REACTION OF AZINIUM CATIONS. 5.* ADDITION OF WATER AND METHANOL TO 1,4-DIAZINIUM CATIONS IN THE PRESENCE OF BASES. EQUILIBRIUM CONSTANTS AND PMR SPECTRA OF THE MONO- AND DIADDUCTS

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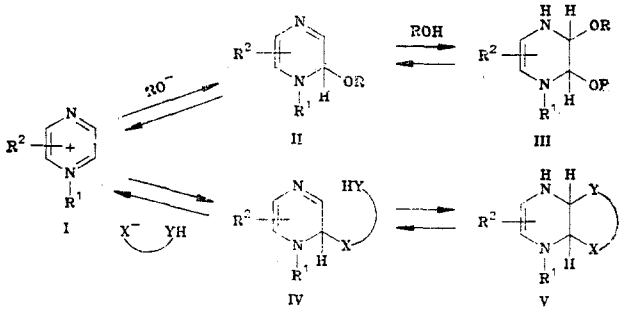
The PK_{R^+} values and equilibrium constants for the addition of hydroxide ions to 1,4-diazinium ions were determined by spectrophotometry. The ratios 1:1 and 1:2 of the methoxyl adducts of the 1,4-diazinium ions in the sodium methoxide–methanol-D_4 system and the equilibrium constants for the transformations of the mono-adducts into the diaddition products were determined by PMR spectroscopy.

The progress in the investigation of nucleophilic substitution reactions in the series of aromatic and azaaromatic compounds is due to the development of theories about the nature, structure, and characteristics of the products from the addition of nucleophiles to the aromatic ring (anionic or neutral σ-adducts) and also to the accumulation of quantitative data on the formation rates of the σ-complexes and their stability constants [2]. There are published data [3] on the covalent adducts of some azinium ions with the hydroxide ion, but the addition of nucleophiles to 1,4-diazinium ions has been studied little. At the same time, a distinctive feature of heterocycles containing the 1,4-diazine structure and their protic and quaternary salts is the addition of nucleophilic reagents to the carbon atoms of both C=N bonds in the pyrazine ring. This effect has been observed in a series of derivatives of pyrazine [4], quinoxaline [5, 6], pyrido[2,3-b]pyrazine [7, 8], pteridine [9, 10], pyrazino[2,3-e]-1,2,4-triazine [11], and other heterocycles. Using this property, we used the addition of 1,3- and 1,4-bifunctional nucleophiles to 1,4-diazinium ions for the annellation of the most varied five- and six-membered carbocycles and heterocycles to the pyrazine ring [12, 13]. The general scheme for such cyclizations is largely similar to that for diaddition reactions; the differences lie in the fact that the second stage is realized by an intramolecular mechanism and can be regarded as a manifestation of a ring–chain equilibrium.



X, Y = O, N, S, and CH-active center; R=H, CH_3; R^1 = alkyl; R^2 = substituent, annellated benzene, or azaaromatic ring

In both cases, the first stage is the reversible addition of the nucleophiles at the α-position of the 1,4-diazinium ions with the formation of adducts (II) and (IV). Realization of the second stage, i.e., displacement of the equilibria II ⇄ III and IV ⇄ V toward the diadducts (III) or the cyclic adducts (V), requires the following conditions: a) the σ-adducts (II) and (IV) must be relatively stable and exist at least for the time required for approach and interaction of the second pair of reaction centers; b) the carbon atom of the C=N bond must be sufficiently electrophilic to undergo attack by the nucleophile; c) the process of addition to the C=N bond must be thermodynamically favorable; in particular,

*For Communication 4, see [1].

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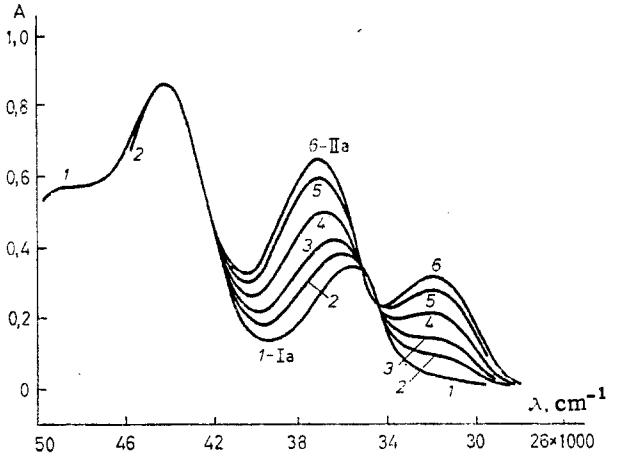
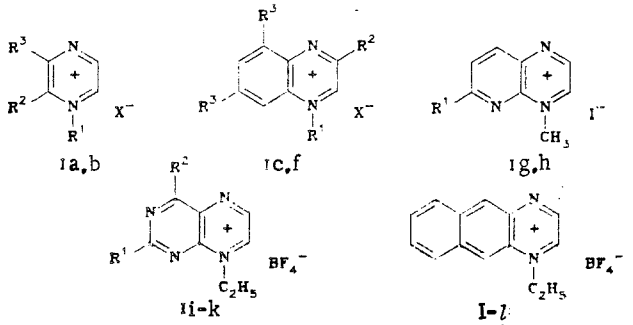


