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Studies on Organic Fluorine Compounds. XX.[1] Synthesis and Reactions of a Substituted Dewar Pyridine[2]

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Photolysis of 2,4,6-trimethyl-3,5-bis(trifluoromethyl)pyridine (I) afforded 2,4,6-trimethyl-3,5-bis(trifluoromethyl)-1-azabicyclo[2.2.0]hexa-2,5-diene (II), a stable derivative of 1,4-bonded Dewar pyridine. Protons of 2- and 6-methyl groups in II were exchanged with deuterium atoms in the presence of a base, while those of 4-methyl group were not. II was converted to I on thermolysis or catalysis by the action of some metal ions. Stable complexes, $Pd(II)_2Cl_2$ (VI) and $Pt(II)_2Cl_2$ (VI'), were isolated. VI was thermally converted to $Pd(I)(II)Cl_2$ (VII), which was in turn converted to $Pd(I)_2Cl_2$ (VIII). The structure of VII was established as square and coplanar *trans*-(N-)σ-structure by X-ray analysis.

There are many reports on the syntheses and reactions of stable Dewar benzenes. However, only two examples of syntheses of Dewar pyridines were reported; Wilzbach and Rausch[4] showed the presence of quite unstable 2,5-bonded Dewar pyridine in solution on irradiation of pyridine and Haszeldine, *et al.*[5] isolated a rather stable 1,4-bonded Dewar pyridine on irradiation of pentakis(pentafluoroethyl)pyridine. Little is known, however, about the reaction of these Dewar pyridines, which seem to be quite important in connection with the photoisomerization of pyridines and other synthetic application.

In this paper, we report the synthesis and some reactions of a stable 1,4-bonded Dewar pyridine. Irradiation of 2,4,6-trimethyl-3,5-bis(trifluoromethyl)pyridine (I) with a low-pressure mercury lamp gave 2,4,6-triemthyl-3,5-bis(trifluoromethyl)-1-azabicyclo[2.2.0]hexa-2,5-diene, a 1,4-bonded Dewar pyridine (II), which showed interesting behaviors in the deuterium exchange reaction and in the reaction with metal ions.

The change of ultraviolet (UV) spectrum on irradiation of I in pentane is shown in Fig. 1. Absorption maximum at 265 nm of I decreased gradually with the appearance of an isosbestic point at about 248 nm. In ^{1}H-nuclear magnetic resonance (NMR) spectrum, two signals attributable to I (δ 2.75 and 2.55) decreased gradually with the appearance and increase of new signals (δ 2.10 and 1.60) on irradiation of I in perfluoro-pentane.

The main products in both pentane and perfluoro-pentane were identified by gas–liquid chromatography (GLC). Further, it was confirmed that this isomerization is free from solvent effect.

Isolation of the main product by preparative GLC gave a pale yellow oil (II). The fact that the fragmentation pattern of II in mass spectrum is quite similar to that of Isuggests that II is one of the valence bond isomers of I. The presence of other valence bond isomers was shown by GLC–mass spectrum, but they were too small in amount to be isolated.

1) Part XIX: Y. Kobayashi, I. Kumadaki, A. Ohsawa, Y. Sekine, and H. Mochizuki, *Chem. Pharm. Bull.* (Tokyo), **23**, 2045 (1975).
2) Presented at the 5th Symposium on Heterocyclic Chemistry, Gifu, Japan, Nov. 1972. Preliminary communication: Y. Kobayashi, A. Ohsawa, and Y. Iitaka, *Tetrahedron Letters*, **1973**, 2643.
3) Location: *1432-1, Horinouchi, Hachioji-shi, Tokyo.*
4) K.E. Wilzbach and D.J. Rausch, *J. Am. Chem. Soc.*, **92**, 2178 (1970).
5) M.G. Barlow, J.G. Dingwall, and R.N. Haszeldine, *Chem. Commun.*, **1970**, 1580; *idem*, *J. Chem. Soc., Perkin Trans., I*, **1973**, 1542.

