# Reactions of isoquinoline derivatives with pyridinium salts yielding 4-naphthylpyridines

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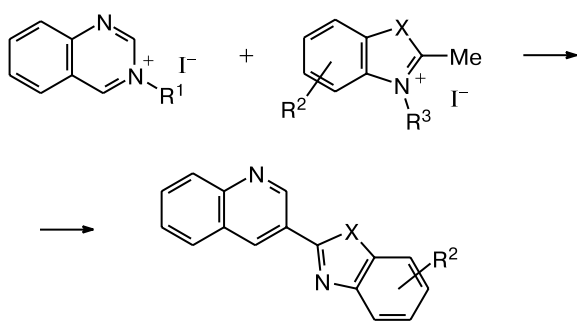
Regiospecific introduction of the 2-naphthyl residue into position 4 of the pyridine ring occurs in the reactions of isoquinolinium salts with 4-methylpyridinium salts through the intermolecular transformation of the isoquinoline bicyclic system involving the methyl group of the pyridinium salt. The reaction occurs under the action of methylammonium sulfite in an aqueous medium on heating. This method provides ring transformation not only for isoquinolinium salts but even for unsubstituted isoquinoline.

**Key words:** isoquinolinium salts, isoquinoline, pyridinium salts, methylammonium sulfite, ring transformation, 4-naphthylpyridines.

Isoquinolinium salts can be considered as both pyridine derivatives, whose reactions of nucleophilic addition and ring transformation have been studied, and a fused azine system, which is more electron-deficient, as a whole, toward nucleophiles.[1—4] The pyridinium ring of *N*-alkyl- and *N*-arylisoquinolinium salts is readily attacked by nucleophilic agents. $^1$H NMR spectroscopy shows that various anions[5—7] preferentially add to the C(1) atom, and strong nucleophiles are capable of pyridine ring opening.[8] For instance, hydroxylamine reacts with 2-(2,4-dinitrophenyl)isoquinolinium chloride to form a non-cyclic intermediate, which readily undergoes ring closure yielding isoquinoline *N*-oxide.[9]

We have previously[10,11] shown that the reactions of 3-methylquinazolinium iodide with quaternary salts of some 2(4)-methyl-substituted heterocyclic bases in pyridine result in the transformation of the quinazoline bicycle to form 3-hetarylquinolines (Scheme 1).

**Scheme 1**




X = S, O, HC=CH

Unlike quinazolinium salts, isoquinolinium salts contain no additional N atom in the heterocycle. It was of interest to study specific features of their reactions with quaternary salts of heterocyclic bases under the action of bases. This would provide an information on a possibility of ring transformation of this type for isoquinoline derivatives and simultaneously can be useful for the development of methods for syntheses of promising hetarylnaphthalenes.

However, experiments showed that 2-methylisoquinolinium iodide did not give expected 2-hetarylnaphthalenes even on prolonged heating with quaternary salts of heterocyclic bases in pyridine. This reaction does not occur either in the presence of alcoholic methylamine, although this reagent turned out to be efficient for ring closure of quaternary salts of 1- and 3-methylisoquinolinium salts with formation of naphthylamines, which occurs, as known,[12,13] with an intermediate opening of the pyridinium ring of the isoquinoline bicycle.

We have recently found that pyridinium salts react with 4-methylpyridinium salts in the presence of methylammonium sulfite to form 4-arylpyridines[14,15] through a new transformation of the pyridine ring. It could be assumed that the sulfite or bisulfite ion adds to 2-alkylisoquinolinium salts and thus provides the intermolecular transformation of the isoquinoline ring involving the pyridinium salt containing the Me group in position 4. In fact, we synthesized 4-naphthylpyridine **3a** in 45—62% yields on heating of a mixture of 2-alkylisoquinolinium salts **1a—c** and 1-alkyl-4-methylpyridinium salts **2a—c** with methylammonium sulfite (Scheme 2).

