimate its chemical shift and coupling constants from an examination of a separate *J* spectrum (not shown in Figure 1).

(ii) Irradiation of the 13- and 8-Me peaks induced 30% and 12% NOE's on the 9-H and 19-H signals, respectively (see conformational drawing **1b**).

(iii) The acetate ^{13}C NMR signals (Table I, 168.7 s/20.5 q and 169.9 s/20.7 q) were assigned as follows by the long-range selective proton decoupling technique (LSPD).[7] Irradiation of the 2-H peak at δ_H 5.91 (**1b**) (the assignment of which is unambiguous from its coupling pattern), with very low power, simplified the δ_C 168.7 carbonyl signal but not the δ_C 169.9 signal; similarly LSPD of the δ_H 2.03 methyl (**1a**) decoupled the δ_C 168.7 carbonyl. Thus the δ_C 168.7 resonance was correlated with the 5.91- and 2.03-ppm proton peaks. The δ_H 2.03 peak was then correlated with the δ_C 20.5 quartet by conventional selective decoupling. The ^1H and ^{13}C NMR peaks of the 3-OAc group were determined similarly.

(iv) Oxidation of trichilins A and B with pyridinium chlorochromate[8] at 5 °C in CH_2Cl_2 both afforded in ca. 10% yield the same α-diketone **3** (Scheme II) (high-performance LC separation, yellow oil); thus A and B are 12-epimers.[9] When left in MeOH for 1 day, the dione is converted into an equilibrium mixture favoring diosphenol **4** as shown from spectral data: UV (MeOH), 290 (ε 2300, ππ* of **4**), 217 (ε 5800, furan); CD (MeOH) 433 (Δε −1.4, nπ* of **3**), 334 (Δε +3.5, nπ* of **4**), 290 (Δε −5.2, ππ* of **4**) 225 nm (Δε +2.3, furan).

Scheme II



(v) The fact that the 12-OH is β in trichilin A and α in trichilin B was deduced from the finding that in their *p*-bromobenzoates, the aromatic protons of the benzoate and furan rings were all at higher field in B. Thus the shifts are (for trichilins A/B): *o*-H 7.99/7.65, *m*-H 7.51/7.59, 21-H 7.20/7.02, 22-H 6.36/5.98, 23-H 7.37/7.10 ppm. The higher chemical shifts in B can be accounted for by the ring currents of the two aromatic rings which are located on the same side of the molecule. More directly, however, the 12-OH configurations were independently derived from a new additivity relation found in general in the Cotton effects of multiple coupled chromophores.[10]

(vi) When trichilin A was dissolved in "100%" $CDCl_3$ for NMR measurements, the spectrum underwent a gradual change to that of trichilin C.[11] As this suggested an acid-induced isomerization, A was left at room temperature for 2 h in CH_2Cl_2 with a catalytic amount of TsOH, upon which it was converted quantitatively into the C isomer **5**; ^1H NMR, 11-H at 4.10 (s, hence 11-H is α), 9-H at 3.25 ppm (s, in isomer A it is 4.71).

(vii) Treatment of trichilin **1** with $Zn(BH_4)_2$ in an attempt to reduce the 11-one led unexpectedly to an acryl migration in ring A and gave a mixture of **1** and its 1,2-diacetyl and 1,3-diacetyl isomers which were separated. The acylation pattern in **1**, namely, that **1** has a free 1-OH, was shown by the fact that the 9-H signal in **1** was at 4.72 ppm, whereas in the 1,3-diacetate it was shifted upfield to 4.17 ppm. The low shift of 4.72 ppm in **1** can be attributed to the effect of the 1-OH in a 1,3-diaxial relation (see **1b**).

