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SYNTHESIS OF PYRAZOLE, 1,3,4-THIADIAZOLE, AND 1,2,4-TRIAZOLE DERIVATIVES BY CONDENSATOIN OF 1,3-DIOXO COMPOUNDS WITH THIOSEMICARBAZIDE DERIVATIVES

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The reaction of β-diketones with 2-unsubstituted thiosemicarbazides leads to the formation of the corresponding 1-thiocarbamoyl-5-hydroxy-2-pyrazolines, which readily undergo aromatization to give pyrazoles, while the reaction of benzoylacetaldehyde leads to the formation of the corresponding hydrazone. Acetylacetone 2-methyl- and 2,4-dimethylthiosemicarbazones are inclined to undergo tautomerization and, depending on the conditions, can exist in enehydrazine, hydrazone, 1,2,4-triazoline, and 1,3,4-thiadiazoline forms or mixtures of these forms. Upon heating these substances are converted to mixtures of the 1,3,5-trimethylpyrazole and the corresponding 1,2,4-triazoline-5-thione. The structures of the compounds were studied by means of IR and ^1H, ^{13}C, and ^{15}N NMR spectroscopy and mass spectrometry.

The reaction of thiosemicarbazide derivatives (four reaction centers) with 1,3-dioxo compounds (two reaction centers) is a typical example of the condensation of polyfunctional reagents that is used for the synthesis of various heterocycles. The primary products (I) of condensation due to the participation of the amino $N_{(1)}$ atom [which are capable, like other hydrazines of β-dicarbonyl compounds, of existing in hydrazone (A) or enehydrazine (B) forms [1, 2]] upon subsequent cyclization can, in principle, be converted to pyrazole [3, 4], 1,2,4-triazole, 1,3,4-thiadiazepine [6, 7], and 1,2,4-triazepine [8] derivatives (see scheme on following page).

On the basis of the information set forth above, a detailed study of the reaction under discussion is necessary.

For this we again examined the structures of the products of condensation of thiosemicarbazide and 4-methylthiosemicarbazide with acetylacetone and of thiosemicarbazide with dibenzoylmethane [3, 4], and we additionally synthesized products of the reaction of 4-methylthiosemicarbazide with dibenzoylmethane and of thiosemicarbazide with benzoylacetaldehyde and benzoylacetone (Ia-f, respectively). The characteristics of Ia-c were published previously [3, 4, 6], and data on Id-f are presented in the Experimental section of the present paper. These results provide unambiguous evidence that Ia-d have a cyclic structure; thus tautomeric or isomeric forms A and B should be excluded. Furthermore, for them it is not necessary to take into account structures F and I·HX, since the IR spectra of Ia-d do not contain absorption of a carbonyl group at 1650-1800 cm^{-1}, while the ^{13}C NMR spectra do not contain signals above 190 ppm. Compounds Ib, d also cannot exist in forms D' and E, since in their PMR spectra the signal of the methyl group attached to the nitrogen atom is a doublet, which constitutes evidence in favor of the presence of an $NHCH_3$ fragment, and since the spectral characteristics of all Ia-d are completely analogous, the possibility of the existence of Ia, c also in the same forms is doubtful.

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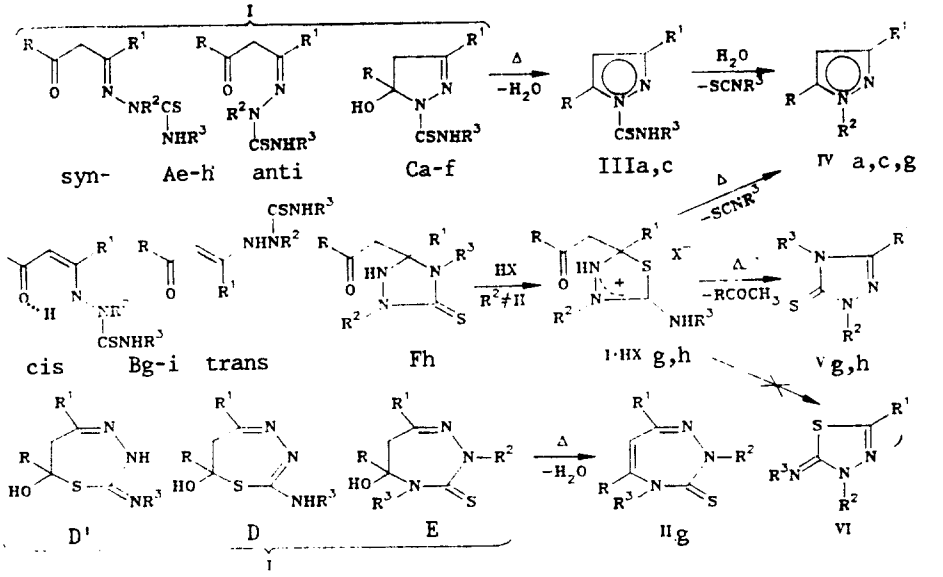
TABLE 1. Mass Spectra* of Ia-c, e-i and Vg, h

