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1,2,4-TRIAZINES – PRODUCTS OF REACTION OF THIOCARBOHYDRAZIDE AND ITS ALKYL(ARYL)-SUBSTITUTED DERIVATIVES WITH 1,2-DICARBONYL COMPOUNDS

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The reaction of a series of 1,2-dicarbonyl compounds with thiocarbohydrazide and its 1- and 1,4-alkyl-(aryl)-substituted analogs has been studied. Treatment of diacetyl with the polynucleophiles indicated gives monohydrazones and/or 5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thiones. Reaction of phenylglyoxal and benzil with thiocarbohydrazide yields 5-hydroxy- or 5-alkoxy-4,5-dihydro-2H-[1,2,4]triazine-3-thiones depending on the nature of the solvent. The products of condensation with 1,1-dimethylthiocarbohydrazide showed a thiocarbonohydrazone – 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thione ring-chain type equilibrium.

Keywords: 1,2-dicarbonyl compounds, thiocarbonohydrazones, 1,2,4-triazines, ring-chain tautomerism.

Thiocarbonohydrazones of mono- and 1,3-dicarbonyl compounds show a clear trend towards ring-chain and ring-linear-ring tautomeric conversion amongst various nitrogen- and sulfur-containing heterocycles [1]. Data regarding the structure of the condensation products of 1,2-dicarbonyl compounds and thiocarbohydrazide and its analogs and also their tendency towards tautomeric conversion is quite contradictory [2-10].

Treatment of phenylglyoxal hydrate with thiocarbohydrazide in benzene gives the corresponding 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thione while reaction in ethanol forms the 5-ethoxy analog [11]. 1-Phenylthiocarbohydrazide and diacetyl gave the 5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione derivative.

In continuation of these investigations we have studied the reaction of diacetyl, phenylglyoxal hydrate, and benzil with thiocarbohydrazide and its 1-alkyl(aryl)-, 1,1-dialkyl-, and 1,1,4-trialkyl-substituted derivatives.

Reaction of diacetyl with thiocarbohydrazide under mild conditions (1:1 molar ratio of reagents, methanol, cooling in ice) gives a mixture which ^{1}H NMR spectroscopy shows to contain about 30% of the monohydrazone **1** and 70% of the 5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione **5**. The latter was separated in the pure state by extraction with hexane and was characterized by ^{1}H and ^{13}C NMR spectroscopy (Tables 1 and 2). The ^{1}H NMR spectrum of compound **5** indicates the geminal protons on the C=C(5) bond

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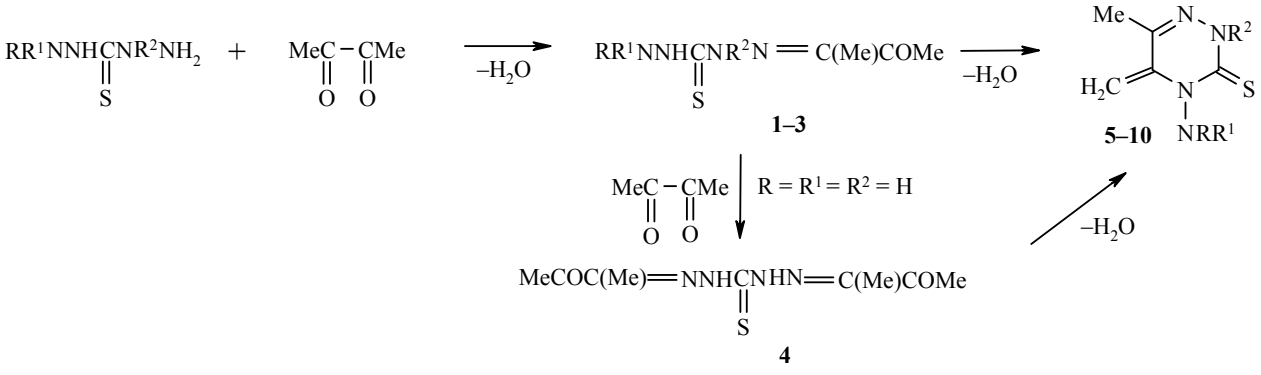
appearing as two doublet signals at 4.50 and 4.95 ppm (J = 1.5 Hz). The ^{13}C NMR spectrum shows resonance signals for carbon atoms at 88.94, 132.75, and 167.39 ppm which can be rationalized as due to the CH_2= group, the carbon atom at position 5 of the heterocycle, and the C=S bond respectively. This data is practically the same as for the model structured 5-methylene-1,2,4-triazoline compounds which are the products of reaction of thiosemicarbazide and its substituted analogs with 1,2-dicarbonyl compounds [12, 13]. The hydrazone **1** could not be obtained in a pure state as attempts to separate it from the reaction mixture using TLC gave samples containing both compound **1** and a certain amount of the methylene derivative **5**. Formation of this latter compound can be explained through conversion of monohydrazone **1** to the corresponding 5-hydroxy-2H-[1,2,4]triazoline-3-thione and its subsequent dehydration.



