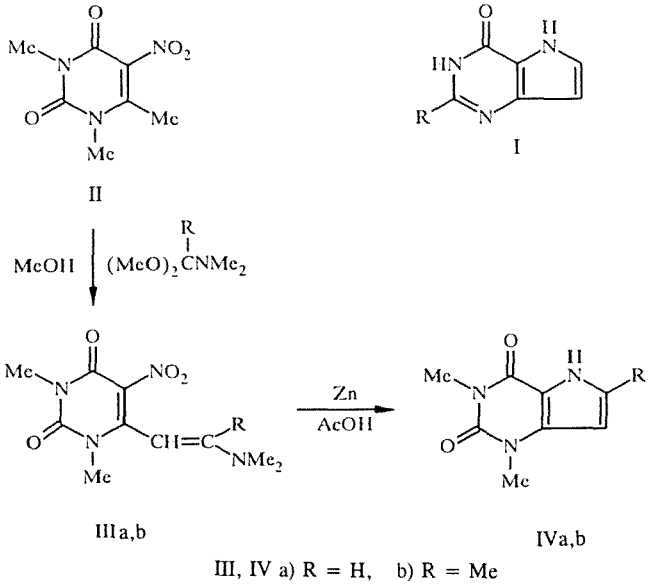
Chemistry of Heterocyclic Compounds, Vol. 30, No. 9, 1994

PYRROLOPYRIMIDINES. 1.* ELECTROPHILIC SUBSTITUTION REACTIONS OF 1,3-DIMETHYLPYRROLO[3,2-d]PYRIMIDINE-2,4-DIONE

E. B. Tsupak, Yu. N. Tkachenko, and A. F. Pozharskii

The reactions of halogenation, aminomethylation, acylation, and azo coupling in 1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione proceed at position 7, whereas nitration in acetic acid is directed primarily to position 6. In a number of cases, products of substitution of both hydrogen atoms in the pyrrole ring have been synthesized.

Even though there have been numerous reports of high biological activity of various derivatives of pyrrolo[3,2-d]pyrimidine [2, 3], less information is available on the reactivities of these compounds, particularly in electrophilic substitution reactions. For example, it is known that derivatives of pyrrolo[3,2-d]pyrimidin-4-one (I) undergo bromination [4-6], nitration [7], and aminomethylation [8-11] at position 7. However, for the more accessible pyrrolo[3,2-d]pyrimidine-2,4-diones, which should be regarded as very promising from the pharmacological standpoint (in view of the presence of the uracil ring), no such studies have been reported, so far as we can determine. With the aim of filling in this information gap, in the present work we have investigated the direction taken by electrophilic substitution reactions in 1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (IVa). It was of interest to determine whether this compound, the same as compound I, would be similar to indole in that the substitution would take place exclusively in the β-position of the pyrrole ring, or whether its behavior would be more like that of pyrrole, for which reactions with electrophiles are known to take place primarily at the α-position.



III, IV a) R = H, b) R = Me

*Communication 11 from series "Purines, pyrimidines, and condensed systems based on these compounds." For Communication 10, see [1].

Rostov State University, Rostov-na-Donu 344104. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 9, pp. 1242-1248, September, 1994. Original article submitted September 6, 1994.

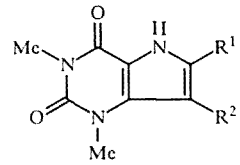
0009-3122/94/3009-1077$12.50

TABLE 1. Effective Charge q and Electrophilic Localization Energy L^+ in Molecule IVa*

Atom	q^{π} (HMO)	$q^{\sigma+\pi}$ (MNDO)	$L^+(\beta)$ (HMO)
$C_{(6)}$	+0,082	+0,047	2,14
$C_{(7)}$	-0,122	-0,173	2,27

*The N-methyl groups were not taken into account in the calculation.

