1,3-DIPOLAR CYCLOADDITION REACTIONS OF *N*-ARYL-2,4,6-CYCLOHEPTATRIEN-1-IMINES WITH *p*-SUBSTITUTED BENZONITRILE OXIDES: FORMATIONS OF 1,2,4-OXADIAZASPIRO[4.6]UNDECA-6,8,10-TRIENES

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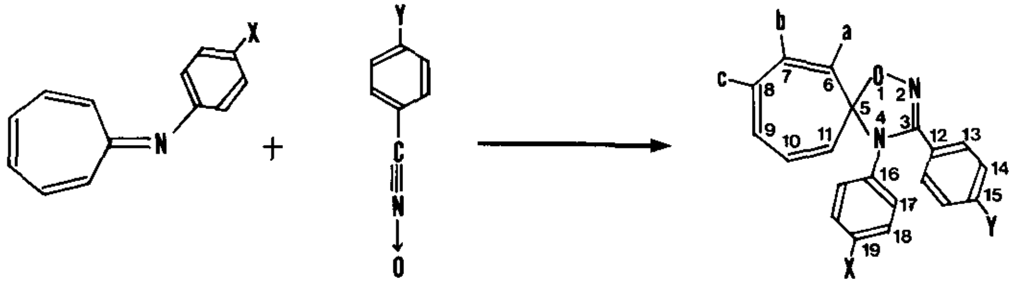
Abstract ——— Reactions of *N*-aryl-2,4,6-cycloheptatrien-1-imines with *p*-substitutied benzonitrile oxides afforded 1,2,4-oxadiazaspiro[4.6]undeca-6,8,10-trienes *via* [2+4] type cycloadditions. The study of substituent effects on the reaction rates suggested the nucleophilic attacks of the imines to the nitrile oxides.

Nitrile oxides are known to be active 1,3-dipoles in 1,3-dipolar cycloaddition reactions and have been extensively investigated from viewpoints of their utility for synthesis of five membered heterocyclic compounds and of the elucidation of the reaction mechanism in 1,3-dipolar cycloaddition reactions.[1] However we were unaware of any reactions of nitrile oxides with troponoid compounds, except for the reaction with 2,4,6-cycloheptatrien-1-one.[1a]

2,4,6-Cycloheptatrien-1-imines possess large dipole momenta due to contributions of 6π-aromatic structures.[2] Despite their aromaticities, 2,4,6-cycloheptatrien-1-imines are fairly active in cycloaddition reactions and are known to react only as 8π-components.[4] Previously, Gandolfi *et al.* reported an exceptional case; the reactions of 2,4,6-cycloheptatrien-1-imines with diphenyl nitrile imine afforded [8+4] type adducts *via* [2+4] type cycloaddition reactions, where the imine acted as 2π-components. But they did not succeed in the isolation of the [2+4] type cycloadducts.[3,4]

We report here the first example of the isolation of the [2+4] type cycloadducts in the reactions of *N*-aryl-2,4,6-cycloheptatrien-1-imines with *p*-substituted benzonitrile oxides.

A mixture of *N*-aryl-2,4,6-cycloheptatrien-1-imine (1) and two equimolar amounts of *p*-substituted benzonitrile oxide (2) was stirred at room temperature for 30 min to give [2+4] type adducts, 1,2,4-oxadiazaspiro[4.6]undeca-6,8,10-trienes, in 77–98 % yields.[5,6] The results of the reactions were summarized in Table 1.



1 2 3

a : X=OMe , c : X=Cl ,
b : X=Me , d : X=Br

a : Y=H , c : Y=Me ,
b : Y=OMe , d : Y=Cl

Talbe 1. Results of The Reactions of *N*-Aryl-2,4,6-cycloheptatrien-1-imines (1) with *p*-Substituted Benzonitrile Oxides (2)

cycloheptatriene -1-imines (1)	nitrile oxides (2)	adducts (3)	yields/%
1a	2a	3a	90
1b	2a	3b	86
1c	2a	3c	92
1d	2a	3d	98
1b	2b	3e	77
1b	2c	3f	89
1b	2d	3g	95

The structural elucidation of 3 was accomplished on the basis of the spectral data. ^1H and ^{13}C Nmr spectra showed the existences of 7,7-disubstituted 2,4,6-cycloheptatriene and two aryl moieties. The chemical shifts of the signals of C_5 (*ca.* 100 ppm) on oxadiazoline skeltons of 3 well resembled to those of the anologous compound.[7] NOE experiments clarified the neighboring configuration of two aryl groups, supporting the structures of 3. The relative rate ratios (k_X/k_H) of the reactions of 1b with *p*-substituted benzo-