Fig. 1. The variations in the electronic spectra of 3-aminocarbonylpyrazinium iodide (Ia) in aqueous solutions at 20°C as a function of the pH: 5.69 [1, 100% cation (Ia)]; 7.49 (2); 7.85 (3); 8.31 (4); 8.86 (5); 9.36 [6, 100% hydroxyl complex (IIa)].

cyclizations with dinucleophiles IV → V can be realized on the condition of the closure of unstrained rings. Our previously published papers on the reactions of quaternary 1,4-diazinium salts with nucleophiles and 1,3- and 1,4-dinucleophiles (see [12, 13]) indicate that substituents in the pyrazine ring, including a condensed benzene or azaaromatic ring, have a significant effect both on the stability of the σ-adducts (II) or (IV) and on the secondary addition of the nucleophiles to the C=N bond and, in particular, on the ring–chain equilibrium IV ⇄ V.

In order to evaluate the effects of the substitutents on the reactivity of the α and β position of the pyrazinium salts and also on the stability of their adducts with nucleophiles quantitatively, in the present work we studied the addition of water and methanol to a series of 1,4-diazinium quaternary salts (Ia-l). In the cations (Ia-l) the structure was varied by the introduction of substituents into the pyrazine system and by annellation of the benzene ring and also the pyridine and pyrimidine rings. The choice of substituents in the pyrido[2,3-b]pyrazinium (Ig, h) and pteridinium (Ii-k) salts was based on their steric and electronic effects, which direct the quaternization to the pyrazine ring [14]. The choice of nucleophilic reagents was based on the fact that investigation of the equilibria in an aqueous medium at various pH values made it possible to characterize the formation of the pseudobases (II) (R = H) quantitatively, while the use of the sodium methoxide–deuteromethanol system is suitable for analysis of the structure of the addition products (II) and (III) (R = CH_3) and determination of their ratios by PMR spectroscopy.



Ia,b Ic,f Ig,h Ii-k I-l

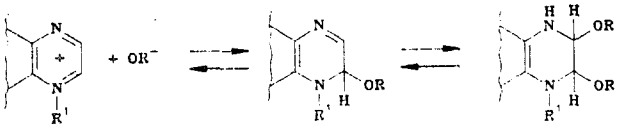
a,c–f X=I, b X=BF_4; a,c,e,f R^1=CH_3, b,d R^1=C_2H_5; a,c,d,f R^2=H, b R^2=$COOCH_3$, e R^2=C_6H_5; a R^3=$CONH_2$, b R^3=$COOCH_3$, c-e R^3=H, f R^3=CH_3; g R^1=$N(CH_3)_2$, h R^1= piperidino, i R^1=H, j R^1=SCH_3, k R^1= morpholino, i,j R^2= morpholino, k R^2=CH_3

The equilibrium between the quaternary azinium salts (I) and the pseudobase (II) (R = H) is usually described by Eq. (1) and the equilibrium constant K_1 (2) or by scheme (3) and the K_{R^+} values (4), which are related to K_1 by Eq. (5) through the ionic product of water K_{H_2O} [3]:

TABLE 1. Spectral Characteristics of the 1,4-Diazinium Salts (Ia-l) in Water at 20°C

