Transformations of *gem*-dibromoarylcyclopropanes under nitrosation conditions on treatment with $NOCl \cdot (SO_3)_n$*

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The reaction of 2-aryl-1,1-dibromocyclopropanes with adduct $NOCl \cdot (SO_3)_n$ leading to 3-aryl-5-bromoisoxazoles as a result of nitrosation—heterocyclization of the cyclopropane ring was studied. The reaction is accompanied with electrophilic aromatic bromination. The mechanism of the transformation was discussed, the optimal reaction conditions to enhance the reaction selectivity were developed.

Key words: 2-aryl-1,1-dibromocyclopropanes, nitrosation, adduct $NOCl \cdot (SO_3)_n$, 3-aryl-5-bromoisoxazoles, electrophilic aromatic bromination.

Haloisoxazoles are very promising for further chemical transformations. They found wide application in the transition metal catalyzed cross-couplings (the Heck reaction, the Stille coupling, the Suzuki, Sonogashira, and Nigishi cross-couplings)[1,2] opening a versatile excess to highly-substituted isoxazole-containing frameworks and are used for the design of the combinatorial libraries of new heterocyclic compounds.[3—5] It is of note that bioscreening and structural design of the isoxazole derivatives are of great interest due to a known wide range of physiological activity exhibiting by isoxazoles; they are also the constituent parts of many pharmaceuticals used for the treatment of various disorders.[6—10]. Haloisoxazoles possess different biological activity (for instance, anthelmintic[11] and herbicide[12]) and a series of other useful properties.[13]

It is known that direct halogenation of isoxazole ring proceeds exclusively as 4-halogenation.[14—17] The attempts to lithiate isoxazoles in the positions 3 or 5 followed by halogenation were unsatisfactory since the reactions are accompanied by the N—O bond cleavage and the ring opening.[18—19].

To date, several approaches to 5-bromoisoxazoles have been described. For instance, 5-bromoisoxazoles have been synthesized by the reaction of phosphorus oxybromide with 3-arylisoxazolones, which in turn have been prepared by the reaction of β-keto esters with hydroxylamine.[12,20] The other approach is 1,3-dipolar cycloaddition of nitrile oxides to alkynes.[5] Both methods produce the target compounds in moderate yields. Thus, the development of versatile preparative procedure to access 5-bromoisoxazoles is still ongoing challenge.

5-Haloisoxazoles can be synthesized by nitrosation of *gem*-dihalocyclopropanes.[21] It is notable that the starting compounds are readily available. Synthesis of *gem*-dihalocyclopropanes *via* the Doering reaction[22] under phase-transfer catalysis conditions[23] leads to nearly unlimited number of substrates varying in structure.

Studying nitrosation reactions, we introduced the adduct of nitrosyl chloride with sulfur trioxide as a nitrosating agent.[24] According to Paul *et al.*,[25] the $NOCl \cdot (SO_3)_n$ adduct comprises either one or two molecules of sulfur trioxide. We successfully used this adduct in the synthesis of isoxazolines from arylcyclopropanes bearing in the aromatic ring both electron-donating and electron-withdrawing substituents.[26] This adduct was found very promising for nitrosation of *gem*-dichlorocyclopropanes of different structures including polycyclic species.[27,28] In the present work, we describe the behavior of *gem*-dibromoarylcyclopropanes under nitrosation with the adduct of nitrosyl chloride with sulfur trioxide.

Preliminary experiments have shown that nitrosation of the small ring of 2-aryl-1,1-dibromocyclopropanes **1a—e** and subsequent heterocyclization led to the corresponding 3-aryl-5-bromoisoxazoles **2a—e**. However, despite the complete conversion of the starting compounds the yields of the target isoxazoles were relatively low (Schemes 1—3). Isolation of all products of the reaction of cyclopropane **1a** with the $NOCl \cdot (SO_3)_n$ adduct by preparative column chromatography gave the following compounds: 5-bro-

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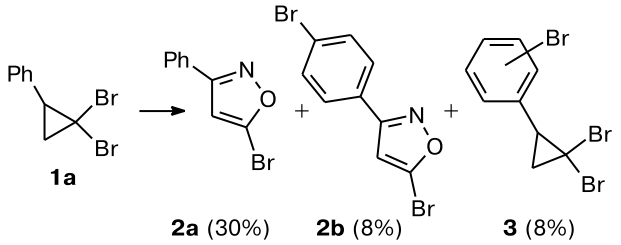
mo-3-phenylisoxazole (**2a**) contaminated with isoxazole **2b** and cyclopropanes **3** identified by ^{1}H NMR spectroscopy and LC/MS (see Scheme 1).