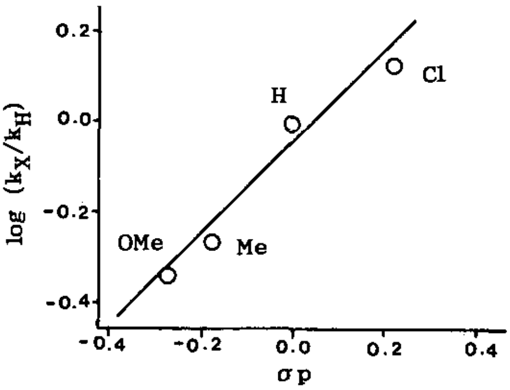


Figure 1. Correlation of Relative Rate Ratio with Hammett's σp

nitrile oxides (2a–d) were measured in a similar way to our previous method.[8] The ratio of 1.00 : 0.46 : 0.54 : 1.35 for **2a** : **2b** : **2c** : **2d** was obtained. There is a good linear relation between their logarisms (log k_X/k_H) and Hammett's sigma values (σp). The positive ρ-value (+0.99) suggests the nucleophilic attack of **1** to **2**.

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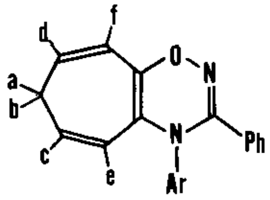
3. a) G. Gandolfi and L. Toma, *Tetrahedron*, 1980, 36, 935. b) K. Ito, K. Saito, and K. Takahashi, *Heterocycles*, 1991, 32, 1117; *idem*, *Bull. Chem. Soc. Jpn.*, 1992, 65, 812; K. Ito, K. Saito, S. Takeuchi, and K. Takahashi, *Heterocycles*, 1992, 34, 1415.
4. Gandolfi *et al.* reported that the [2+4] type adducts could be isolated in the reactions of tricarbonyl(*N*–aryl–2,4,6–cycloheptatriene–1–imines)iron complex with diphenyl nitrile imine.[4a]
5. Physical data of **3a–g** are as follows. **3a**: mp 118–119°C (from toluene). Hrms: m/z 330.1343. Calcd for $C_{21}H_{18}N_2O_2$: m/z 330.1367. Ms m/z (rel intensity): 330 (M^+, 19), 149 (100). ^{1}H Nmr ($CDCl_3$) δ 3.71 (s, 3H, Me), 6.04 (m, 2H, H_a), 6.42 (m, 4H, H_b and H_c), 6.65–6.95 (m, 4H, aryl protons), 7.20–7.60 (m, 5H, phenyl protons). ^{13}C Nmr ($CDCl_3$) δ 55.3 (OMe), 99.6 (C_5), 114.0 (C_{18}), 125.8 (C_{12}), 127.3 (C_6, C_{11}, and C_{17}), 128.2 (C_7 and C_{10}), 128.4 (C_{13} or C_{14}), 129.0 (C_{14} or C_{13}), 129.7 (C_8 and C_9), 130.1 (C_{15}), 130.9 (C_{16}), 153.9 (C_3), 157.8 (C_{19}). **3b**: mp 92–94°C (from benzene). Hrms: m/z 314.1410. Calcd for $C_{21}H_{18}N_2O$: m/z 314.1417. Ms m/z (rel intensity): 314 (M^+, 19), 149 (100). ^{1}H Nmr ($CDCl_3$) δ 2.26 (s, 3H, Me), 6.04 (m, 2H, H_a), 6.42 (m, 4H, H_b and H_c), 6.70–7.05 (m, 4H, aryl protons), 7.15–7.65 (m, 5H, phenyl protons). ^{13}C Nmr ($CDCl_3$) δ 20.9 (Me), 99.6 (C_5), 125.8 (C_{12}), 126.9 (C_6 and C_{11}), 127.4 (C_{17}), 127.5 (C_7 and C_{10}), 128.3 (C_{13} or C_{14}), 128.4 (C_{14} or C_{13}), 129.1 (C_{19}), 129.4 (C_{18}), 129.8 (C_8 and C_9), 130.1 (C_{15}), 135.6 (C_{16}), 153.7 (C_3). **3c**: mp 91–92°C (from benzene). Hrms: m/z 334.0893. Calcd for $C_{20}H_{15}N_2OCl$: m/z 334.0872. Ms m/z (rel intensity): 336 (M^+, 5), 153 (100). ^{1}H Nmr ($CDCl_3$) δ 6.02 (m, 2H, H_a), 6.45 (m, 4H, H_b and H_c), 6.74–7.22 (m, 4H, aryl protons), 7.25–7.70 (m, 5H, phenyl protons). ^{13}C Nmr ($CDCl_3$) δ 100.2 (C_5), 125.4 (C_{12}), 127.1 (C_6