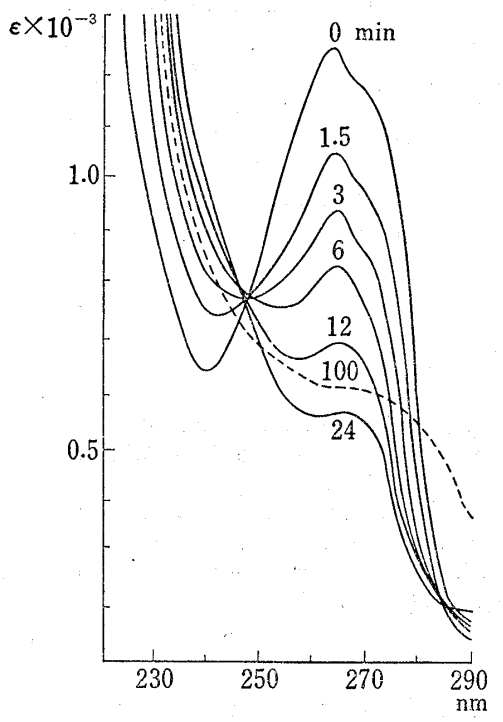


Fig. 1. Changes of UV Spectrum of I during Irradiation

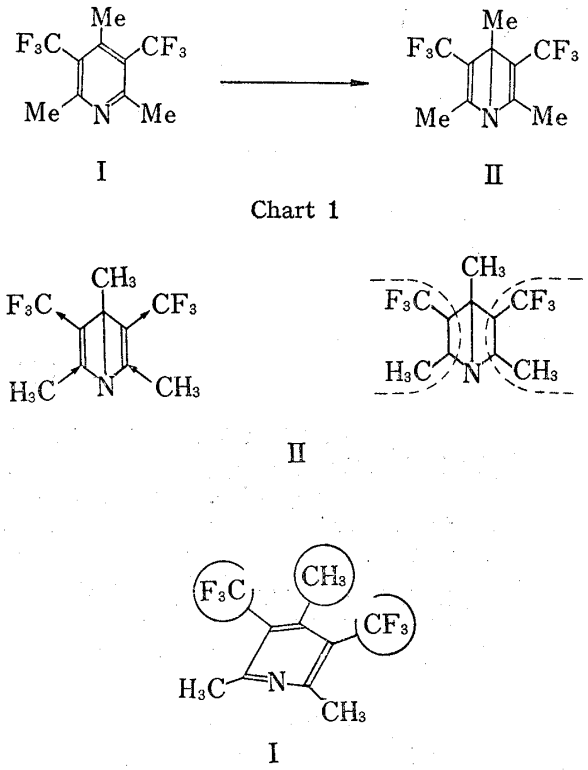


Chart 1

Chart 2

II showed two signals (δ: 2.10, q and 1.60, s, intensity ratio 2: 1) in ^{1}H-NMR and one signal (δ: 0.00 towards benzotrifluoride as an internal standard) in ^{19}F-NMR, and an absorption (1725 cm^{-1}) in the infrared (IR) spectrum characteristic of a four-membered ring olefin substituted with perfluoroalkyl group. From these data, the structure of II is assigned as a symmetrical 1,4-bonded Dewar pyridine.

It seemed of interest to see why II was preferably produced and stable enough to be isolated. Therefore, we tried photoisomerization of pentamethylpyridine and 2,6-dimethyl-3,5-bis(trifluoromethyl)pyridine, but only starting materials were recovered in both cases. Kellogg and van Bergen[6] obtained 1,4-dihydro compound by photoreaction of dimethyl 2,4,6-trimethylpyridine-3,5-dicarboxylate, which seemed to be substituted with the groups having an electronic effect similar to those of I. Thus, isolation of the stable Dewar pyridine must depend on both electronic pull-push effect and steric factors of the substituents (Chart 2).