The reaction discovered also occurs in the presence of dimethylammonium sulfite, for example, between com-

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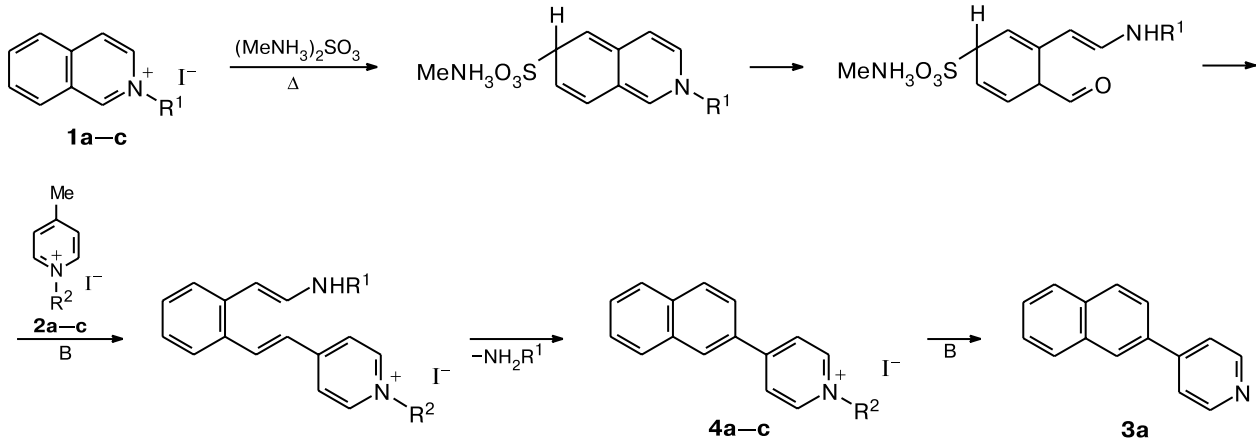
**Scheme 2**




B is base

**1:** $R^1$ = Me (**a**), Et (**b**), $Pr^i$ (**c**); **2:** $R^2$ = Me (**a**), Et (**b**), $Pr^i$ (**c**)

pounds **1a** and **2a**, although the yield of 4-naphthylpyridine **3a** is much lower in this case (9%).

As we have shown previously,[15,16] the behavior of the sulfite ion, which is a "soft" nucleophile, is rather unusual: it adds preferentially to the C(4) atom of the pyridinium salt, *i.e.*, 1,4-dihydropyridines are the primary products. Then they undergo solvolysis with ring opening followed by ring closure with elimination of the reagent and formation of a product of pyridine ring transformation. The ring transformation described in this work does not occur under conditions of easy pyridine ring opening in isoquinolinium salts.[4,12] This indicates that the reaction is likely nontraditional as well. It is known that position 6 of isoquinolinium salts is activated for nucleophilic substitution.[17–21] We believe that the sulfite ion, in our case, also adds to isoquinolinium salt **1a—c** at position 6, to form 2,6-dihydroisoquinoline as an intermediate. The violation of aromaticity of the isoquinoline bicycle facilitates its opening. The resulting non-cyclic intermediate, being treated with a base, is condensed with the active Me group of 4-methylpyridinium salt **2a—c**. The subsequent ring closure results in the formation of a naphthalene residue and, correspondingly, quaternary 4-naphthylpyridinium salt **4a—c**. 4-Naphthylpyridine **3a** is formed in the last step due to *N*-dealkylation.

The study of the influence of substituents on the efficiency of 4-naphthylpyridine formation makes it possible to elucidate some features of the reaction mechanism. The introduction of another alkyl group instead of methyl to the N atom of 4-methylpyridinium salt **2a—c** decreases noticeably the yield of 4-naphthylpyridine **3a** (Table 1). In the case of the second component **1a—c**, a similar dependence of the influence of the donor ability and the volume of the alkyl substituent at the N atom on the efficiency of the reaction is observed. In this case, a substituent at the N atom, which is more bulky than the Me group and characterized by a higher donor ability, hinders, most likely, nucleophile addition and pyridine ring opening, which impedes ring transformation. However, pyridine ring opening in isoquinolinium salts occurs easily, as a whole, and the non-cyclic intermediate that formed is highly reactive, because even the presence of two isopropyl *N*-substituents ($R^1 = R^2 = Pr^i$) does not decrease considerably the yield of 4-naphthylpyridine **3a** (45%).

