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Studies on Organic Fluorine Compounds. XXI.[1] Isomerization of Fluorinated Dewar Pyridine Derivative and Its Metal Complexes[2]

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Kinetic studies were made on the thermal isomerization of 2,4,6-trimethyl-3,5-bis(trifluoromethyl)-1-azabicyclo[2.2.0]hexa-2,5-diene (I) to 2,4,6-trimethyl-3,5-bis(trifluoromethyl)-pyridine (II), $M(I)_2Cl_2$ ($M=Pd^{II}$ and Pt^{II}) to $M(II)_2Cl_2$, and $M(I).(II)Cl_2$ to $M(II)_2Cl_2$. The isomerization of I or I moiety of metal complexes to II or II moiety, respectively, was found to be first-order in various solvents. Mechanism of isomerization was discussed and was suggested to be a symmetry forbidden state-conservative concerted mechanism facilitated through configuration interaction, or a process through recombination of two skewed allyl radical parts. The isomerization I→II was facilitated by the presence of strong acids or Lewis acids and this isomerization catalyzed by acids seems to pass through the ionic mechanism.

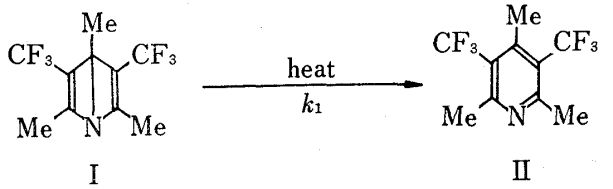
In the preceding paper,[1] we showed that 2,4,6-trimethyl-3,5-bis(trifluoromethyl)-1-azabicyclo[2.2.0]hexa-2,5-diene (I), obtained by photolysis of the corresponding pyridine, was converted to the parent pyridine (II) in substantially quantitative yields by thermolysis or addition of acids or metallic reagents.

The mechanism of aromatization of Dewar benzenes *via* thermal rearrangement has been discussed by Lemal, *et al.*,[4] Breslow, *et al.*,[5] and Haszeldine, *et al.*,[6] but there is no detailed report on the isomerization of the Dewar pyridines. We report here the isomerization of the Dewar pyridine (I) mentioned above (Chart 1).

A kinetic study using ^1H- and ^{19}F-nuclear magnetic resonance (NMR) spectra and gas–liquid participation chromatography (GLC) showed that transformation from I to II is first-order reaction, and that Arrhenius lines are independent of solvent effects (Fig. 1). Similarly, isomerization of ligand(s), *i.e.*, Dewar pyridine moiety to pyridine moiety, was observed when III, IV, VI, or VII was heated in solvent. The isomerization of IV (VII) to V (or VIII) was also a first-order reaction independent of solvent effect as shown in Fig. 2 (Line A).

On the other hand, as mentioned in the preceding paper,[1] when III (or VI) was used as a starting material, IV (or VII), which subsequently converted to V (or VIII), was formed. Consequently, the reaction mixture contained III, IV, and V (or VI, VII, and VIII) as a result of successive conversion in ligand, Dewar pyridine→pyridine. Discrimination and separate estimation of the Dewar pyridine moiety between III (or VI) and IV (or VII), and also pyridine moiety between IV (or VII) and V (or VIII) in ^1H- and ^{19}F-NMR are difficult, because of the proximity of their signals. As it was actually difficult to determine directly the quantities of III (or VI), IV (or VII), and V (or VIII), the total amount of Dewar pyridine moiety existing as ligands in the mixture was measured by NMR. While the rate of isomerization of

1) Part XX: Y. Kobayashi, A. Ohsawa, M. Baba, T. Sato, and I. Kumadaki, *Chem. Pharm. Bull.* (Tokyo), **24**, 2219 (1976).
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) D.M. Lemal and L.H. Dunlap, Jr., *J. Am. Chem. Soc.* **94**, 6563 (1972).
5) R. Breslow, J. Napierski, and A.H. Schmidt, *J. Am. Chem. Soc.*, **94**, 5906 (1972).
6) A.M. Dabbagh, W.T. Flowers, R.N. Haszeldine, and P.J. Robinson *J. Chem. Soc., Chem. Commuu.*, **1975**, 323.