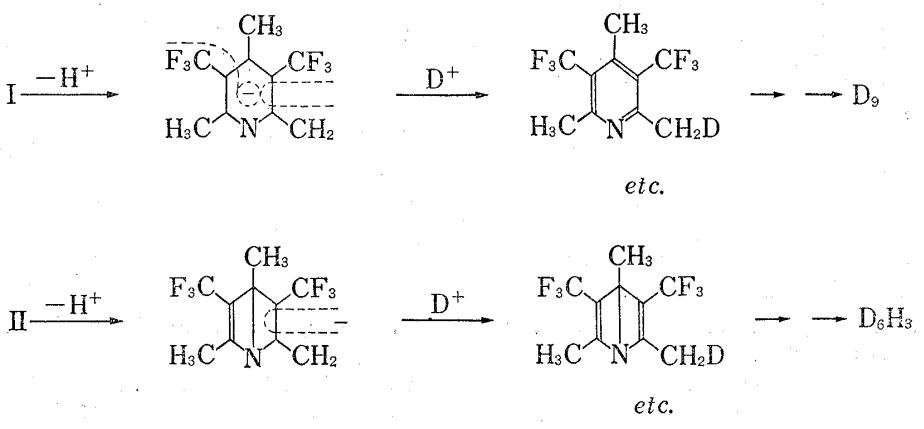


Chart 3

6) T.J. Van Bergen and R.M. Kellogg, *J. Am. Chem. Soc.*, **94**, 8451 (1972).

This electronic pull-push interaction between the methyl and the trifluoromethyl groups through the double bond is supported by the NMR data and deuterium exchange reaction. Methyl protons at 2 and 6 positions of II are split into a quartet by H–F coupling with fluorine atoms in the trifluoromethyl group, while the methyl protons at 4 position is a singlet. Methyl protons at 2 and 6 positions of II were exchanged with deuterium atoms by treatment with alkali in CD_3OD; but those at 4 position were unaffected, while all the methyl protons in I were smoothly exchanged under the same condition (Chart 3).

The photoisomerization of I to II was unaffected by triplet quenchers such as piperylene, triplet sensitizers such as acetophenone, or polarity of solvents, and did not proceed at all by the use of a high-pressure mercury lamp with a Pyrex filter. These facts suggest that this reaction passed through a concerted process by π–π^* excitation. The predominant formation of II over other isomers must depend on the electronic and steric effects discussed above.

Next, some reactions of II will be discussed. As has already been mentioned, deuterium exchange occurred only on α-methyl groups, showing that the trifluoromethyl groups exert an electronic effect on α-methyl groups through double bonds but not on γ-methyl group.

II is stable enough to be kept at room temperature for several days but reverted to I on heating. This reversion was accelerated by the presence of Brönsted and Lewis acids and gave I quantitatively; namely, addition of an acid decreased the intensity of peaks in ^{1}H- and ^{19}F-NMR attributable to II with the appearance and increase of those attributable to I. This phenomenon was also observed in GLC. Since this reversion was initiated with much less amount of the acid than molar equivalent and the changes in NMR and GLC were continuous, the acid must have worked as a catalyst in the transition state, as shown in Eq. (1).

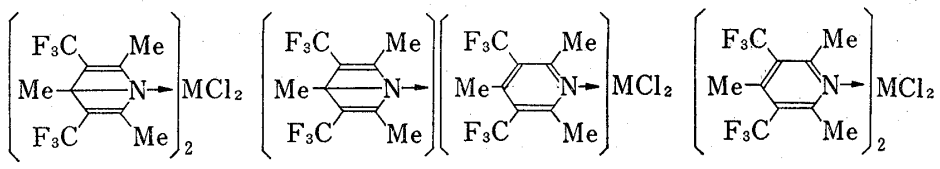
$$A + II \leftrightharpoons [A \cdot II \longrightarrow A \cdot I] \rightleftharpoons A + I \qquad (1)$$

