REACTIONS OF QUATERNARY SALTS OF BENZO DERIVATIVES OF PHENAZINE WITH NUCLEOPHILIC REAGENTS

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The electronic structures of benzo[a] phenazine and dibenzo[a,c] phenazine have been studied by the MO LCAO method. The reactions of four quaternary salts with oxomethylene compounds and with quaternary salts of nitrogenous heterocycles have been described. The absorption spectra of the dyes obtained are given.

The condensation of quaternary salts of phenazine with quaternary salts of nitrogen heterocycles containing active methylene groups, and also with oxomethylene compounds, leads to the formation of deeplycolored dyes of the cyanine or merocyanine type [1-3].

In the present work we have studied the analogous reactions of salts of benzo[a]phenazine and dibenzo-[a,c]phenazine. It appeared of interest to determine the reactivities of these compounds with nucleophilic reagents, to establish at what carbon atom of the heterocycle this type of reaction takes place, and to study the electronic spectra of the dyes obtained. For this purpose, a calculation of the molecules of the bases phenazine (I), benzo[a]phenazine (II) and dibenzo[a, c]phenazine (III) was performed by the MO LCAO method in Huckel's approximation [4]. For the nitrogen atom we adopted the Streitwieser parameters: the Coulomb integrals of the nitrogen atoms $\alpha_N = \alpha + 0.5\beta$ and the resonance integrals of the C-N bonds, $\beta_{CN} = \beta$.

It can be seen from molecular diagrams of compounds (II) and (III) (Fig. 1) that the orders of the N-C bonds directed towards the condensed rings B and C are far higher than for the bonds with the benzene ring A. This indicates that their multiplicity is higher and that the nitrogen atoms are better conjugated with the naphthalene and phenanthrene residues B and C than with the benzene ring A. Because of this the positive charges on atoms 9 and 10 in compounds (II) and 11 in compound (III) are smaller than the charges on atoms 2, 3, 7, or 8 in the unsubstituted phenazine (I). At the same time, on atom 5 in the molecule of (II) the positive charge is sharply increased. A similar pattern will be observed in the quaternary salts of these compounds.

It was shown previously [5] that quaternary salts of benzo[a] phenazine readily take part in reactions with amines, forming 5-amino derivatives. The condensation reactions of the 7-methylbenzo[a] phenazinium salt (IV) with quaternary salts of 2-methylbenzothiazole (VI) and quinaldine (VII) also take place at position 5, as was shown by the identification of the compounds (VIII) and (IX) obtained with the analogous products of the condensation of the 5-chlorobenzo[a] phenazinium salt (V) [6].



$$\begin{split} & IV \ R_1 - H_1 \ A = CH_5 O_4; \ V \ R_1 = A = CI; \ VI \ R_2 = CH_3, \ Y = S, \ X = CH_3 SO_4; \ VII \ R_2 = C_2 H_5, \ Y = CH - CH, \\ & X = CH_3 C_6 H_4 SO_5; \ VIII \ R_2 = CH_3, \ Y = S; \ IX \ R_2 = C_2 H_5, \ Y = CH = CH \end{split}$$

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Fig. 1. Molecular diagrams of phenazine (I), benzo[a]phenazine (II), and dibenzo[a,c]-phenazine (III).

The yields of the dyes and the ease of occurrence of the reaction show the higher reactivity of the salt (IV) than of the phenazinium salt not containing a fused-on ring [1]. However, the reaction of (IV) with



with malonic and cyanoacetic esters and with rhodanine takes place with difficulty, apparently because of the increased steric hindrance, but the orientation remains the same in this case; the condensation products isolated were identical with compounds (X-XII) obtained from the chlorine-substituted salt (V).

The quaternary salts of dibenzo[α , c]phenazine also react readily with nucleophilic reagents [7], and it has been shown that condensation with amines takes place in position 11 [8]. On the basis of the results of calculation and of experimental investigation, it may be assumed that with quaternary salts of 2-methylbenzothiazole and quinaldine and with rhodanine the salt (XIII) forms reaction products with the structures (XVI), (XVII), and (XVIII).