TABLE 2. Parameters of PMR Spectra of Compounds in DMSO-d_6



Compound	R^1	R^2	Chemical shifts, δ, ppm (and SSCC, J, Hz)				
			R^1	R^2	NH, br.s	N_3—Me s	$N_{(1)}$Me s
IVa	H	H	7,21 dd, $J_{NH,6-H}$ = $J_{6-H,7-H}$ = 2,9	6,14 dd, $J_{NH,7-H}$ = $J_{7-H,6-H}$ = 2,9	11,96	3,38	3,24
IVb	Me	H	2,26 s	5,88 d, $J_{NH,7-H}$ = 2	11,71	3,33	3,22
Va	D	D	7,25 (0,96H) dd, $J_{NH,6-H}$ = $J_{6-H,7-H}$ = 2,1	6,175 (0,14H) dd, $J_{NH,7-H}$ = $J_{7-H,6-H}$ = 1,35	12,09 (0,18H)	3,38	3,22
Vb	H	Br	7,37 s	—	12,47	3,66	3,24
Vc	H	I	7,33 s	—	12,43	3,70	3,24
Vd	H	CHO	8,00 s	9,80 s	13,01	3,75	3,26
Ve	H	CH_3CO	8,05 s	2,47 s	12,75	3,63	3,25
Vf	H	CH_2NMe_2	7,13 s	2,08 s (NMe_2), 3,29 s (CH_2)	11,93	3,69	3,23
Vg	H	$C_6H_5N{=}N$	7,54 s	7,81 s (H_{ortho}), 7,57 m (H_{meta} + H_{para})	13,20	3,81	3,32
Vh	H	NO_2	8,37 s	—	*	*	*
VIb	Br	Br	—	—	13,44	3,65	3,23
VIh	NO_2	NO_2	—	—	(NH_4^+) 7,175 t J = 48,7	3,51	3,41
VIi	Cl	Cl	—	—	13,48	3,61	3,23
VII	NO_2	H	—	7,18 s	12,86	3,41	3,27

*No assignment was made.

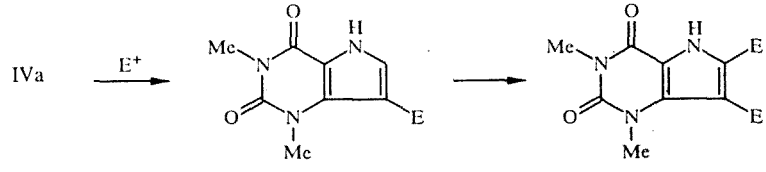
Compound IVa was obtained in two stages, starting with 1,3,6-trimethyl-5-nitrouracil and the dimethylacetal of dimethylformamide. We slightly simplified the first stage, which leads to the formation of the enamine IIIa, by replacing the straight dimethylacetal of dimethylformamide [11] or the previously proposed complex dimethylsulfate–dimethylformamide in the presence of triethylamine [12] by a methanol solution of the acetal. This approach also gives better results in the synthesis of the enamine IIIb, in which we used the dimethylacetal of acetamide.

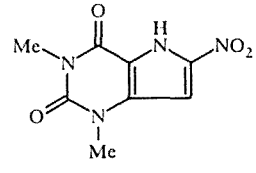
In the PMR spectrum of compound IVa, signals of the 6-H and 7-H protons are manifested at 7.21 and 6.14 ppm (Table 2). The upfield signal can be assigned unambiguously to the 7-H proton, since in the spectrum of compound IVb, in which the 7-H proton is replaced by a methyl group, the sole signal of the aromatic proton 7-H is located at 5.88 ppm, and the slight additional screening of this proton is characteristic for the donor effect of the ortho-methyl group. Attention is

directed to the large difference (> 1.0 ppm) between the chemical shifts of the 6-H and 7-H protons, much greater than the analogous difference for the 2-H and 3-H protons in pyrrole ($\Delta\delta$ = 0.46 ppm) or in indole ($\Delta\delta$ = 0.23 ppm) [13]. This is almost entirely due to the downfield shift of the signal of the 6-H proton, whereas the chemical shifts of the β-protons in the molecules of IVa, pyrrole, and indole are very little different from each other (6.14, 6.22, and 6.29 ppm, respectively). The source of this phenomenon is completely obvious: position 6 in the molecule of IVa is conjugated with the $C_{(4)}$=O group, which leads to a lowering of the π-electron density on this position. In good agreement with these conclusions are the results obtained in quantum-chemical calculations of the molecule of IVa, both by the simple Hückel method (HMO) and by the MNDO method (Table 1). These calculations indicate a high π-excess of position 7 and, in contrast, a small positive charge on position 6. On the basis of these data, we can assume that electrophilic substitution reactions in compound IVa should take place primarily at the β-carbon atom of the pyrrole ring. However, the magnitudes of the electrophilic localization energy are somewhat contradictory to this assumption, indicating preferential substitution at the α-carbon atom of the pyrrole ring. It is known that the same sort of contradiction exists for the pyrrole molecule [14]. Such a situation usually indicates that under conditions of kinetic control, the reaction will take place at the atom with the highest electron density, whereas with thermodynamic control, product formation is possible at the particular position corresponding to the lowest value of the localization energy.