1–3, 5–7 R= H; **8, 9** R = Me; **1, 5** R^1 = H; **2, 6** R^1 = *i*-Pr; **3, 7** R^1 = Ph; **8, 9** R^1 = Me;
1–3, 5–8, 10 R^2 = H; **9** R^2 = Me; **10** R+R^1 = MeCOC(Me)=

It should be noted that hydrazone **1** presents as a single geometric isomer, evidently with a (*Z*)-configuration relative to the C=N bond and allowing the formation of a chelating intramolecular hydrogen bond (IHB) involving the NH and C=O bonds.

TABLE 1. ^1H NMR Spectra of Compounds **1-10**

Compound	Chemical shifts, δ, ppm (*J*, Hz)*
1	1.94 (3H, s, CH_3C=N); 2.40 (3H, s, CH_3C=O); 4.85 (2H, s, NH_2); 8.90 (1H, br. s, NHCS); 10.12 (1H, s, NHCS)
2	0.96 (6H, d, *J* = 5.9, CH($C\underline{H}_3$)$_2$); 1.98 (3H, s, CH_3C=N); 2.36 (3H, s, CH_3C=O); 3.2-3.6 (1H, m, C$\underline{H}$(CH_3)$_2$); 5.05 (1H, br. s, NH); 8.50 (1H, br. s, NHCS); 10.12 (1H, s, NHCS)
3	1.95 (3H, s, CH_3C=N); 2.40 (3H, s, CH_3C=O); 6.7-7.3 (5H, m, C_6H_5); 7.90 (1H, s, NH); 8.75 (1H, br. s, NHCS); 10.14 (1H, s, NHCS)
4	2.04 (6H, s, CH_3C=N); 2.25-2.55 (6H, br. s, CH_3C=O); 10.10 (1H, s, NHCS); 10.52 (1H, s, NHCS)
5	2.03 (3H, s, CH_3C=N); 4.50 (1H, d, *J* = 1.5, CH($\underline{H}$)=C(5)); 4.95 (1H, d, *J* = 1.5, C$\underline{H}$(H)=C(5)); 5.10 (2H, s, NH_2); 9.92 (1H, s, NHC=S)
6	0.98 (6H, d, *J* = 5.9, CH($C\underline{H}_3$)$_2$); 2.02 (3H, s, CH_3C=N); 3.2-3.6 (1H, m, C$\underline{H}$(CH_3)$_2$); 4.45 (1H, d, *J* = 0.9, CH($\underline{H}$)=C(5)); 5.11 (1H, d, *J* = 0.9, C$\underline{H}$(H)=C(5)); 5.60 (1H, d, *J* = 6.0, NH); 9.85 (1H, s, NHC=S)
7	2.02 (3H, s, CH_3C=N); 4.50 (1H, d, *J* = 0.8, CH($\underline{H}$)=C(5)); 4.96 (1H, d, *J* = 0.8, C$\underline{H}$(H)=C(5)); 6.7-7.3 (5H, m, C_6H_5); 7.40 (1H, s, NH); 9.62 (1H, s, NHC=S)
8	1.93 (3H, s, CH_3C=N); 2.95 (6H, s, N(CH_3)$_2$); 4.40 (1H, d, *J* = 1.0, CH($\underline{H}$)=C(5)); 5.08 (1H, d, *J* = 1.0, C$\underline{H}$(H)=C(5)); 9.52 (1H, s, NHC=S)
9	1.98 (3H, s, CH_3C=N); 2.98 (6H, s, N(CH_3)$_2$); 3.65 (3H, s, NCH_3); 4.32 (1H, d, *J* = 1.0, CH($\underline{H}$)=C(5)); 4.92 (1H, d, *J* = 1.0, C$\underline{H}$(H)=C(5))
10	1.86 (3H, s, CH_3C=N); 2.02 (3H, s, CH_3C=N); 2.55 (3H, s, CH_3C=O); 4.30 (1H, d, *J* = 0.9, CH($\underline{H}$)=C(5)); 4.46 (1H, d, *J* = 0.9, C$\underline{H}$(H)=C(5)); 12.14 (1H, s, NHCS)