Com- pound	mp, °C (from acetic an- hydride)	Empirical formula	N, %		1		
			found	calc.	λ _{max} , nm	log e	%
x	Above 300	$C_{24}H_{22}N_2O_4$	6,8	7,0	550* 596 650*	3,98 4,16 4,08	44
XI	211—213	$C_{22}H_{17}N_3O_2$	11,6	11,8	556* 594 640*	4,19 4,32 4,18	63
XX7	229—230	$C_{33}H_{26}N_2O_4$		-	620* 670 740*	4,37 4,41 4,19	75
. XXI7	Above 300	$C_{31}H_{21}N_3O_2$			634* 690 756*	4,4 4,57 4,47	-80
XXII	250—251	$C_{33}H_{24}Br_2N_2O_4$	4,0	4,2	620* 668 736*	4,33 4,37 4,14	76
XXIII	Above 300	$C_{31}H_{19}Br_2N_3O_2$	6,5	6,7	640* 696 756*	4,35 4,50 4,36	80
XXIV	237—239	$C_{26}H_{19}N_3O_2$	10,2	10,4	634* 686 748	4,21 4,39 4,31	38
XXIX	218—220	$C_{27}H_{21}N_{3}O_{3}$	9,7	9,6	594* 650 706	4,27 4,4 4,32	18

TABLE 1. Products of the Condensation of Quaternary Salts of Benzo Derivatives of Phenazine with Oxomethylene Compounds

*Shoulder on the absorption curve.



 $\begin{aligned} & \text{XX} \quad \mathbf{R}_1 = \mathbf{C}_6 \mathbf{H}_5, \quad \mathbf{R}_2 = \mathbf{H}, \quad \mathbf{X} = \mathbf{COOC}_2 \mathbf{H}_5; \quad \mathbf{XXI} \quad \mathbf{R}_1 = \mathbf{C}_6 \mathbf{H}_5, \\ & \mathbf{R}_2 = \mathbf{H}, \quad \mathbf{X} = \mathbf{CN}; \quad \mathbf{XXII} \quad \mathbf{R}_1 = \mathbf{C}_6 \mathbf{H}_5, \quad \mathbf{R}_2 = \mathbf{Br}, \quad \mathbf{X} = \mathbf{COOC}_2 \mathbf{H}_5; \\ & \text{XXIII} \quad \mathbf{R}_1 = \mathbf{C}_6 \mathbf{H}_5, \quad \mathbf{R}_2 = \mathbf{Br}, \quad \mathbf{X} = \mathbf{CN}; \quad \mathbf{XXIV} \quad \mathbf{R}_1 = \mathbf{CH}_3, \quad \mathbf{R}_2 = \mathbf{H}, \quad \mathbf{X} = \mathbf{CN}; \end{aligned}$

The condensation of the salt (XIII) with malonic and cyanoacetic esters also probably takes place at position 11 with the formation of (XX) and (XXI).

The introduction of bromine into position 6 does not change the direction of the reaction of the salt (XIV) with malonic and cyanoacetic esters, which apparently leads to the condensation products (XXII) and (XXIII).

It must be mentioned that the replacement of a phenyl group by a methyl group [salt(XV)] has a fundamental influence on the reactivity of a quaternary salt of dibenzo[a, c]phenazine, substantially lowering the yields of the dyes (XIX) and (XXIV) in analogous reactions (Tables 1 and 2).

If there is a substituent in position 11 of the dibenzo[a, c] phenazinium salt such as the methoxy group [the salt (XXV)], the reaction can take place, as Kiprianov et al. [9] have suggested, without the displacement of the substituent, at the carbon atom in position 13. However, in the molecule of a quaternary salt of dibenzo[a, c] phenazine there is another electrophilic center – the carbon atom in position 6, and, judging from the results of calculation, it is more likely that in the reactions of the salt (XXV) nucleophilic attack will be directed to position 6.

To confirm this point of view we studied the condensation reactions of the salts (XXV) and (XXVI), the latter containing a methyl group in position 13. The products isolated from the two reactions, (XXVII) and (XXVIII), had almost identical absorption spectra but since in the molecule of the salt (XXVI) the possibility of attack at position 13 is excluded and condensation apparently takes place at the carbon atom in position 6, it may be assumed that with rhodanine and cyanoacetic ester the salt (XXV) forms compounds (XXVII) and (XXIX).

