peri-Naphthylenediamines
25.* Evidence for the participation of a radical cation of 1,8-bis(dimethylamino)naphthalene ("proton sponge") in reactions with nitrating agents. The formation of 1,1′-binaphthyl "proton sponge" and the regioselective synthesis of 4-chloro-1,8-bis(dimethylamino)naphthalene

V. A. Ozeryanskii, A. F. Pozharskii, and A. M. Fomchenkov*

Rostov State University,
7 ul. Zorge, 344090 Rostov-on-Don, Russian Federation.
Fax: +7 (863 2) 28 5667

First indirect evidence for the formation of a radical cation of 1,8-bis(dimethylamino)naphthalene ("proton sponge") in reactions with HNO_3, HNO_2, NO_2, and I_2 has been obtained. In all cases, the products of reaction of the radical cation with nucleophiles and/or its dimer, 4,5,4′,5′-tetrakis(dimethylamino)-1,1′-binaphthyl, have been isolated. 4-Chloro-1,8-bis(dimethylamino)naphthalene has been regioselectively synthesized in high yield.

Key words: 1,8-bis(dimethylamino)naphthalene, 1,1′-binaphthyls, "proton sponge," radical cation, nitration, oxidation, chlorination.

It has been reported previously that the "proton sponge," 1,8-bis(dimethylamino)naphthalene (**1**), has a low ionization potential[2,3] and produces radical cation (RC) $\mathbf{1}^{\cdot+}$ under conditions of electrochemical oxidation.[4] Compounds with such properties should also easily generate radical cations in chemical oxidation and nitration. It is believed that nitration of all aromatic substrates that are better π-donors than toluene proceeds *via* the stage of one-electron transfer with the formation of a radical pair.[5] In this work, we obtained the first evidence also confirming this assumption using compound **1** as an example.

According to the previously reported data,[6] treatment of compound **1** with a HNO_3—H_2SO_4 mixture at −20 °C resulted in 4-nitro derivative **2** in 70% yield. We found that 4,5,4′,5′-tetrakis(dimethylamino)-1,1′-binaphthyl (**3**), recently prepared following a different procedure,[1] is another product of this reaction. Obviously, compound **3** is formed as a result of one-electron oxidation of 1,8-bis(dimethylamino)naphthalene by nitronium cation to radical cation $\mathbf{1}^{\cdot+}$ and its subsequent dimerization. The formation of biaryls upon nitration of π-excessive aromatic substrates was reported repeatedly, for instance, for *N,N*-dimethylaniline.[7] It is hardly probable that the "proton sponge" could exist in the acid medium as a neutral base **1**. Most likely, it is cation $\mathbf{1}\cdot H^+$ that is directly oxidized and transformed further into RC $\mathbf{1}^{\cdot+}$ after abstraction of a proton.

According to HT calculations performed for compound **1** without considering the effect of methyl groups, the frontier electron density on the highest occupied molecular orbital (HOMO) is 0.117, 0.033, and 0.178 for C(2), C(3), and C(4), respectively. Since the spin density in RC $\mathbf{1}^{\cdot+}$ changes in parallel with these values, it is likely that the direction of dimerization agrees with its distribution: C(4) > C(2) > C(3).

It is known that the action of HNO_2 on π-excessive aromatic compounds results in their nitrosation (as in the case of *N,N*-dialkylanilines and phenols) or nitration (for perimidines,[8] carbazoles,[9] and porphyrins[10]). It should be noted that nitration is characteristic of substrates that form more stable RCs in one-electron oxidation. These RCs are then subjected to nucleophilic attack by the nitrite ion. In this connection, it was also of interest to study the action of HNO_2 on the "proton sponge." We established that compound **1** remains virtually unchanged under the action of $NaNO_2$ in acetic acid (Table 1, runs *2—4*). The formation of only small amounts of nitro derivative **2** was detected chromatographically. Traces of dimer **3** appeared only upon boiling for 3 h (run *5*), which is indirect evidence for the radical character of this reaction. Obviously, the concentration of the RC generated by nitrous acid appears to be higher in this case than in runs *2—4*, and a portion of RC $\mathbf{1}^{\cdot+}$ has time to dimerize.