Compound	m/z (I_{rel}, %)
Ia	155 (26), 96 (100), 95 (90), 91 (64), 81 (27), 68 (13), 65 (9), 60 (46), 59 (63), 54 (35)
Ib	187 (88), 130 (79), 99 (48), 97 (44), 96 (39), 74 (47), 73 (41), 72 (50), 57 (42), 43 (100), 42 (41)
Ic	297 (13), 220 (53), 191 (14), 178 (62), 117 (7), 105 (100), 104 (14), 91 (9), 77 (65), 59 (17), 51 (17)
Id	221 (13), 146 (5), 144 (6), 105 (100), 102 (76), 77 (67), 76 (7), 74 (5), 60 (16), 59 (6), 51 (35)
Ie	235 (6), 158 (100), 157 (30), 129 (12), 128 (18), 116 (27), 105 (56), 77 (54), 59 (44), 51 (33), 50 (13)
If	187 (9), 130 (94), 129 (24), 113 (17), 111 (24), 89 (64), 84 (33), 69 (19), 60 (33), 57 (100), 43 (94)
Ig	201 (4), 144 (40), 113 (28), 111 (34), 84 (23), 74 (80), 71 (100), 69 (36), 56 (23), 55 (78), 43 (60)
Ih	311 (0,2), 234 (43), 192 (33), 191 (20), 105 (100), 104 (32), 103 (25), 91 (13), 77 (98), 60 (16), 51 (31)
Vi	129 (100), 128 (24), 96 (10), 88 (10), 70 (11), 69 (32), 60 (62), 59 (14), 56 (10), 55 (52), 44 (58)
Vj	143 (73), 142 (11), 74 (100), 73 (10), 72 (11), 70 (14), 69 (92), 56 (15), 43 (13), 42 (45), 41 (13)

*The averaged data of five spectra. The $M^{+\cdot}$ ions and the ten most intense peaks are presented.



Compound*	R	R¹	R³	Compound*	R	R¹	R³	Compound*	R	R¹	R³
Ia	CH_3	CH_3	H	Id	C_6H_5	C_6H_5	CH_3	Ig	CH_3	CH_3	H
Ib	CH_3	CH_3	CH_3	Ie	C_6H_5	H	H	Ih	CH_3	CH_3	CH_3
Ic	C_6H_5	C_6H_5	H	If	C_6H_5	CH_3	H	Ii	C_6H_5	C_6H_5	H

Thus one should choose between the 5-hydroxy-2-pyrazoline (C) and 1,3,4-thiadiazepine (D) tautomers. We hoped to obtain the answer to this question from ^{15}N NMR spectral data; however, at room temperature the solubilities of Ia, c in various solvents proved to be insufficient to obtain such spectra; if these compounds are heated in d_6-DMSO to increase their solubilities, they decompose completely after 30 min at 100°C. 1-Thiocarbamoylpyrazoles IIIa, c are formed as a result. This follows, in particular, from the ^{15}N NMR spectrum of IIIa [singlets of imino and amino nitrogen atoms at 295.5 and 224.5 ppm, respectively, and a triplet of a thiocarbamoyl nitrogen atom at 133.4 ppm (J = 92.5 Hz)]. The ^{13}C NMR spectra of

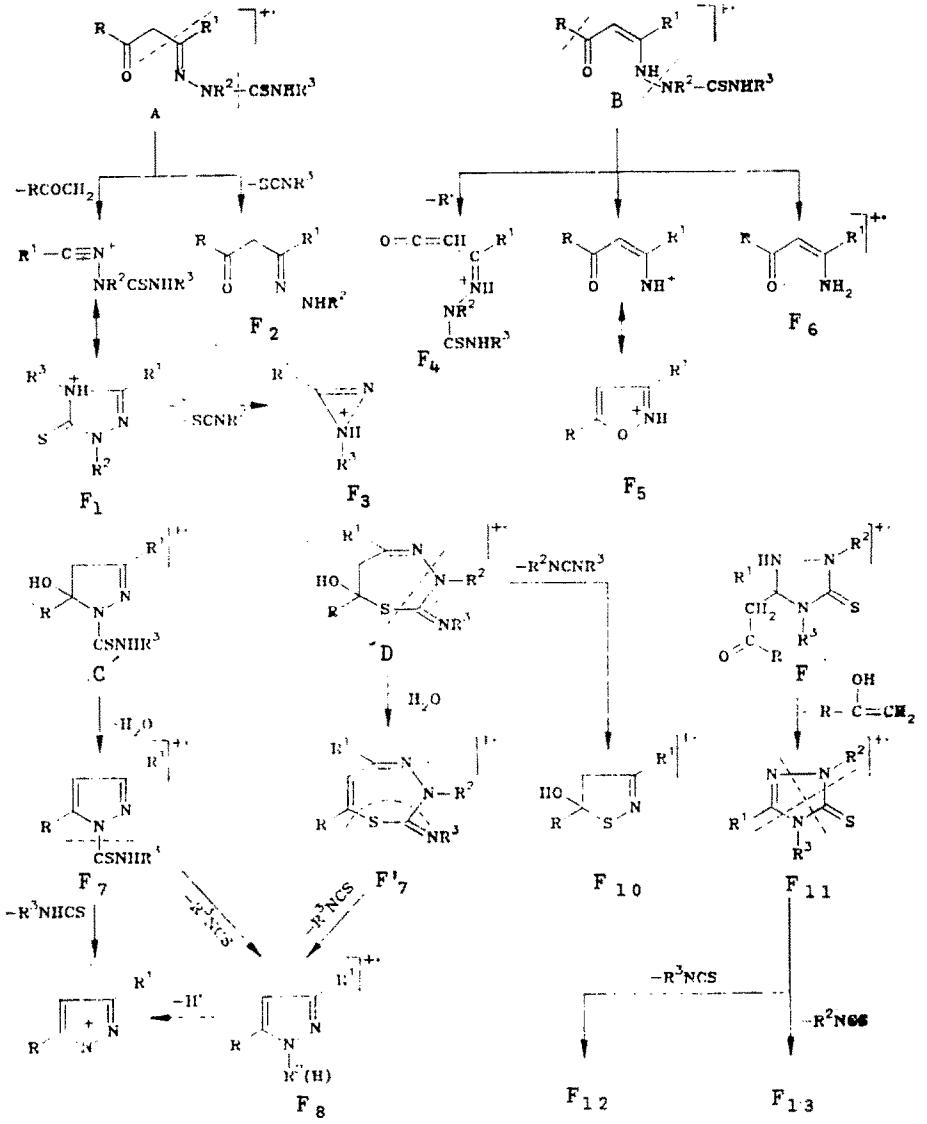
*Ia-f R^2 = H, g-i R^2 = CH_3.

