2-(N-Isatinomethylene)-3(2H)-benzo[b]thiophenone (I, $C_{17}H_9NO_3S$). The potassium salt (II) 0.4 g, 1 mmole) was dissolved with heating in 20 ml of acetic anhydride, and the solution boiled for three minutes, and cooled. The solid (I) which separated was filtered off and washed with chloroform, mp 269-270°C (from acetic anhydride). Yield 0.28 g (95%). IR spectrum: 1740, 1670 cm^{-1} (CO). PMR spectrum (DMSO-D_6): 7.35-7.86 (Ar), 7.95 ppm (CH).

2-(N-o-Methoxalylphenylaminomethylene)-3(2H)-benzo[b]thiophenone (III, $C_{15}H_{13}NO_4S$). Compound (I) (0.2 g, 5 mmole) was dissolved with heating in 10 ml of methanol, and the solution boiled for 15 min. On cooling, orange-colored crystals of (III) separated, mp 168-169°C. Yield 0.1 g (45%). IR spectrum: 1730, 1670, 1650 (CO), 1200 (CO), 3400 cm^{-1} (NH).

LITERATURE CITED

1. E. N. Shepelenko, A. D. Dubonosov, A. É. Lyubarskaya, V. A. Bren', and V. I. Minkin, Khim. Geterotsikl. Soedin., No. 6, 774 (1989).
2. G. D. Palui, A. É. Lyubarskaya, B. Ya. Simkin, V. A. Bren', Yu. A. Zhadanov, V. I. Minkin, and M. I. Knyazhanskii, Zh. Org. Khim., 15, 1348 (1979).
3. G. Stefanovic, L. Lorens, and M. L. Mihoilovich, Rec. Trav. Chim., 80, 149 (1961).
4. L. M. Sitkina, A. D. Dubonosov, V. A. Bren', S. M. Aldoshin, V. I. Minkin, and L. O. Atovmyan, Zh. Org. Khim., 23, 803 (1987).
5. V. A. Bren', Khim. Geterotsikl. Soedin., No. 7, 878 (1986).
6. G. I. Zhungietu and M. A. Rekhter, Isatin and Its Derivatives [in Russian], Shtiintsa, Kishinev (1977), p. 227.
7. V. M. Rodionov, Z. S. Kazakova, and B. M. Bogoslovskii, Izv. Akad. Nauk SSSR, Ser. Khim., No. 3, 536 (1948).

DEPENDENCE OF THE REACTIVITY OF FIVE-MEMBERED AROMATIC HETEROCYCLES ON THEIR STRUCTURE.

4.* PROTON AFFINITY OF N-AMINOAZOLES

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781'79:519.25

Proton affinity of the amino groups of 10 N-aminoazoles is calculated using the STO-3G basis set. The nature of the heterocyclic effect on proton affinity of the amino groups depends on its conformation which in turn is determined by the number of nitrogen atoms in the α-position. The accuracy of the proton affinity calculation can be raised considerably by taking into account the interaction of heteroatoms in the ring.

We demonstrated that the proton affinity (PA) in the case of C-aminoazoles upon protonation at the amino group can be calculated by a simple additive scheme [2] by studying the dependence of PA of aminoazoles on the number and position of the heteroatoms. In the present case, we studied the possibility of using this scheme for description of the effect of heteroatoms on the PA of the amino group in a number of N-aminoazoles. The PA (Table 1) of all possible N-aminoazoles which also contain from 0 to 4 nitrogen atoms in the ring are estimated from the formula

$$\mathrm{PA} = E^0 - E^+, \qquad (1)$$

where E^0 and E^+ are the total energies of the starting and protonated azole which are calculated using the STO-3G minimal basis set according to the procedure described in [2].

Optimization of the geometry of the N-NH_2 fragment within the framework of the semiempirical MNDO method shows that the tetrahedral amino group in N-aminoazoles with one α-nitrogen

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*For Communication 3, see [1].

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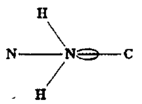
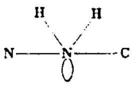
TABLE 1. PA Values of N-Aminoazoles and σ_1 of N-Azolyl Substituents

Position of aza atoms in the ring	PA, kcal/mole		σ_I	
	STO-3G basis set	from equation (4)	from [5]	from equation (6)
—	249,0	249,1	0,24	0,23
2	241,4	241,2	0,26	0,31
3	241,4	241,2	0,46	0,42
2, 3	230,3	231,0	0,48	0,50
2, 4	231,4	231,0	—	0,50
2, 5	243,3	243,1	0,44	0,39
3, 4	231,0	231,0	—	0,61
2, 3, 4	218,6	218,5	0,69	0,69
2, 3, 5	230,3	230,6	—	0,58
2, 3, 4, 5	215,8	215,7	—	0,77