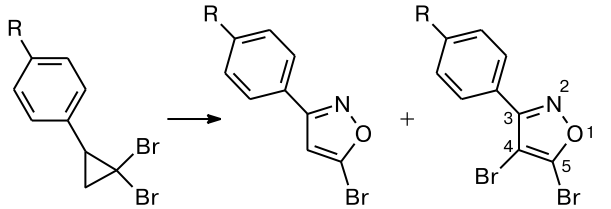
Scheme 1



Reagents and conditions: $NOCl \cdot (SO_3)_n$ (1.5 equiv.), $MeNO_2$, 20 °C.

In the case of *para*-substituted aryldibromocyclopropanes **1b—d**, isoxazoles **4a—c** bearing two bromine atoms in the isoxazole cycle were isolated along with isoxazoles **2b—d** (see Scheme 2).

Scheme 2



R = Br (**1b**, **2b**, **4a**), Cl (**1c**, **2c**, **4b**), NO_2 (**1d**, **2d**, **4c**)

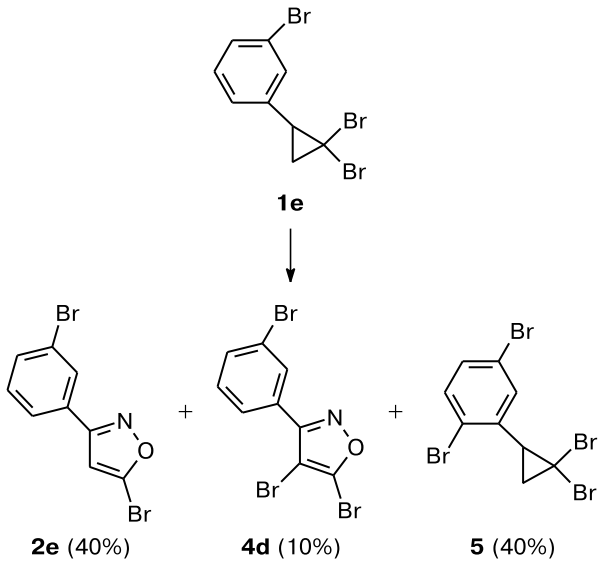
Reagents and conditions: $NOCl \cdot (SO_3)_n$ (1.5 equiv.), $MeNO_2$, 20 °C, 20 h.

Nitrosation of 2-(3-bromophenyl)-1,1-dibromocyclopropane (**1e**) afforded equal amounts of isoxazole **2e** and *gem*-dibromoarylcyclopropane **5** and small amounts of isoxazole **4d** (see Scheme 3).

Structures and compositions of the isolated compounds were established by spectral methods (Table 1) and elemental analysis.

In ^{1}H NMR spectra, heterocyclic protons of isoxazoles **2a—e** resonate as singlets at about δ_H 6.60, which is characteristic of the H(4) proton of the isoxazole cycle.[29] In ^{13}C NMR spectra of isoxazoles **2a—e**, three characteristic signals of the isoxazole ring carbon atoms were observed, namely, two low-field weak signals at δ_C 163.0 (C=N) and 142.0 (BrC—O) corresponding to the quaternary carbon atoms and an intense signal at δ_C 104.0 confirming

Scheme 3



Reagents and conditions: $NOCl \cdot (SO_3)_n$ (1.8 equiv.), $MeNO_2$, 20 °C, 20 h.

the presence of the C(4)—H bond.[29] The C(5) atom signal is shifted to the strong field by ~14.0 ppm than the same signal of 5-chloroisoxazoles,[28] which can be explained by a heavy atom effect.[30] Note that in the case of arylated *gem*-dibromocyclopropanes nitrosation—heterocyclization reaction sequence involving the small ring is regioselective and gives exclusively 3-aryl-5-bromoisoxazoles **2a—d**; other regioisomers were not detected.

