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Mendeleev Commun., 2009, **19**, 12–13
Mendeleev Communications

Unexpected mode of reactivity in nitrosation of *cis*-1,1-dichloro-2,3-diphenylcyclopropane with $NOCl·2SO_3$

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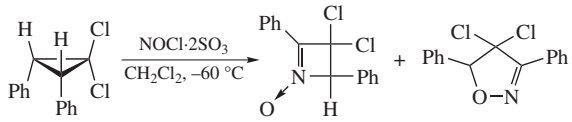
DOI: 10.1016/j.mencom.2009.01.005

cis-1,1-Dichloro-2,3-diphenylcyclopropane reacts with $NOCl·2SO_3$ to provide new heterocyclic compounds, *N*-oxide of 3,3-dichloro-2,4-diphenylazetine and 4,4-dichloro-3,5-diphenylisoxazoline, with 45 and 30% yields, respectively. The structure of the products was unambiguously stated by X-ray crystallography.

Nitrosation of arylcyclopropanes proceeds at cyclopropane ring and results in the formation of 5-arylisoxazolines.[1] 1,1-Dihalo-2-arylcyclopropanes give 3-aryl-5-haloisoxazoles[2] or acyclic products of cyclopropane ring cleavage[3] depending on the nature of the nitrosating reagent.

Here, we report the reaction of *cis*-1,1-dichloro-2,3-diphenylcyclopropane **1** with complex $NOCl·2SO_3$, which leads to the formation of unusual heterocyclic products: *N*-oxide of 3,3-dichloro-2,4-diphenylazetine **2** and 4,4-dichloro-3,5-diphenylisoxazoline **3** with 45 and 30% yields, respectively. Note that nobody has previously reported about the formation of azetines in nitrosation of cyclopropanes with different nitrosating agents. It is the first example of such transformation. Reaction proceeds vigorously even at –60 °C.†

N-oxide of azetine **2** and isoxazoline **3** were isolated chromatographically and characterized by ^{1}H and ^{13}C NMR and IR spectroscopy and mass spectrometry. The structure of the compounds was unambiguously stated by X-ray crystallography.



1 **2** (45%) **3** (30%)

Figures 1 and 2 depict the structures of the isolated compounds, as well as selected bond lengths and intramolecular angles.

Heterocyclic fragment N(1), C(7), C(8), C(9) of the molecule of compound **2** is flat;‡ deviation of the atoms from mean-square plane is less than 0.002 Å. The oxygen atom O(1) of N-oxide group and C(6) atom of C(1)–C(6) aromatic ring are situated in the same plane [deviation of O(1) and C(6) atoms from this plane is 0.010 and 0.044 Å, respectively], C(1)–C(6) aromatic ring is coplanar to the plane of the heterocycle (the dihedral angle between these planes is 5.3°); C(10) carbon atom of the second aromatic ring goes out of the plane of the heterocycle for 1.149 Å; C(10)–C(15) aromatic ring is perpendicularly oriented to the heterocycle (the dihedral angle between their planes is 74.9°). The heterocyclic ring contains C(7)–N(1) double bond [1.320(2) Å]. Upon the whole the geometry of azetine cycle is closely related to that found for 2-(*N*,*N*-diethylcarbamoyl)-2,4-dimethyl-3-phenyl-2,3-dihydroazete-1-oxide.[4]

The data of ^{1}H and ^{13}C NMR spectroscopy absolutely correspond to the results of X-ray crystallography.