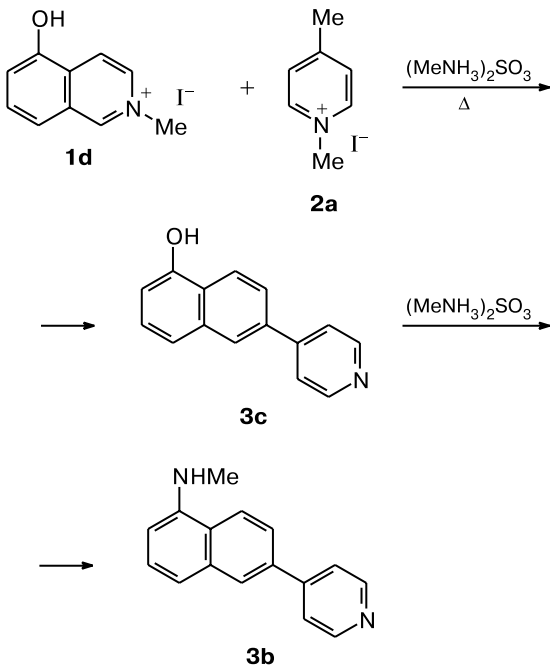
**Table 1.** Influence of substituents in isoquinolinium salts **1a—c** and 4-methylpyridinium salts **2a—c** on the formation of 4-naphthylpyridine **3a**

| **1** | $R^1$ | **2** | $R^2$ | Yield of **3a** (%) |
|---|---|---|---|---|
| **a** | Me | **a** | Me | 62 |
| **a** | Me | **b** | Et | 57 |
| **a** | Me | **c** | $Pr^i$ | 52 |
| **b** | Et | **a** | Me | 54 |
| **c** | $Pr^i$ | **a** | Me | 52 |
| **c** | $Pr^i$ | **c** | $Pr^i$ | 45 |

As should be expected according to the assumed reaction mechanism, the introduction of a donor group into the benzene ring of isoquinoline hinders or almost completely prevents the addition of the sulfite ion, which results in a considerable decrease in the yield or the entire absence of the target product. For instance, the reaction of 1,4-dimethylpyridinium iodide (**2a**) with 5-hydroxy-2-methylisoquinolinium iodide (**1d**) affords naphthylpyridine (**3b**) in 22% yield only (Scheme 3). The reaction likely proceeds in two steps. Hydroxy derivative **3c** appears in the first step. Its presence in a minor amount is confirmed by $^1$H NMR analysis of the reaction mixture.

In the second step, the hydroxy group is replaced by the methylamine group *via* the Bucherer reaction,[22,23] which is known to occur especially easily in the naphthalene series.

**Scheme 3**




This sequence of transformations is additionally confirmed by the fact that quaternary 5-aminoisoquinolinium salt does not react with **2a** under these conditions. The presence of two donor methoxy groups in positions 6 and 7 also completely blocks isoquinoline bicycle transformation.

It could be assumed that the final step of the process under study is the *N*-dealkylation of intermediate salt **4a—c** with formation of 4-naphthylpyridine **3a**. This possibility is indirectly confirmed by the $^1$H NMR detection of isoquinoline and 4-methylpyridine among the reaction products. They are formed in low yields likely due to the side *N*-dealkylation reaction of isoquinolinium salts **1a—c** and pyridinium salts **2a—c**. In addition, heating of 1-methyl-4-naphthylpyridinium iodide (**4a**) in the presence of methylammonium sulfite under the conditions of the studied reaction afforded 4-naphthylpyridine **3a** in 82% yield. It is known that *N*-alkylpyridinium salts on treatment with liquid ammonia, aqueous ammonia, or ammonium sulfite transform into pyridine base due to the exchange of the alkylamine residue by the amine residue in the intermediate non-cyclic structure.[7,24,25] When the reagent used contains no ammonia in the free state or as the ammonium cation, dealkylation can occur without ring opening.[16,26] In our case, the *N*-substituent is lost *via* the second route, *i.e.*, by the direct attack of the nucleophile to the R—N bond, because the reaction sphere contains no ammonia or ammonium ions (non-alkylated).