^{1}H NMR spectra of isoxazoles **4a—d** exhibit only aromatic proton signals. In ^{13}C NMR spectra, a weak signal of the C(4) atom, which is in a quaternary state, is shifted upfield by ~9.0 ppm as compared with the similar signal of isoxazoles **2a—e** (heavy atom effect) and appeared at δ_C ~95.0. The compositions of isoxazoles **4a—d** were confirmed by elemental analysis and mass spectrometry data. The cleavage pattern of the molecular ions of compounds **4a—c** showing the fragment ion with *m/z* 114 corresponding to the $[C_6H_4C_2N]^+$ azirinium ion indicates the presence of the aromatic substituent at the C(3) heterocyclic carbon atom. Thus, compounds **4a—d** are the products of bromination of isoxazoles **2b—e** at the 4-position.

The structure of cyclopropane **5** was examined by X-ray diffraction analysis (Fig. 1). The unit cell contains two symmetrically independent molecules with nearly the same conformations. The spectral and microanalysis data are in complete agreement with the X-ray data. From Fig. 1 it follows that the benzene ring plane significantly deviates from the plane passing though the bisector of the C(8)—C(7)—C(9) angle thereby lowering the conjugation between the small ring and the aromatic system. This deviation can be explained by the effect of the *ortho*-substit-

Table 1. ^{1}H and ^{13}C NMR spectra ($CDCl_3$) of isoxazoles **2a—e** and **4a—d**

Compound	^{1}H NMR, δ_H (J/Hz)		^{13}C NMR, δ_C					
	C(4)H	Benzene ring	Isoxazole cycle			Benzene ring		Other C atoms
			C(3)	C(4)	C(5)	C—Het	C—R	
2a	6.62	7.50 (m, 3 H), 7.78 (m, 2 H)	164.2	104.4	141.7	128.0	130.5	126.7, 129.0
2b	6.59	7.62 (d, 2 H, ^3J = 8.9); 7.65 (d, 2 H, ^3J = 8.9)	163.3	104.3	142.2	126.9	125.0	129.0, 132.3
2c	6.59	7.46 (d, 2 H, ^3J = 8.7); 7.72 (d, 2 H, ^3J = 8.7)	163.2	104.3	142.1	126.5	136.7	128.0, 129.4
2d	6.71	7.98 (d, 2 H, ^3J = 8.9); 8.36 (d, 2 H, ^3J = 8.9)	163.0	104.7	143.9	129.1	149.2	124.4, 127.7
2e	6.61	7.36 (t, 1 H, ^3J = 8.0); 7.62 (ddd, 1 H, ^3J = 8.0, ^4J = 1.0, ^4J = 1.9); 7.71 (ddd, 1 H, ^3J = 8.0, ^4J = 1.0, ^4J = 1.5); 7.94 (br.s, 1 H)	163.0	104.4	142.2	129.9	123.1	125.3, 129.7, 130.6, 133.5
4a	—	7.67 (d, 2 H, ^3J = 8.4); 7.75 (d, 2 H, ^3J = 8.4)	161.4	95.8	144.0	125.5	125.9	129.6, 132.2
4b	—	7.51 (d, 2 H, ^3J = 8.8); 7.82 (d, 2 H, ^3J = 8.8)	161.3	95.8	143.9	125.5	137.1	129.2, 129.4
4c	—	8.09 (d, 2 H, ^3J = 8.4); 8.40 (d, 2 H, ^3J = 8.4)	160.5	95.9	144.8	129.8	149.2	124.1, 129.1
4d	—	7.41 (t, 1 H, ^3J = 8.0); 7.68 (ddd, 1 H, ^3J = 8.0, ^4J = 1.0, ^4J = 2.0); 7.81 (ddd, 1 H, ^3J = 8.0, ^4J = 1.0, ^4J = 1.5); 8.02 (br.s, 1 H)	161.0	95.8	144.0	128.9	122.9	126.7, 130.4, 131.0, 133.8

uent. Consequently, cyclopropane **5** does not undergo small ring nitrosation. Similar deactivation effect of the *ortho*-substituent has been described for the series of nitro-substituted *gem*-dichloroarylcyclopropanes.[28]