these substances are also in complete agreement with the proposed structures (see Experimental). When 1-thiocarbamoylpyrazoles IIIa, c are heated further under the same conditions, they undergo quantitative conversion to 3,5-disubstituted pyrazoles IVa, c [9, 10].

The PMR and ^{13}C NMR spectra of Ia-d cannot be used as a reliable criterion of the structure in choosing between isomers C and D. However, the appreciable similarity between the spectral characteristics of these compounds and those obtained for 5-hydroxy-2-pyrazolines as a whole [4, 11-13], synthesized by the reaction of acylhydrazines, thioacylhydrazines, amidrazones, semicarbazides, and aminoguanidine with 1,3-dioxo compounds, is noteworthy. In particular, one's attention should be directed to such a detail as the long-range spin-spin coupling of the protons of the methyl group attached to the C=N bond with the protons of the diastereoscopic CH_2 group in the PMR spectra of the corresponding acetylacetone (Ia, b) and benzoylacetone (If) derivatives that is characteristic precisely for 5-hydroxy-2-pyrazolines [14].

To ascertain the primary structures of Ia-c, e-i in the gas phase (without a solvent) we made a thorough analysis of their mass spectra (Table 1).

The molecular ion of Ia proved to be the least stable ion (it was absent in the spectrum), while the ion with the highest m/z value corresponded to the F_7 ([M – H_2O]) fragment. This indicated a cyclic (C) structure of the $M^{+\cdot}$ ion, since the F_7 ion successively lost HNCS and H to give F_8 and F_9 fragments. In addition to this, fragments formed from the linear form of the molecular ion (F_1 and F_2) were observed in the spectrum, but their percentage in the total ion current was small (Table 2).



Compound Ib proved to be more resistant to electron impact, possibly owing to the lower percentage of cyclic form C in the gas phase. Correspondingly, the intensities of the peaks of F_1-F_3 and F_4-F_6 ions, which are characteristic for linear forms A and B, increase in its mass spectrum, and the intensities of peaks of ions of cyclic form C (the F_7-F_9 ions) decrease.

The F_7 ion is already completely absent in the mass spectrum of Ic, and the character of the fragmentation of the molecular ion indicates the presence in the vapors of only its hydrazone (A) and enehydrazine (B) forms. Let us note that in [6] the

TABLE 2. Mass Spectra of Ia-c, e-i (Σ_{40}, %)

Compound	W_M	Intensities of the peaks of the characteristic ions															Form, %*[1]			
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{11}	F_{12}	F_{13}	RCO⁺	R²NCS⁺·	R²N·HCS	R¹⁺	A	B	C	F
Ia	—	0,2	0,3	—	—	—	—	4,3	18,5	15,0	—	—	—	2,5	10,5	7,7	—	1	—	99	—
Ib	12,0	9,5	1,7	2,0	1,1	—	5,8	1,1	4,7	4,1	—	—	—	12,1	5,0	5,7	—	44	23	33	—
Ic	3,1	12,2	—	—	10,4**	—	—	—	—	—	—	—	—	21,2	3,3	0,6	12,8	54	46	—	—
Ie	3,4	16,9	—	4,2	1,3	1,1	—	0,1	0,1	—	—	—	—	24,0	1,3	3,6	15,0	89	10	1	—
If	1,4	5,2	—	—	—	—	—	0,2	23,4***	5,8	—	—	—	10,6	8,5	0,5	10,3	15	—	85	—
Ig	1,4	12,7	0,5	13,5	1,4	1,2	1,9	—	—	—	3,2	0,7	1,4	12,7	0,7	4,5	—	73	12	—	15
Ih	0,7	5,5	2,5	13,9	1,4	—	1,9	—	—	—	—	—	—	8,3	1,3	11,0	—	87	13	—	—
Ii	0,1	5,9	—	—	—	1,4	0,9	0,5****	7,7*****	—	3,6	0,9	0,9	17,8	1,8	2,9	17,5	26	10	—	24*****

*A = $[(F_1 + F_2 + F_3)/F]\cdot 100$, B = $[(F_4 + F_5 + F_6)/F]\cdot 100$, C = $[(F_7 + F_8 + F_9)/F]\cdot 100$, D = $[(F_7 + F_8 + F_{10})/F]\cdot 100$, and F = $[(F_{11} + F_{12} + F_{13})/F]\cdot 100$.