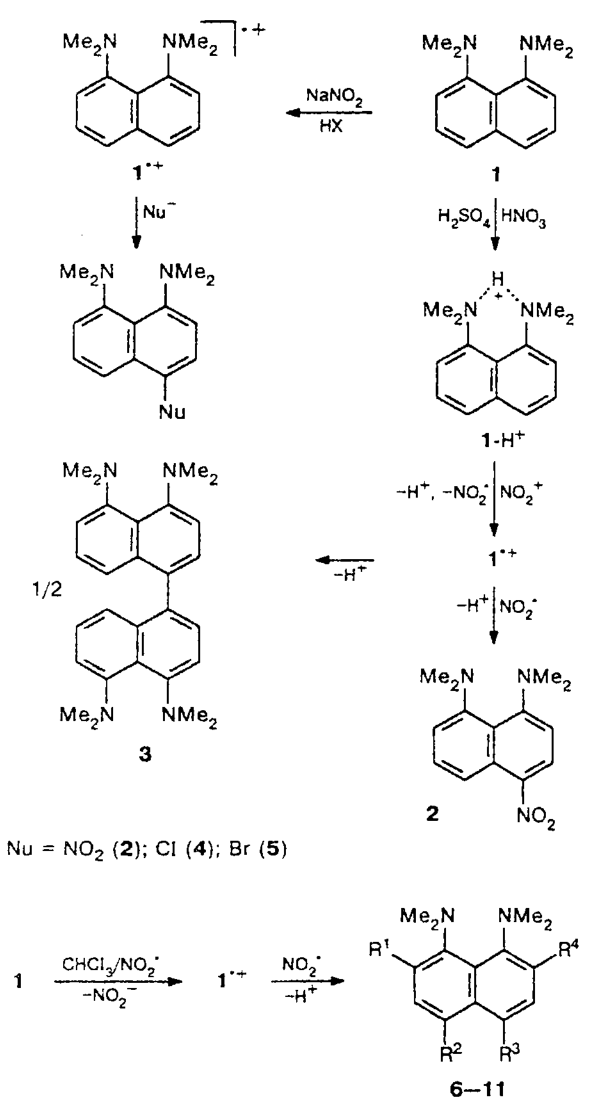
It is likely that the relative amount of RC $\mathbf{1}^{\cdot+}$ that formed depends on the amount of HNO_2, which is rather low in a relatively weak acetic acid, rather than

---

* For Part 24, see Ref. 1.

Translated from *Izvestiya Akademii Nauk. Seriya Khimicheskaya*, No. 2, pp. 320—324, February, 1998.

Scheme 1



Nu = NO_2 (**2**); Cl (**4**); Br (**5**)

Compound	R^1	R^2	R^3	R^4
6	H	NO_2	H	NO_2
7	H	H	NO_2	NO_2
8	H	NO_2	NO_2	H
9	NO_2	H	NO_2	NO_2
10	H	NO_2	NO_2	NO_2
11	NO_2	NO_2	NO_2	NO_2

on the form (base or cation) of the reacting "proton sponge" (see Table 1, run *6* with diluted AcOH and runs *3*, and *4*). In fact, it is possible not only to increase the concentration of the RC of the "proton sponge" in strong mineral acids using the $NaNO_2$—HX system (which can be seen from the increase in the yield of the products of its transformations), but also to trap it using nucleophiles, chloride, or bromide ions (*cf.* Ref. 11), which are more nucleophilic[12] than the nitrite ion in polar protic media. For instance, 4-chloro-1,8-bis(dimethylamino)naphthalene (**4**) was obtained in 90% yield under conditions of run *7*. An attempt to introduce the second Cl atom into the other *peri*-position of compound **4** under the same conditions failed.