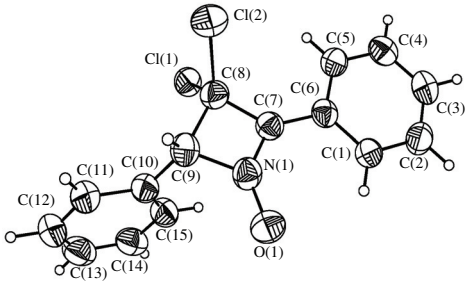


Figure 1 Molecular structure of 3,3-dichloro-2.4-diphenylazetine *N*-oxide **2** (50% probability thermal ellipsoids). Selected bond lengths (pm): N(1)–C(7) 1.320(2), C(7)–C(8) 1.488(2), C(8)–C(9) 1.568(3), N(1)–C(9) 1.501(2), N(1)–O(1) 1.2623(19), C(6)–C(7) 1.435(2), Cl(1)–C(8) 1.7628(19), Cl(2)–C(8) 1.7769(18), C(9)–C(10) 1.489(3); selected bond angles (°): N(1)–C(7)–C(8) 93.00(14), N(1)–C(7)–C(6) 131.48(16), C(7)–C(8)–C(9) 87.19(13), C(7)–C(8)–Cl(1) 115.86(13), C(7)–C(8)–Cl(2) 114.25(13), O(1)–N(1)–C(7) 134.93(16), O(1)–N(1)–C(9) 128.58(14).

† *Synthesis*. Equimolar amounts of *cis*-1,1-dichloro-2,3-diphenylcyclopropane **1** (0.50 g, 1.9 mmol), synthesized by dichlorocyclopropanation of *cis*-stilbene, and suspension of $NOCl·2SO_3$ (0.45 g, 2 mmol) in 10 ml of anhydrous CH_2Cl_2 were vigorously stirred at –60 °C for 1 h. The resultant mixture was quenched with 1 M sodium bicarbonate solution and extracted with CH_2Cl_2 (3×10 ml). The organic layers were washed with water and dried over Na_2SO_4. The solvent was evaporated under reduced pressure and the products were isolated chromatographically (silica gel 40/60, blend – ethyl acetate:light petroleum, 1:10).

2: 0.250 g (45%); R_f 0.4; mp 124.0–124.8 °C. IR (ν/cm^{-1}): 2940, 2870, 1610, 1500, 1455, 1405, 1125, 955, 715. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 6.10 (s, 1H), 7.42 (m, 2H), 7.49 (m, 3H), 7.56 (m, 3H), 8.27 (m, 2H, ^3J 7.8 Hz, ^4J 1.6 Hz). ^{13}C {^{1}H} NMR (100 MHz, $CDCl_3$) δ: 76.86 (CCl_2), 95.2 (HCN), 124.1 (C^1), 126.2, 128.7, 128.85, 128.90 (C$^{1'}$), 129.1, 130.4 (C^4), 131.1 (C$^{4'}$), 148.2 (C=N). MS (EI), *m*/*z*: ($I_{rel.}$, %): 291 (9) [M]$^+$, 256 (26), 225 (78), 189 (70), 165 (20), 125 (37), 105 (83), 89 (42), 77 (100), 63 (47), 51 (74). Found (%): C, 62.02; H, 3.51; N, 4.65. Calc. for $C_{15}H_{11}Cl_2NO$ (%): C, 61.64; H, 3.77; N, 4.79.

3: 0.165 g (30%); R_f 0.70; mp 99.4–99.8 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 5.92 (s, 1H), 7.52 (m, 6H), 7.61 (m, 2H), 8.09 (dd, 2H, ^3J 8.4 Hz, ^4J 1.8 Hz). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 89.4 (CCl_2), 94.9 (HCO), 125.7 (C^1), 127.7, 127.8, 128.4, 128.7, 129.8 (C^4), 130.9 (C$^{4'}$), 131.4 (C$^{1'}$), 158.0 (C=N). MS (EI), *m*/*z* (%): 291 (3), 255 (61), 220 (32), 192 (12), 184 (25), 165 (15), 149 (12), 105 (47), 104 (100), 76 (53). Found (%): C, 61.34; H, 3.74; N, 4.31. Calc. for $C_{15}H_{11}Cl_2NO$ (%): C, 61.64; H, 3.77; N, 4.79.