**Sulfur is included in the composition of the ion.

***Sulfur is not included in the compositon of the ion.

****In addition, the F_{10} ion (0.9%).

*****In addition, 40% of the D form.

TABLE 3. PMR Spectra of Ig, h

Compound	Form	Content, %	Solvent	T of the solvent, °C	Chemical shift, ppm				
					CH_3—C, S, 3H	CH_3—$N_{(2)}$, S, 3H	CH_3—$N_{(4)}$, 3H or $HN_{(4)}$	CH_2, 2H or CH, 1H	NH
Ig	cis-B	100	$CDCl_3$	26(freshly prepared)	1,95; 2,03	3,49	6,65 (2H, s, NH_2)	5,23 s, 1H	—*
Ih	cis-B	100	—	—	1,83; 2,03	3,50	3,08 d **	5,28 s, 1H	6,60 br.s 11,11 s
Ih	cis-B	90	$CDCl_3$	60 (after 3 days)	1,83; 2,03	3,50	3,08 d**	5,28 s, 1H	6,60 br.s*
	trans-B	10	—		1,94; 2,25	3,50	3,10 d**	5,12 s, 1H	—*
Ih	cis-B	35	CD_3OD	60	1,84; 2,12	3,46	2,99 s	—***	—*
	trans-B	10	—	—	2,10; 2,24	3,45	3,00 s	—***	—*
	syn-A	45	—	—	2,03; 2,32	3,66	3,48 s	—***	—*
	anti-A	10	—	—	2,17; 2,20	3,64	3,19 s	—***	—*
Ig	cis-B	54	d_7-DMF	26	1,78; 1,88	3,44	—*	5,20 s, 1H	—*
	trans-B	14	—	—	1,88; 2,15	3,44	—*	5,12 s, 1H	—*
	syn-A	32	—	—	1,86; 2,18	3,34	—*	3,68 s, 2H	—*
Ih	cis-B	40	—	—	1,80; 1,97	3,45	2,97 d**	5,25 s, 1H	8,06 q **; 11,01 s
	trans B	40	—	—	1,97; 2,18	3,45	2,97 d**	5,10 s, 1H	8,04 q **; 8,75 s
	syn-A	10	—	—	1,92; 2,21	3,67	3,36 s	3,62 s, 2H	—*
	F	10	—	—	1,49; 2,15	3,17	2,96 s	3,43 and 3,49; AB-system (J_{AB}=16,0), 2H	5,70 s
Ig	I·HX	100	CF_3COOH	26	1,67; 2,26	3,37	7,55 (s, 2H, NH_2)	3,25 s, 2H	7,55 s
Ih	I·HX	100	—	—	1,67; 2,27	3,27	3,05 d**	3,15 s, 2H	7,28 q **; —*

*The signal was not localized.

**SSCC J = 5 Hz.

***Deuterium exchange.

TABLE 4. ^{13}C NMR Spectra of Ih

Form	Content, %	Solvent	Chemical shift, ppm				
			C=O,s	C=S, s ($C\overset{s}{=}N^{+}$, s)	C=N,s (C=C–N s; $C_{(5)}$, s)	HC=C, (CH_2, d t)	CH_3, q
cis-B	100	$CDCl_3$	197,7	183,1	161,6	99,1d	41,9; 31,9; 28,9; 17,0
cis-B	55	d_6-DMSO	194,9	181,9	160,8	97,3d	40,8; 31,2; 27,9; 15,9
trans-B	25	—	193,4	181,0	155,4	93,1d	37,9; 31,0; 30,2; 15,3
syn-A	10	—	203,6	179,0	171,5	50,9 t	39,2; 30,7; 29,0; 18,3
anti-A	5	—	201,7	179,7	172,0	46,3 t	39,6; 30,5; 29,3; 22,7
F	5	—	204,0	178,3	77,3	46,1 t	34,1; 30,6; 28,4; 19,9
I·HX	100	CF_3COOH—$CDCl_3$, 10:1	206,0	174,3	76,6	49,9 t	35,5; 35,1; 29,5; 24,9

presence of an intense peak of an [M – 77] ion in the spectrum of this compound was interpreted as an [M – H_2O – HNCS] process which, in the opinion of Glotova and coworkers [6], constituted evidence in favor of thiadiazepine structure **D**. However, the primary loss of a molecule of water by this ion leads to a rather stable structure (the F_7 ion), the peak of which should have been observed in the mass spectrum. Our investigations of the isotope ratio of the ion with m/z 220 ([M – 77]) demonstrated the presence of a sulfur atom in its composition, which made it possible to interpret this ion as F_4 ([M – C_6H_5]$^+$) and, consequently, indicated the noncyclic character of the structure of Ic in the gas phase. In fact, loss of radical R is extremely characteristic for the enol forms of the molecular ions of 1,3-dicarbonyl compounds and their derivatives [15, 16].

According to the PMR spectral data recorded in $CDCl_3$, If, which was synthesized from benzoylacetone and thiosemicarbazide, like derivatives Ia-d, exists in 5-hydroxy-2-pyrazoline form C; however, 12% of the linear hydrazone form (probably syn-A) develops in the spectrum recorded in d_7-DMF. However, the derivative (Ie) of benzoylacetaldehyde exists entirely in the linear syn-A hydrazone form (see Experimental for the PMR spectral data for Ie, f).

It follows from an analysis of the mass spectra that If in the gas phase exists primarily in cyclic hydroxypyrazoline form C, since the F_8 ion (judging from the isotope ratio) does not contain a sulfur atom. Compound Ie primarily has an acyclic form of the molecular ion (primarily A) (Table 2).