On the other hand, addition of palladium chloride (III), palladium chloride-bisbenzonitrile (IV), or platinum chloride (V) showed quite different features in NMR and GLC. When a quarter molar equivalent of IV was added to the solution of II in $CDCl_3$, intensity of the signals attributable to II decreased to one-half of the original intensity and new signals (δ 2.38 and 2.35 in ^{1}H-NMR, intensity ratio 2: 1; δ 1.3 in ^{19}F-NMR) appeared. Presence of free II in this solution was observed in GLC, but not that of the isomers. When this solution was allowed to stand at room temperature, these new signals became smaller with the appearance and growth of additional new signals (δ 3.90 and 2.60 in ^{1}H-NMR, intensity ratio 2: 1; δ −10.0 in ^{19}F-NMR). These additional new signals correspond to those of the complex obtained from I and IV. Presence of free II was still observed by NMR and GLC after allowing it to stand at room temperature till the apparent change of peak ratios in NMR was not observed, but no other isomers of II were observed. When an excess IV was added, signals of II disappeared at once, with the appearance of new signals, which decreased slowly with the appearance of the additional new signals. Neither free II nor I was detected by GLC just after addition of IV or after allowing it to stand at room temperature. The fact that neither I nor II was detected by GLC suggests that a stable complex between II and palladium was formed, and that it slowly isomerized to other stable complexes containing I, as exemplified in Eq. (2).

$$II + M \xrightarrow{\text{fast}} II \cdot M \xrightarrow{\text{slow}} I \cdot M \not\longrightarrow I + M \qquad (2)$$

Next, isolation of these complexes was attempted. When an excess IV was added to the solution of II in chloroform–methanol, unstable crystals (VI) and rather stable ones (VII) were obtained. Recrystallization of VI from chloroform–methanol gave crystals (VII), and by heating the solution of VII in chloroform–methanol stable brown powder (VIII) was obtained, which was identified with the complex obtained from one mol of IV and two mol of I. Use of III instead of IV gave the same result and use of V gave similar complexes, VI′, VII′, and VIII′ although VIII′ was not obtained from I and V.

Complexes VI, VII, and VIII did not show any melting point but underwent decomposition above 120°, leaving III. The molecular weight observed by osmometry in carbon tetra-



VI, VI′ VII, VII′ VIII, VIII′

VI, VII, VIII : M=Pd^{II}
VI′, VII′, VIII′ : M=Pt^{II}

Chart 4

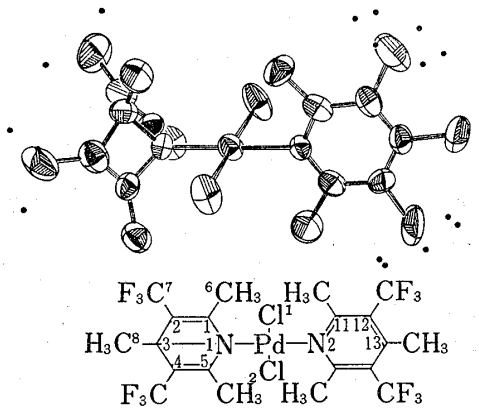
chloride and elemental analyses are consistent with those for $Pd(C_{10}H_9NF_6)_2Cl_2$, in the cases of VI, VII, and VIII. Chlorine atoms in these complexes were not exchanged by treatment with ion exchange resin (I^--type) in chloroform–methanol. On addition of excess pyridine, II, II and I, and I were released from VI, VII, and VIII, respectively. Hence, molecular formulas of VI, VII, and VIII would be shown as $Pd(II)_2Cl_2$, $Pd(I)(II)Cl_2$, and $Pd(I)_2Cl_2$, respectively. NMR data summarized in Table I support these structures.

What interested us next was the structure of these complexes. It is known that hexamethyl-Dewar benzene forms π-complexes[7] and that pyridines form (N-)σ-complexes with palladium. Strong absorption at 1730 cm^{-1} in the IR spectra of VI and VII suggests that coordination did not occur through the π-system of II. Actually the structure of VII was

Table I. NMR Data of Complexes in $CDCl_3$

Complex	^{1}H-NMR (δ)				^{19}F-NMR (δ)[a]	
	II		III		II	III
	α-CH_3	γ-CH_3	α-CH_3	γ-CH_3	β-CF_3	β-CF_3
VI	2.35	2.38	—	—	1.3	—
VII	2.36	2.40	3.90	2.60	1.3	−10.0
VIII	—	—	3.95	2.60	—	−10.0
VI′	2.35	2.17	—	—	1.25	—
VII′	2.40	2.33	3.88	2.68	1.25	−10.3
VIII′	—	—	3.90	2.68	—	−10.3

a) benzotrifluoride=0 ppm as internal standard



N-1, C-1	1.50 Å
C-1, C-2	1.30
C-2, C-3	1.53
N-1, C-3	1.56
N-2, C-11	1.35
C-11, C-12	1.38
C-12, C-13	1.39
Pd, N-1	2.06
Pd, N-2	2.04
Pd, Cl-1	2.28
∠N-1, C-1, C-2	96°
∠C-1, C-2, C-3	94
∠C-2, C-3, N-1	85
∠C-3, N-1, C-1	85