The first reaction that we studied was acid deuterium exchange. We found that after 10-min heating of compound IVa at 60°C in deuterotrifluoroacetic acid, the 7-H proton is 87% replaced, whereas the 6-H proton is no more than 4.5% replaced. On this basis we can conclude that the ratio of activities of positions 7 and 6 under these conditions is approximately 20:1.

As would be expected, most of the other electrophilic substitution reactions that we investigated also took place at position 7. Among these are the Vilsmeier formylation reaction, acylation with acetic anhydride in the presence of boron trifluoride etherate, aminomethylation, azo coupling, iodination with iodine in the presence of potassium iodide and sodium bicarbonate, and bromination in acetic acid. As a result of these conversions, we obtained compounds Vb-g with yields of 58-86%. We established that subsequent replacement of the hydrogen in position 6 is also possible. Thus, in the room-temperature action of excess bromine or chlorine in acetic acid on compound IVa, we obtained the 6,7-dihalo derivatives VIb, i. Interestingly, dichlorination is observed even when using only one equivalent of chlorine. It is known that the same sort of phenomenon is encountered in the pyrrole and imidazole series [15]. The disubstitution is explained on the basis that the implantation of the first atom of chlorine increases the NH-acidity of the substrate so that the second substitution can proceed through an equilibrium concentration of the N-anion, which strongly accelerates the reaction in comparison with substitution in the neutral molecule.





VII

E = D(a), Br (b), I (c), CHO (d), MeCO (e), CH_2NMe_2 (f), Ph–N=N (g), NO_2 (h), Cl (i)

The nitration of compound IVa, the same as in the case of pyrroles [16], is less clear-cut. As a result of the room-temperature action of excess nitric acid (d 1.42) in acetic acid on compound IVa, we unexpectedly recovered only the 6-nitro derivative VII, in a 44% yield. The action of one equivalent of nitric acid (d 1.41) on compound IVa at 95°C for a period of 10 min, judging from NMR data, produces a mixture containing about 10% of the 7-nitro isomer Vh along with the 6-nitro isomer, and also a considerable quantity of unidentified compounds giving singlets at δ 5.5 and 6.2 ppm. These unidentified

compounds are presumably products from the addition of nitric acid at the double bond of the pyrrole ring. In view of the complexity and ambiguity of nitration processes, we will deal with this problem in a separate communication. In the nitration of compound IVa with a nitrating mixture containing 2 moles of nitric acid (d 1.42), the main product is the 6,7-dinitro derivative VIh, which we recovered with a yield of 50%.

The structures of all of the synthesized compounds were confirmed unambiguously by the PMR spectra (Table 2). Characteristic for compounds Vb-h is the disappearance of the signal of the 7-H proton in the strong field and a downfield shift of the signal of the 6-H proton by an amount that is characteristic for the descreening effect of the corresponding constituents in five-membered heterocycles [17]. In the case of compound VII, the only singlet in the aromatic region is located at 7.18 ppm. This is the natural shift for the signal of the 7-H proton (1 ppm) under the influence of the ortho-nitro group. It cannot be assigned to a signal of the 6-H proton, since this would mean that the signal, in comparison with the original compound, would not undergo any such shift under the influence of as strong an electron acceptor as the NO_2 group. The signal of the 6-H proton in the unisolated isomer Vh is manifested at 8.4 ppm.

Thus, our study has shown that, in respect to reactivity with electrophiles, the 1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione behaves more like indole than like pyrrole. However, the nitration reaction displays a certain similarity to that of pyrrole — a matter that merits a more detailed study.

EXPERIMENTAL

The IR spectra were obtained in IKS-40 and Specord IR-75 spectrometers on suspensions of the substances in white mineral oil. The PMR spectra were measured in a Bruker WH-90/DS spectrometer at 90 MHz (for compounds Vb-g and VIb,h,i) or in a Varian UNITY 300 spectrometer at 300 MHz (for compounds Va,h,f and VII), in DMSO-d_6 solvent with TMS internal standard. The course of the reaction and the individuality of the compounds obtained were monitored by TLC on Silufol UV-254 plates and on Al_2O_3 (degree III activity) in a 30:1 chloroform:ethanol system, with development by iodine vapor.

Elemental analyses of the compounds obtained for contents of C, H, Br, Cl, and I matched the corresponding calculated data.