The data on the relative stabilities of the linear and cyclic hydroxypyrazoline form C of acetylacetone, dibenzoylmethane, benzoylacetaldehyde, and benzoylacetone derivatives are in agreement with data on the tautomerism of aroylhydrazones of the same β-dicarbonyl compounds [17].

Thus the formation of seven-membered heterorings **D** and **E** (taking into account their subsequent transformations) should have been expected only if cyclization to a 5-hydroxy-2-pyrazoline (C) is excluded ($R^2 \neq H$). We examined this variant in the case of the condensation of 2-methyl- and 2,4-dimethylthiosemicarbazides with acetylacetone (products Ig, h) and of 2-methylthiosemicarbazide with dibenzoylmethane (Ii); of these products, Ig was already known [8].

According to the PMR and ^{13}C NMR spectral data, Ig, h on dissolving in $CDCl_3$ exist in enehydrazine form **B**, which, on the basis of known structure criteria [2, 17] should be regarded as the cis stereoisomer. Upon prolonged storage in $CDCl_3$ up to 10% of the trans isomer accumulates in the mixture (see Table 3). Two sets of signals corresponding to the two stereoisomers [104.8 (d, J = 91.8 Hz, $HN_{(4)}$), 121.4 (s, $N_{(2)}$), 133.2 ppm (d, J = 101.8 Hz, $HN_{(1)}$) due to the cis-B isomer); 102.7 (d, J = 91.5 Hz, $HN_{(4)}$), 120.1 (s, $N_{(2)}$), 129.2 ppm (d, J = 103.5 Hz, $HN_{(1)}$) due to the trans-B isomer] are present in the ^{15}N NMR spectrum of Ih. The positions of these signals are in agreement with the data for thiosemicarbazides [18] and constitute evidence that Ih exists in the form of enehydrazine tautomer **B**.

An analysis of the mass spectra of Ig, h also indicates the primarily linear structures of their molecular ions, although hydrazone form **A** apparently predominates in the gas phase. In addition to this, the presence in the mass spectrum of Ig of the F_{11} ion ([M – 58]) and of the F_{12} and F_{13} ions formed during its subsequent fragmentation can be associated with the presence also of triazoline structure **F** of the $M^{+\cdot}$ ion in the vapors.

An examination of the mass spectrum of Ii also makes it possible to assume the presence in the ionization chamber of the mass spectrometer of an appreciable percentage of the **F** form of the molecular ion (peaks of F_{11}-F_{13} ions). But, in addition to this, [M – 18] (F_7) ions, as well as [M – 56] and [M – 77] ions, are formed in the fragmentation of $M^{+\cdot}$; whereas the first two of these fragments contains a sulfur atom, the last does not. This can be explained only by starting from the assumption of the presence in the gas phase of an appreciable percentage of thiadiazepine structure **D** (Table 2).

On dissolving in deuteromethanol Ig, h with time undergo partial (up to 55%) conversion to hydrazone form A, which is a mixture of syn and anti isomers. The fact of the existence of hydrazone tautomers was proved by the presence of signals of C=N and CH_2 carbon atoms in the ^{13}C NMR spectra (Table 4), while the conformational assignment was based on data for known acetylacetone hydrazones [2, 17].

Compound Ih behaves even more interestingly on dissolving in d_6-DMSO or d_7-DMF. Only enehydrazine tautomers **B** initially exist in such solutions; however, up to 15% of hydrazone form **A** accumulates after a few hours. Simultaneously with this one also observes a very small amount of cyclic tautomer **F**. However, after these solutions are allowed to stand for 1 week, the percentage of tautomer **F** is 85-90%. The 1,2,4-triazoline structure of this form follows from the virtually complete coincidence of its PMR and ^{13}C NMR spectra with the spectra of 2,3,3,4-tetramethyl-1,2,4-triazolidine-5-thione – the product of condensation of 2,4-dimethylthiosemicarbazide with acetone (compare the data in Tables 3 and 4 and in [5]) – with the exception of the positions and character of the signals of the CH_3CO group.

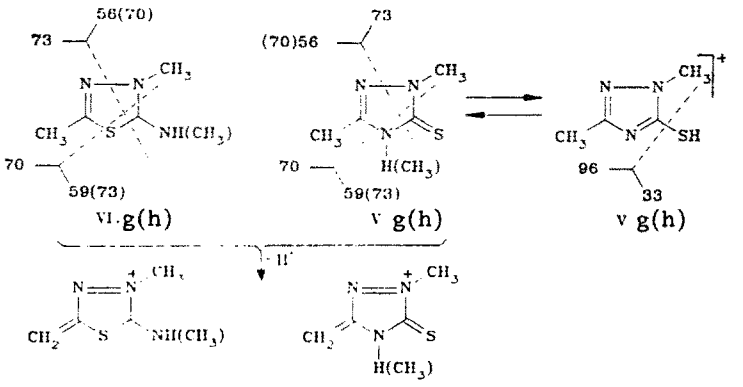
Compounds Ig, h do not undergo cyclization in d_6-DMSO and d_7-DMF; Ih retains its enehydrazine form in d_6-DMSO (see Experimental). The data on the tendency to undergo cyclization to 1,2,4-triazoline derivatives are in agreement with the behavior of more simply constructed acetone 2-methyl- and 2,4-dimethylthiosemicarbazones [5, 19].