No formation of compound **2** is observed in the case of a more nucleophilic bromide anion[12] (see Table 1, runs *8* and *9*), but the yield of bromo derivative **5** was unexpectedly low (~20%). This can be explained by both the low solubility of the salt **1** $\cdot$ HBr and the enhanced oxidizability of the Br^- anion as compared to the Cl^- anion. The fluoride anion as nucleophile can no longer compete with the NO_2^- anion; for this reason, RC $\mathbf{1}^{\cdot+}$ only enters into nitration and dimerization reactions in the $NaNO_2$—HF system (see Table 1, run *10*), and this system differs only little in its action from the $NaNO_2$—H_2SO_4 mixture (*cf.* runs *10*, *12*, and *13*). An increase in the amount of nitrating agent over the equimolar amount does not result in the formation of polynitration products (**6**—**11**) and only leads to resinification (runs *11* and *14*).

Thus, the balance between good nucleophilicity and low oxidizability of the chloride anion makes it possible to take advantage of the high regioselectivity of its interaction with RC $\mathbf{1}^{\cdot+}$ for synthetic purposes. Previously,[13] compound **4** has only been synthesized from perimidinium salts using a multi-stage procedure.

The results obtained prompted us to carry out several reactions of the "proton sponge" with NO_2, which possesses the properties of an oxidant and can initiate the formation of a RC. We established that the action of nitrogen dioxide on the "proton sponge" in chloroform results in an appreciable resinification (see Table 1, runs *16*—*19*). It is likely that 2 equiv. of NO_2 are required for the reaction with compound **1**, since one NO_2 molecule nitrates (or oxidizes) the "proton sponge" molecule, while the other is converted into HNO_2 (runs *15* and *16*). Varying the amount of nitrating agent, we succeeded in obtaining an array of nitro derivatives of the "proton sponge" (**6**—**11**) including the previously unknown 2,5-dinitro- (**6**), 2,4-dinitro- (**7**) (run *17*), 2,4,7-trinitro- (**9**), and 2,4,5-trinitro derivatives (**10**) (runs *17* and *18*). The highest yield of binaphthyl **3** (23%) was obtained in run *16* (in the reaction with 2 equiv. of NO_2). Most likely, further increase in the amount of NO_2 results in an increase in the nitration rate of RC $\mathbf{1}^{\cdot+}$ and oxidation of dimer **3**. All this decreases drastically its content among the reaction products, which, however, do not contain nitro derivatives of compound **3**.

Thus, nitration of the "proton sponge" by NO_2 proceeds with a low selectivity; however, judging by the ratio of the reaction products, one can assume that the first nitro group goes to one of the two *peri*-positions of compound **1** (see Table 1, runs *15* and *16*). The *ortho*-position of the unnitrated ring is the preferred position

Table 1. The results of the action of nitrating agents on the "proton sponge"

Run	Nitrating agent (equiv.)	Medium	T/°C	t /min	Composition of the products (%)				
					1	**2**	**3**	**4(5)**	Resins[a]
1	HNO_3 (1)	H_2SO_4	−20	5	—	60	10	—	30
2	$NaNO_2$ (1)	AcOH	0	5	92	1	—	—	7
3	$NaNO_2$ (1)	AcOH	30	5	95	1	—	—	4
4	$NaNO_2$ (1)	AcOH	100	240	87	3	—	—	10
5	$NaNO_2$ (1)	AcOH	120	180	77	6	1	—	16
6	$NaNO_2$ (1)	50% AcOH	100	60	93	1	—	—	6
7	$NaNO_2$ (1)	20% HCl	20	90	—	4	—	90	6
8	$NaNO_2$ (1)	20% HBr	20	90	75	—	—	20	5
9	$NaNO_2$ (1)	20% HBr	40	1 day	80	—	—	10	10
10	$NaNO_2$ (1)	20% HF	20	90	59	20	17	—	4
11	$NaNO_2$ (3)	20% HF	20	10 days	19	36	13	—	32
12	$NaNO_2$ (1)	20% H_2SO_4	20	90	65	10	11	—	14
13	$NaNO_2$ (1)	20% H_2SO_4	20	7 days	58	13	17	—	12
14	$NaNO_2$ (10)	20% H_2SO_4	20	10 days	—	—	—	—	Resinification
15	NO_2 (1)	$CHCl_3$	−15	30	90	2	4	—	4
16	NO_2 (2)	$CHCl_3$	0	180	10	45	23	—	22
17	NO_2 (4)	$CHCl_3$	0	180	—	—	—	—	48[b]
18	NO_2 (8)	$CHCl_3$	0	180	—	—	—	—	35[c]
19	NO_2 (20)	$CHCl_3$	0	10 days	—	—	—	—	Resinification