Spectra recorded in $CDCl_3$ (compounds **1-9**) or DMSO-d_6 (compound **10**).

Reaction of diacetyl with thiocarbohydrazide in water in a 2:1 molar ratio gave a precipitate which according to NMR spectroscopic (Tables 1 and 2) and mass-spectroscopic data (*m/z* 242 $[M]^+$), is the product of reaction of two molecules of diacetyl with one molecule of thiocarbohydrazide (compound **4**) and most likely with a (*Z*,*Z*)-configuration. Its NMR spectrum shows two NH signals at 10.10 and 10.52 ppm of comparable intensity. Evidently this involves two stereoisomers with a (*Z*,*Z*)-configuration relative to the C=N bond but with different positioning relative to the thioamide bond. The ^{13}C NMR spectroscopic data was also in agreement with doubling of the carbon signals (Table 2). The NMR spectrum of the reaction product obtained after removal of solvent showed both compound **4** and also the presence of the methylene derivative **10** which arises by loss of water from the product of intramolecular cyclization of compound **4**. This is demonstrated by the doublet signals for the methylene protons at 4.30 and 4.46 ppm in the ^1H NMR spectrum of compound **10** and also the ^{13}C NMR signals at 90.06 (CH_2=), 131.12 (C(5)), and 177.26 ppm (C=S). This data also correlates with the spectroscopic parameters discussed above for the methylene compound **5** which is the product of reaction of equimolar amounts of thiocarbohydrazide and diacetyl. It should additionally be noted that the ^{13}C NMR spectrum of compound **10** shows carbon signals for three methyl groups and for the C=N and C=O bonds.

Holding compound **4** in $CDCl_3$ for a prolonged time showed no kind of change in its ^1H NMR spectrum but dissolving it in DMSO-d_6 showed the presence of about 10% of the methylene derivative **10**. The fraction of compound **10** gradually increases and after 2 weeks reaches 50%. Holding it for longer leads to its decomposition.

Carrying out the reaction of diacetyl with 1-phenylthiocarbohydrazide without solvent gave the monohydrazone **3** (Table 1) as the sole product. This exists in $CDCl_3$ solution as a singly configured isomer which is likely to have the (*Z*)-configuration relative to the C=N bond for the same reason as discussed before.

Reaction in methanol or chloroform gives a product which ^1H NMR spectroscopic data shows to be a mixture of the monohydrazone **3** and 6-methyl-5-methylene-4-phenylamino-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**7**). Compounds **3** and **7** were separated in the pure state using TLC. The methylene structure of the latter was identified specifically by the presence in the ^1H NMR spectrum of methylene proton doublets at 4.50 and 4.96 ppm.