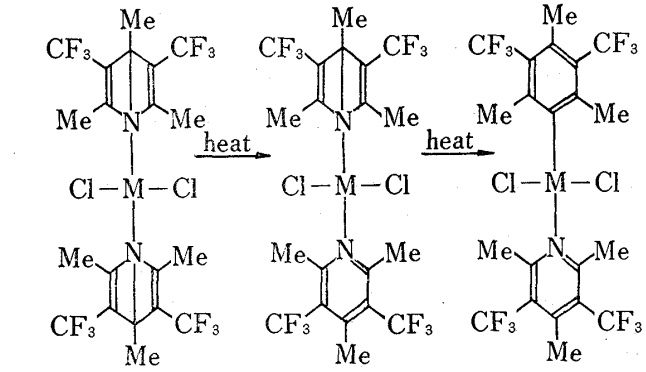


Chart 1

VI (or III) to VIII (or V) *via* VII (IV) is not affected by solvent, it was initially rapid and gradually became slower, and the slope of its asymptote finally became identical with that of line A at a given temperature (Fig. 2, line B). Figure 2 illustrates the conversion of Dewar pyridine moiety of complexes VI and VII at 50°.[7] The fact that addition of excess $PdCl_2(PhCN)_2$ did not accelerate the transformation of VI (or III) to VIII (or V) denies the process of dissociation, isomerization by the catalytic action of a metal and recoordination series (Eq. 2). The excellent agreement between the slopes of line A and asymptote of curve B suggests that VII (or IV) is an intermediate in the conversion of VI (or III) to VIII (or V) and that k_4 (or k_2) is greater than k_5 (or k_3) in Eq. 1.

$$\text{III (VI)} \xrightarrow{k_2(k_4)} \text{IV (VII)} \xrightarrow{k_3(k_5)} \text{V (VIII)} \qquad (1)$$

$$\left.\begin{array}{l} \text{III (VI)} \rightleftarrows MCl_2 + 2\times\text{I} \\ \text{I} \xrightarrow[\text{(catalytic)}]{\text{metal}} \text{II} \\ \text{I} + \text{II} + MCl_2 \rightleftarrows \text{IV (VII)} \\ 2\times\text{II} + MCl_2 \rightleftarrows \text{V (VIII)} \end{array}\right\} \qquad (2)$$

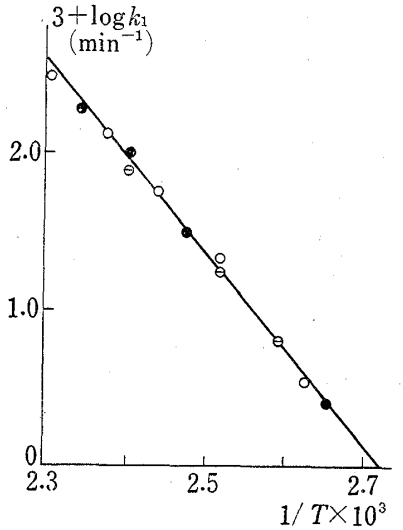


Fig. 1. Change of k_1 with Change of Temperature

heat
I ⟶ II
●: in toluene ⊖: in glycerin
○: in DMSO

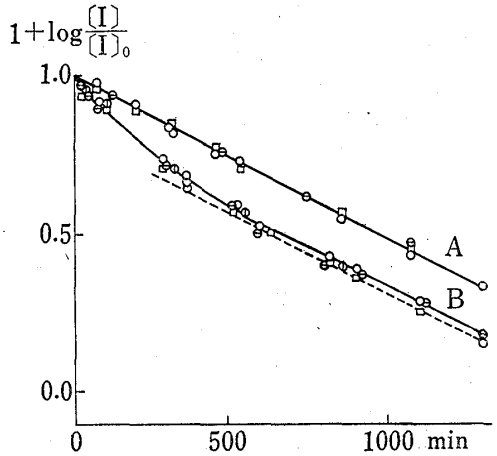


Fig. 2. Decrease of I followed by ^{19}F-NMR

50°
○: in C_6H_6
⊖: in $CDCl_3$
□: in CD_3OD–$CDCl_3$
⊕: in $CDCl_3$ (+$PdCl_2(C_6H_5CN)_2$)
A: VII ⟶ VIII
B: VI ⟶ VIII

7) This situation for complexes VI and VII is the same as for kinetic plotting about complexes III and IV in the range of temperarure shown in Table I.