[a] Including minor products. [b] In addition: **6** (24%), **7** (10%), **8** (5%), **9** (11%), and **10** (2%). [c] In addition: **9** (5%) and **11** (60%).

for the second nitration; it is followed by the other *ortho*-position and the unoccupied but sterically hindered *peri*-position (compounds **6**, **7**, and **8**, rspectively). The introduction of one more NO_2 group mainly results in the 2,4,7-trinitro derivative of the "proton sponge" **9**, in which the nitro groups are distant from each other, rather than in the 2,4,5-trinitro derivative **10**.

One of the most convenient oxidants for the generation of RC is I_2 (in CH_2Cl_2 or, more often, in acetonitrile[14]). We investigated its action on the "proton sponge" as well. Theoretically, taking into account that the iodide anion is a poor nucleophile in aprotic media, the RC that could be formed upon the action of iodine on the "proton sponge" would either undergo dimerization or would interact with the remaining free base **1** as a nucleophile. This could result in an increase in the yield of the binaphthyl derivative **3**. In fact, binaphthyl **3** appeared to be the only reaction product when compound **1** was boiled with I_2 in anhydrous MeCN; a portion of the "proton sponge" is regenerated due to its binding to HI, while the degree of resinification is low (Table 2, runs *1*—*4*). The highest yield of dimer **3** (60%) is observed in the reaction of base **1** with an equimolar amount of I_2 (run *4*). The increase in the concentration of I_2 leads to resinification of the reaction mass (run *5*). Stirring of the reagents for 48 h at ~20 °C in acetonitrile instead of boiling (*cf.* runs *3* and *4*) gives analogous results; however, in this case a larger amount of resin is formed over the same time.

Attempts to oxidize the "proton sponge" with iodine in the presence of the fluoride anion, which is the most nucleophilic of all the halide ions in aprotic media,[12] aimed at preparing the 4-fluoro derivative of the "proton sponge" (under the action of the I_2—AgF, I_2—NaF—$AgNO_3$, and I_2—NaF systems in MeCN or DMSO) failed. In all cases, the formation of only binaphthyl **3** was observed as if the fluoride anion was absent from the solution.

Thus, reactions of 1,8-bis(dimethylamino)naphthalene with HNO_3—H_2SO_4, HNO_2, NO_2, and I_2 proceed with the formation of a RC, which affects the ratio and character of the reaction products. The transformations observed are not only of theoretical interest, but also extend considerably the synthetic potentials of the reactions with the participation of the "proton sponge."

Experimental

^1H NMR spectra were recorded on a Unity-300 spectrometer (300 MHz) using tetramethylsilane as the internal standard. Chromatography was performed on a column with Al_2O_3 (Brockmann activity III) using chloroform as the eluent. Melt-

Table 2. The results of the action of the I_2—MeCN system on the "proton sponge"

Run	$[I_2]$ /equiv.	T/°C	t/h	Composition of the products (%)		
				1	**3**	Resins
1	0.25	82	2	74	25	1
2	0.5	82	2	64	34	2
3	1	20	48	33	57	10
4	1	82	2	35	60	5
5	5	82	2	—	—	Resinification

ing points were measured in sealed capillaries on a PTP instrument and were not corrected.