Compound	Cations		Hydrated forms	
	pH	λ_{max}, nm (lg ε)	pH	λ_{max}, nm (lg ε)
Ia	6,0	226 (4,10), 280 (3,71)	9,4	229 (4,08), 267 (3,97), 313 (3,66)
Ib	1,5	287 (3,85)[a]	7,0	265 (3,83), 312 (3,85)
Ic	4,0	336 (3,84)[a]	10,5	301 (3,33), 340 (3,13)[a]
Id	4,0	338 (3,90)[b]	12,0	309 (3,34), 347 (3,35)[b]
Ie	6,0	259 (4,50), 381 (3,99)	10,4	230 (4,48), 372 (3,89)
If	6,3	225 (4,25), 255 (4.52), 347 (3,92)	12,6	229 (4,40), 290 (3,60), 346 (3,51)
Ig	6,3	227 (4,23), 251 (4.28), 439 (4,20)	13,9	358 (4,26)
Ih	6,0	225 (4,42), 446 (4,21)	13,9	358 (4,23)
Ii	3,0	247 (4,18), 272 (3,85), 445 (3,97)	9,0	262 (4,35), 311 (3,81)
Ij	3,5	242 (4,24), 299 (3,95), 444 (4,04)	9,5	227 (4,18), 265 (4.42), 328 (3,98)
Ik	3,5	249 (4,36), 286 (4.03)	9,4	234 (4,30), 323 (4.18)
Il	3,4	227, 285, 386, 479[c]	9,1	234, 354[c]

[a]Published data [6].
[b]Analogous spectra were obtained for N-ethylquinoxolinium fluoroborate and its hydroxyl complex, which indicates the absence of an effect from the counter-ion.
[c]The ε value was not determined on account of the poor stability.



(1)

$$K_1=\frac{[II]}{[I][OH^-]}, \quad (2)$$

$$I+H_2O \rightleftharpoons II+H^+, \quad (3)$$

$$K_{R^+}=\frac{[II][H^+]}{[I]}, \quad (4)$$

$$K_1=\frac{K_{R^+}}{K_{H_2O}}. \quad (5)$$

In order to determine the pK_{R^+} values for the cations (Ia-l) we studied the variation of the electronic absorption spectra for the salts (Ia-l) in relation to the pH of their aqueous solutions and used a method of calculation similar to that in which the ionization constants of acids pK_a are calculated [15]. As an example, Fig. 1 shows the variation in the spectra of an equilibrium mixture of 3-aminocarbonylpyrazinium iodide (Ia) and its covalent hydration product (IIa) (R = H) with variation in the pH of the solution. The spectral characteristics of aqueous solutions of compounds (Ia-l) at the same pH values, where only the cation or only its hydrated forms exist in the solution, are given in Table 1. The values of the constants $pK_{R^+}^{expt}$ calculated from the experimental data are summarized in Table 2. It should be noted that in a number of cases the diaddition products (III) are formed in addition to the pseudobases (II) during the hydration of the 1,4-diazinium ions, by virtue of which the experimental (apparent) values of the constants $K_{R^+}^{expt}$ reflect the overall contribution from the mono- and diadducts in the addition of water to the cations (I) and, consequently,

$$K_{R^+}^{expt}=\frac{[H^+]([II]+[III])}{[I]}=K_{R^+}+\left(1+\frac{[III]}{[II]}\right). \quad (6)$$

The true pK_{R^+} values will in this case be smaller than $pK_{R^+}^{expt}$ by log (1 + [III]/[II]). Since it is difficult to determine the [III]/[II] ratio in the aqueous medium by spectrophotometry on account of the overlap of their absorption bands, to calculate the pK_{R^+} values we measured the ratio of the corresponding methoxyl adducts in CD_3OD solution by the PMR method,

TABLE 2. pK_{R^+} Values and Equilibrium Constants K_1 for the Addition of OH^- to 1,4-Diazinium Ions (Ia-ζ) in Aqueous Solutions at 20°C and also the Constants K_2 for the Equilibrium between the Mono- and Diadducts (II) and (III) in Methanol at 20°C

Cation	λ_{anal}, nm	$pK^{expt}_{R^+}$	[III]/[II]	pK_{R^+}	K_1, liter/mole	K_2, liter/mole
Ia	267	8,04±0.06	0/1	8,04	$1,35\times10^{6}$	—
Ib	312	3,22±0,05	2/5	3,07	$1,26\times10^{11}$	$1,6\times10^{-2}$
Ic	335	8.62±0.06 [6]	2/3	8.40[a]		—
		8,67±0,06	3/5	8,47	$5,01\times10^{5}$	$2,4\times10^{-2}$
Id	338	9.26±0.05	3/5	9,06	$1,29\times10^{5}$	$2,4\times10^{-2}$
Ie	259	8.39±0,06	0/1	8,39	$6,00\times10^{5}$	—
If	255	10,4±0,1	2/5	10,25	$8,3\times10^{3}$	$1,6\times10^{-2}$
Ig	439	12,5	0/1	12,5	46,8	—
Ih	446	12,5	0/1	12,5	46,8	—
Ii	445	5.00±0.02	0/1	5,00	$1,48\times10^{9}$	—
Ij	441	7,01±0,06	0/1	7,01	$1,45\times10^{7}$	—
Ik	323	6,74±0,04	1/23	6,72	$2,82\times10^{7}$	$1,76\times10^{-3}$
Il	285	6,32±0,03	3/1	5,72	$2,82\times10^{8}$	$1,2\times10^{-1}$

assuming that the transition from water to methanol does not give rise to significant displacements of the equilibrium II ⇄ III. Such an approach has already been used before to determine the pK_{R^+} values of the N-methylquinoxalinium ion (Ic) [6].