This method makes it possible to transform the ring of both 1-alkylisoquinolinium salts **1a—c** and isoquinoline itself. In fact, prolonged heating of isoquinoline and 4-methylpyridinium salt **2a** with an aqueous solution of methylammonium sulfite yields 4-naphthylpyridine **3a** in a yield up to 48%. A rather high yield of **3a** indicates that the pyridine ring of isoquinoline is activated to the nucleophilic reaction of this type to a much greater extent than non-annelated pyridine.[15]

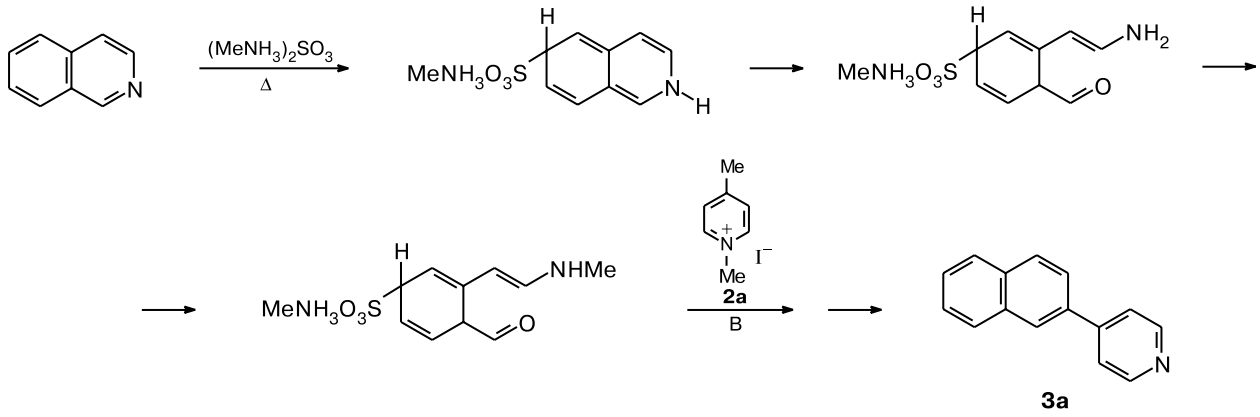
There are no published data on the ability of unsubstituted isoquinoline to participate in pyridine ring transformations. In the previous report, we described the transformation of the pyridine ring in the presence of methylammonium sulfite to form 4-phenylpyridine.[15] The driving force of this reaction is the exchange of the amine residue by methylamine in the intermediate non-cyclic structure. In our case, an analogous non-cyclic intermediate is also condensed, most likely, only with 4-methylpyridinium salt **2a** in the presence of bases followed by the formation of 4-naphthylpyridine **3a** (Scheme 4).

The structures of all synthesized compounds were established by $^1$H and $^{13}$C NMR spectroscopy, including 2D COSY and NOESY spectra, and confirmed by the data of mass spectrometry and elemental analysis.

Arylpyridines compose an important class of heterocyclic compounds, whose derivatives are used in the production of mesomorphic materials and as ligands, organic luminophores, and biologically active compounds.[27,28] The framework of naphthylpyridine integrated in more complicated biologically active compounds is described in patent literature.[29] Different variants of the Suzuki reaction, free-radical arylation, and regioselective addition of the Grignard reagents are presently proposed as the main approaches to syntheses of 4-arylpyridines. However, these methods are rather expensive and highly toxic, or their starting reagents are inaccessible.[30—33]

Thus, we discovered a new reaction of the simplest isoquinoline derivatives, which can be significant for the chemistry of isoquinoline. The reaction is based on the interaction of isoquinoline salts or isoquinoline itself with 4-methylpyridinium salts in the presence of alkylammonium sulfite. Simultaneously we found a simple and convenient method for the synthesis of 4-naphthylpyridine, which produces high-purity 4-naphthylpyridine in high yields from accessible substances (products and waste of by-product-coking industry). It should be emphasized that the previously found approach[15] is general for both pyridine derivatives and another most important heterocyclic system, *viz.*, isoquinoline.