TABLE 2. ^{13}C NMR Spectra of Compounds **4-6**, **8-11**, **13**, **15-17**

Compound	Chemical shifts, δ, ppm*
4	9.14 ($\underline{C}H_3C$=N); 9.42 ($\underline{C}H_3C$=N); 24.37 (2$\underline{C}H_3C$=O); 146.87 (C=N); 151.29 (C=N); 176.00 (C=S); 195.55 (C=O); 197.46 (C=O)
5	18.76 ($\underline{C}H_3C$=N); 88.94 (CH_2=); 132.75 (C-5); 145.75 (C=N); 167.39 (C=S)
6	18.82 ($\underline{C}H_3C$=N); 19.24 (CH($\underline{C}H_3$)(CH_3)); 19.59 (CH(CH_3)($\underline{C}H_3$)); 48.10 ($\underline{C}H(CH_3)_2$); 89.90 (CH_2=); 134.19 (C-5); 146.45 (C=N); 170.21 (C=S)
8	18.80 ($\underline{C}H_3C$=N); 40.03 (N(CH_3)$_2$); 90.16 (CH_2=); 135.09 (C-5); 146.49 (C=N); 170.31 (C=S)
9	18.74 ($\underline{C}H_3C$=N); 39.66 (N(CH_3)$_2$); 44.03 (NCH_3); 90.10 (CH_2=); 134.82 (C-5); 146.43 (C=N); 170.87 (C=S)
10	13.90 ($\underline{C}H_3C$=N); 18.59 ($\underline{C}H_3C$=N); 25.82 ($\underline{C}H_3C$=O); 90.06 (CH_2=); 131.12 (C-5); 145.59 (C=N); 164.09 (C=N); 177.26 (C=S); 197.33 (C=O)
11	80.39 (C-5); 126.0-140.8 (C_6H_5); 140.34 (C=N); 170.71 (C=S)
13	78.85 (C-5); 125.7-134.4 (C_6H_5); 140.81 (C=N); 172.79 (C=S)
15	51.01 (CH_3O); 88.12 (C-5); 126.5–133.6 (C_6H_5); 142.36 (C=N); 170.85 (C=S)
16	14.56 (CH_3); 59.13 (CH_2); 87.36 (C-5); 126.5–133.6 (C_6H_5); 142.71 (C=N); 170.35 (C=S)
17	42.48 (N(CH_3)($\underline{C}H_3$)); 43.23 (N($\underline{C}H_3$)(CH_3)); 50.81 (CH_3O); 90.69 (C-5); 126.5-133.6 (C_6H_5); 142.64 (C=N); 170.81 (C=S)

* Spectra recorded in a mixture of the solvents $CDCl_3$–DMSO-d_6 (2:1) (compound **4**) or DMSO-d_6 (compounds **5**, **6**, **8-11**, **13**, **15-17**).