(viii) Similar treatment of trichilin B (**2**) with $Zn(BH_4)_2$ yielded the cytotoxic aphanastatin (**6**), the structure of which was determined by single-crystal X-ray analysis.[12] As in the case of trichilin A, the treatment induces an acyl migration (^1H NMR); this unexpected conversion establishes the structure of trichilin B.[13]

(ix) Trichilin D, $C_{35}H_{46}O_{12}$, CI-MS *m/e* 659 $(M + 1)^+$, is represented by structure **7**; the 12-H's appear as a two-proton singlet at 2.44 ppm.[14]

A remarkably clear-cut structure/activity relation has been found with trichilin and derivatives as tested by the conventional leaf disk method against the Southern army worm.[15] Independent

(5) Bruker WM-250 and WM-300 instruments were employed in the NMR studies.
(6) (a) Aue, W. P.; Karlan, J.; Ernst, R. R. *J. Chem. Phys.* **1976**, *64*, 4226. (b) Hall, L. D.; Sanders, J. K. M. *J. Am. Chem. Soc.* **1980**, *102*, 5703.
(7) Takeuchi, S.; Uzawa, J.; Seto, H.; Yonehara, H. *Tetrahedron Lett.* **1977**, 2943.
(8) Corey, E. J.; Suggs, J. W. *Tetrahedron Lett.* **1975**, 2647.
(9) The other oxidation products were the 7-one and the 7,11,12-trione.
(10) Liu, H. W., to be submitted for publication. Nakatani, M., to be submitted for publication.
(11) After this observation, the NMR spectra were measured in 99.8% $CDCl_3$.
(12) Polonsky, J.; Varon, Z.; Arnoux, B.; Poscard, C. *J. Am. Chem. Soc.* **1978**, *100*, 2575. We are grateful to Judith Polonsky for a sample of aphanastatin (also an antifeedant).
(13) Recently we have been able to isolate aphanastatin from *T. roka*.
(14) Trichilin E appears to be 12-epiaphanastatin.
(15) M. Nakatani, to be submitted for publication.

of the substitution patterns in ring A, the most potent are the compounds with a 12α-OH function (trichilin B type) which are active at 200 ppm; this is followed by the 12β-OH compounds, 300 ppm, and then the 12-desoxy type, e.g., trichilin D, 400 ppm, and 12α-acetoxy compounds, also 400 ppm. Acetoxylation or ketonization of 7-OH or ketonization at C-12, i.e., **3**/**4** or trichilin C (**5**), renders the compounds inactive. Feeding of trichilin A over a 10-day period to the third instar larvae of *S. eridania* killed the insects. The trichilin structures are too complex to be synthesized on a practical scale. However, their potent activities, comparable to azadirachtin,[16] should be noted.[17]

(16) Zanno, P. R.; Miura, I.; Nakanishi, K.; Elder, D. *J. Am. Chem. Soc.* **1975**, *97*, 1975 and references cited therein. The azadirachtin molecule again is far too complex to be synthesized practically. However, the leaves and fruits of the neem tree from which it was isolated have strong insect antifeedant activity and, in fact, cultivation of the neem tree is under serious consideration.[16a] Also the First International Conference on the neem tree was held in Germany, Aug 1980, because of its potential practical use in pest insect control.

(17) Supported by NIH Grant AI 10187.

New Reaction Chemistry of *cis*-Diammineplatinum(II) with α-Pyridone. Crystalline Relatives of the α-Pyridone Blue

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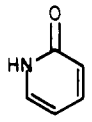
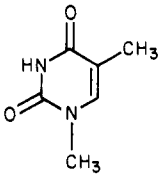
The platinum blues are a family of compounds that have generated much current interest.[1-7] To date, only *cis*-diammineplatinum α-pyridone blue (**1**, Figure 1) has been fully


α-pyridone


1-methylthymine

characterized structurally.[2] Studies on this and related *cis*-diammineplatinum blues strongly suggest that they are all mixed valent, metal-metal bonded, amidate-bridged oligomers.[2-4] Although several nonblue crystalline products (**2**-**4**, Figure 1) have been isolated[8-10] from reaction mixtures that ultimately produce *cis*-diammineplatinum pyrimidine blues, an interesting subclass known to have antitumor properties,[11] no crystals of the pyrimidine blues themselves have yet been obtained.