**Scheme 4**




B is base

## Experimental

$^1$H and $^{13}$C spectra were recorded on a Bruker DRX-500 spectrometer (500.13 and 125.76 MHz, respectively) in $CDCl_3$ and DMSO-$d_6$ using $Me_4Si$ as an internal standard. For signal assignment, homonuclear 2D $^1$H—$^1$H COSY and NOESY spectra and heteronuclear $^1$H—$^{13}$C COSY spectra (HSQC and HMBC) were used. Chemical shifts were measured with an accuracy of 0.01 ppm, and spin-spin coupling constants were measured with an accuracy of 0.01 Hz. IR spectra were recorded on a Bruker IFS-113V spectrophotometer in KBr. Mass spectra were obtained on a Finnigan MAT 8430 instrument at an ionization energy of 70 eV with direct injection of samples. The reactions were monitored by TLC on DC-Alufolien Kieselgel 60 $F_{254}$ plates (Merck). Column chromatography was carried out using Kieselgel 60 silica gel (0.063—0.100 mm, Merck). 1-Ethyl-4-methylpyridinium iodide (**2b**) and 1-isopropyl-4-methylpyridinium iodide (**2c**) were synthesized according to previously described procedures.[15,34] 2-Methylisoquinolinium iodide (**2a**) and 2-isopropylisoquinolinium iodide (**2c**) were synthesized according to a general procedure.[35,36]

**2-Ethylisoquinolinium iodide (2b).** Isoquinoline (2.35 mL, 20 mmol) was added to EtI (2.4 mL, 30 mmol). The reaction mixture was stored at ~20 °C for 20 days. The precipitate that formed was filtered off, successively washed with benzene and pentane, and dried *in vacuo*. The yield was 1.56 g (91%), m.p. 149—150 °C. Found (%): C, 46.11; H, 4.19; N, 4.91. $C_{11}H_{12}IN$. Calculated (%): C, 46.34; H, 4.24; N, 4.91. $^1$H NMR (DMSO-$d_6$), δ: 1.64 (t, 3 H, Me, $J$ = 7.3 Hz); 4.75 (q, 2 H, $NCH_2$, $J$ = 7.3 Hz); 8.07 and 8.25 (both m, 2 H, H(6), H(7)); 8.35 and 8.48 (both d, 2 H, H(8), H(5), $J$ = 8.2 Hz, $J$ = 8.3 Hz); 8.59 (d, 1 H, H(4), $J$ = 6.7 Hz); 8.81 (d, 1 H, H(3), $J$ = 6.7 Hz); 10.10 (s, 1 H, H(1)).

**5-Hydroxy-2-methylisoquinolinium iodide (1d).** 5-Hydroxyisoquinoline (0.51 g, 3.5 mmol) and MeI (0.4 mL, 7 mmol) were added to MeOH (20 mL). The reaction mixture was stored for 8 days. The precipitate that formed was filtered off, successively washed with cold MeOH and benzene, and dried *in vacuo*. The yield was 1.01 g (100%), m.p. 240—241 °C. Found (%): C, 41.98; H, 3.44; N, 4.71. $C_{10}H_{10}INO$. Calculated (%): C, 41.83; H, 3.51; N, 4.88. $^1$H NMR (DMSO-$d_6$), δ: 4.45 (s, 3 H, NMe); 7.51 and 7.88 (both m, 3 H, H(6), H(7), H(8)); 8.51 (d, 1 H, H(4), $J$ = 6.7 Hz); 8.58 (d, 1 H, H(3), $J$ = 6.7 Hz); 9.90 (s, 1 H, H(1)); 11.47 (br.s, 1 H, OH).