Compounds Ih, i behave just like acetone 2,4-dimethylthiosemicarbazone on dissolving in trifluoroacetic acid, i.e., they are converted completely and irreversibly to 2-imino-1,3,4-thiadiazolium salts I·HX. (See Tables 3 and 4 for the PMR and ^{13}C NMR spectra of the $I{\cdot}H^+$ cations of Ig, h, while see Experimental and compare with [5, 19] in the case of Ii.) The ^{15}N NMR spectrum of derivative Ih contains a doublet signal at 92.9 ppm (J = 94.0 Hz, HN_{exo}) and singlets at 131.8 and 135.8 ppm; this coincides completely with the spectra of a solution of the product of condensation of 2,4-dimethylthiosemicarbazide with acetone in trifluoroacetic acid [5].

It then remained to ascertain the possibility of the formation in this reaction of 1,2,4-triazepine-3-thione II derivatives, which was previously asserted [8]. With this in mind, we accomplished the condensation of 2-methylthiosemicarbazide and 2,4-dimethylthiosemicarbazide with acetylacetone by varying the conditions extensively – changing the solvent and the temperature and using various acidic and alkaline additives, including those used under the conditions in [8]. From the results of TLC and PMR and ^{13}C NMR spectroscopy of the reaction mixtures it may be asserted that, aside from the starting reagents, products Ig, h, and another two compounds which, it was found, are products of thermolysis of Ig, h, no other substances were detected.

One of the products of thermolysis of Ig, h obtained in 50% yield by heating in DMSO is 1,3,5-trimethylpyrazole (IVg) which, according to data from the PMR and ^{13}C NMR spectra, as well as TLC data, is identical to the authentic preparation [20]. It is accompanied by 1,3-dimethyl-1,2,4-triazoline-5-thione (Vg) in the case of the thermolysis of Ig and by 1,3,4-trimethyl-1,2,4-triazoline-5-thione (Vh) in the case of the destruction of Ih (50% yield).

In principle, in the case of V one should also have taken into account the alternative formation of isomer VI with a 1,3,4-thiadiazoline structure. This is especially likely, since both 1,2,4-triazole and 1,3,4-thiadiazole derivatives can be obtained in the oxidation of thiosemicarbazones [21, 22]. Moreover, this possibility cannot be disregarded if one takes into account the possibility of the 5-mercapto-1,2,4-triazole → 2-imino-1,3,4-thiadiazole transformation [23, 24].



The PMR and ^{13}C NMR spectra of Vg, h (see Experimental) do not provide a basis for a definitive conclusion. The mass spectra of Vg, h (Table 1) are characterized by high-intensity molecular-ion peaks that eliminate a hydrogen atom and then isothiocyanate or methyl isocyanate fragments; this is characteristic for thiazoline and thiazolidine structures [25]. A comparison of the principal proposed fragments, the formation of which should be expected in the mass-spectral fragmentation of structures V and VI (see the scheme), shows that there are virtually no differences between the latter. However, a mercapto-tautomeric structure of the $M^{+\cdot}$ ion, in the fragmentation of which the probability of the formation of an $[M - SH]^+$ ion, which is actually present in the mass spectrum (the ion with m/z 96), is possible in the case of Vg. This makes it possible to speak in favor of structure V over structure VI with a higher degree of probability.

Finally, singlet signals at 167.8, 195.8, and 279.1 ppm are present in the ^{15}N NMR spectrum of the product of thermolysis of acetylacetone 2,4-dimethylthiosemicarbazone (Ih); this confirms structure Vh [signals of $N_{(4)}$, $N_{(1)}$, and $N_{(2)}$ atoms, respectively].

Thus it follows from the data obtained that a thorough analysis of the structures of the products of the condensation under consideration is necessary in each individual case. However, for 2-unsubstituted thiosemicarbazides one should primarily expect the formation of 5-hydroxy-2-pyrazolines (or their linear tautomers) which, under more severe conditions, undergo aromatization to pyrazoles or their 1-thiocarbamoyl derivatives. However, the possibilities of the use of this condensation for the synthesis of seven-membered heterocycles seem doubtful.

EXPERIMENTAL

The PMR (100 MHz) and ^{13}C NMR (20.41 MHz) spectra were recorded with a Tesla BS-497 spectrometer with hexamethyldisiloxane (HMDS) as the internal standard. The ^{15}N NMR spectra (50.69 MHz) were recorded with a Bruker AM-500 spectrometer; the chemical shifts were measured relative to an external standard [a 90% solution of formamide (FA) in DMSO] and were converted to the NH_3 scale (δ_{FA} 112.5 ppm). The mass spectra were obtained with a Varian MAT-111 spectrometer with direct introduction of the substances into the ion source at an ionization energy of 70 eV. The purity of the preparations was monitored by TLC on Silufol UV-254 plates. The compositions of the compounds obtained for the first time (Id-f, h, i) were confirmed by determining the percentages of C, H, N, and S.

1-Thiocarbamoyl-5-hydroxy-2-pyrazolines Ia-c were synthesized by the methods in [3, 4].

1-N-Methylthiocarbamoyl-5-hydroxy-3,5-diphenyl-2-pyrazoline (Id, $C_{17}H_{17}N_3OS$). This compound was synthesized under the conditions used to obtain Ic [4] and had mp 199-200°C (methanol). PMR spectrum ($CDCl_3$): 3.15 (3H, d, J= 5.0 Hz, CH_3), 3.39 and 3.75 (2H, J_{AB} = 18.0 Hz, CH_2), 6.65 (1H, s, OH), 7.2-7.8 ppm (11H, m, $2C_6H_5$ + NH).