6-(2-Dimethylaminovinyl)-1,3-dimethyl-5-nitrouracil (IIIa). To 19.9 g (0.1 mole) of a dimethylsulfate–dimethylformamide complex [18], over the course of 1 min, a solution of sodium methylate was added, this solution having been prepared from 2.3 g (0.1 mole) of sodium and 22 ml of absolute methanol. The methanol solution of dimethylformamide acetal was redistilled at 110°C. The distillate, consisting of a mixture of methanol and dimethylformamide dimethylacetal, containing 11.9 g of the acetal (0.1 mole), was refluxed for 4 h with 6.2 g (31 mmoles) of 1,3,6-trimethyl-5-nitrouracil (II) [12]. The methanol and the excess dimethylformamide acetal were driven off by heating on a water bath. The red crystals of compound IIIa were washed with cold methanol and dried. Yield 6.4 g (81%); mp 185°C, in agreement with literature data [12].

1,3-Dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (IVa). To a solution of 3.36 g (13.2 mmoles) of compound IIIa in 27 ml of acetic acid, heated to 60°C, 15 g (0.23 mole) of zinc dust was added. After adding all of the zinc dust, the mixture was refluxed for 5-10 min until it was completely decolorized. After cooling the mixture, the zinc salts and the unreacted zinc were filtered off and washed with a small quantity of acetic acid. The filtrate was diluted with three volumes of water and extracted with chloroform (4 × 20 ml). The combined chloroform extracts were reextracted twice with an equal volume of water and then with a saturated solution of $NaHCO_3$ until neutralized, then dried with Na_2SO_4. The chloroform was evaporated to dryness, and the residue was recrystallized from 4% acetic acid. Yield 1.55 g (65.5%); mp 210°C, literature mp 210°C [12].

1,3,6-Trimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (IVb). A mixture of 30 ml of a methanol solution of the dimethylacetamide dimethylacetal (13.3 g, 0.1 mole), obtained by analogy with the solution of dimethylformamide acetal from a dimethylsulfate–dimethylacetamide complex (the complex was prepared in the same manner as the dimethylsulfate–dimethylformamide complex), and 6.2 g (31 mmoles) of compound II was refluxed for 6 h. The methanol was driven off; the residue, containing 6-(2-dimethylamino-2-methylvinyl)-1,3-dimethyl-5-nitrouracil (IIIb), was dissolved in 70 ml of acetic acid and heated to 50°C. Then zinc dust (35.3 g, 0.54 mole) was added to the solution in small portions, after which the reaction mass was refluxed 5 min and immediately cooled; the zinc salt was filtered off and washed with acetic acid. The filtrate was diluted with three volumes of water and extracted with chloroform (5 × 20 ml). The chloroform extracts were shaken with

water, neutralized with Na_2CO_3 solution, and dried. The chloroform was driven off, and the residue was recrystallized from water. Yield 1.6 g (27%); mp 262°C, literature mp 262°C [19].

Deuteration of 1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (IVa). To 50 mg of compound IVa, 1 ml of deuterotrifluoroacetic acid was added, and the mixture was held for 10 min at 60°C. After evaporating the solvent, the residue was dissolved in DMSO-d_6, and the PMR spectrum was registered.

7-Bromo-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (IVb). To a solution of 0.5 g (2.8 mmoles) of compound IVa in 5 ml of acetic acid, 0.43 g (2.7 mmoles) of bromine in 5 ml of acetic acid was added dropwise with stirring, after which 1.2 ml of water was added. The reaction mixture was stirred for another 20 min and diluted with two volumes of cold water. After 3 h, the precipitate was filtered off and recrystallized from 2-propanol. Yield 0.42 g (68%); colorless prisms, mp 259-260°C (decomp.). IR spectrum, cm^{-1}: 3167 (NH); 1680, 1660 (C=O).

7-Iodo-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (Vc). To a solution of 0.5 g (2.8 mmoles) of compound IVa and 2.0 g of sodium bicarbonate in 80 ml of water, a solution of 0.7 g (2.8 mmoles) of iodine and 2.0 g of potassium iodide in 15 ml of water was added dropwise. The reagent was added at such a rate that the blue color had time to disappear before introducing the next portion of reagent. The light-yellow crystals of Vc were filtered off and recrystallized from 2-propanol. Yield 0.54 g (64%); mp 236-239°C (decomp.). IR spectrum, cm^{-1}: 3140 (NH); 1680, 1650 (C=O).