The results obtained permit a hypothesis of the greater electrophilic activity of position 6 than of position 13 in the quaternary salt (XXV).

Com- pound	mp, °C (from acetic an- hydride)	Empirical formula	N, %			1	Yield
			found	calc.	λ _{max} , nm	log 8	%
VIII	Above 300	$C_{26}H_{20}CIN_{3}O_{4}S$	8,3	8,3	408 644 682	4,35 4,54 4,56	60
IX	241242	C ₂₉ H ₂₄ ClN ₃ O ₄	8,2	-8,2	420 674 708	4,23 4,64 4,63	57
XII	Above 300	$C_{21}H_{15}N_3OS_2$	10,8	10,8	620* 668 730*	3,96 4,05 3,85	48
XVI	Above 300	C35H24CIN3O4S	6,6	6,8	750	5,68	70
XVII	312	C38H28CIN3O4	6,6	6,7	408 500 780	5,15 4,98 5,49	73
XVIII	Above 300	$C_{30}H_{19}N_3OS_2$	8,3	8,4	700* 764	4,29 4,42	49
XIX	243244	$C_{25}H_{17}N_3OS_2$	9,3	9,6	770	4,36	20
XXVII	Above 300	$C_{26}H_{19}N_3O_2S_2$	8,9	8,9	680 744	4,02 4,31	12
XXVIII	Above 300	$C_{27}H_{21}N_3O_2S_2$	8,7	8,7	682 746	4,1 4,29	10

TABLE 2. Products of the Condensation of Quaternary Salts of Benzo Derivatives of Phenazine with Quaternary Salts of Nitrogen Heterocycles and with N-Methylrhodanine

*Shoulder on the absorption curve.



XXV R = H; XXVI $R = CH_3$; XXVII R = H; XXVIII $R = CH_3$

The reaction of the salts (IV) and (XIII) with morpholine gave the amino-substituted salts (XXX) and (XXXI).



On comparing the absorption spectra of a polymethine dye without a phenazine ring (A) and the quaternary salt of an aniline-substituted phenazine (B) with the same length of chromophore but differing from the former compound by the isolated structural element, a fairly pronounced bathochromic shift of the



absorption maximum in the latter can be seen. Apparently, such a deep coloration of the phenazine derivatives is caused by the fact that the isolated fragment plays the role of an electronegative substituent added by two bonds to the even-numbered carbon atoms of the chromophore which, according to the Dewar-Knott rule [10, 11] should lead to a deepening of the color. The electronegativity of the fragment is due to conjugation with the nitrogen atom.

It is interesting that the dyes derived from benzo[a] phenazine absorb at shorter wavelengths than the analogous phenazine derivatives. For example, compounds (VIII, IX, X, XII, and XXX) have absorption maxima at 682, 708, 594, 668, and 510 nm, while the analogous phenazine derivatives absorb at 744, 735, 626, 700, and 548 nm [1, 2, 9]. The observed hypsochromic effect in the benzo[a] phenazine derivative is probably connected with a weakening of the conjugation in the fragment [compound (XXX)] since here the benzene ring C is polarized with greater difficulty than the ethylene bond in compound B, which leads to a fall in its electronegativity and to a lightening of the color of the corresponding dyes.

The dyes derived from dibenzo [a, c] phenazine (XVI, XVII, XVIII, XX, and XXI) absorb at longer wavelengths than the analogous dyes derived from phenazine [1, 2, 9]. The nature of the N-substituent has very little influence on the absorption spectra of the dyes (XXI) and (XXIV). Only a very slight long-wave shift of the absorption maximum in (XXI) as compared with (XXIV) is observed.

EXPERIMENTAL

The electronic absorption spectra of the compounds were taken on an SF-10 instrument in chloroform and those of compounds (XXX) and (XXXI) in ethanol ($c = 0.2 \cdot 10^{-4} - 0.4 \cdot 10^{-4}$ M).

