50% ethanol) with mp 166-167°C was 38%. IR spectrum (mineral oil): 1680 (C=O) and 3250 cm^{-1} (NH). Found: C 56.5; H 3.1; N 5.9%. $C_{11}H_7NOS_2$. Calculated: C 56.6; H 3.0; H 6.0%.

Bis(thieno[3,2-d]thiazol-2-yl) Disulfide (XV). A 2.46-g (0.22 mole) sample of 30% hydrogen peroxide was added dropwise at 70°C to a suspension of 1.56 g (0.09 mole) of IX in 4 ml of concentrated hydrochloric acid, and the mixture was heated at 70-75°C for 30 min, after which it was diluted with 15 ml of water. The resulting precipitate was removed by filtration, washed with water, treated with 5% sodium hydroxide solution, washed with water, and dried to give 1.2 g (78%) of XV as yellowish prisms (from benzene) with mp 175-176°C. Found: C 34.7; H 1.1; N 8.0%. $C_{10}H_4N_2S_6$. Calculated: C 34.8; H 1.2; N 8.1%.

The acidic filtrate after isolation of disulfide XV was made alkaline with a solution of sodium hydroxide and extracted with ether. The extract was washed with water and dried with potassium carbonate. The ether was removed by distillation, and the residue was vacuum distilled to give 0.5 g (4%) of thieno[3, 2-d]thiazole as a light-yellow oil with bp 110-115°C (25 mm). Found: C 42.4; H 2.0; N 10.0%. $C_5H_3NS_2$. Calculated: C 42.5; H 2.1; N 9.9%. The picrate had mp 164-165°C (from ethanol). Found: C 35.5; H 1.7; N 15.3%. $C_5H_3NS_2 \cdot C_6H_3N_3O_7$. Calculated: C 35.7; H 1.6; N 15.1%.

Bis(5-phenylthieno[2,3-d]thiazol-2-yl) Disulfide. This compound was obtained by a method similar to that used to prepare XV by oxidation of 0.1 mole of mercaptan I. Workup gave yellowish prisms (from benzene) with mp 194-195°C in 72% yield. Found: C 53.0; H 2.3; N 5.7%. $C_{22}H_{12}N_2S_6$. Calculated: C 53.2; H 2.4; N 5.6%.

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1,3-THIAZINEDIONES AND PYRIMIDINEDIONES.

4.* TAUTOMERISM OF 2-SUBSTITUTED 4,6-DIOXODIHYDRO-1,3-THIAZINES

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The character of the effect of substituents on the position of the keto–enol equilibrium in 2-substituted 4,6-dioxodihydro-1,3-thiazines and the structure of the enol form are examined. 2-Phenyl-4,6-dioxodihydro-^{15}N-1,3-thiazine was synthesized. It was shown by ^{13}C NMR spectroscopy that the 2-phenyl-4-hydroxy-1,3-thiazin-6-one structure corresponds to the enol form.

It has been shown [2] that 2-substituted 1,3-thiazinediones are potentially tautomeric compounds. The specificity of enolization in the unsymmetrical β-dicarbonyl fragment and the reasons for the different effects of substituents on the position of the keto–enol equilibrium have not been previously discussed. Enol forms A and B are presented in the literature without any stipulation [1-5].

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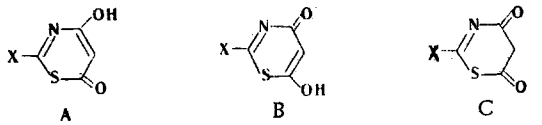
TABLE 1. Position of the Ketone ⇌ Enol Equilibrium in 2-Substituted 1,3-Thiazinediones*

X	$C_6H_5NCH_3$	C_6H_5	C_2H_5O	CH_3	$C_6H_5CH_2S$
Ketone/enol	0/100	0/100	30/70	60/40	100/0

*For 15% solution (10% for X = C_6H_5) in d_6-DMSO with an EM-360 spectrometer at 35°C.



A B C

An understanding of these questions, at least within the framework of a general approach, would make it possible to predict the character of the reactivity of 2-substituted thiazindiones [3] and to represent the structure of their derivatives in a more rigorous manner.

Since only the substituent varies in the molecules of various 2-substituted thiazinediones, that substituent which by virtue of its peculiarities will better stabilize the heteroaromatic system (the enol form) should evidently promote enolization to a greater degree.

Examples of the effect of the principal types of investigated substituents on the position of the keto–enol equilibrium are presented in Table 1 (the system was assumed to be an equilibrium system if the ketone–enol ratio did not change after the addition of catalytic amounts of triethylamine [2]).