Fig. 2. X-Ray Analysis Data of VII

7) H. Dietl and P.M. Maitlis, *Chem. Commun.*, **1967**, 759.

established as square and coplanar *trans*-(N-)σ-structure by X-ray diffraction analysis,[2] as shown in Fig. 2. Other complexes (VI, VIII, VI′, VII′, and VIII′) must have similar structures. Kinetic studies on the reversion of II to I in both the presence of a catalyst, *e.g.*, Lewis acid, or metal ions, will be discussed in the following paper.

Experimental

Low-pressure mercury lamp (Ushio ULO-6AB, 6W) and high-pressure mercury lamp (Ushio UM-102, 100 W) were used as a light source for irradiation. Gas–liquid partition chromatography (GLC) analyses were obtained with Shimadzu Model GC-3AF using a 3 m column of 15% diethylene glycol succinate (DEGS) on Shimalite. Preparative GLC was carried out with Shimadzu Model GC-1C preparative GLC system using Helium as a carrier, at 85°. GC–mass spectra were obtained with a Hitachi Model K-53 (GLC)-RM-TL (mass) system. ^{1}H- and ^{19}F-NMR spectra were recorded with a Varian T-60 and JEOL Model JMN-4H-100 spectrometers IR and UV spectra were run on a Nihon Bunko Model DS-301 and Hitachi ESP-3 spectrophotometer, respectively.

2,4,6-Trimethyl-3,5-bis(trifluoromethyl)pyridine (I)——2,4,6-Trimethyl-3,5-bis(trifluoromethyl)pyridine (I) was prepared by usual fluorination of the corresponding 3,5-dicarboxylic acid with SF_4. The carboxylic acid (12 g), SF_4 (22 ml), and H_2O (1 ml) were charged in 50 ml autoclave made of Hasteroy-C and heated at 180° for 22 hr. After the vessel was cooled to room temperature, the gaseous part was discharged at atmospheric pressure. The residue was extracted with 50 ml of ether; the ether was washed with 5% aqueous Na_2CO_3, and dried over Na_2SO_4. A dark-colored oily mixture obtained after distillation of ether was distilled under a reduced pressure. A colorless oil of I was obtained as a major fraction, bp 160° at 10 mm (bath temp.). Yield, 4.4 g (30%).

Irradiation of I——Figure 1 was obtained by the measurement of UV absorption of diluted solution of I in pentane during irradiation. The solution was irradiated in quartz UV cell at 2 cm from the low-pressure mercury lamp.

Substantially the same results were obtained by the irradiation of perfluoro-pentane and of MeOH solutions, while small differences in absorption patterns were obserbed after prolonged irradiation in these solvents.

Changes in ^{1}H-NMR spectrum were measured in a perfluoropentane solution of I (*ca.* 5%) which was sealed in a quartz NMR-tube in vacuum and was irradiated with a low-pressure mercury lamp at the distance of *ca.* 2 cm. This solution was employed for GLC sample and GC–mass spectra after complete conversion of ^{1}H-NMR spectrum.

No remarkable decrease in concentration of I (measured by ^{1}H-NMR, GLC, and UV) was observed by irradiation with a high-pressure mercury lamp in a similar condition as mentioned above.

In the case of preparative experiment, a quartz tube (ϕ=1 cm) containing 5 g of I sealed in vacuum was placed horizontally and irradiated at room temperature for *ca.* 100 hr with a low-pressure mercury lamp which was placed in a parallel position below the sample tube at a distance of 5 cm. A yellow mixture, accompanied with a small amount of cloudy precipitate and tarry film on the wall, was distilled under a reduced pressure at a temperature below 100°, and the distillate (*ca.* 3 g) was separated by preparative GLC. Approximately the same amounts of pure 2,4,6-trimethyl-3,5-bis(trifluoromethyl)-1-azabicyclo[2.2.0]hexa-2,5-diene (II, *ca.* 1 g) and I (*ca.* 1 g) were obtained. Other minor fractions were not able to be isolated because of their low yield. Irradiation of about 20% solutions of I in pentane and in perfluoro-pentane under similar conditions gave substantially the same results as above. Presence of inert gas, such as N_2 or air, showed no remarkable inhibition on the conversion.