We have found some publications dealing with the formation of such heterocycles.[5] One of them reports on the formation of azetines *via* thermal decomposition of azides of disubstituted *gem*-dichlorocyclopropanes. The authors suggest the formation of nitrene nitrogen atom in the course of the reaction and its following attack at the neighbouring carbon atom. Note that the products forming as a result of C–CCl_2 bond cleavage were absent.

In our case, nitrosonium cation also attacks only C^2–C^3 bond of cyclopropane **1**; at that, in the formation of *N*-oxide of azetine **2** nitrogen atom acts as an electrophile and nucleophile simultaneously.

Five-membered cycle of the molecule of compound **3** has envelope conformation,‡ O(1), N(1), C(1), C(2) fragment is flat, deviation of C(3) atom from mean-square plane of the fragment is 0.44 Å. The bond lengths of the cycle coincide with the corresponding typical bonds. Dihedral angles between phenyl rings and mean-plane of the five-membered ring are 18.0 and 56.7°, respectively.

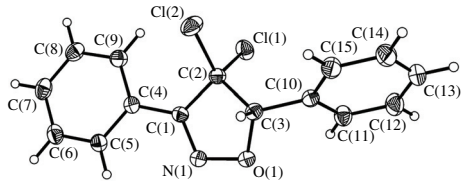


Figure 2 Molecular structure of 4,4-dichloro-3,5-diphenylisoxazoline **3** (50% probability thermal ellipsoids). Selected bond lengths (pm): N(1)–C(1) 1.289(2), C(1)–C(2) 1.510(2), C(2)–C(3) 1.532(2), O(1)–C(3) 1.444(2), O(1)–N(1) 1.404(2), C(1)–C(4) 1.467(2), C(2)–Cl(1) 1.7852(19), C(2)–Cl(2) 1.7671(19), C(3)–C(10) 1.496(3); selected bond angles (°): C(1)–N(1)–O(1) 109.91(14), N(1)–C(1)–C(2) 111.34(15), N(1)–C(1)–C(4) 121.12(16), C(4)–C(1)–C(2) 127.49(15), C(1)–C(2)–C(3) 99.79(14), C(1)–C(2)–Cl(1) 107.81(12), C(1)–C(2)–Cl(2) 115.45(12), C(3)–C(2)–Cl(1) 113.18(12), C(3)–C(2)–Cl(2) 111.36(12), Cl(2)–C(2)–Cl(1) 109.08(9), C(2)–C(3)–O(1) 102.37(14), C(2)–C(3)–C(10) 120.42(15), O(1)–C(3)–C(10) 110.92(14), C(3)–O(1)–N(1) 108.23(12).

‡ *Crystal data for* **2**: $C_{15}H_{11}Cl_2NO$, light yellow prism single crystals were obtained by slow diffusion of ethyl acetate– light petroleum blend, M = 292.15, monoclinic, space group $P2_1/c$, a = 9.607(3), b = 8.769(2) and c = 16.152(4) Å, β = 96.665(6)°, V = 1351.4(6) Å^3, Z = 4, d_{calc} = = 1.436 g cm^{-3}, μ = 0.470 mm^{-1}, $F(000)$ = 600, T = 100 K, crystal size 0.25×0.25×0.20 mm, 13792 reflections collected in the range $3.0 < \theta < 30.0°$, 3570 unique (R_{int} = 0.0311), 2494 with $I > 2\sigma(I)$. Parameters 172, final $R(F_{hkl})$: R_1 = 0.0401, wR_2 = 0.1170. GOF = 1.000.

Crystal data for **3**: $C_{15}H_{11}Cl_2NO$, colourless prism single crystals were obtained by slow diffusion of ethyl acetate–light petroleum blend, M = = 292.15, monoclinic, space group $P2_1/c$, a = 8.666(3), b = 14.334(5) and c = 11.099(4) Å, β = 92.664(7)°, V = 1377.3(8) Å^3, Z = 4, d_{calc} = 1.409 g cm^{-3}, μ = 0.461 mm^{-1}, $F(000)$ = 600, T = 293(2) K, crystal size 0.3×0.2×0.2 mm, 13852 reflections collected in the range $2.3 < \theta < 26.8°$, 3302 unique (R_{int} = 0.0218), 2518 with $I > 2\sigma(I)$. Parameters 172, final $R(F_{hkl})$: R_1 = = 0.0566, wR_2 = 0.1089, GOF = 1.020.