It is apparent from these data that in the series of 2-substituted 1,3-triazinediones with a heteroatomic substituent the equilibrium percentage of the enol form changes in the same direction as the capacity of the heteroatom for conjugation (+M effect): N > O > S. It follows from the concept of electron migration via a conjugation mechanism that the relative intensity of the effect should correspond to the relative tendency of a substituent to increase its covalent character (double bond character). Since the effectiveness of overlapping of the 2p orbitals of the sp^2 C_2 atom with the orbitals of the unshared electrons of the sulfur atom is considerably less than the effectiveness of overlapping with the orbitals of the unshared electrons of atoms of the second period (oxygen and nitrogen), the capacity of the 2-alkylthio group for conjugation with the heteroring decreases sharply. 2-Phenylthiazinedione, which, like 2-methylphenylaminothiazinedione, is completely enolized, should be dealt with separately. The phenol group in this case is particularly "convenient" since the absence of substituents in the 1 and 3 positions of the heteroring and overlapping of the p orbitals of the adjacent sp^2 carbon atoms create the optimum conditions for the formation of a coplanar system and delocalization of the π-electron density with participation of the benzene ring. It is probable that precisely these factors lead in this case to the high stability of the enol form. The ethoxy group (+M and strong –I effects) and methyl group are situated in the middle of the series under consideration; this is reflected in the position of the keto–enol equilibrium.

In the case of inclusion of a substituent in conjugation with the heteroring, the effective negative charge on the alternately remote atoms should increase in conformity with the electron-donor capacity of the substituent. Data on the $^{13}C_5$ chemical shifts, which are related to the magnitude of the effective charge on the carbon atom [6] in the conjugated system of the heteroring $X–C_{(2)}=N_{(3)}–C_{(4)}(OH)=C_{(5)}–C_{(6)}=O$ (the selection of precisely this pathway for transmission of conjugation is substantiated below), are presented in Table 2.

A comparison of the chemical shifts of the $^{13}C_5$ atoms and the protons attached to C_5 for the enol forms confirms the assumptions expressed above regarding the character of the effect of the substituents. The increase in the electron-donor capacity of the methylphenylamino group as compared with the ethoxy group corresponds to the shift of the signals to weak field. The phenyl group, which stabilizes the enol form well due to factors that favor

*See [1] for communication 3.

TABLE 2. $^{13}C_5$ and 5-H Chemical Shifts in the NMR Spectra of 2-Substituted Thiazinediones*

X	δ $^{13}C_{(5)}$, ppm		δ 5-H, ppm	
	ketone	enol	ketone	enol
$C_6H_5NCH_3$	—	82,8	—	5,08
C_2H_5O	44.7	87,1	3,42	5,14
CH_3	†	90,1	3,68	5,40
C_6H_5	—	90,7	—	5,85
$C_6H_5CH_2S$	43,4	—	3,53	—

*For 15% (10% for X = C_6H_5) solutions in DMSO and d_6-DMSO with CFT-20 and EM-360 spectrometers at 35°C.
†The signals of the diketo form could not be recorded because of the slow establishment of equilibrium in dry DMSO and the insufficient stability of the compound [2].

conjugation, is a relatively weak electron-donor group, which is also manifested in the weak-field shift of the $^{13}C_5$ and 5-H signals. The greater degree of interaction of the methyl group of 2-methyl-1,3-thiazinedione with the enol form as compared with the diketone form is confirmed by the weak-field shift of the signal of the protons of the methyl group of the enol form (0.46 ppm) [2].

Thus, the possibility of an increase in its thermodynamic stability due to conjugation with the substituent should be regarded as the decisive structural factor that promotes the formation of the enol form of 2-substituted 1,3-thiazindiones. A decrease in the degree of conjugation leads to comparable thermodynamic stability of the enol and dicarbonyl forms. The comparable percentages of both forms (X = RO, CH_3) or even a complete shift of the equilibrium to favor the thermodynamically more favorable dicarbonyl form (X = RS) are a consequence of this.

The problems of the specificity of enolization in 2-substituted thiazinediones evidently cannot be solved unambiguously by means of the traditional examination of the possibility for delocalization of the bonds and charges in structures A and B, since both enol forms are described by almost identical sets of principal limiting structures.

To estimate the relative stabilities of enol forms A and B we calculated the atomization energies (E_{at}) of these structures by the Pariser–Parr–Pople (PPP) method in the Dewar σ, π parametrization [7], which has been previously used successfully for a study of the benzoid–quinoid equilibrium of azomethines [9]. The results of the calculation showed that tautomer A is the most stable tautomer (Table 3). The development of an effective negative charge in structure A is in good agreement with the experimental results, which confirm the possibility of facile electrophilic substitution in this position [1].