TABLE 3. ^{1}H NMR Spectra of Compounds **11-17**

Com-pound	Configuration, %	δ, ppm, $CDCl_3$	Configuration, %	δ, ppm, DMSO-d_6
1	2	3	4	5
11	**B**, 100	4.66 (2H, s, NH_2); 5.61 (1H, s, OH); 6.81 (1H, s, HC=N); 7.3-7.9 (5H, m, C_6H_5); 9.45 (1H, s, NH)	**B**, 100	5.03 (2H, s, NH_2); 6.80 (1H, s, HC=N); 7.2-7.5 (5H, m, C_6H_5); 7.58 (1H, s, OH); 11.60 (1H, s, NH)
12	(*Z*,*E*′)-**A**, 49	2.70 (6H, s, $N(CH_3)_2$); 7.4-8.0 (5H, m, C_6H_5); 8.12 (1H, s, HC=N); 8.17 (1H, s, NH); 14.31 (1H, s, NH)	(*Z*,*E*′)-**A**, 7	2.60 (6H, s, $N(CH_3)_2$); 7.3-7.9 (5H, m, C_6H_5); 8.01 (1H, s, NH); 8.27 (1H, s, HC=N); 14.61 (1H, s, NH)
	(*Z*,*Z*′)-**A**, 22	2.73 (6H, s, $N(CH_3)_2$); 7.4-8.0 (5H, m, C_6H_5); 7.65 (1H, s, NH); 8.36 (1H, s, HC=N); 13.56 (1H, s, NH)	(*Z*,*Z*′)-**A**, 3	2.63 (6H, s, $N(CH_3)_2$); 7.3-7.9 (5H, m, C_6H_5); 14.32 (1H, s, NH)
	(*E*,*E*′)-**A**, 20	2.68 (6H, s, $N(CH_3)_2$); 7.4-8.2 (5H, m, C_6H_5); 7.92 (1H, s, HC=N); 8.09 (1H, s, NH); 10.84 (1H, s, NH)	(*E*,*E*′)-**A**, 35	2.56 (6H, s, $N(CH_3)_2$); 7.3-8.4 (5H, m, C_6H_5); 8.24 (1H, s, HC=N); 9.79 (1H, s, NH); 11.84 (1H, s, NH)
	(*E*,*Z*′)-**A**, 9	2.64 (6H, s, $N(CH_3)_2$); 7.4-8.2 (5H, m, C_6H_5); 7.69 (1H, s, NH); 7.82 (1H, s, HC=N); 10.57 (1H, s, NH)	(*E*,*Z*′)-**A**, 13	2.56 (6H, s, $N(CH_3)_2$); 7.3-8.4 (5H, m, C_6H_5); 7.99 (1H, s, HC=N); 8.97 (1H, s, NH); 11.87 (1H, s, NH)
	B, 0	—	**B**, 42	2.40 (3H, s, $N(C\underline{H}_3)(CH_3)$); 3.01 (3H, s, $N(CH_3)(C\underline{H}_3)$); 6.79 (1H, s, HC=N); 7.3-7.9 (5H, m, C_6H_5); 7.32 (1H, s, OH); 11.42 (1H, s, NH)
13	**B**, 100	4.57 (2H, s, NH_2); 6.01 (1H, s, OH); 7.1-7.6 (10H, m, C_6H_5); 9.52 (1H, s, NH)	**B**, 100	5.05 (2H, s, NH_2); 7.0-7.6 (10H, m, C_6H_5); 8.02 (1H, s, OH); 11.89 (1H, s, NH)
14	(*Z*,*E*′)-**A**, 21	2.56 (6H, s, $N(CH_3)_2$); 7.1-7.9 (10H, m, C_6H_5); 7.97 (1H, s, NH); 10.82 (1H, s, NH)	(*Z*,*E*′)-**A**, 0	—
	(*Z*,*Z*′)-**A**, 17	2.32 (6H, s, $N(CH_3)_2$); 7.1-7.9 (10H, m, C_6H_5); 8.40 (1H, s, NH); 10.57 (1H, s, NH)	(*Z*,*Z*′)-**A**, 0	—
	(*E*,*E*′)-**A**, 10	2.71 (6H, s, $N(CH_3)_2$); 7.1-7.9 (10H, m, C_6H_5); 8.22 (1H, s, NH); 9.23 (1H, s, NH)	(*E*,*E*′)-**A**, 0	—
	(*E*,*Z*′)-**A**, 22	2.28 (6H, s, $N(CH_3)_2$); 7.1-7.9 (10H, m, C_6H_5); 7.86 (1H, s, NH); 8.90 (1H, s, NH)	(*E*,*Z*′)-**A**, 0	—
	B, 30	2.38 (3H, s, $N(C\underline{H}_3)(CH_3)$); 3.08 (3H, s, $N(CH_3)(C\underline{H}_3)$); 6.47 (1H, s, OH); 7.1-7.6 (10H, m, C_6H_5); 9.83 (1H, s, NH)	**B**, 100	2.24 (3H, s, $N(C\underline{H}_3)(CH_3)$); 3.05 (3H, s, $N(CH_3)(C\underline{H}_3)$); 7.1-7.6 (10H, m, C_6H_5); 7.91 (1H, s, OH); 11.78 (1H, s, NH)
15	**B**, 100	3.38 (3H, s, CH_3O); 4.58 (2H, s, NH_2); 7.1-7.7 (10H, m, C_6H_5); 9.90 (1H, s, NH)	**B**, 100	3.27 (3H, s, CH_3O); 4.95 (2H, s, NH_2); 7.1-7.6 (10H, m, C_6H_5); 12.17 (1H, s, NH)