**1-Methyl-4-(2-naphthyl)pyridinium iodide (4a).** 4-(2-Naphthyl)pyridine **3a** (60 mg, 0.3 mmol) and MeI (0.036 mL, 0.6 mmol) were added to benzene (5 mL). The reaction mixture was heated for 1 h in a sealed ampule in a water bath at 40 °C and then left for 3 days at ~20 °C. After the ampule was opened, the precipitate that formed was filtered off and successively washed with benzene and pentane. The yield was 90 mg (88%), m.p. 215—216 °C. Found (%): C, 54.91; H, 4.04; N, 3.89. $C_{16}H_{14}IN$. Calculated (%): C, 55.35; H, 4.06; N, 4.03. $^1$H NMR ($CDCl_3$), δ: 4.67 (s, 3 H, NMe); 7.61 (m, 2 H, H(6), H(7)); 7.79 (d, 1 H, H(3), $J$ = 7.4 Hz); 7.88 (d, 1 H, H(4), $J$ = 7.4 Hz); 7.99 (m, 2 H, H(5), H(8)); 8.35 (m, 3 H, H(1), H(3′), H(5′)); 9.25 (m, 2 H, H(2′), H(6′)).

**4-(2-Naphthyl)pyridine (3a).** ***A.*** A 40% aqueous solution of $MeNH_2$ (5.4 mL) and a 68% solution of $MeNH_3HSO_3$ (2.6 mL) were added to a mixture of 2-alkylisoquinolinium salt **1a—c** (2 mmol) and 1-alkyl-4-methylpyridinium salt **2a—c** (2 mmol) dissolved in water (0.2 mL). The mixture was heated for 40 h in a sealed ampule placed in a metallic autoclave in a bath filled with silicon oil at 190 °C. After the ampule was opened, the content was diluted with water and extracted with benzene. The extract was dried with $MgSO_4$ and concentrated. The resulting 4-naphthylpyridine **3a** was separated from isoquinoline and 4-methylpyridine by column chromatography on $SiO_2$ using benzene and then a benzene—AcOEt (1 : 1) mixture as eluents. The yield was 185—255 mg (45—62%), m.p. 104—105 °C. Found (%): C, 87.96; H, 5.31; N, 6.65. $C_{15}H_{11}N$. Calculated (%): C, 87.77; H, 5.40; N, 6.82. $^1$H NMR ($CDCl_3$), δ: 7.55 (m, 2 H, H(6), H(7)); 7.63 (m, 2 H, H(3′), H(5′)); 7.75 (dd, 1 H, H(3), $J$ = 8.5 Hz, $J$ = 1.7 Hz); 7.89 and 7.93 (both m, 2 H, H(5), H(8)); 7.96 (d, 1 H, H(4), $J$ = 8.5 Hz); 8.12 (s, 1 H, H(1)); 8.71 (m, 2 H, H(2′), H(6′)). $^{13}$C NMR ($CDCl_3$), δ: 121.76 (dd, C(3′), C(5′), $J$ = 161.7 Hz, $J$ = 6.7 Hz); 124.46 (dd, C(3), $J$ = 158.6 Hz, $J$ = 7.0 Hz); 126.37 (d, C(1), $J$ = 157.5 Hz); 126.65 and 126.78 (both dd, C(6), C(7), $J$ = 160.0 Hz, $J$ = 8.4 Hz, $J$ = 160.2 Hz, $J$ = 8.6 Hz); 127.67 and 128.39 (both d, C(5), C(8), $J$ = 160.0 Hz); 128.89 (dd, C(4), $J$ = 159.0 Hz);

133.37 and 133.40 (both m, C(4a), C(8a)); 135.32 (m, C(2)); 148.17 (m, C(4′)); 150.28 (dd, C(2′), C(6′), $J$ = 177.8 Hz, $J$ = 11.4 Hz). MS, $m/z$ ($I_{rel}$ (%)): 205 $[M]^+$ (100), 204 (41), 177 (11), 176 (15), 152 (11), 151 (12), 88 (11), 76 (24), 75 (10), 58 (11).