Our determination of the pK_{R^+} values for a series of quinoxalinium cations (Ic-f) gave results which agree well with published data. For 1-methyl-3-phenylquinoxalinium iodide (Ie), which according to the PMR spectra only forms the monoaddition product, we obtained the value pK_{R^+} = 8.39, almost coinciding with pK_{R^+} = 8.40 for the cation (Ic) [6] (Table 2).

The variation of the K_1 values in the series of 1,4-diazinium ions (Table 2) indicates enhanced stability for the hydroxyl complexes with the introduction of accepting substituents or with enlargement of the aromatic system. This is consistent with the relationships governing the formation of anionic σ-complexes in the series of polynitro aromatic compounds [2, 16]. Thus, it was not possible to determine the pK_{R^+} value for N-methylpyrazinium iodide not substituted in the ring on account of the instability of the hydroxyl adduct at 20°C and the irreversibility of the transformations in the alkaline medium. The introduction of an accepting amide group at position 3 of the pyrazinium salt (Ia) confers stability on the covalent adduct (IIa). The effect of the amide group on K_1 is comparable with the effect of an annellated benzene ring (Table 2). Even more stable hydroxyl complexes are formed in the reactions of cations containing two accepting groups (Ib) or an annellated pyrimidine ring (Ii-k) (Table 2). The formation of the adducts (IIa-ζ) is a reversible process; the electronic spectra of the acidified aqueous solutions indicate total regeneration of the cations (Ia-ζ).

The dependence of the electronic spectra of the 1,4-diazinium ions on the pH of the medium makes it possible to control the formation of the hydroxyl complexes, but by this method it is difficult to determine whether the diaddition products (III) are formed in the solution in addition to the adducts (II) and in what amount. In order to determine the degree to which the reversible addition of water to the C=N bond of the hydroxyl adducts (II) is realized and to determine the [III]/[II] ratio we investigated the mono- and diaddition of sodium methoxide to 1,4-diazinium ions (Ia-ζ) by PMR spectroscopy. The PMR spectra of the salts (Ia-ζ) are given in Table 3.

The adducts of the 1,4-diazinium ions (Ia-ζ) with sodium methoxide are stable at 20°C and are detected in the PMR spectra by the characteristic signals for the protons of the pyrazine ring in the region of 5.3-5.9 (the absorption of the H_α proton at the tetragonal carbon atom) and 7.0-7.6 ppm (the H_β proton of the azomethine bond). The adduct of the pteridinium salt (Ij) with sodium methoxide [compound (IIj)] could not only be recorded in the PMR spectra but could also be isolated from the solution in the form of crystals melting at 86-87°C (see the experimental section).

As well as the monoaddition products, the cations (Ib-d, f, k, ζ) also form the products from diaddition of methanol (IIIb-d, f, k, ζ). In the diadducts (III) the H_α and H_β protons belong to tetragonal carbon atoms and resonate in the region of 4.4-4.7 ppm (Table 3), free

TABLE 3. PMR Spectra of the Products from Covalent Addition of Methanol (IIa-j, IIIb, c, d, f, k) to Pyrazinium Salts (IIa-k) in a Solution of CD_3ONa (1 M) in CD_3OD at 20°C