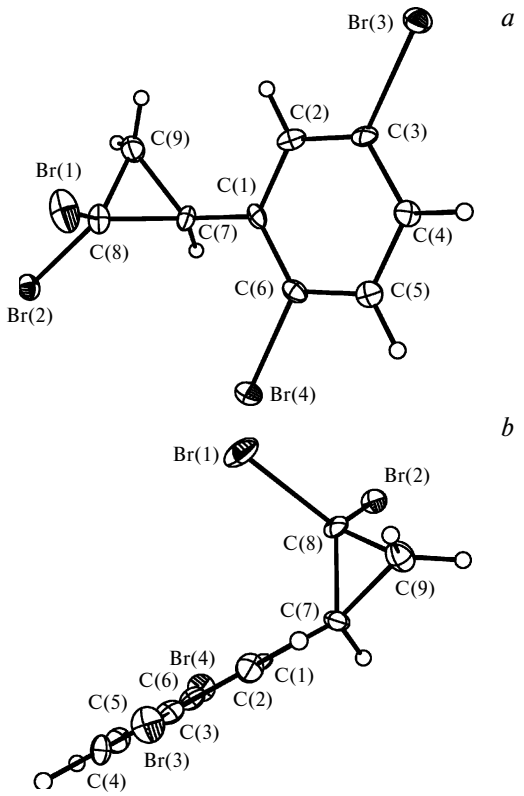


Fig. 1. General view of one of the crystallographically independent molecules of compound **5** in two different projections (*a*, *b*) according to X-ray data. Non-hydrogen atom are shown as 50% thermal ellipsoids. Conformation of the second independent molecule is virtually the same.

Formation of isoxazoles **4a—c** and cyclopropanes **3** and **5** can be regarded as a result of electrophilic aromatic bromination. It is known[14—17] that the isoxazole cycle readily undergoes halogenation at the 4-position. For compound **1e**, the concerted effect of the substituents at the benzene ring facilitates electrophilic substitution reaction. Since neither solvent nor nitrosating agent can serve as a source of electrophilic bromine, we suggest that hydrogen bromide formed in the reaction medium upon the isoxazole synthesis undergoes oxidation and then reacts with the starting cyclopropane or isoxazole. The role of oxidizing agent can play the nitrosonium cation, which is known as a relatively strong oxidant.[31] The generated brominating species are further involved into electrophilic aromatic substitution to produce the bromination products (Scheme 4).

Thus, we were able to demonstrate that the bulky bromine atoms bonded to the small cycle impeding nitrosation and releasing hydrogen bromide readily oxidizing upon the reaction favor electrophilic aromatic bromination.

With the aim to optimize the conditions for the high yields of isoxazoles **2a—e**, we performed ^{1}H NMR studies of the reaction mixture compositions at different reaction times using cyclopropane **1e** as a model compound. It was found that with the 1.5-fold excess of the adduct the low conversion of cyclopropane **1e** was achieved; under these conditions formation of isoxazole **2e** was detected only 3 h after the reaction onset. Note that 5 h after the reaction onset, the reaction mixture contained equal amounts of both isoxazole **2e** and brominated cyclopropane **5** (Table 2, entries *8—11*). This fact indicates that hydrogen bromide released upon the reaction readily oxidizes and is immediately involved in further transformations.

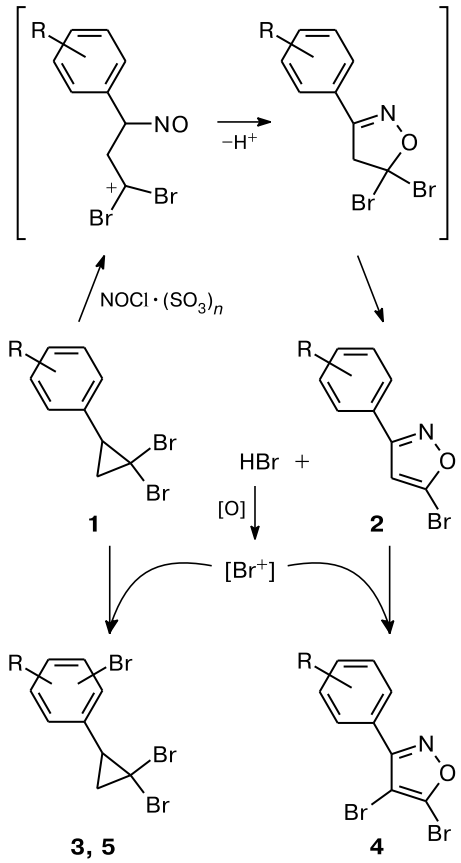
It is obvious that the rate of cyclopropane nitrosation can be increased by increasing the concentration of the reacting species. The compositions of the reaction mixtures