***B.*** A 40% aqueous solution of $MeNH_2$ (5.4 mL) and a 68% solution of $MeNH_3HSO_3$ (2.6 mL) were added to 1-methyl-4-(2-naphthyl)pyridinium iodide (**4a**) (87 mg, 0.25 mmol) dissolved in water (0.2 mL). The reaction was carried out similarly to method *A*. The yield was 40 mg (82%).

***C.*** Compound **3a** was synthesized from isoquinoline and 1,4-dimethylpyridinium iodide **2a** similarly to method *A*. The mixture was heated for 240 h. 4-Naphthylpyridine **3a** was isolated according to method *A*. The yield was 197 mg (48%).

***N*-Methyl-*N*-[6-(4-pyridyl)-1-naphthyl]amine (3b)** was synthesized similarly to compound **3a** (method *A*) from 5-hydroxy-2-methylisoquinolinium iodide **1d** and 1,4-dimethylpyridinium iodide **2a** and purified by column chromatography on $SiO_2$, eluting with benzene and then with a benzene—AcOEt (up to 100% of the latter) mixture. The yield was 103 mg (22%), m.p. 167—168 °C. Found (%): C, 81.98; H, 6.00; N, 11.75. $C_{16}H_{14}N_2$. Calculated (%): C, 82.02; H, 6.02; N, 11.96. $^1$H NMR ($CDCl_3$), δ: 3.07 (s, 1 H, NMe); 6.67 (d, 1 H, H(2), $J$ = 7.5 Hz); 7.33 (d, 1 H, H(4), $J$ = 8.1 Hz); 7.45 (m, 1 H, H(3)); 7.67 (m, 2 H, H(3′), H(5′)); 7.71 (dd, 1 H, H(7), $J$ = 8.7 Hz, $J$ = 1.6 Hz); 7.92 (d, H(8), $J$ = 8.7 Hz); 8.09 (d, 1 H, H(5), $J$ = 1.6 Hz); 8.71 (m, 2 H, H(2′), H(6′)). $^{13}$C NMR ($CDCl_3$), δ: 104.75 (C(3′), C(5′)); 117.70 (C(3)); 121.09 (C(1)); 121.82 (C(6), C(7)); 123.07, 127.21 and 127.69 (C(5), C(8), C(4)); 149.98 (C(2′), C(6′)). IR (KBr), ν/cm$^{-1}$: 3431 (N—H). MS, $m/z$ ($I_{rel}$ (%)): 234 $[M]^+$ (100), 233 (64), 232 (21), 206 (21), 205 (21), 204 (15), 192 (40), 191 (12), 117 (24), 58 (22).