Compound	Chemical shifts, δ, ppm (J, Hz)				
	H_α[a]	H_β	$J_{(H_\alpha-H_\beta)}$	N—R'	other protons
IIa	5,38 dd	7,03 dd	3,0	3,25 s	7,53 dd (2-H, $J_{2,5}=1$, $J_{2,6}=1,2$)
IIb	5,42d	7,18 d	3,2	3,41 q ($N-CH_2$); 1,26 t ($-CH_3$)	3,93 s (6H, $COOCH_3$)
IIIb	4,49[b] d	4,59[b] d	2,1	1,10 t ($-CH_3$); 3,40 q ($N-CH_2$)	3,78 s (6H, $COOCH_3$)
IIc	5,32 d	7,60 d	3,2	3,19 s	6,7—7,5 (4H of benzene ring)
IIIc	4,58s	4,58s	—	3,14 s	6,63 s (4H of benzene ring)
IId	5,39 d	7,53 d	3,3	1,27 t ($-CH_3$); 3,60 q ($N-CH_2$)	6,7—7,5 (4H of benzene ring)
IIId	4,52s	4,52 s	—	1,17 t ($-CH_3$); 3,60 q ($N-CH_2$)	6,58 s (4H of benzene ring)
IIe	5,89 s	—	—	3,27 s	6,7—7,7 (7H); 7,9—8,3 (2H)
IIf	5,26 d	7,51 d	3,0	3,18s	6,58 s (2H, 6-H, 8-H); 2,31 s (CH_3); 2,43 s (CH_3)
IIIf	4,58[b] d	4,68[b] d	1,0	3,18 s	6,35 s (2H, 6-H, 8-H); 2,20 s (CH_3); 2,37 s (CH_3)
IIg	5,48 d	7,16 d	3,0	3,22 s	3,08 s [6H, $N(CH_3)_2$]; 5,99 (7-H); 7,35 (8-H, $J_{7,8}=8,5$)
IIh	5,49 d	7,17 d	3,0	3,23 s	1,3—1,9 m (6H of piperidine ring); 3,2—3,8 m (4H, $N-CH_2$); 6,15 d (7-H); 7,38 d (8-H, $J_{7,8}=8,5$)
IIi	5,50 d	7,36 d	3,2	1,28 t ($-CH_3$)	3,6—4,1 m (10H, protons of morpholine ring and $N-CH_2$); 8,08 s (2-H)
IIj	5,45 d	7,21d	3,0	1,22 t ($-CH_3$)	2,41 s (3H, SCH_3); 3,2—4,0 m (10H, protons of morpholine ring and $N-CH_2$)
IIk	5,55 d	7,25 d	3,0	1,31 t ($-CH_3$)	2,42 s (3H, CH_3); 3,4—4,1 (10H, protons of morpholine ring and $N-CH_2$)
IIIk	4,50[b] d	4,70[b] d	2,4	1,20 t ($-CH_3$)	2,20 s (3H, CH_3); 3,4—4,1 m (10H, protons of morpholine ring and $N-CH_2$)
IIl	5,32 d	Under aromatic protons	3,7	1,33 t ($-CH_3$); 3,75 q ($N-CH_2$)	6,8—8,0 m (7H, protons of benbenzene rings and 3-H)
IIIl	4,59[b] d	4,67[b] d	2,5	1,31 t ($-CH_3$); 3,65 q ($N-CH_2$)	6,8—7,9 m (6H, protons of benzene rings

[a]Protons at tetragonal carbon atom.
[b]The assignment of the signals may be reversed.

from absorption of the H_α protons of the monoadduct. This makes it possible to detect the formation of the mono- and diadducts clearly. The ratios of the mono- and diadducts [III]/[II], used for the calculation of K_1 and pK_{R^+}, are given in Table 2. The K_2 values, which characterize the equilibrium II ⇄ III, were also determined (Table 2):

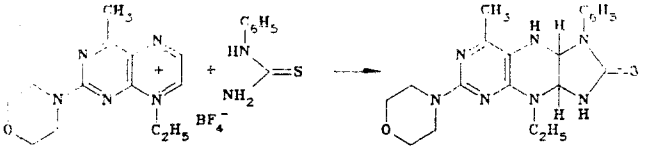
$$K_2=\frac{[III]}{[II]\,[CH_3OH]},$$

where the concentration of methanol was taken as ρ/mole wt. = 24.7 M.

The obtained values of the K_2 constants show that in the series of 1,4-diazinium ions the capacity for diaddition is most characteristic of the pyrazinium salts having an extended aromatic system on account of the annellation of one or two benzene rings (Ic-f, l) or two accepting groups [the cation (Ib)]. It is these salts which enter readily into cyclization with dinucleophiles [12, 13]. Diaddition appears to a lesser degree in the reaction of the 2-morpholino-4-methylpteridinium ion (Ik) with methanol at 20°C. The K_2 value for the

equilibrium IIk ⇄ IIIk is an order of magnitude lower than the corresponding constants for the equilibrium between the mono- and diadducts of quinoxalinium and two orders of magnitude lower than for the benzoquinoxalinium derivatives (Table 2). In the reactions of monocyclic and pyrido-annellated pyrazinium salts (Ia, g, h) with sodium methoxide in methanol the diaddition products were not detected.