Table 2. Nitrosation of 2-aryl-1,1-dibromocyclopropanes with adduct $NOCl \cdot (SO_3)_n$[a]

Entry	Compound **1**	$[NO^+]$ /equiv.	[**1**] /mol L^{-1}	*t*/h	Conversion **1** (%)	Reaction products (Yield (%))
1[b,c]	**1a**	1	0.30	1	89	**2a** (30) + **2b** (8) + **3** (8)
2[b,c]	**1b**	2.5	0.20	4	80	**2b** (25) + **4a** (25)
3[c]	**1b**	4	0.06	0.25	75	**2b** (50)
4[c]	**1c**	4	0.06	0.25	75	**2c** (46)
5[c]	**1c**	4	0.06	0.5	85	**2c** (45) + **4b** (10)
6[c]	**1c**	4	0.06	1	100	**2c** (40) + **4b** (30)
7[c]	**1c**	6	0.05	0.25	75	**2c** (56)
8	**1e**	1.5	0.10	0.25	0	—
9	**1e**	1.5	0.10	1	0	—
10	**1e**	1.5	0.10	3	5	**2e** (5)
11	**1e**	1.5	0.10	5	40	**2e** (20) + **5** (20)

[a] Reaction conditions: $MeNO_2$, 20 °C.
[b] Reaction is accompanied by noticeable resinification.
[c] According ^1H NMR spectroscopy, the reaction mixture contains also 1,3-disubstituted 1-arylpropanes.

Scheme 4



obtained by nitrosation of cyclopropane **1e** with an excess of the nitrosating agent at different reaction times are summarized in Table 3. The data in Table 3 show that 4-fold molar excess of adduct $NOCl \cdot (SO_3)_n$ leads to a significant increase in the conversion of cyclopropane **1e** (*cf.* Table 2, entries *8*—*11*) and 1 h after the reaction onset the content of isoxazole **2e** riches 30%. Note that no formation of both cyclopropane **5** and isoxazole **4d** was detected at the earlier stages of the reaction. An increase in the reaction time results in formation and accumulation of the products of bromination of the starting cyclopropane **1e** and/or formed isoxazole **2e**. Similar results were obtained for compound **1c** (see Table 2, entries *4*—*6*).

An increase in cyclopropane concentration is negatively affects the yield of isoxazoles. In the case of cyclopropanes **1a**—**c** bearing substituents stabilizing the benzylic cation, we observed strong resinification of the reaction mixture and loss of chemoselectivity. Thus, at relatively high conversions of cyclopropanes **1a**,**b** reaching 80% and more the yields of isoxazoles **2a**,**b** do not exceed 25% due to formation of the large amounts of acyclic products of 1,3-nitrosohalogenation and three-membered cycle halogenation[28] (see Table 2, entries *1* and *2*).

The yields of isoxazoles (without lowering the nitrosation rate) can be increased by decreasing the cyclopropane concentration and simultaneously increasing the nitrosat-

Table 3. Effect of the reaction time on the compositions of the reaction mixtures obtained by nitrosation of cyclopropane **1e***

Entry	*t*/h	Reaction mixture composition (%)			
		1e	**2e**	**4d**	**5**
1	0.25	75	25	—	—
2	1	70	30	—	—
3	3	6	40	30	24
4	5	—	36	35	29

* Reaction conditions: the starting concentration [**1e**] = 0.06 mol L^{-1}, $MeNO_2$, 20 °C, **1e** : $NOCl \cdot (SO_3)_n$ = 1 : 4.