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## References


1. H. C. van der Plas, *Ring Transformations of Heterocycles*, Academic Press, London, New York, 1973, **1—2**.
2. A. N. Kost, S. P. Gromov, and R. S. Sagitullin, *Tetrahedron*, 1981, **37**, 3423.
3. S. P. Gromov and A. N. Kost, *Heterocycles*, 1994, **38**, 1127.
4. S. P. Gromov, *Heterocycles*, 2000, **53**, 1607.
5. J. W. Bunting and W. G. Meathrel, *Can. J. Chem.*, 1972, **50**, 917.
6. J. A. Zoltewicz and J. K. O´Holloran, *J. Am. Chem. Soc.*, 1975, **97**, 5531.
7. J. A. Zoltewicz, Z. S. Helmick, and J. K. O´Holloran, *J. Org. Chem.*, 1976, **41**, 1308.
8. Th. Zincke and G. Weisspfenning, *Ann.*, 1913, **396**, 103.
9. J. Tamura and N. Tsujimoto, *Chem. Ind.*, 1972, 926.
10. S. P. Gromov and M. A. Razinkin, *Izv. Akad. Nauk, Ser. Khim.*, 1994, 549 [*Russ. Chem. Bull.*, 1994, **43**, 508 (Engl. Transl.)].
11. S. P. Gromov, M. A. Razinkin, V. S. Drach, and S. A. Sergeev, *Izv. Akad. Nauk, Ser. Khim.*, 1998, 1210 [*Russ. Chem. Bull.*, 1998, **47**, 1179 (Engl. Transl.)].
12. A. N. Kost, L. G. Yudin, R. S. Sagitullin, V. I. Terenin, and A. A. Ivkina, *Khim. Geterotsikl. Soedin.*, 1979, 1386 [*Chem. Heterocycl. Compd.*, 1979 (Engl. Transl.)].
13. A. N. Kost, V. I. Terenin, L. G. Yudin, and R. S. Sagitullin, *Khim. Geterotsikl. Soedin.*, 1980, 1272 [*Chem. Heterocycl. Compd.*, 1980 (Engl. Transl.)].
14. Pat. RF 2150466, 2000; *Byul. Izobret.* [*Invention Bulletin*], 2000, 16 (in Russian).
15. S. P. Gromov and N. A. Kurchavov, *Izv. Akad. Nauk, Ser. Khim.*, 2003, 1522 [*Russ. Chem. Bull., Int. Ed.*, 2003, **52**, 1606].
16. R. S. Sagitullin, S. P. Gromov, and A. N. Kost, *Dokl. Akad. Nauk SSSR*, 1978, **243**, 937 [*Dokl. Chem.*, 1978, **243**, 573 (Engl. Transl.)].
17. S. Naruto, H. Mizuta, I. Nakano, and H. Nishimura, *Tetrahedron Lett.*, 1976, 1595.
18. S. Naruto, H. Mizuta, and H. Nishimura, *Tetrahedron Lett.*, 1976, 1597.
19. D. Beaumont and R. D. Waigh, *Chem. Ind.*, 1978, 808.
20. D. Beaumont and R. D. Waigh, *Chem. Ind.*, 1980, 291.
21. V. I. Terenin, L. G. Yudin, R. S. Sagitullin, V. N. Torocheshnikov, V. I. Dulenko, Yu. A. Nikolyukin, and A. N. Kost, *Khim. Geterotsikl. Soedin.*, 1983, 73 [*Chem. Heterocycl. Compd.*, 1983 (Engl. Transl.)].
22. N. L. Drake, *Org. React.*, 1942, **1**, 105.
23. H. Seeboth, *Angew. Chem.*, 1967, **79**, 329.
24. R. S. Sagitullin, S. P. Gromov, and A. N. Kost, *Tetrahedron*, 1978, **34**, 2213.
25. R. Lukeš and J. Jizba, *Chem. Listy*, 1958, **52**, 1131.
26. A. R. Katritzky, *Tetrahedron*, 1980, **36**, 679.
27. S. P. Stanforth, *Tetrahedron*, 1998, **54**, 263.
28. S. G. Speciale, C. L. Liang, P. K. Sonsalla, R. H. Edwards, and D. C. German, *Neuroscience*, 1998, **84**, 1177.
29. US Pat. 6,313,152, 2001; *Chem. Abstrs*, 2000, **133**, 223044h.
30. I. Fenger and C. Le Drian, *Tetrahedron Lett.*, 1998, **39**, 4287.
31. O. Lohse, P. Theverin, and E. Waldvogel, *Synlett*, 1999, 45.
32. V. Martinez-Barrasa, A. García de Viedma, C. Burgos, and J. Alvarez-Builla, *Org. Lett.*, 2000, **2**, 3933.
33. A. R. Katritzky, H. Beltrami, and M. P. Sammes, *J. Chem. Soc., Perkin Trans. 1*, 1980, 2480.
34. M. Katcka and T. Urbanski, *Bull. Acad. Pol. Sci., Ser. Sci. Chem.*, 1967, **15**, 413.
35. E. Shlitter and J. Muler, *Helv. Chim. Acta*, 1948, **31**, 914.
36. W. Bradley and S. Jeffrey, *J. Chem. Soc.*, 1954, 2770.


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