Table I

Reaction	Solvent[a]	Rate const.[b] (sec^{-1}, 50°)	$t_{1/2}$ (min·100°)	Ea (kcal, mol^{-1})	ΔS^{*}[c] (kcal·mol^{-1}·deg^{-1})
I→II[d]	T G D	—	350[e]	28.3	−5∼−6
III→IV→V[f]	B[g] C[h] M[i]	3.7×10^{-6} (k_3')[j]	—	—	—
IV→V[f]	B[g] C[h] M[i]	3.63×10^{-6}	11[e]	26.7	−2.5∼−3.5
VI→VII→VIII[f]	B[g] C[h] M[i]	1.8×10^{-5} (k_5')[j]	—	—	—
VII→VIII[f]	B[g] C[h] M[i]	1.91×10^{-5}	1.9[e]	22.9	−11∼−12

a) T: toluene, D: DMSO, G: glycerin, B: C_6D_6, C: $CDCl_3$, M: CD_3OD–$CDCl_3$ (1:1)
b) observed value
c) defined by $\ln k=\ln(\kappa T/h)+(\Delta S^{*}/R)-(Ea/RT)+1$
d) analyzed by GLC (and assisted by NMR), temp. range: 103—160°
e) values from extrapolation
f) analyzed by ^{1}H-NMR and ^{19}F-NMR, temp. range: 50—85°
g) used internal standards are benzene for ^{1}H-NMR and benzotrifluoride (BTF) for ^{19}F-NMR
h) internal standard: $CHCl_3$ for ^{1}H-NMR and BTF for ^{19}F-NMR
i) internal standard: $H_nD_{3-n}COD$ for ^{1}H-NMR and BTF for ^{19}F-NMR
j) slope of asymptote of line B

Some kinetic data and activation parameters are shown in Table I.

Further, examinations of transformation I to II in the presence of acids or metals using NMR and GLC showed the order of their abilities accelerating conversion I→II as follows: $AlCl_3\simeq CF_3SO_3H$ (>) $CF_3COOH>BF_3\cdot$ether$>BCl_3>ZnCl_2\simeq RhCl_3\cdot3H_2O\simeq PtCl_2\simeq PdCl_2=PdCl_2(PhCN)_2>Fe(CO)_5\simeq Fe_2(CO)_9$ but $AgBF_4$, $AgClO_4$, $Rh(Ph_3P)_3Cl$, K_2PtCl_4 showed no effect. No change was observed in NMR of I by the addition of $Fe(CO)_5$ and other metals following this in the above order; also quantitative amount of free I was observed by GLC just after the addition of these salts. These facts show that coordinating abilities of these salts are low.

Metal salts or acids from $AlCl_3$ through $RhCl_3\cdot3H_2O$ are hard acids and act as a strong electron-acceptor when they are coordinated with an amine but, by the addition of these salts, formation of stable complexes was not observed by NMR or GLC.

The fact that the acceleration of isomerization by these reagents is greater than that of the salts from $PtCl_2$ through $PdCl_2(PhCN)_2$, with which the formation of stable complexes was observed as shown above, suggests that not only the stability of complexes but also electron-attracting effect of the group in an intermediate complex plays an important role in the isomerization accelerated by them. Thus, it is proposed that the transformation of I with strong acids proceeds *via* an ionic mechanism in which polar intermediates participate.

On the other hand, in the case of isomerization of I with reagents from $PtCl_2$ through $PdCl_2(PhCN)_2$ it was rather moderate though quantitative complexation was observed. The fact that there is no essential difference of the parameters Ea and ΔS^{*} between IV and VII suggests that their isomerization proceeds *via* similar transition states. Moreover, the facts that there was no enhancement of rate by the polarity of solvents[8] and that the Pt-complexes VI and VII (electronegativity of Pt is less than that of Pd) isomerized more smoothly than Pd complexes of III and IV, respectively, rule out the stabilization of the transition state of ring-opening process by the contribution of charge transfer[9] or push-pull effect,[10] and also rule out the potential charge-separated (or ionic) intermediate. Direct aromatization process through the disrotatory ring-opening pathway of aza-cyclobutene ring is disallowed[11,12] by the Woodward-Hoffmann rule, while the conrotatory process is sterically unfavorable.[12]