However, even the calculated data do not give direct evidence of the structure of the enol form (our previous attempt to solve this problem by means of the IR spectra of a number of model compounds also did not make it possible to make an unambiguous assignment). It was found that it was possible to realize an experimental verification in the case of 2-phenyl-^{15}N-1,3-thiazinedione, which was synthesized by the scheme in [1, 10]:

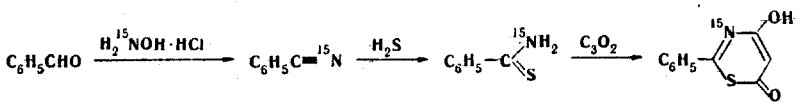


TABLE 3. Results of the Calculation of the Enol Forms of 2-Substituted 1,3-Thiazinediones

X	E_{at}, kcal/mole		ΔE_{at}, kcal/mole	Effective charge on the C_5 atom	
	form A	form B		form A	form B
H	1160,8	1153,4	7,4	−0,1468	+0,0027
C_6H_5	2375,7	2370,1	5,6	−0,1647	+0,0039
OH	1257,2	1251,7	5,5	−0,1547	+0,0053
NH_2	1334,0	1328,4	5,6	−0,1574	+0,0058

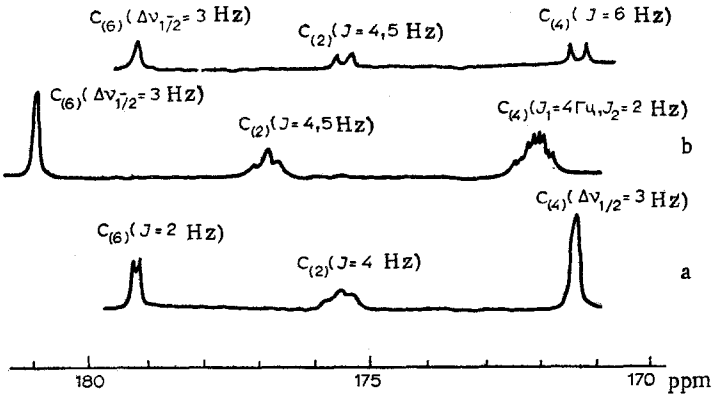


Fig. 1. a) 2-Phenyl-4-hydroxy-1,3-thiazin-6-one (10%, d_6-DMSO); b) 2-phenyl-4-methoxy-1,3-thiazin-6-one (15%, $CDCl_3$); c) 2-phenyl-4-hydroxy-^{15}N-1,3-thiazin-6-one (10%, d_6-DMSO).

The weak-field region of the ^{13}C NMR spectrum of 2-phenyl-1,3-thiazinedione in DMSO (Fig. 1a) contains three signals at δ 179.2, 175.5, and 171.2 ppm, which are related to the C_6, C_2, and C_4 atoms. To confirm this assignment of the signals we recorded the ^{13}C NMR spectrum of the O-methyl ether of 2-phenyl-1,3-thiazinedione (Fig. 1b), which models the enol form [2]. The signals of the C_6, C_2, and C_4 atoms lie in the low-field portion of the spectrum of this compound in $CDCl_3$ at 181.2, 176.9, and 172.8 ppm (at 179.4, 175.1, and 171.6 ppm, respectively, in DMSO). Splitting of the signal at 172.8 ppm to give a doublet of quartets (J_1 = 4 Hz, J_2 = 2 Hz) in the spectrum without suppression of the ^{13}C—^{1}H spin—spin coupling made it possible to assign it to the carbon atom bonded to the methoxy (enol) group. The insignificant decrease in the C_4—H_5 SSCC in the enol form of 2-phenyl-1,3-thiazinedione as compared with its methyl ether and the corresponding increase in the C_6—H_5 SSCC (Fig. 1) should be described to the greater degree of delocalization of the π-electron density in a strongly basic solvent. The signal of the C_2 atom in the spectrum of 2-phenyl-1,3-thiazinedione and its methyl ether is split into a triplet (Figs. 1a and 1b) as a result of coupling with the two ortho protons of the benzene ring. To determine whether the carbon atom bonded to the hydroxy group is in the 4 or 6 position, we obtained the ^{13}C NMR spectrum with complete suppression of the ^{13}C-^{1}H spin—spin coupling of 2-phenyl-^{15}N-1,3-thiazinedione (Fig. 1c). Distinct splitting of the signals of the C_2 (175.5 ppm) and C_4 (171.2 ppm) atoms into doublets with J = 4.5 and 6.0 Hz was observed in this spectrum. The 2-phenyl-4-hydroxy-1,3-thiazin-6-one structure consequently corresponds to the enol form.

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