9-Phenyldibenzo[a, c]phenazinium nitrate (XIII) was obtained by the method of Ullman and Cassirer [12].

<u>3,6-Dibromo-9-phenyldibenzo[a, c]phenazinium Nitrate (XIV)</u>. A mixture of 0.3 g (0.001 mole) of 3,6-dibromophenanthraquinone [13] and 0.18 g (0.001 mole) of o-aminodiphenylamine was heated in 5 ml of CH₃COOH, 20 ml of water was added, and the solution was filtered from the quinone that had not taken part in the condensation. A few drops of nitric acid was added to the hot solution and it was cooled and the resulting precipitate was filtered off. Yield quantitative, mp 258°C (chars, from ethanol). Found: Br 27.5%. $C_{26}H_{15}Br_2N_3O_3$. Calculated: Br 27.7%.

<u>11-Methoxy-9,13-dimethyldibenzo[a,c]phenazinium methosulfate (XXVI)</u> was obtained by heating the base [14] with dimethyl sulfate in nitrobenzene. Yield 60%, mp 215°C (from ethanol).

<u>Condensation of Quaternary Salts with Oxomethylene Compounds.</u> This was performed in absolute methanol in the presence of sodium methoxide [2] (Table 1).

Condensation of Quaternary Salts with N-Methylrhodanine and Quaternary Salts of Nitrogen Heterocycles. This was performed in ethanol or water with the addition of sodium acetate (Table 2).

 $\frac{7-\text{Methyl-5-morpholinobenzo}[a]\text{phenazinium Iodide (XXX)}. This was obtained from (IV) and morpholine [2]. The isolated methosulfate was dissolved in hot water and, with stirring, a saturated solution of potassium iodide was added and then the mixture was cooled and the resulting precipitate was filtered off. Yield 68\%, mp 227°C (from ethanol). <math>\lambda_{\max}$ 401 nm (log ε 3.87), 510 nm (log ε 4.25). Found: N 9.0%. C₂₁H₂₀IN₃O. Calculated: N 9.2%.

<u>11-Morpholino-9-phenyldibenzo[a, c]phenazinium Perchlorate (XXXI)</u>. This was obtained in a similar manner to (XXX) from (XIII) and morpholine. The isolated methosulfate was converted into the perchlorate by the addition of a saturated solution of sodium perchlorate. Yield 50%, mp 278-279°C (from ethanol). λ_{\max} 584 nm (log ε 4.41). Found: N 7.8%. C₃₀H₂₄ClN₃O₅. Calculated: N 7.7%.

LITERATURE CITED

- 1. A. I. Kiprianov and É. A. Ponomareva, Ukr. Khim. Zh., 26, 78 (1960).
- 2. V. N. Rudenko, A. Ya. Il'chenko, and Yu. S. Rozum, Dokl. Akad. Nauk UkrSSR, B, 159 (1970).
- 3. A. Ya. Il'chenko and V. N. Rudenko, Khim. Geterotsikl. Soedin., 10, 1425 (1972).
- 4. A. Streitwieser, Molecular Orbital Theory for Organic Chemists, Wiley (1961).
- 5. F. Kehrmann and W. Shaposhnikov, Ber., 30, 1565 (1897).
- 6. O. Fischer and E. Hepp, Ber., <u>30</u>, 1827 (1897).
- 7. F. Sachs and G. Bargellino, Ber., <u>38</u>, 1742 (1905).
- 8. F. Kehrmann and J. Eichler, Ber., <u>34</u>, 1210 (1901).
- 9. A. I. Kiprianov, É. A. Ponomareva, and Ya. P. Skavinskii, Ukr. Khim. Zh., 26, 237 (1960).
- 10. M. J. S. Dewar, J. Chem. Soc., 2329 (1950).

- 11. E. B. Knott, J. Chem. Soc., 1024 (1951).
- 12. F. Ullmann and E. Cassirer, Ber., <u>43</u>, 439 (1910).
- 13. M. V. Bhatt, Tetrahedron, <u>20</u>, 803 (1964).
- 14. M. J. S. Dewar, J. Chem. Soc., 619 (1944).