Table 4. Effect of the reaction time and the starting concentration of the substrate on the compositions of the reaction mixtures obtained by nitrosation of cyclopropane **1d***

Entry	[**1d**]/ /mol L^{-1}	*t*/h	Reaction mixture composition (%)		
			1d	**2d**	**4c**
1	0.140	2.5	10	25	65
2	0.014	20	85	15	—
3	0.014	70	30	60	10

* Reaction conditions: $NOCl \cdot (SO_3)_n$ (4 equiv.), $MeNO_2$, 20 °C.

ing agent concentration. The strong dilution leads also to a decrease in both the oxidation rate of hydrogen bromide due to its low concentration and the electrophilic bromination rate also due to low concentration of the reacting species. These facts are confirmed by the data obtained upon nitrosation of cyclopropane **1d** (Table 4). At the relatively high starting concentration of cyclopropane [**1d**] = 0.14 mol L^{-1} and at the presence of 4-fold excess of complex $NOCl \cdot (SO_3)_n$, the conversion of this substrate deactivated by the nitro group reached 90% within 2.5 h; however, the main component of the reaction mixture was 4,5-dibromoisoxazole (**4c**) (see Table 4, entry *1*). The 10-fold dilution of the reaction mixture retaining the same reagent ratio (entry *2*) led to a significant decrease in the conversion of cyclopropane **1d**; nevertheless, formation of **4c** was not observed. The relatively high yield of isoxazole **2d** free from dibromo derivative **4c** or containing minimum amount of **4c** can be achieved carefully choosing the reaction time (entry *3*).

The best results were obtained performing the reaction for 30 min in the presence of 10-fold excess of complex $NOCl \cdot (SO_3)_n$ and at the cyclopropane concentration of 0.014—0.02 mol L^{-1}. Under these conditions, the yields of isoxazoles were 57—70%.[32]

In summary, we studied transformations of 2-aryl-1,1-dibromocyclopropanes on treatment with an adduct of nitrosyl chloride with sulfur trioxide leading to 3-aryl-5-bromoisoxazoles *via* nitrosation—heterocyclization reaction sequence. It was found that hydrogen bromide released upon the reaction readily oxidizes and reacts further with species present in the reaction mixture following the electrophilic aromatic substitution mechanism. We optimized the reaction conditions towards chemoselective formation of 3-aryl-5-bromoisoxazoles in good yields and also gave reasonable explanation of this choice.

Experimental

The starting compounds and solvents were purchased from Reakhim, Aldrich, and Acros Organic. ^1H and ^{13}C NMR spectra were run with a Bruker Avance-400 instrument in $CDCl_3$ at working frequencies of 400 (^1H) and 100 (^{13}C) MHz. The chemical shifts are given in the δ scale relative to hexamethyldisiloxane (an internal standard). The accuracy of the chemical shift measurements were 0.01 ppm, the accuracy of the spin-spin coupling measurements were 0.1 Hz. IR spectra were recorded using a UR-20 spectrophotometer in Nujol or neat. Mass spectrometry was performed with a GC/MS Finnigan MAT SSQ 7000 system (energy of ionizing electrons of 70 eV; quartz capillary column OV-1 (25 m); temperature programming: 70 °C for 2 min, heating at a rate of 20 °C min^{-1}, maintaining at 280 °C for 10 min). Melting points were measured with a Mel-TempII apparatus and given uncorrected. The reaction course and the purity of compounds were monitored by TLC on the Silufol precoated plates. All solvents were purified and dried following the standard procedures.[33] 2-Aryl-1,1-dibromocyclopropanes **1a—d** were synthesized as earlier described.[34,35] 1,1-Dibromo-2-(4-nitrophenyl)cyclopropane **1e** was synthesized by direct nitration of cyclopropane **1a**.

X-ray diffraction study of cyclopropane **5** was performed with a Bruker SMART APEX II CCD automatized diffractometer (graphite monochromator, λ(MoKα) = 0.71073 Å, ω scan mode). Accounting empirical absorption and correction of systematic errors were performed by SADABS program.[36] The structure was solved by direct method and refined by full-matrix least squares method against F^2_{hkl} with anisotropic thermal parameters for all non-hydrogen atoms. Hydrogen atoms were calculated geometrically and refined by the riding model with $U_{iso}(H_i) = 1.2U_{eq}(C_i)$. Main crystallographic and refinement parameters are given in Table 5. The structure was solved and refined with SHELX program package, version SHELXL-2014/7.[37] Crystallographic data for structure **5** were deposited with the Cambridge Crystallographic Data Center[38] (CCDC 1437333).