II, pale yellow highly volatile oil; bp 67—70° (40—45 mm); IR ($CHCl_3$) cm^{-1}: 1725, 1430, 1385, 1365, 1342, 1155, 1130, and 1055; ^{1}H-NMR (in CCl_3CN) δ: 1.60 (3H, s, γ-CH_3), 2.10 (6H, q, J=3 Hz, α-CH_3); ^{19}F-NMR (in CCl_3CN) δ: 0.0 (towards benzotrifluoride as an internal standard). Mass spectrum of II showed an almost identical fragment pattern to that of I, *m/e* 257 (base peak, M^+), 242 (M^+-CH_3), 238 (M^+-F), 237 (M^+-HF), 222 (M^+-CH_3-HF), 216 (M^+-CH_3-CN), 188 (M^+-CF_3). *Anal.* Calcd. for $C_{10}H_9F_6N$: C, 46.7; H, 3.5; F 44.4; N, 5.4. Found: C, 45.8; H, 3.0; F, 40.2; N, 5.0. (The high volatility of II caused the lower value in the analysis.)

Deuteration Reaction of I and II——^{1}H-NMR of solution in NMR-tube (*ca.* 5% in CD_3OD with a small amount of CD_3ONa) were measured at intervals at room temperature.

Transformation of II with Acids or Metal Salts——A catalytic amount of acid or metal salt was added to the solution of II (*ca.* 5%) in NMR-tube and decrease in the amount of II and increase of I were measured by ^{1}H- and ^{19}F-NMR and GLC.

Isolation of Palladium Complexes——To a solution of 0.1 g (0.39 mmol) of II in 2 ml of $CHCl_3$–MeOH (1: 1), 0.25 g (0.65 mmol) of $PdCl_2$–bisbenzonitrile (IV) was added with stirring, and the mixture was kept at room temperature for 1 hr with stirring. After the solvent and benzonitrile were evaporated in vacuum at room temperature, 2 ml of ether was added to the residue. The solution was filtered and solvent was evaporated at room temperature under a reduced pressure. Resulting solid was dissolved in a small amount of $CHCl_3$–benzene (1: 1) (and filtered if insoluble precipitate existed), concentrated to one-half the volume at room tem-

perature, and kept at −20°. Orange prisms (VII) were obtained in a yield of 0.05 g (19%). VII showed no melting point; UV $\lambda_{max}^{CH_2Cl_2}$: 245 (ε 23400) and 280 (5400) nm; IR ($CHCl_3$) cm^{-1}: 1730, 1580, 1435, 1380, 1372, 1341, 1313, 1298, 1150, and 1068; molecular weight (osmometry in CCl_4) Calcd. for $C_{20}H_{18}Cl_2F_{12}N_2Pd$: 691.5; Found: 699. *Anal.* Calcd. for $C_{20}H_{18}Cl_2F_{12}N_2Pd$: C, 34.73; H, 2.60; Cl, 10.27; F, 33.00; N, 4.05. Found: C, 34.74; H, 2.65; Cl, 10.67; F, 34.10; N, 4.39. Mass spectrum of VII showed no molecular ion peak while it showed a fragment pattern identical to I (or II).

After VII was filtered off, the solvent was removed rapidly in vacuum at room temperature. The residue was dissolved in a small amount of CCl_4–ether (1: 1) at room temperature and half the amount of the solvent was evaporated at room temperature. Resulting solution was kept at −20°. Yellowish needles (VI) were obtained in a yield of 0.08 g (29%). VI showed no mp; UV $\lambda_{max}^{CH_2Cl_2}$ 280 nm (ε 4000); IR ($CHCl_3$) cm^{-1}: 1730, 1572, 1500, 1418, 1380, 1365, 1342, 1145, and 1068. Molecular weight Calcd. for $C_{20}H_{18}Cl_2F_{12}N_2Pd$: 691.5. Found: 669. *Anal.* Calcd for: C, 34.73; H, 2.60; Cl, 10.27; F, 33.00; N, 4.05. Found: C, 34.59; H, 2.44; Cl, 11.33; F, 30.10; N, 4.25. VI showed a fragment pattern identical to I and no molecular ion peak.