8) For solvent effect in CT contributive 2+2 process, see N.D. Epiotis, *J. Am. Chem. Soc.*, **94**, 1924 (1972).
9) For stabilization of transition state with charge transfer in Dewar benzene→benzene process, see Ref.5.
10) For push-pull effect in Dewar benzene→benzene process, see Ref.5 and Ref. therein.
11) R.B. Woodward and R. Hoffmann, "The Conservation of Orbital Symmetry," Academic Press, N.Y., 1970.
12) For a discussion of thermal rearrangement of Dewar benzene *via* conrotatory mode, see E.E. van Tamelen, S.P. Pappas, and K.L. Kirk, *J. Am. Chem. Soc.*, **93**, 6092 (1971) and E.E. van Tamelen, *Accounts Chem. Res.*, **5**, 186 (1972).

Thus, one of the reasonable propositions for the above facts is the concept of a symmetry forbidden state-conservative concerted mechanism facilitated through configuration interaction (CI) (Chart 2a)[13] or a process through the recombination of two somewhat skewed allyl radicals resulting from 1,4-bond fission *via* a quasi-conrotatory skewing distortion of Dewar pyridine framework, as suggested by Woodward and Hoffmann (Chart 2b).[14] In these schemes, facilitation of the isomerization by coordination of the nitrogen atom to the metal and its difference between the use of Pt and Pd are explained by the difference in bond delocalization of group M on the nitrogen atom (and, perhaps, with other substituents in IX), and also by the promotion of ring-opening process due to the steric repulsion between the methyl group at 4-position and group M.

Since there is no essential difference of activation parameters among I, IV, and VII, as shown in Table I, it suggests that the isomerization of free I proceeds *via* a mechanism analogous to the case of foregoing complexes; and since the isomerization of I was facilitated by coordination of the nitrogen atom, it seems that the ring-opening process is not favored by the inversion of the nitrogen atom[15] even in the case of free I.

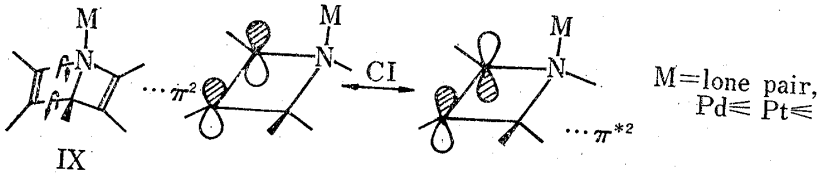


Chart 2a

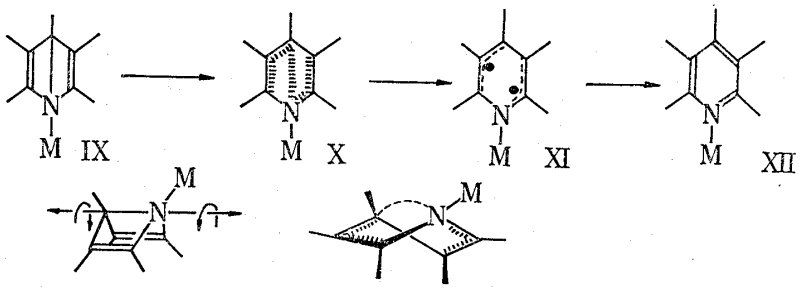


Chart 2b

Experimental

GLC was run on a Shimadzu Model GC-3AF with a column of diethyleneglycol succinate. ^{1}H and ^{19}F-NMR spectra were obtained with Varian T-60 and JEOL Model JMN-4H-100 spectrometers.

Kinetic data of isomerization of I and of complexes were mainly obtained using ^{1}H- and ^{19}F-NMR, and GLC when available.

Initial concentrations of solutions were 5—10%. Errors of the reaction temperature in a thermostat and and reaction time were ±1° and ±5 sec or less, in each case. Determination methods of components in individual cases are shown in footnotes to Table I.

Acknowledgement We express our sincere gratitude to Dr. I. Kumadaki of this laboratory for his helpful cooperation.

13) For a discussion of symmetry forbidden concerted process facilitated by CI, see J.E. Baldwin, A.H. Andrist, Jr., *Accounts Chem. Res.*, 5, 402 (1972).
14) Ref. 11, p. 174.
15) For isomerization of fused azocyclic system through inversion at the nitrogen atom, see Ref. 11, p. 51.