TABLE 3 (continued)

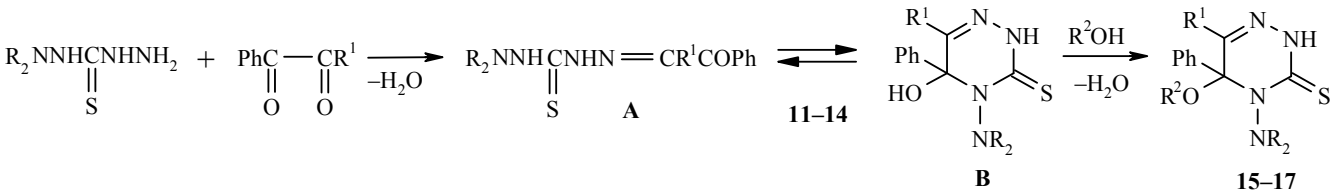
1	2	3	4	5
16	**B**, 100	1.31 (3H, t, J = 6.9, C<u>H</u>$_3$CH$_2$); 3.49 (2H, q, J = 6.9, CH$_3$C<u>H</u>$_2$); 4.52 (2H, s, NH$_2$); 7.1-7.6 (10H, m, C$_6$H$_5$); 10.22 (1H, s, NH)	**B**, 100	1.28 (3H, t, J = 6.9, C<u>H</u>$_3$CH$_2$); 3.36 (1H, q, J = 6.9, CH$_3$C<u>H</u>$_2$); 3.47 (1H, q, J = 6.9, CH$_3$C<u>H</u>$_2$); 4.90 (2H, s, NH$_2$); 7.1-7.6 (10H, m, C$_6$H$_5$); 12.05 (1H, s, NH)
17	**B**, 100	2.32 (3H, s, N(C<u>H</u>$_3$)(CH$_3$)); 3.07 (3H, s, N(CH$_3$)(C<u>H</u>$_3$)); 3.40 (3H, s, CH$_3$O); 7.1-7.6 (10H, m, C$_6$H$_5$); 9.98 (1H, s, NH)	**B**, 100	2.25 (3H, s, N(C<u>H</u>$_3$)(CH$_3$)); 3.08 (3H, s, N(CH$_3$)(C<u>H</u>$_3$)); 3.31 (3H, s, CH$_3$O); 7.1-7.6 (10H, m, C$_6$H$_5$); 11.99 (1H, s, NH)

Exchanging the aromatic for an aliphatic substituent (changing to the 1-isopropylthiocarbohydrazide) and carrying out the reaction of diacetyl either without solvent or in methanol or chloroform gives a mixture of the monohydrazone **2** and 4-isopropylamino-6-methyl-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**6**). Both compounds were separated in a pure state using TLC. The methylene structure of compound **6** was also confirmed by the presence in the ^{13}C NMR spectrum of characteristic carbon atom resonance signals for the CH$_2$= group at 89.90 ppm (Table 2) [12, 13]. If the hydrazone **2** is held for a week in methanol it is fully converted to the corresponding methylene **6**.