and C_{11}), 127.7 (C_7 and C_{10}), 128.0 (C_{17}), 128.1 (C_{13} or C_{14}), 128.6 (C_{14} or C_{13}), 128.8 (C_{18}), 129.9 (C_8 and C_9), 130.5 (C_{15}), 131.3 (C_{19}), 136.9 (C_{16}), 153.3 (C_3). 3d: mp 120–121°C (from toluene). Hrms: m/z 378.0354. Calcd for $C_{20}H_{15}N_2OBr$: m/z 378.0367. Ms m/z (rel intensity): 380 (M^+, 13), 378 (M^+, 14), 103 (100). ^1H Nmr ($CDCl_3$) δ 6.06 (d, 2H, H_a), 6.50 (m, 4H, H_b and H_c), 6.68–7.70 (m, 9H, aromatic protons). ^{13}C Nmr ($CDCl_3$) δ 100.2 (C_5), 119.1 (C_{19}), 125.4 (C_{12}), 127.1 (C_6 and C_{11}), 127.7 (C_7 and C_{10}), 128.2 (C_{13} or C_{14}), 128.2 (C_{17}), 128.6 (C_{14} or C_{13}), 129.9 (C_8 and C_9), 130.5 (C_{15}), 131.8 (C_{18}), 137.4 (C_{16}), 153.2 (C_3). 3e: mp 131–132°C (from benzene). Hrms: m/z 344.1522. Calcd for $C_{22}H_{20}N_2O_2$: m/z 344.1522. Ms m/z (rel intensity): 344 (M^+, 12), 328 (100). ^1H Nmr ($CDCl_3$) δ 2.20 (s, 3H, Me), 3.70 (s, 3H, OMe), 5.92 (m, 2H, H_a), 6.30 (m, 4H, H_b and H_c), 6.50–7.50 (m, aromatic protons, 8H). ^{13}C Nmr ($CDCl_3$) δ 20.9 (Me), 55.2 (OMe), 99.3 (C_5), 113.8 (C_{14}), 117.9 (C_{12}), 127.0 (C_6 and C_{11}), 127.3 (C_{17}), 127.6 (C_7 and C_{10}), 129.3 (C_{18}), 129.8 (C_8, C_9 and C_{13}), 130.0 (C_{19}), 135.7 (C_{16}), 153.5 (C_3), 161.0 (C_{15}). 3f: mp 142–143°C (from benzene). Hrms: m/z 328.1583. Calcd for $C_{22}H_{20}N_2O$: m/z 328.1575. Ms m/z (rel intensity): 328 (M^+,4), 117 (100), 78 (100). ^1H Nmr ($CDCl_3$) δ 2.27 (s, 3H, Me), 2.32 (s, 3H, Me), 6.04 (m, 2H, H_a), 6.42 (m, 4H, H_b and H_c), 6.72–7.44 (m, 8H, aromatic protons). ^{13}C Nmr ($CDCl_3$) δ 20.9 (Me), 21.4 (Me), 99.4 (C_5), 122.8 (C_{12}), 126.9 (C_6 and C_{11}), 127.3 (C_{17}), 127.6 (C_7 and C_{10}), 128.1 (C_{13} or C_{14}), 129.1 (C_{14} or C_{13}), 129.3 (C_{18}), 129.7 (C_8 and C_9), 135.5 (C_{16} or C_{19}), 135.7 (C_{19} or C_{16}), 140.3 (C_{15}), 153.7 (C_3). 3g: mp 90–92°C (from benzene). Hrms: m/z 350.0978. Calcd for $C_{21}H_{17}N_2OCl$: m/z 350.0998. Ms m/z (rel intensity) : 348 (M^+, 2), 133 (100). ^1H Nmr ($CDCl_3$) δ 2.20 (s, 3H, Me), 5.90 (m, 2H, H_a), 6.40 (m, 4H, H_b and H_c), 6.60–7.50 (m, 8H, aromatic protons). ^{13}C Nmr ($CDCl_3$) δ 21.0 (Me), 99.9 (C_5), 124.4 (C_{12} or C_{15}), 127.1 (C_6 and C_{11}), 127.3 (C_{17}), 127.5 (C_7 and C_{10}), 128.7 (C_{13} or C_{14}), 129.5 (C_{14} or C_{13} and C_{18}), 129.8 (C_8 and C_9), 130.0 (C_{19}), 135.3 (C_{16}), 136.1 (C_{15} or C_{12}), 152.9 (C_3).

6. Upon heating at 60°C for 50 h 3c gave an isomer (4) whose structure was tentatively specurated to be shown in the figure according to the following spectral data: Ms m/z (rel intensity): 334 (M^+, 8), 180 (100). ^1H Nmr ($CDCl_3$) δ 2.55 (dd, 2H, H_a and H_b), 5.30–5.55 (m, 2H, H_c and H_d), 6.15 (d, H_e), 6.87 (d, H_f), 7.10–7.50 (m, 9H, aromatic protons). The detailed investigation on this reaction is now in progress.



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