Examination of the characteristics of the pteridinium ions (Ii-k) in comparison with the quinoxalinium ions (Ic-f) makes it possible to see that the equilibrium constants K_1 at the stage of the formation of the products from the monoaddition of methanol (Ii-k) are several orders of magnitude larger than the corresponding constants K_1 for the adducts (IIc-f), whereas the capacity for diaddition in the pteridines (Ii-k) is appreciably reduced and only appears in the cation (Ik) with a methyl group at position 4 of the pyrimidine ring. The morpholine residue at $C_{(4)}$ is conjugated mesomerically in the cations (Ii, j) with the $C_{(6)}$ atom and significantly reduces its electrophilicity, thereby excluding both diaddition and cyclization with dinucleophiles, whereas the electron-donating effect of the same substituent at position 2 of the cation (Ik) on the reactivity of the $C_{(6)}$ atom is smaller and allows it to react with nucleophiles. Thus, the reactions of the cations (Ii, j) with dinucleophiles stop at the formation of the product from addition to $C_{(7)}$ [17], whereas the cations (Ik) forms cyclic adducts with thioureas and with the anilides of β-dicarbonyl compounds through addition at the $C_{(6)}$ and $C_{(7)}$ atoms, i.e., derivatives of 5,5a,6,7,8a,9-hexahydro-8H-imidazo-[4,5-g]- and 5,5a,7,8,8a,9-hexahydro-6H-pyrrolo[2,3-d]pteridine, respectively [18].



Thus, the quantitative data characterizing the equilibrium processes in the formation of the mono- and diadducts of 1,4-diazinium ions with methanol make it possible to understand the differences in their transformations under the influence of bifunctional nucleophiles. They may prove useful for evaluating the possibility of the participation of pyrazinium salts in cyclizations with dinucleophiles.

EXPERIMENTAL

The electronic spectra of aqueous solutions of the salts (Ia-ℓ) were investigated on a Specord UV-vis spectrometer at 20°C by monitoring the pH of the medium with an ÉV-74 universal ionometer. The method described in [15] was used to calculate the pK_R^+expt values. The PMR spectra of solutions of the salts (Ia-ℓ) (c = 0.45 M) in a solution of sodium methoxide (c = 1 M) in methanol-D_4 were recorded at 20°C on a Bruker WP-80 spectrometer at 80.13 MHz with TMS as internal standard.

The pyrazinium (Ib) [19], quinoxalinium (Ic-f) [20], pyrido[2,3-b]pyrazinium (Ig, h) [21], and pteridinium (Ii) [14] quaternary salts were obtained by the previously described methods.

3-Aminocarbonyl-1-methylpyrazinium Iodide (Ia). To 25 g (0.2 mole) of aminocarbonylpyrazine we added 200 ml of methyl iodide and 70 ml of DMSO. The solution was kept at 50°C for 24 h. The precipitate was filtered off and washed with ethanol and ether. The yield was 53 g (98%). The product formed orange plates (from ethanol); mp 194-198°C. PMR spectrum (DMSO-D_6): 4.48 (3H, s, N–CH_3); 8.28 and 8.63 (2H, bs, NH_2); 9.3-9.7 ppm (3H, protons of pyrazine ring). Found, %: C 27.0; H 2.9; N. 16.1 $C_6H_8IN_3O$. Calculated, %: C 27.2; H 3.0; N 15.9.

2-Methylthio-4-morpholinopteridine was obtained in three stages from 4,5-diamino-2,6-dimercaptopyrimidine [22].

Stage 1. 4,5-Diamino-2,6-dimethylthiopyrimidine. To a solution of 5 g (29 mmoles) of 4,5-diamino-2,6-dimercaptopyrimidine and 2 g (50 mmoles) of sodium hydroxide in 30 ml we added 6 ml of ethanol. We then added dropwise with stirring 7.2 g (57 mmoles, 5.4 ml) of dimethyl sulfate. Spontaneous heating of the reaction mass was observed, and a precipitate was formed. The precipitate was filtered off, washed with ethanol, dried in air, and recrystallized from ethanol. The yield was 3.9 g (67%); mp 193-194°C. Found, %: C 35.8; H 5.0; N 27.4; S 31.9. $C_6H_{10}N_4S_2$. Calculated, %: C 35.6; H 5.0 N 27.7; S 31.7.