Benzoylacetaldehyde Thiosemicarbazone (Ie, $C_{10}H_{11}N_3OS$) and 1-Thiocarbamoyl-5-hydroxy-3-methyl-5-phenyl-2-pyrazoline (If, $C_{11}H_{13}N_3OS$). These compounds were obtained by a general method. A 0.3-mole sample of thiosemicarbazide hydrochloride was dissolved in 40 ml of water, and 0.35 mole of the sodium salt of the carbonyl component was added to the solution. After 24 h, the precipitate was removed by filtration and recrystallized. **Compound Ie** had mp 140-141°C (ethanol) and was obtained in 48% yield. PMR spectrum (d_6-DMSO): 4.25 (2H, d, J = 6.0 Hz, CH_2), 7.5-8.0 (6H, m, C_6H_5 + CH), 9.50 (1H, s, NH), 9.80 (1H, s, NH), 11.50 ppm (1H, s, NH). **Compound If** had mp 87-89°C (methanol) and was obtained in 42% yield. PMR spectrum ($CDCl_3$), form C, 100%: 1.95 (3H, t, J = 1.0 Hz, CH_3), 2.97 and 3.39 (2H, J_{AB}^1 = 18.0 Hz, J^2 = 1.0 Hz, CH_2), 6.10 (1H, s, NH), 6.44 (1H, s, OH), 6.90 (1H, s, NH), 7.20 ppm (5H, m, H_{arom}); (d_7-DMF), form C, 88%: 1.95 (3H, t, J = 1.0 Hz, CH_3), 3.01 and 3.37 (2H, J_{AB}^1 = 18.0 Hz, J^2 = 1.0 Hz, CH_2), 6.68 (1H, s, OH), 7.20 (5H, s, H_{arom}), 7.70 (1H, s, NH), 7.90 ppm (1H, s, NH); form A, 12%: 2.05 (3H, s, CH_3), 4.07 ppm (2H, s, CH_2); the remaining signals were covered by the signals of principal form C.

Acetylacetone 2-Methylthiosemicarbazone (Ig) [8] and Acetylacetone 2,4-Dimethylthiosemicarbazone (Ih, $C_8H_{15}N_3OS$). These compounds were synthesized in the same way. A 0.01-mole sample of the thiosemicarbazide was dissolved in 50 ml of methanol, 0.01 mole of acetylacetone was added, and the mixture was allowed to stand for 24 h. The precipitate was separated and washed with ether. The yield was 75%. By additionally extracting the product from the mother liquor one could raise the yield to 95%. The product was recrystallized from ethanol. **Compound Ig** had mp 107-109°C (mp 104-105°C [8]). **Compound Ih** had mp 118-120°C (the PMR and ^{13}C NMR spectra are presented in Tables 3 and 4).

Dibenzoylmethane 2-Methylthiosemicarbazone (Ii, $C_{17}H_{17}N_3OS$). Methanol solutions of 0.2 mole of 2-methylthiosemicarbazide and 0.22 mole of dibenzoylmethane and 1 ml of trifluoroacetic acid were mixed. The crystals that precipitated after 24 h were separated and recrystallized to give a product with mp 156-158°C (methanol, decomp.) in 60% yield. PMR spectrum (d_6-DMSO): 3.11 (3H, s, CH_3), 6.23 (1H, s, CH), 7.3-7.7 and 7.9-8.2 (10H, m, $2C_6H_5$), 8.10 (2H, s, NH_2), 11.78 ppm (1H, s, NH); (CF_3COOH): 2.98 (3H, s, CH_3), 3.57 and 3.80 (2H, br. s, CH_2), 6.8-7.5 ppm (10H, m, $2C_6H_5$). ^{13}C NMR spectrum (d_6-DMSO): 41.3 (NCH_3), 97.0 (CH), 126.8-132.6 (C_{arom}), 164.2 (C=C), 183.4 (C=O), 189.0 ppm (C=S).

1-Thiocarbamoyl-3,5-dimethylpyrazole (IIIa) [4]. This compound was obtained by heating Ia at 100°C in DMSO for 30 min and had mp 90-91°C (ethanol). See [4] for the PMR spectrum. ^{13}C NMR spectrum (d_6-DMSO): 12.2 (CH_3), 16.1 (CH_3), 111.1 ($C_{(4)}$), 143.5 and 147.8 ($C_{(3)}$ and $C_{(5)}$), 177.4 ppm (C=S). ^{15}N NMR spectrum (d_6-DMSO): 133.4 (t, J = 92.5 Hz, NH_2), 224.4 (s, $N_{(1)}$), 295.5 ppm (s, $N_{(2)}$).

1-Thiocarbamoyl-3,5-diphenylpyrazole (IIIc) [4]. This compound was obtained by heating Ic at 100°C in DMSO for 30 min and had mp 74-76°C (ethanol–water). PMR spectrum (d_6-DMSO): 6.77 (1H, s, CH), 7.3-7.6 (6H, m, H_{arom}), 7.8-8.0 (4H, m, H_{arom}), 8.70 and 9.30 ppm (2H, br. s, NH_2).

3,5-Dimethylpyrazole (IVa) [9, 10]. This compound was obtained by heating IIIa in DMSO at 100°C for 3 h. ^{13}C NMR spectrum (d_6-DMSO): 9.8 (CH_3), 105.2 ($C_{(4)}$), 143.8 ppm ($C_{(3)}$ and $C_{(5)}$).