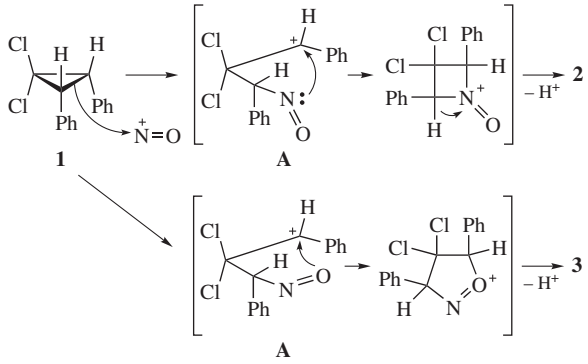
Single-crystal X-ray diffraction experiments were carried out on a Bruker SMART 1000 CCD area detector, using graphite monochromated MoKα radiation (λ = 0.71073 Å, ω-scans with a 0.3° step in ω and 10 s per frame exposure). Low temperature of the crystals was maintained with a Cryostream (Oxford Cryosystems) open-flow N_2 gas cryostat. Reflection intensities were integrated using the SAINT software and semi-empirical method SADABS.

The structures were solved by a direct method and refined by the full-matrix least-squares against F^2 in anisotropic (for non-hydrogen atoms) approximation. All carbon atoms were located from the difference Fourier syntheses, the H(C) atoms were placed in geometrically calculated positions. All hydrogen atom positions were refined in isotropic approximation in riding model with the U_{iso}(H) parameters equal to $1.2U_{eq}(C_i)$, where $U(C_i)$ are respectively the equivalent thermal parameters of the atoms to which corresponding H atoms are bonded. All calculations were performed using the SHELXTL software.

CCDC 693088 and 693089 contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre *via* www.ccdc.cam.ac.uk/data_request/cif. For details, see 'Notice to Authors', *Mendeleev Commun.*, Issue 1, 2009.

The data of ^{1}H and ^{13}C NMR spectroscopy are in full correlation with the adduced structure. Thus, the ^{1}H NMR spectrum of isoxazoline **3** exhibits singlet at δ 5.92 ppm with the intensity equal to one proton, corresponding to that of isoxazoline cycle. In addition, *ortho*-protons of the aromatic ring situated at the third position of isoxazoline cycle are shifted to the low field (8.09 ppm). The ^{13}C NMR spectrum exhibits signals of tertiary carbon atoms at δ 89.4 and 158.0 ppm referred to CCl_2 and C=N groups, respectively, a signal of CH atom of isoxazoline ring at δ 94.9 ppm, as well as full set of the signals of aromatic rings.

One can suggest the following way for the formation of compounds **2** and **3**. It is possible that nitrosonium cation attacks one of two carbon atoms connected with benzene rings with the following C^2–C^3 bond cleavage and formation of benzylic carbonium cation **A**. The formed benzylic carbonium cation is stabilized joining a nucleophile. The latter can be the unshared electron pair of nitrogen atom (the formation of azetine **2**) or the oxygen atom of nitroso group (the formation of isoxazoline **3**).



However, one cannot exclude that azetine **2** and isoxazoline **3** were formed as a result of concerted process, and the high yields of these unusual products are stipulated by convenient geometry (*cis* position of phenyl substituents) of the initial cyclopropane, but this hypothesis demands further investigations.

This work was supported by the Russian Foundation for Basic Research (project no. 08-03-00707-a) and the Programme of the Presidium of the Russian Academy of Sciences 'The Theoretical and Experimental Study of the Nature of Chemical Bond and Mechanisms of Chemical Reactions and Processes'.

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Received: 7th July 2008; Com. 08/3168