Stage 2. 2,4-Dimethylthiopteridine. A 13-g sample (64.3 mmoles) of 4,5-diamino-2,6-thiomethylpyrimidine was suspended in 120 ml of ethanol and heated to 70°C. A boiling solution of 10 ml of 40% aqueous glyoxal in 16 ml of ethanol was added in portions (with frothing). After a few minutes a precipitate began to separate from the solution. The mixture was heated for a further 30 min and cooled. The precipitate was filtered off and recrystallized from a 1:1 mixture of ethanol and high-boiling petroleum ether. The yield was 10 g (69%). PMR spectrum (deuterochloroform): 2.65 (3H, s, SCH_3); 2.69 (3H, s, SCH_3); 8.73 (1H, d, 6-H, $^3J_{6,7}$=1.9 Hz); 9.06 ppm (1H, d, 7-H). Found %: C 42.7; H 3.8; N 25.0; S 28.7. $C_8H_8N_4S_2$. Calculated, %: C 42.9; H 3.6; N 25.0; S 28.5.

Stage 3. 2-Methylthio-4-morpholinopteridine. A mixture of 2 g (8.9 mmoles) of 2,4-dimethylthiopteridine and 8 ml of morpholine in 50 ml of ethanol was boiled for 24 h. The precipitate was then filtered off. The yield was 2 g (85%); mp 185-187°C (from petroleum ether, bp 80-100°C). PMR spectrum (deuterochloroform): 2.62 (3H, s, SCH_3); 3.86 and 4.48 (8H, m, morpholino); 8.49 (1H, d, 6-H, $^3J_{6,7}$ = 2.0 Hz); 8.83 ppm (1H, d, 7-H). Found, %: C 50.0; H 4.9; N 26.3; S 12.2. $C_{11}H_{13}N_5OS$. Calculated, %: C 50.2; H 5.0; N 26.3; S 12.2.

2-Methylthio-4-morpholino-4-ethylpteridinium Fluoroborate (Ij). To a suspension of 1.5 g (5.7 mmoles) of 2-methylthio-4-morpholinopteridinium [21] in 7 ml of dry chloroform we added a solution of 2.2 g (11.4 mmoles) of triethyloxonium fluoroborate in 8 ml of dry chloroform. The mixture was heated to boiling and kept for 1 h. The precipitate represented a mixture of the fluroborates of (Ij) and 2-methylthio-4-morpholino-1-ethylpteridinium, as follows from the PMR spectra and comparison with the published [14] characteristics of the isomeric pteridinium salts. The mixture was separated by fractional crystallization from absolute ethanol, giving 1.1 g (51%) of the salt (Ij); mp 180-183°C. PMR spectrum (deuterochloroform): 1.69 (3H, t, N=CH_3); 2.65 (3H, s, SCH_3); 3.8-4.7 (8H, m, protons of morpholine ring); 4.90 (2H, q, N—CH_2); 8.92 (1H, d, 7-H); 9.00 ppm (1H, d, 6-H, $^3J_{6,7}$ = 3.5 Hz). Found, %: C 41.1; H 4.7; N 18.2. $C_{13}H_{18}BF_4N_5OS$. Calculated, %: C 41.2; H 4.8; N 18.5. 2-Methylthio-4-morpholino-1-ethylpteridinium fluoroborate was obtained with a yield of 0.6 g (28%); mp 135-139°C. PMR spectrum (deuterochloroform): 1.49 (3H, t, CH_3); 2.76 (3H, s, SCH_3); 3.98 (4H, m, protons of morpholine ring); 4.37 (2H, m, protons of morpholine ring); 4.66 (2H, q, N—CH_2); 5.02 (2H, m, protons of morpholine ring); 8.82 (1H, d, 7-H, $^3J_{6,7}$ = 1.8 Hz); 8.90 ppm (1H, d, 6-H). Found, %: C 41.3; H 4.8; N 18.0. $C_{13}H_{18}BF_4N_5OS$. Calculated, %: C 41.3; H 4.8; N 18.5.

2-Methylthio-4-morpholino-7-methoxy-8-ethyl-7,8-dihydropteridine (IIj). A 0.4-g sample (1.1 mmoles) of (Ij) was suspended in 2.8 ml of a solution of sodium methoxide in methanol and was stirred until the initial salt had completely dissolved. This took place with the spontaneous release of heat and was accompanied by the simultaneous formation of a colorless precipitate of (IIj). The precipitate was filtered off, washed with water and with methanol, and dried in air. The yield was 0.3 g (89%); mp 86-87°C. PMR spectrum (deuterochloroform): 1.29 (3H, t, CH_3); 2.48 (3H, s, SCH_3); 3.25 (3H, s, OCH_3); 3.40-4.30 (8H, m, H of morpholine ring); 5.45 (1H, d, 7-H, $^3J_{6,7}$ = 3.0 Hz); 7.15 ppm (1H, d, 6-H). Found, %: C 51.6; H 6.6; N 21.8; S 10.0. $C_{14}H_{21}N_5SO_2$. Calculated, %: C 52.0; H 6.6; N 21.7; S 9.9.