7-Formyl-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (Vd). At a temperature of 5-10°C, 0.91 g (16.6 mmoles) of phosphorus oxychloride was mixed with 1.04 g (16.6 mmoles) of dimethylformamide; then a solution of 0.5 g (2.8 mmoles) of compound IVa in 2 ml of dimethylformamide was added while stirring. The reaction mixture was held for 2 h at 95°C, cooled, and poured onto 20 g of ice. The precipitate of Vd was filtered off and recrystallized from water. Yield 0.5 g (86%); light-yellow needles with mp 298°C. IR spectrum, cm^{-1}: 3151 (NH); 1680, 1643, 1631 (C=O).

7-Acetyl-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (Ve). To a solution of 0.2 g (1.125 mmoles) of compound IVa in 10 ml of dry acetonitrile, at 50°C, 0.43 g (3 mmoles) of boron trifluoride etherate and 0.13 g (1.12 mmoles) of acetic anhydride were added dropwise, after which the mixture was refluxed for 2 h. Then 1 ml of water was added, and the reaction mixture was cooled. The precipitated crystals of Ve were filtered off, washed with water, and dried. Yield 0.15 g (65%); pale yellow needles (from water), mp 268-270°C. IR spectrum, cm^{-1}: 3186 (NH); 1685, 1656, 1647 (C=O).

7-Dimethylaminomethyl-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (IVf). To a mixture of 0.4 ml (5 mmoles) of 50% dimethylamine, 0.4 ml of acetic acid and 0.4 ml (5 mmoles) of 38% formaldehyde were added, after which 0.44 g (2.46 mmoles) of compound IVa was added. The reaction mixture was refluxed for 10 min, then held for 20 min at 90°C, followed by cooling and dilution with three volumes of water and filtration. After driving off the chloroform and crystallizing from acetonitrile, obtained 0.42 g (58%) of compound Vf in the form of colorless prisms, mp 218-220°C. Yield 0.42 g (58%). IR spectrum, cm^{-1}: 3190 (NH); 1693, 1643 (C=O).

7-Phenylazo-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (Vg). To a suspension of 0.5 g (2.8 mmoles) of compound IVa in 20 ml of water containing 0.22 g (5.5 mmoles) of NaOH, after cooling to 5°C, a solution of phenyldiazonium chloride was added while mixing, this solution having been prepared from 0.26 g (2.8 mmoles) of aniline, 0.72 ml (8.2 mmoles) of concentrated hydrochloric acid, 0.19 g (2.8 mmoles) of sodium nitrite, and 9 ml of water. The mixture was stirred for 1 h, after which the precipitate was filtered off, dried, and chromatographed in a column with aluminum oxide (Brockman activity IV, chloroform eluent), collecting the fraction with R_f 0.08. Obtained 0.47 g (59%) of compound Vg in the form of brown crystals; mp 240-243°C. IR spectrum, cm^{-1}: 3114 (NH), 1689, 1654 (C=O).

6,7-Dichloro-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (VIi). To a solution of 0.5 g (2.8 mmoles) of compound IVa in 5 ml of acetic acid, a freshly prepared solution of 0.6 g (8.5 mmoles) of chlorine in 7.5 ml of acetic acid was added while stirring. The reaction mixture was stirred for another 30 min at room temperature, then heated to 90°C and cooled. The precipitated crystals of compound VIi were filtered off, washed with water, and dried. After crystallization from acetic acid, obtained 0.48 g (69%); mp 305-307°C. IR spectrum, cm^{-1}: 3130 (NH); 1700, 1650 (C=O).

Chlorination of IVa with Equimolar Quantity of Chlorine. Upon the interaction of 1 g (5.6 mmoles) of compound IVa in the form of a saturated solution in acetic acid with 2 ml of an acetic acid solution of chlorine (0.39 g, 5.5 mmoles) at 5-10°C with mixing for 30 min followed by dilution of the solution with two volumes of water, 0.42 g of precipitate was formed, containing (according to TLC data) the dichloro derivative VIi and also at least one more compound that is probably a monochloro derivative.

6,7-Dibromo-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (VIb). To a solution of 0.5 g (2.8 mmoles) of compound IVa in 5 ml of acetic acid, with vigorous stirring, a solution of 1.3 g (8.4 mmoles) of bromine in 5 ml of acetic acid was introduced as a single dose. The reaction mixture was stirred for 20 min and then diluted with water. The greenish

yellow precipitate was filtered off, washed with water, and suspended in 10 ml of 2 N NaOH solution. After 15 min it was neutralized with acetic acid, and the precipitate of VIb was filtered off, washed with water, dried, and recrystallized from acetic acid (colorless needles). Yield 0.45 g (50%); mp 279-280°C (decomp.). IR spectrum, cm^{-1}: 3107 (NH); 1700, 1660 (C=O).