Nitration of 1,8-bis(dimethylamino)naphthalene (1). A. HNO_3—H_2SO_4. A solution of compound **1** (4.29 g, 0.02 mol) in conc. H_2SO_4 (20 mL) prepared at 0 °C for a period no longer than 10 min was cooled to −20 °C. Then a mixture of HNO_3 (1.28 mL, 0.02 mol, d = 1.41) and conc. H_2SO_4 (4 mL) was added to the above solution dropwise with stirring. The red-brown mixture was stirred for an additional 5 min at −20 °C, poured onto crushed ice (300 g), and neutralized with conc. NH_4OH (120 mL). The products were extracted with chloroform (5×50 mL), and the extract was concentrated to minimum volume and chromatographed. The dark claret-colored fraction (4.67 g) was recrystallized from EtOH (200 mL). After separation of nitro derivative **2** (3.00 g, 58%, dark claret-colored leaflets, m.p. 134—135 °C[6]), the mother liquor was concentrated to dryness, and the light brown finely crystalline residue (0.64 g) was dissolved in 10% aqueous HCl (50 mL). The yellowish solution was gradually neutralized with 15% KOH with vigorous stirring. At pH 6—7, precipitation of red compound **2** (0.11 g, (2%), overall yield 60%, pK_a = 14.11 (MeCN)[15]) occurred. At pH 10—11, precipitation of a colorless binaphthyl "proton sponge" **3** (0.52 g, 10%, pK_a = 18.10 (MeCN)[16]) occurred, m.p. 185—186 °C (from *n*-heptane) (*cf.* Ref. 1).

B. $NaNO_2$—HCl. $NaNO_2$ (0.021 g, 0.3 mmol) was added to a solution of compound **1** (0.064 g, 0.3 mmol) in 20% HCl (3 mL). The dark brown mixture was kept for 1.5 h at 20 °C with occasional shaking. After neutralization with conc. ammonia (10 mL), the products were extracted with benzene (3×3 mL), the extract was concentrated, and the residue was chromatographed. The dark red zone was first eluted (nitro derivative **2**, yield 3 mg, 4%), and then a light yellow fraction was collected. Chloro derivative **4** (0.069 g, 90%) was obtained as a light yellow oil whose physicochemical characteristics were identical with those of the compound obtained previously.[13]

C. NO_2 (4 equiv). Nitrogen dioxide (0.092 mL, 3.0 mmol) was added with vigorous stirring to a solution of compound **1** (0.160 g, 0.75 mmol) in anhydrous $CHCl_3$ (20 mL) cooled to 0 °C. The reaction mass was kept under these conditions for 3 h, concentrated to minimum volume, and chromatographed. **1,8-Bis(dimethylamino)-2,5-dinitronaphthalene (6)** (0.055 g, 24%, red-brown needles) was eluted first, m.p. 184—186 °C (from EtOH). Found (%): C, 55.40; H, 5.17. $C_{14}H_{16}N_4O_4$. Calculated (%): C, 55.26; H, 5.30. ^1H NMR ($CDCl_3$), δ: 2.92 (s, 6 H, 8-NMe_2); 3.00 (s, 6 H, 1-NMe_2); 6.78 (d, 1 H, H(7)); 7.76 (d, 1 H, H(3), $J_{3,4}$ = 9.67 Hz); 8.31 (d, 1 H, H(6), $J_{6,7}$ = 9.09 Hz); 8.34 (d, 1 H, H(4)).

Then the red-orange fraction was collected, which was a mixture (~1 : 1) of compounds **7** and **9** with close chromatographic mobilities.