Here we report the syntheses and structures of three new, nonblue compounds (**5**-**7**, Figure 2) obtained in the reaction of *cis*-diammineplatinum(II) with α-pyridone. The most striking compound is the yellow head-to-head "tetramer" **7**, platinum oxidation state 2.0, which has a geometry nearly identical with that of the α-pyridone blue **1**, average platinum oxidation state 2.25. The longer Pt-Pt distances in **7** are consistent with and strongly support the previous analysis of the electronic structure of **1**. Unlike **7**, the head-to-head 1-methylthyminato complex **4** is only a dimer, and the difference between these two structures provides some insight into the question of why a 1-methylthyminate blue analogous to **1** has not yet been crystallized. The present work also demonstrates that the crystalline complexes previously obtained in the reaction of *cis*-diammineplatinum(II) with 1-methylthymine also form in its reactions with α-pyridone. In particular, there is a close correspondence in molecular geometry between the head-to-tail 1-methylthyminato (**2**) and α-pyridonato (**5**) dimers, the bis(1-methylthyminato) (**3**) and bis(2-hydroxypyridine) (**6**) complexes, and the head-to-head compounds **4** and **7**. The new reaction chemistry found for *cis*-diammineplatinum(II) with α-pyridone, a pyrimidine analogue, provides a foundation for understanding the more complex chemistry that leads to the platinum pyrimidine blues and also expands the list of possibilities for the interaction of the antitumor drug *cis*-$[Pt(NH_3)_2Cl_2]$ with cyclic amides such as those present in the G, C, and T bases of DNA.

Table I. Geometric Comparison of *cis*-Diammineplatinum Complexes

	distance, Å				dihedral angle, deg[a]		
compd	Pt-Pt	Pt-NH_3	Pt-N	Pt-O	τ	ω	ref
1	2.77 2.88	2.06 (av)	2.05 (av)	2.04 (av)	27.4	22	2
2	2.97	2.05 (av)	2.04 (av)	2.04 (av)	36.1	14	8
4	2.91	*b*	*b*	*b*	29.5	1	9
5	2.90	2.05 (av)	2.03	2.02	28.9	13	*c*
6		2.04	2.03				*c*
7	2.88 3.13	2.05 (av)	2.05 (av)	2.04 (av)	30.0	21	*c*

[a] τ is the tilt angle between adjacent platinum coordination planes, and ω is the average torsion (or twist) angle about the Pt-Pt vector (see ref 2). [b] Values not reported. [c] This work.

Crystals of the head-to-tail dimer **5**, $[Pt(NH_3)_2(C_5H_4ON)]_2(NO_3)_2 \cdot 2H_2O$, were isolated in 40-60-mg quantities by cooling the filtrate of the solution from which the α-pyridone blue crystals were harvested[3] for an additional 12-24 h at 3 °C. The light yellow compound was characterized by analytical and spectroscopic data[12] and a complete X-ray crystal structure analysis.[13]