A solution of 0.05 g of VI in 0.5 ml of $CHCl_3$–benzene (1: 1) was heated at 60° for 0.5 min, cooled to room temperature immediately, and filtered and evaporated to dryness at room temperature. Recrystallization of this residue from $CHCl_3$–benzene (1: 1) gave 0.025 g (50%) of VII. VI was not recovered from the mother liquid.

On the other hand, when a solution of VI (0.05 g) in the same solvent as above was heated at 60° for 3 hr and recrystallization of the residue of this solution from $CHCl_3$ gave 0.02 g (40%) of brown powder (VIII), which was identified (by IR and NMR) with a powdery product obtained from 0.1 g of I and 0.25 g of IV, while neither VI nor VII was isolated from the mother liquid. VIII showed no mp; UV $\lambda_{max}^{CH_2Cl_2}$: 245 (ε 22900) and 280 (7600) nm; IR cm^{-1}: 1575, 1313, 1299, 1165, 1145, and 1073; *Anal.* Calcd. for $C_{20}H_{18}Cl_2F_{12}N_2Pd$: C, 34.73; H, 2.60; Cl, 10.27; F, 33.00; N, 4.05. Found: C, 34.99; H, 2.55; Cl, 10.29; F, 31.25; N, 3.59. Osmometric measurement of molecular weight was not possible, as VIII does not dissolve clearly in solvents used for osmometry. VI, VII, and VIII decomposed on a TLC plate of active Al_2O_3 and did not show a clear spot. These compounds showed orange single spots respectively in silica gel TLC development: *Rf* (1:1 pentane–ether) VI (0.6); VII (0.6); VIII (0.4).

Halogen Exchange of Palladium Complexes with Ion-exchange Resin——A solution of 0.05 g of VI in $CHCl_3$–MeOH (1: 4) was passed through a column charged with Amberlite IRA-400 substituted with an iodide anion. Resulting solution was evaporated. No iodide ion was detected in the effluent by qualitative analysis. Recrystallization of the effluent resulted in the recovery of VI (0.045 g).

Ligand Exchange of Palladium Complexes by Pyridine——To a solution of VI, VII, or VIII (*ca.* 10%) in $CDCl_3$, pyridine was added, and the mixture was allowed to stand at room temperature. Pale yellow flakes $[Pd(C_6H_5N)_2Cl]$ precipitated. Quantitative and qualitive analyses on released amines were carried out by NMR and GLC over the mother liquid.

Formation and Isolation of Platinum Complexes——To a solution of 0.1 g (0.39 mmol) of II in 2 ml of MeOH, 0.2 g (0.75 mmol) of V was added, the mixture was stirred at room temperature for 60 hr, and 1 ml of CH_2Cl_2 was added. The mixture was filtered and the filtrate was evaporated to dryness. The platinum complex was isolated in a similar manner as shown in the case of palladium complexes. Complex VI′ (yellow needles), yield 0.045 g (15%); no mp; IR ($CHCl_3$) cm^{-1}: 1730, 1510, 1421, 1382, 1365, 1342, 1269, 1170, 1145, 1068, and 1039. Complex VII′ (yellow prisms), no mp; IR ($CHCl_3$) cm^{-1}: 1735, 1580, 1540, 1434, 1382, 1368, 1341, 1319, 1296, 1230, 1165, 1145, 1070, and 1039. Complex VIII′ (yellow needles), yield 0.045 g (90%) from 0.05 g of VI′ or VII′; no mp; IR ($CHCl_3$) cm^{-1}: 1580, 1538, 1437, 1380, 1319, 1297, 1230, 1165, 1145, and 1075. Elemental analyses for C, H, Cl, F, and N of these complexes satisfied the calculated values.