Table 5. Crystallographic characteristics, X-ray data collection, and refinement statistics for compound **5**

Parameter	Value
Molecular formula	$C_9H_6Br_4$
Molecular weight	433.78
T/K	120(2)
Crystal system	Rhombic
Space group	$Pca2_1$
Z/*Z*′	8/2
a/Å	11.9711(5)
b/Å	8.7239(4)
c/Å	21.1888(10)
V/Å^3	2212.85(17)
d_{calc}/g cm^{-3}	2.604
μ/cm^{-1}	145
F(000)	1600
$2\theta_{max}$/deg	50
Number of collected reflections	27202
Number of independent reflections	6451
Number of reflections with $I > 2\sigma(I)$	5507
Number of refined parameters	235
R_1	0.0315
wR_2	0.0496
GOF	1.034
Residual electron density, e Å^{-3} (ρ_{max}/ρ_{min})	0.605/−0.739

Nitrosation of 2-aryl-1,1-dibromocyclopropanes 1 with an adduct $NOCl \cdot (SO_3)_n$ (general procedure). To adduct $NOCl \cdot (SO_3)_n$ (0.70—0.80 g, 3.0—3.5 mmol) in nitromethane (4 mL), *gem*-dibromoarylcyclopropane **1** (2.0 mmol) in nitromethane (1 mL) was added and the resulting solution was stirred for 20 h at room temperature (~20 °C). After the reaction completion (TLC monitoring), the reaction mixture was neutralized with a $NaHCO_3$ solution and washed with water. The combined aqueous layers were extracted with chloroform (3×10 mL), the combined organic layers were dried with anhydrous sodium sulfate. The solvent was removed *in vacuo*, the products were isolated by silica gel column chromatography (silica gel 40—100 μm; elution with ethyl acetate—petroleum ether gradient 1 : 20→1 : 10). The retention factor values (R_f) were determined using Silufol precoated plates eluting with ethyl acetate—petroleum ether (1 : 10). The microanalysis data for isoxazoles **2d** and **4c** are given in our previous work.[32] ^1H and ^{13}C NMR spectral data for isoxazoles **2a—e** and **4a—d** are summarized in Table 1.

Reaction involving **1,1-dibromo-2-phenylcyclopropane (1a)** (0.550 g, 2.0 mmol) afforded **1,1-dibromo-2-(bromophenyl)-cyclopropane (3)** (yield 0.057 g (8%)), **5-bromo-3-phenylisoxazole (2a)** (yield 0.134 g (30%), creamy crystals, m.p. 49—51 °C (*cf.* Ref. 20: m.p. 48—50 °C), R_f 0.40), and **5-bromo-3-(4-bromophenyl)isoxazole (2b)** (yield 0.049 g (8%), R_f 0.58).

Reaction involving **1,1-dibromo-2-(4-bromophenyl)cyclopropane (1b)** (0.71 g, 2.0 mmol) afforded **5-bromo-3-(4-bromophenyl)isoxazole (2b)** (yield 0.212 g (35%), creamy crystals, R_f 0.58, m.p. 128—129 °C (*cf.* Ref. 12: m.p. 127—128 °C)) and **4,5-dibromo-3-(4-bromophenyl)isoxazole (4a)** (yield 0.344 g (45%), R_f 0.78, m.p. 98 °C).

Compound 4a. MS (EI, 70 eV), m/z (I_{rel} (%)): 379 $[M]^+$ (18), 381 (36), 383 (35), 385 (15); 300 $[M - Br]^+$ (30), 302 (54), 304 (32); 272 $[M - Br - CO]^+$ (22), 274 (48), 276 (22); 221 $[M - 2\ Br]^+$ (100), 223 (100); 114 $[M - 3\ Br - CO]^+$ (30), 102 $[C_6H_4CN]^+$ (32), 75 $[C_6H_3]^+$ (50), 50 (51). Found (%): C, 28.41; H, 0.89; N, 3.30. $C_9H_4Br_3NO$. Calculated (%): C, 28.27; H, 1.04; N, 3.66.