(1) For a literature review, see: Barton, J. K.; Lippard, S. J. *Ann. N.Y. Acad. Sci.* **1978**, *313*, 686.
(2) (a) Barton, J. K.; Rabinowitz, H. N.; Szalda, D. J.; Lippard, S. J. *J. Am. Chem. Soc.* **1977**, *99*, 2827. (b) Barton, J. K.; Szalda, D. J.; Rabinowitz, H. N.; Waszczak, J. V.; Lippard, S. J. *Ibid.* **1979**, *101*, 1434.
(3) Barton, J. K.; Best, S. A.; Lippard, S. J.; Walton, R. A. *J. Am. Chem. Soc.* **1978**, *100*, 3785.
(4) Barton, J. K.; Caravana, C.; Lippard, S. J. *J. Am. Chem. Soc.* **1979**, *101*, 7269.
(5) Goodgame, D. M. L.; Jeeves, I. *Z. Naturforsch. C* **1979**, *34C*, 1287.
(6) (a) Zaplatynski, P.; Neubacher, H.; Lohmann, W. *Z. Naturforsch. B* **1979**, *34B*, 1466. (b) Ettore, R. *Inorg. Chim. Acta* **1980**, *46* (*B1*), L27.
(7) Laurent, M. P.; Tewksbury, J. C.; Krogh-Jespersen, M-B.; Patterson, H. *Inorg. Chem.* **1980**, *19*, 1656.
(8) Lock, C. J. L.; Peresie, H. J.; Rosenberg, B.; Turner, G. *J. Am. Chem. Soc.* **1978**, *100*, 3371.
(9) Lippert, B.; Neugebauer, D.; Schubert, U. *Inorg. Chim. Acta* **1980**, *46* (*B1*), L11.
(10) Lippert, B.; Neugebauer, D., unpublished results cited in ref 9. See also: Lippert, B.; Neugebauer, D. *Inorg. Chim. Acta* **1980**, *46* (*B1*), 171.
(11) Davidson, J. P.; Faber, P. J.; Fischer, R. G., Jr.; Mansy, S.; Peresie, H. J.; Rosenberg, B.; Van Camp, L. *Cancer Chemother. Rep.* **1975**, *59*, 287.

(12) Chemical and spectroscopic data. Anal. Calcd for $Pt_2C_{10}H_{24}N_8O_{10}$ (**5**): C, 14.89; H, 3.00; N, 13.89. Found: C, 14.85; H, 3.06; N, 13.83. NMR (Me_2SO-d_6) δ 8.10 (d, Pt satellites, H_6), 7.24 (t, H_4), 6.42 (t, H_3, H_5), 4.54, 4.39 (br, overlapping peaks, Pt satellites, NH_3). Anal. Calcd for $PtC_5H_{11}N_3OCl_2$ (**8**): C, 15.20; H, 2.81; N, 10.63; Cl, 17.94. Found: C, 15.15; H, 2.72; N, 10.57; Cl, 17.72. NMR (Me_2SO-d_6) δ 8.28 (d, Pt satellites, H_6), 7.80 (t, H_4), 6.88 (m, H_3, H_5), 4.48 (br t, Pt satellites, NH_3), 4.24 (s, OH).
(13) X-ray analysis. Compound **5** crystallized in the monoclinic system (space group $C2/c$) with the following cell parameters: a = 15.440 (4), b = 14.350 (2), c = 10.667 (1) Å; β = 118.09 (2)°, ρ_{obsd} = 2.56 (2), ρ_{calcd} = 2.57 g/cm³ for Z = 4 formula units. The structure was solved by standard heavy-atom Patterson and Fourier methods using 2402 unique reflections collected with Mo Kα (λ = 0.7107 Å) radiation out to 2θ = 55° on a Nonius CAD-4F diffractometer. Refinement of the absorption corrected data with all atoms assigned anisotropic temperature parameters, except hydrogens which were refined isotropically with constraints, has converged to a value of 0.033 for the discrepancy index $R_1 = \sum||F_o| - |F_c||/\sum|F_o|$. Compound **6** also crystallizes in the monoclinic system (space group $C2/c$) with cell parameters a = 9.072 (2), b = 22.875 (3), c = 8.003 (1) Å, β = 109.24 (1)°, ρ_{obsd} = 2.08 (2), ρ_{calcd} = 2.07 g/cm³ for Z = 4 formula units. The structure was solved as above, using 1802 unique reflections; the refinement converged at R_1 = 0.038. Compound **7** crystallizes in the monoclinic system (space group $P2_1/n$) with the following cell parameters: a = 9.158 (1), b = 9.907 (1), c = 21.405 (1) Å; β = 96.98 (8)°, ρ_{obsd} = 2.67 (2), ρ_{calcd} = 2.66 g/cm³ for Z = 4 formula units. The structure was solved as above using 4417 unique reflections and refinement has converged at R_1 = 0.038. Atomic positional and thermal parameters for all three compounds are provided as supplementary material. Full details will be reported at a later date.

0002-7863/81/1503-1230$01.25/0