Then **1,8-bis(dimethylamino)-4,5-dinitronaphthalene (8)** (0.012 g, 5%, dark-red crystals) was eluted, m.p. 280—282 °C (decomp., from DMF).[17] Found (%): C, 55.35; H, 5.31. $C_{14}H_{16}N_4O_4$. Calculated (%): C, 55.26; H, 5.30. ^1H NMR ($CDCl_3$), δ: 2.95 (s, 12 H, 1-NMe_2 and 8-NMe_2); 6.73 (d, 2 H, H(2), H(7)); 8.13 (d, 2 H, H(3), H(6), $J_{2,3}$ = 8.90 Hz). The last to elute was **1,8-bis(dimethylamino)-2,4,5-trinitronaphthalene (10)** (0.005 g, 2%, red-brown crystals), m.p. 268—270 °C (decomp., from DMF). Found (%): C, 48.09; H, 4.27. $C_{14}H_{15}N_5O_6$. Calculated (%): C, 48.14; H, 4.33. ^1H NMR ($CDCl_3$), δ: 2.84 (s, 6 H, 8-NMe_2); 3.19 (s, 6 H, 1-NMe_2); 6.86 (d, 1 H, H(7)); 8.11 (d, 1 H, H(6), $J_{6,7}$ = 9.15 Hz); 8.98 (s, 1 H, H(3)). The mixture of compounds **7** and **9** was chromatographed on a column with silica gel L 40/100 in $CHCl_3$. **1,8-Bis(dimethylamino)-2,4-dinitronaphthalene (7)** (0.023 g, 10%) was isolated as red crystals, m.p. 187—189 °C (from EtOH). Found (%): C, 55.42; H, 5.22. $C_{14}H_{16}N_4O_4$. Calculated (%): C, 55.26; H, 5.30. ^1H NMR ($CDCl_3$), δ: 2.83 (s, 6 H, 8-NMe_2); 3.29 (s, 6 H, 1-NMe_2); 6.96 (d, 1 H, H(7)); 7.54 (t, 1 H, H(6), $J_{6,7}$ = 7.91 Hz); 8.23 (dd, 1 H, H(5), $J_{5,6}$ = 8.20 Hz, $J_{5,7}$ = 0.73 Hz); 9.10 (s, 1 H, H(3)). Then **1,8-bis(dimethylamino)-2,4,7-trinitronaphthalene (9)** (0.025 g, 11%) was isolated as orange crystals, m.p. 212—214 °C (decomp., from EtOH). Found (%): C, 48.20; H, 4.11. $C_{14}H_{15}N_5O_6$. Calculated (%): C, 48.14; H, 4.33. ^1H NMR ($CDCl_3$), δ: 2.92 (s, 6 H, 8-NMe_2); 3.29 (s, 6 H, 1-NMe_2); 7.85 (d, 1 H, H(6)); 8.39 (d, 1 H, H(5), $J_{5,6}$ = 9.30 Hz); 9.19 (s, 1 H, H(3)).

D. NO_2 (8 equiv.). Nitrogen dioxide (0.184 mL, 6.0 mmol) was added with vigorous stirring to a solution of compound **1** (0.160 g, 0.75 mmol) in anhydrous $CHCl_3$ (20 mL) cooled to 0 °C. The reaction mass was kept under the same conditions for 3 h and concentrated. The residue was separated, and the solution was chromatographed to give nitro derivative **9** (15 mg, 5%) whose physicochemical characteristics were identical with those of the compound obtained above.

The rest of the reaction mass insoluble in chloroform was recrystallized from DMF to give **1,8-bis(dimethylamino)-2,4,5,7-tetranitronaphthalene (11)** (0.176 g, 60%) as yellow-brown crystals, m.p. 256 °C (decomp., the previously reported[15] melting point of 104 °C is erroneous). The data of elemental analysis corresponded to the crystal solvate of composition **11** · 1/2 DMF. Found (%): C, 43.12; H, 3.89. $2C_{14}H_{14}N_6O_8 \cdot C_3H_7NO$. Calculated (%): C, 43.21; H, 4.10. ^1H NMR (acetone-d_6), δ: 3.39 (s, 12 H, 1-NMe_2 and 8-NMe_2); 8.93 (s, 2 H, H(3), H(6)).