3,5-Diphenylpyrazole (IVc) [10]. This compound was similarly obtained. PMR spectrum (d_6-DMSO): 6.87 (1H, s, CH), 7.4-7.6 (6H, m, H_{arom}), 7.8-8.1 ppm (4H, m, H_{arom}). ^{13}C NMR spectrum (d_6-DMSO): 99.4 ($C_{(4)}$); 124.7, 127.7, 128.1, 129.3 (C_{arom}); 146.6 ppm ($C_{(3)}$ and $C_{(5)}$). ^{15}N NMR spectrum (d_6-DMSO): 232.8 ppm ($N_{(1)}$ and $N_{(2)}$).

Aromatization of Ig. A mixture of IVg and Vg (1:1 according to the PMR spectral data) was formed in quantitative yield when 0.01 mole of acetylacetone 2-methylthiosemicarbazone (Ig) was heated in DMSO for 2 h at 120°C.

1,3,5-Trimethylpyrazole (IVg). This product was found to be identical (without isolation) to the genuine preparation [20]. PMR spectrum ($CDCl_3$): 2.28 (3H, s, CH_3), 2.30 (3H, s, CH_3), 3.89 (3H, s, CH_3), 6.10 ppm (1H, s, CH). ^{13}C NMR spectrum (d_7-DMF): 10.6 (CH_3), 10.9 (CH_3), 34.8 (NCH_3), 106.9 ($C_{(4)}$), 141.1 and 144.9 ppm ($C_{(3)}$ and $C_{(5)}$).

1,3-Dimethyl-1,2,4-triazoline-5-thione (Vg) [26]. This compounds was isolated from the mixture with IVg by repeated extraction with hot benzene and had mp 155-157°C (ethanol) (mp 158°C [26]). PMR spectrum ($CDCl_3$): 2.27 (3H, s, CH_3), 3.64 ppm (3H, s, CH_3).

Aromatization of Ih. The aromatization of Ih in DMSO at 120°C for 2 h led, according to the PMR spectral data, to the formation of a mixture of IVg and Vh in equal amounts.

1,3,4-Trimethyl-1,2,4-triazoline-5-thione (Vh) [27]. This compound was isolated from the mixture with IVg by repeated extraction with hot benzene and had mp 102-103°C (ethanol) (mp 106-107°C [27]). PMR spectrum ($CDCl_3$): 2.29 (3H, s, CH_3), 3.49 (3H, s, CH_3), 3.72 ppm (3H, s, CH_3). ^{13}C NMR spectrum (d_6-DMSO): 10.3 (CH_3), 30.3 ($CH_3N_{(4)}$), 35.0 ($CH_3N_{(1)}$), 146.0 ($C_{(2)}$), 165.3 ppm ($C_{(5)}$). ^{15}N NMR spectrum (d_6-DMSO): 167.8 (s, $N_{(4)}$), 195.8 (s, $N_{(1)}$), 279.1 ppm (s, $N_{(2)}$).

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REACTION OF 3-FORMYLCHROMONE WITH METHYL- AND METHYLENE-ACTIVE AZOCYCLES

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The reaction of 3-formylchromone with quaternary salts of nitrogen heterocycles containing active methyl or methylene groups was investigated. It is shown that the compounds obtained can be used in the synthesis of merocyanine dyes containing an o-hydroxybenzoyl substituent in the polymethine chain. Dicarbocyanines with such a substituent were not isolated, evidently because of the high electrophilicity of the polymethine chain and the ease of formation of a six-membered heteroring.

Aldehydes of the heterocyclic series are used in syntheses of polymethine dyes, where the polymethine chain is constructed through –CH= groups of a heteroring that is cleaved during the reaction [1-3]. Considering that the methods for the synthesis of meso-substituted dicarbocyanines – effective sensitizers [2] – have undergone little development, it seemed of interest to use 3-formylchromone for this purpose. Reactions involving the condensation or recyclization of this compound on reaction with nucleophilic agents, primarily with ketomethylene compounds, are known [4, 5]. The reaction of 3-formylchromone with quaternary salts of nitrogen heterocycles containing active methyl groups has not been described. 3-Formylchromone can be regarded as the cyclic ether of the enol form of a substituted malonaldehyde and, like the latter, it can therefore be used to construct the polymethine chain of meso-substituted dicarbocyanines and tetramethinemerocyanines. The fact that unsubstituted chromone itself reacts in the presence of bases with quaternary salts of nitrogen heterocycles with opening of the pyrone ring [6] also served as a basis for this assumption.

The condensation of 3-formylchromone with 2,3-dimethylbenzothiazolium and 1,2,3,3-tetramethylindolium salts and with N-ethyl-2-thioxo-4-thiazolidinone in acetic anhydride or in absolute alcohol in the presence of sodium acetate leads to the formation of II-V (see scheme on following page).

The IR spectra of these compounds do not contain a band of stretching vibrations of a formyl group (1700 cm^{-1}), but the frequency of the carbonyl group of the chromone ring (1650-1670 cm^{-1}) is retained (Table 1).

One might have expected that the $C_{(2)}$ atom and the carbon atom of the formyl group in the 3-formylchromone molecule would display increased reactivities. Calculations within the Hückel MO approximation, which correctly reflect the dependence of the distribution of the π-electron density on the topology of the conjugated system, show that relatively large posi-

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