4-Methyl-2-morpholinopteridine was obtained in three stages from 4-amino-5-nitro-6-methyl-2-chloropyrimidine [23].

Stage 1. 4-Amino-5-nitro-6-methyl-2-morpholinopyrimidine. A mixture of 7 g (37 mmoles) of 4-amino-5-nitro-6-methyl-2-chloropyrimidine and 10 ml of morpholine in 50 ml of ethanol was boiled for 45 min. The mixture was then cooled, and the precipitate was filtered off. The yield was 5.2 g (62%). The product formed yellow needles (from ethanol); mp 179-180°C. PMR spectrum (deuterochloroform): 2.69 (3H, s, CH_3); 3.6-4.1 ppm (8H, m, protons of morpholine ring). Found, %: C 45.4; H 5.6. $C_9H_{13}N_5O_3$. Calculated, %: C 45.2; H 5.5.

Stage 2. 4,5-Diamino-6-methyl-2-morpholinopyrimidine. A 5-g sample (21 mmoles) of 4-amino-5-nitro-6-methyl-2-morpholinopyrimidine was dissolved in 200 ml of acetone, and 25 g of sodium bicarbonate in 200 ml of water was added to the solution with stirring. Then 25 g of sodium dithionite was added over 15 min. The mixture was stirred for 5 min, and 500 ml of water was added. The solution was concentrated to 300 ml, and the precipitate was filtered off and recrystallized from ethyl acetate. The yield was 1.3 g (30%); mp 166-167°C. PMR spectrum (DMSO-D_6): 2.08 (3H, s, CH_3); 3.3-3.9 (8H, m, protons of morpholine ring); 5.97 ppm (2H, bs, NH_2). Found, %: C 51.6; H 7.2. $C_9H_{15}N_5O$. Calculated, %: C 51.7; H 7.2.

Stage 3. 4-Methyl-2-morpholinopteridine. A 1.2-g sample (5.7 mmoles) of 4,5-diamino-6-methyl-2-morpholinopyrimidine was dissolved in 70 ml of ethanol, and 1.1 g (8.8 mmoles) of

polyglyoxal added to the solution. The mixture was boiled for 40 min. The ethanol was evaporated to dryness, and the solid residue was recrystallized from ethanol. The yield was 0.75 g (60%); bp 125°C. PMR spectrum (deuterochloroform): 2.91 (3H, s, CH_3); 3.60-4.30 (8H, m, protons of morpholine ring); 8.53 (1H, d, 6-H, $^3J_{6,7}$ = 2.0 Hz), 8.86 ppm (1H, d, 7-H). Found, %: C 57.0; H 5.8. $C_{11}H_{13}N_3O$. Calculated, %: C 57.1; H 5.7.

4-Methyl-2-morpholino-8-ethylpteridinium Fluoroborate (Ik). To a suspension of 0.5 g (2.2 mmoles) of 4-methyl-2-morpholinopteridine in 3 ml of methylene chloride we added 0.62 g (3.3 mmoles) of triethyloxonium fluoroborate in 2 ml of methylene chloride. When the initial salt had dissolved, the mixture was kept for 30 min and cooled, and the precipitate was filtered off. The yield was 0.5 g (67%); mp 181-184°C (from ethanol). PMR spectrum (DMSO-D_6): 1.50 (3H, t, CH_3); 2.88 (3H, s, CH_3); 3.60-4.30 (8H, m, protons of morpholine ring); 4.73 (2H, q, N–CH_2); 8.97 (1H, d, 6-H, $^3J_{6,7}$ = 3.5 Hz); 9.21 ppm (1H, d, 7-H). Found, %: C 44.8; H 5.1; N 20.1. $C_{13}H_{18}BF_4N_3O$. Calculated, %: C 45.0; H 5.2; N 20.2.

1-Ethylbenzoquinoxalinium Fluoroborate (Il). To a suspension of 0.8 g (4.4 mmoles) of benzoquinoxaline in 15 ml of methylene chloride we added a solution of 1.25 g (6.6 mmoles) of triethyloxonoium fluoroborate. The mixture was stirred for 10 min until the initial substances had completely dissolved. The solution was kept at 20°C for 1 h, and the precipitated salt (Il) was filtered off, washed with ethanol and with ether, dried in air, and recrystallized from ethanol. The yield was 1 g (76%); mp 183-186°C. Found, %: C 56.5; H 4.4. $C_{14}H_{13}BF_4N_2$. Calculated, %: C 56.8; H 4.4.

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