The reaction of diacetyl with 1,1-dimethyl- and 1,1,4-trimethylthiocarbohydrazides gave only the corresponding methylene derivatives **8** and **9**. Recording of even intermediate appearance of the monohydrazones was not successful and is possibly related to the following circumstances. The appearance of the methylene derivatives is preceded by reversible cyclization of hydrazones to 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thiones. Exchange of the amino group on the nitrogen atom at position 4 of this heterocycle for a dimethylamino group leads to an increase in the steric interactions with the methyl and hydroxyl group substituents bonded to the carbon atom at position 5. Changing to the methylene derivative removes this strain thus accelerating the dehydration process. The initial monohydrazone is rapidly converted to the methylene derivative.

As for the compounds **5-7**, conclusions regarding the structure of derivatives **8** and **9** can be made on the basis of the presence in their ^{1}H NMR spectra of two doublets in the region 4.30-5.10 ppm corresponding to the methylene protons and of resonance signals for methylene group carbon atoms in the region of 90 ppm in the ^{13}C NMR spectra.

Reaction of phenylglyoxal hydrate with thiocarbohydrazide in water and benzene (molar ratio 1:1) gave the 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**11B)**. This was deduced from mass-spectrometric data (*m/z* 222 [M]$^+$) and ^{1}H and ^{13}C NMR spectra (Tables 2 and 3). The spectroscopic parameters for compound **11** are virtually the same as those for 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thiones obtained by treating phenylglyoxal with 4-mono- and 2,4-disubstituted thiosemicarbazides [13]. The latter are characterized by the presence of the heterocycle C(5) atom signal at 80-85 ppm in the ^{13}C NMR spectrum (for compound **11** in DMSO-d$_6$ solution the signal occurs at 80.39 ppm).



11, **13**, **15**, **16** R = H; **12**, **14**, **17** R = Me; **11**, **12** R^1 = H; **13–17** R^1 = Ph; **15**, **17** R^2 = Me; **16** R^2 = Et

TABLE 4. ^{13}C NMR Spectra of Compounds **12**, **14**

Compound	Configuration, %	Chemical shifts, δ, ppm	
		in $CDCl_3$	in DMSO-d_6
12	(*Z*,*E*′)-**A**	46.98 ($N(CH_3)_2$); 128.5-136.1 (C_6H_5); 134.06 (C=N); 180.32 (C=S); 186.49 (C=O)	45.83 ($N(CH_3)_2$); 127.9-135.8 (C_6H_5); 134.36 (C=N); 179.27 (C=S); 186.40 (C=O)
	(*Z*,*Z*′)-**A**	46.98 ($N(CH_3)_2$); 124.8-136.2 (C_6H_5); 133.03 (C=N); 176.24 (C=S); 186.09 (C=O)	—*
	(*E*,*E*′)-**A**	47.09 ($N(CH_3)_2$); 128.5-136.1 (C_6H_5); 133.29 (C=N); 176.29 (C=S); 188.10 (C=O)	46.64 ($N(CH_3)_2$); 126.7-143.9 (C_6H_5); 133.12 (C=N); 178.53 (C=S); 189.09 (C=O)
	(*E*,*Z*′)-**A**	128.5-136.1 (C_6H_5); 176.20 (C=S); 187.25 (C=O)*[2]	45.54 ($N(CH_3)_2$); 126.7-143.9 (C_6H_5); 133.35 (C=N); 176.52 (C=S); 188.61 (C=O)
	B	—	43.10 ($N(CH_3)(\underline{C}H_3)$); 44.94 ($N(\underline{C}H_3)(CH_3)$); 82.69 (C-5); 126.7-143.9 (C_6H_5); 141.01 (C=N); 171.32 (C=S)
14	(*Z*,*E*′)-**A**	47.21 ($N(CH_3)_2$); 126.9-136.9 (C_6H_5); 144.94 (C=N); 175.93 (C=S); 194.93 (C=O)	—
	(*Z*,*Z*′)-**A**	46.59 ($N(CH_3)_2$); 126.9-136.9 (C_6H_5); 151.43 (C=N); 178.02 (C=S); 189.91 (C=O)	—
	(*E*,*E*′)-**A**	47.25 ($N(CH_3)_2$); 126.9-136.9 (C_6H_5); 145.89 (C=N); 178.02 (C=S); 193.43 (C=O)	—
	(*E*,*Z*′)-**A**	46.65 ($N(CH_3)_2$); 126.9-136.9 (C_6H_5); 150.97 (C=N); 178.22 (C=S); 189.93 (C=O)	—
	B	43.54 ($N(CH_3)(\underline{C}H_3)$); 44.97 ($N(\underline{C}H_3)(CH_3)$); 85.04 (C-5); 126.0-141.3 (C_6H_5); 147.36 (C=N); 169.65 (C=S)	42.58 ($N(CH_3)(\underline{C}H_3)$); 44.89 ($N(\underline{C}H_3)(CH_3)$); 85.18 (C-5); 126.9-141.5 (C_6H_5); 146.22 (C=N); 169.32 (C=S)