Reaction involving **1,1-dibromo-2-(4-chlorophenyl)cyclopropane (1c)** (0.620 g, 2.0 mmol) afforded **4,5-dibromo-3-(4-chlorophenyl)isoxazole (4b)** (yield 0.303 g (45%), colorless crystals, m.p. 76—78 °C, R_f 0.54) and **5-bromo-3-(4-chlorophenyl)-isoxazole (2c)** (yield 0.155 g (30%), colorless crystals, R_f 0.48, m.p. 119—122 °C (*cf.* Ref. 12: m.p. 121—122 °C)).

Reaction involving **1,1-dibromo-2-(4-nitrophenyl)cyclopropane (1d)** (0.54 g, 2.0 mmol) afforded **5-bromo-3-(4-nitrophenyl)isoxazole (2d)** (yield 0.270 g (50%), m.p. 233—235 °C, R_f 0.25) and **4,5-dibromo-3-(4-nitrophenyl)isoxazole (4c)** (yield 0.174 g (25%), colorless crystals, m.p. 180 °C, R_f 0.44).

Compound 4c. IR, ν/cm^{-1}: 1560, 1380 (NO_2). MS (EI, 70 eV), m/z (I_{rel} (%)): cluster 347 $[M]^+$ (8), 349 (16), 351 (8); 268 $[M - Br]^+$ (20), 270 (20); 239 $[M - Br - CO]^+$ (20), 241 (20); 189 $[M - 2\ Br]^+$ (25), 158 (63), 114 $[C_6H_4C_2N]^+$ (60), 76 $[C_6H_4]^+$ (100). Found (%): C, 31.05; H, 1.24; N, 8.15. $C_9H_4Br_2N_2O_3$. Calculated (%): C, 31.03; H, 1.15; N, 8.05.

Reaction involving **1,1-dibromo-2-(3-bromophenyl)cyclopropane (1e)** (0.71 g, 2.0 mmol) afforded **4,5-dibromo-3-(3-bromophenyl)isoxazole (4e)** (yield 0.076 g (10%), colorless crystals, m.p. 56—58 °C, R_f 0.70), **5-bromo-3-(3-bromophenyl)-isoxazole (2e)** (yield 0.242 g (40%), colorless crystals, m.p. 86—88 °C (*cf.* Ref. 12: m.p. 89—90 °C), R_f 0.50), and **1,1-dibromo-2-(2,5-dibromophenyl)cyclopropane (5)** (yield 0.347 g (40%), colorless crystals, R_f 0.75, m.p. 102—103 °C).

Compound 5. ^1H NMR ($CDCl_3$), δ: 2.05 (dd, 1 H, CH_2, ^2J = 8.0 Hz, ^3J = 8.2 Hz); 2.23 (dd, 1 H, CH_2, ^2J = 10.2 Hz, ^3J = 8.0 Hz); 2.95 (dd, 1 H, CH, ^2J = 10.2 Hz, ^3J = 8.2 Hz); 7.19 (d, 1 H, arom., ^4J = 2.3 Hz); 7.34 (dd, 1 H, arom., ^3J = 8.4 Hz, ^4J = 2.3 Hz); 7.54 (d, 1 H, arom., ^3J = 8.4 Hz). ^{13}C NMR ($CDCl_3$), δ: 26.6 (CBr_2), 27.5 (CH_2), 36.8 (CH), 121.1 (CBr), 125.8 (CBr), 132.2 (CH_{Ar}), 132.6 (CH_{Ar}), 134.0 (CH_{Ar}), 139.1 (C_{Ar}). Found (%): C, 24.91; H, 1.35. $C_9H_6Br_4$. Calculated (%): C, 24.88; H, 1.38.

Compound 4d. MS (EI, 70 eV), m/z (I_{rel} (%)): 379 $[M]^+$ (7), 381 (15), 383 (16), 385 (8); 300 $[M - Br]^+$ (38), 302 (84), 304 (48); 272 $[M - Br - CO]^+$ (8), 274 (16), 276 (8); 221 $[M - 2\ Br]^+$ (78), 223 (88); 155 $[C_6H_4Br]^+$ (19), 157 (19); 114 (58) $[M - 3\ Br - CO]^+$, 102 $[C_6H_4CN]^+$ (34), 75 (70) $[C_6H_3]^+$, 50 (100).

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