6-Nitro-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (VII). To a solution of 0.36 g (2.01 mmoles) of compound IVa in 5 ml of acetic acid, 1.5 ml (24 mmoles) of nitric acid (d 1.42) was added dropwise over the course of 10 min while stirring; then 10 ml of water was added and the stirring was continued another 10 min. The precipitated compound was filtered off, washed with water, and dried. Yield 0.2 g (44%); yellow needles with mp 310°C (ethanol). IR spectrum, cm^{-1}: 3118 (NH); 1706.5, 1655 (C=O).

6,7-Dinitro-1,3-dimethylpyrrolo[3,2-d]pyrimidine-2,4-dione (Ammonium Salt) (VIh). To a solution of 0.89 g (4.97 mmoles) of compound IVa in 7 ml of concentrated H_2SO_4 chilled to 5°C, a mixture of 2 ml of concentrated H_2SO_4 and 0.7 ml (11 mmoles) of nitric acid (d 1.42) was added dropwise with stirring. Then the mixture was stirred for another 1.5 h and poured onto 20 g of ice. The precipitate was filtered off and washed on the filter with 1.5 ml of concentrated ammonia; the resulting ammonium salt was recrystallized from water (yellow needles). Yield 0.7 g (49%); mp 156-159°C. The compound VIh itself, in contrast to the salt, is difficult to crystallize. IR spectrum, cm^{-1}: 3176 (NH); 1685, 1633 (C=O).

This study has been carried out with the support of the University of Russia program, Fundamental Research in Chemistry section.

REFERENCES

1. A. V. Gulevskaya, A. F. Pozharskii, A. I. Chernyshev, and V. V. Kuz'menko, Khim. Geterotsikl. Soedin., No. 9, 1202 (1992).
2. R. G. Glushkov and O. S. Sizova, Khim. Farm. Zh., No. 6, 713 (1986).
3. M. J. Chu, L. B. Landry, and K. S. Klin, Proc. Am. Assoc. Cancer Res., **23**, 220 (1982).
4. O. S. Sizova and R. G. Glushkov, Khim. Farm. Zh., No. 6, 717 (1984).
5. O. S. Éktova and M. N. Preobrazhenskaya, Khim. Farm. Zh., No. 7, 860 (1988).
6. F. Cassidy, R. K. Olsen, and R. K. Robins, J. Heterocycl. Chem., **5**, 461 (1968).
7. O. S. Sizova and R. G. Glushkov, Khim. Farm. Zh., No. 8, 958 (1984).
8. G. A. Modnikova, O. S. Sizova, and K. Yu. Novitskii, Khim. Farm. Zh., No. 6, 36 (1982).
9. K. Imai, Chem. Pharm. Bull., **12**, 1030 (1964).
10. G. A. Modnikova, O. S. Sizova, K. Yu. Novitskii, N. A. Ryabokon', T. M. Vlasova, and V. A. Chernov, Khim. Farm. Zh., No. 5, 548 (1982).
11. G. A. Modnikova, R. M. Titkova, R. G. Glushkov, A. S. Sokolova, V. A. Silin, and V. A. Chernov, Khim. Farm. Zh., No. 2, 185 (1988).
12. S. Senda and K. Hirota, Chem. Pharm. Bull., **22**, 2593 (1974).
13. A. R. Katritzky, Handbook of Heterocyclic Chemistry, Pergamon Press, New York (1985), p. 58.
14. A. F. Pozharskii, Theoretical Principles of the Chemistry of Heterocyclic Compounds [in Russian], Khimiya, Moscow (1985), p. 191.
15. J. A. Joule and G. F. Smith, Heterocyclic Chemistry, Van Nostrand-Reinhold, New York (1972).
16. G. J. Doddi, P. Mencrelli, A. Razzini, and F. Stegal, J. Org. Chem., **44**, 2321 (1979).
17. Advances in Furan Chemistry [in Russian], É. Lukevits (ed.), Zinatne, Riga (1978), p. 25.
18. L. F. Fieser and M. Fieser, Reagents for Organic Synthesis, Van Nostrand-Reinhold, New York, Vol. 1 (1967).
19. K. Senda, M. Ichiba, and S. Nichigaki, J. Org. Chem., **44**, 3830 (1979).