Dimerization of the radical cation of the "proton sponge" in MeCN. I_2 (0.038 g, 0.15 mmol) was added to a solution of compound **1** (0.064 g, 0.3 mmol) in anhydrous MeCN (5 mL). The mixture was refluxed for 2 h, then 10% KOH (5 mL) was added to the solution, and the mixture was heated to boiling with vigorous stirring. Then the mixture was cooled, and the products were extracted with benzene (3×2 mL). "Proton sponge" **1** (0.041 g, 64%, eluted with hexane) and dimer **3** (0.022 g, 34%, eluted with chloroform) as fine light-gray crystals, m.p. 185—186 °C (from *n*-heptane) were isolated by chromatography (protect from light!).

This work was financially supported by the Russian Foundation for Basic Research (Project No. 96-03-32153a).

References

1. N. V. Vistorobskii, A. F. Pozharskii, and M. I. Rudnev, *Izv. Akad. Nauk, Ser. Khim.*, 1998, 93 [*Russ. Chem. Bull.*, 1998, **47**, 91 (Engl. Transl.)].
2. J. P. Maier, *Helv. Chim. Acta*, 1974, 57, 994.
3. A. F. Pozharskii, A. N. Suslov, N. M. Starshikov, L. L. Popova, N. A. Klyuev, and V. A. Adanin, *Zh. Org. Khim.*, 1980, **16**, 2216 [*J. Org. Chem. USSR*, 1980, **16** (Engl. Transl.)].
4. N. T. Berberova and O. Yu. Okhlobystin, *Zh. Org. Khim.*, 1983, **19**, 1114 [*J. Org. Chem. USSR*, 1983, **19** (Engl. Transl.)].
5. C. L. Perrin, *J. Am. Chem. Soc.*, 1977, **99**, 5516.

6. A. F. Pozharskii, V. V. Kuz'menko, G. G. Aleksandrov, and D. V. Dmitrienko, *Zh. Org. Khim.*, 1995, **31**, 570 [*J. Org. Chem. Russ.*, 1995, **31** (Engl. Transl.)].
7. J. C. Giffney and J. H. Ridd, *J. Chem. Soc., Perkin Trans. 2*, 1979, 618.
8. A. F. Pozharskii, V. N. Koroleva, I. F. Grekova, and I. S. Kashparov, *Khim. Geterotsikl. Soedin.*, 1975, **4**, 557 [*Chem. Heterocycl. Compd.*, 1975, **4** (Engl. Transl.)].
9. B. K. Bandlish and H. J. Shine, *J. Het. Chem.*, 1975, **12**, 287.
10. R. Bonnett, A. A. Charalambides, and R. A. Martin, *J. Chem. Soc., Perkin Trans. 1*, 1978, **9**, 974.
11. B. K. Bandlish, A. G. Padilla, and H. J. Shine, *J. Org. Chem.*, 1975, **40**, 2590.
12. Yu. S. Shabarov, *Organicheskaya khimiya* [*Organic Chemistry*], Khimiya, Moscow, 1994, Pt. 1, 134 (in Russian).
13. V. A. Ozeryanskii, A. F. Pozharskii, and N. V. Vistorobskii, *Zh. Org. Khim.*, 1997, **33**, in press [*J. Org. Chem. Russ.*, 1997, **33** (Engl. Transl.)].
14. C. V. Ristagno and H. J. Shine, *J. Am. Chem. Soc.*, 1971, **93**, 1811.
15. L. A. Kurasov, A. F. Pozharskii, V. V. Kuz'menko, N. A. Klyuev, A. I. Chernyshev, S. S. Goryaev, and N. L. Chikina, *Zh. Org. Khim.*, 1983, **19**, 590 [*J. Org. Chem. USSR*, 1983, **19** (Engl. Transl.)].
16. A. F. Pozharskii, N. L. Chikina, N. V. Vistorobskii, and V. A. Ozeryanskii, *Zh. Org. Khim.*, 1997, **33**, in press [*J. Org. Chem. Russ.*, 1997, **33** (Engl. Transl.)].
17. T. Barth, C. Krieger, F. A. Neugebauer, and H. A. Staab, *Angew. Chem. Int. Ed. Engl.*, 1991, **30**, 1028.

Received June 11, 1997