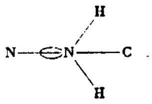
atom is rotated such that the hydrogen atoms are located on different sides of the heterocyclic plane. The orbital of the free electron pair is located in this plane in the position anti to the α-heteroatom (conformation A). In all other cases, the hydrogen atoms are located to one side of the heterocyclic plane whereas the orbital of the free electron pair is perpendicular to it (conformation B):



A



B



C

However, the MNDO method does not accurately describe the conformational behavior of hydrazine itself [3]. Therefore, we also carried out optimization of the torsion angle of the amino group of the three aminoazoles which contain 0, 1, and 2 nitrogen atoms, respectively, in the α-position by a nonempirical method using the STO-3G basis set (since it is known that even with this minimal basis set the optimal conformation of hydrazine can be predicted correctly [4]) and the program GAUSSIAN-80. The results of the nonempirical calculation coincided with the data of the MNDO method. For example, conformer B is more stable by 7.2 kcal/mole and conformer C by 5.0 kcal/mole than conformer A according to the ab initio calculation for N-aminopyrazole.

Thus, the conformation of the amino group determines its interaction with the α-nitrogen atom. From the viewpoint of this interaction, conformer A is most suitable, but it can be realized only in azoles with one α-nitrogen atom. Therefore, such azoles are additionally stabilized due to conformational differences, which in agreement with (1) should lead to a reduction of their PA. As a result, establishment of the dependence between the PA and the structure of the heterocycle by an additive scheme must include in the equation an additional term which considers the conformation of the amino group:

$$\mathrm{PA} = \mathrm{PA}_0 + \Delta E_\alpha n_\alpha + \Delta E_\beta n_\beta + \Delta E_k k, \qquad (2)$$

where PA_0 is the proton affinity of N-aminopyrrole, n_α and n_β are the number of nitrogen atoms in the α and β-positions, ΔE_α and ΔE_β are values which characterize the effect on PA of the corresponding nitrogen atom, ΔE_k is the change of PA upon transition from conformation B to conformation A, and k = 1 for azoles with one α-nitrogen atom and k = 0 for all the others.

The quantities ΔE in (2) were determined by a least squares method:

$$\mathrm{PA} = 251.8 - 5.3n_\alpha - 11.4n_\beta - 10.0k \quad (r = 0.987;\ s = 1.6;\ F = 78). \qquad (3)$$

Equation (3) does not consider the effect on PA of interactions of heteroatoms in the ring with each other. In order to evaluate their importance, we added an additional term which considers paired interactions the number of which is n(n − 1)/2, where n is the number of aza atoms in the ring:

$$\mathrm{PA} = 249.1 - 1.9n_\alpha - 7.9n_\beta - 6.1k - 2.3n(n-1)/2 \qquad (4)$$
$$(r = 0.9996;\ s = 0.3;\ F = 1455).$$

Comparison of Eqs. (3) and (4) shows that consideration of paired interactions considerably increases the quality of the correlation and reliability of the equation, as well as decreases the mean square error by more than five times.

The dependence of PA on the values of induction (σ_1) and resonance constants (σ_R) of the N-azole substituents is interesting [5]. Use of a least squares method found that the PA value correlates well with the induction constants (Eq. (5)), whereas a correlation with the resonance constants is not observed (r = 0.59):

$$\mathrm{PA} = 262.7 - 47.8\sigma_I - 9.9k \quad (r = 0.991;\ s = 1.3;\ F = 84). \qquad (5)$$

This suggests that the change of PA value in the studied series is determined by differences in the induction effects of the rings. The conformational factor must also be considered during evaluation of the correlation with the σ_1 constants.

The existence of regularities which are described by Eqs. (3) and (5) indicates that the σ_1 constants can be calculated by an additive scheme taking into account the number and position of nitrogen atoms in the ring:

$$\sigma_I = 0.23 + 0.08n_\alpha + 0.19n_\beta \quad (r = 0.974;\ s = 0.03;\ F = 28). \qquad (6)$$

Since the experimental values of the σ_1 constant are determined with an accuracy up to 0.1 [5], Eq. (6), can be considered to describe well the dependence of σ_1 on the ring structure and to permit the σ_1 values to be predicted for those N-azolyl substituents for which they are known (Table 1).

LITERATURE CITED

1. V. G. Andrianov, M. A. Shokhen, and A. V. Eremeev, Khim. Geterotsikl. Soedin., No. 4, 508 (1989).
2. V. G. Andrianov, M. A. Shokhen, A. V. Eremeev, and S. V. Barmina, Khim. Geterotsikl. Soedin., No. 1, 54 (1987).
3. M. J. S. Dewar and W. Thiel, J. Am. Chem. Soc., 99, 4908 (1977).
4. U. Chandra Singh, P. K. Basu, and C. N. R. Rao, J. Mol. Struct., 87, 125 (1982).
5. A. F. Pozharskii, Theoretical Principles of the Chemistry of Heterocycles [in Russian], Khimiya, Moscow (1985), p. 118.