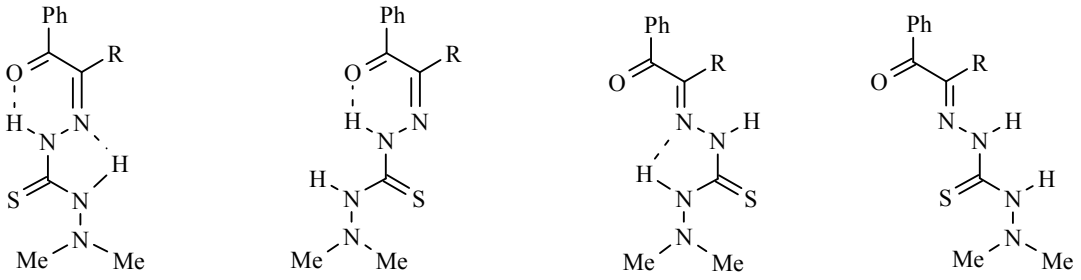
* Signals of the configuration not observed.

*[2] Signals for the carbon atoms of the dimethylamino groups and C=N bond hidden by the signals of the main configuration.

Data for ring-linear-ring tautomerism in thiocarbonohydrazones of monocarbonyl compounds infers the possible existence of compound **11** in the tetrahydro-1,2,4,5-tetrazine (signal for atom C(6) at 60-65) and/or 1,2,4-triazolidine form (signal for atom C(5) at 80-85 ppm) [1]. However, the presence of a resonance signal for the carbon atom of the C=N bond (140-150) and the absence of a signal for a C=O group in the region 185-195 ppm unambiguously shows that the cyclic form of compound **11** is 4-amino-5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**B**).

Carrying out the reaction of phenylglyoxal hydrate with 1,1-dimethylthiocarbohydrazide in chloroform and partial evaporation of the solvent gives a crystalline precipitate. The ^1H NMR spectrum of the crystalline mass in $CDCl_3$, which was separated from the solution by filtration, immediately showed a second set of resonance signals corresponding to the spatially isomeric hydrazone **12A** in the ratio 3:1. The predominant isomer includes singlet signals at 2.70 (methyl groups on nitrogen), 8.12 (proton at C=N bond), 8.17 (N(4)H bond), and 14.31 ppm (N(2)H) bond. The corresponding signals for the minor stereoisomer occur at 2.73, 8.36, 7.65, and 13.56 ppm. The low field position of the N(2)H signals supports a (*Z*)-configuration of the substituent relative to the C=N bond in which a strong, chelating IHB is formed.

Scheme 1



12, 14

12 R = H, **14** R = Ph

The existence of two stereoisomers at the (*Z*)-configured double bond is evidently associated with slow rotation relative to the thioamide N(2)–C=S bond. The predominant isomer most likely has a (*Z*,*E*')-spatial structure (*Z*,*E*')-**12** and the minor a (*Z*,*Z*')-structure (*Z*,*Z*'-**12**). The predominance of the first stereoisomer is possibly connected not only with a difference in spatial interactions but also the possible formation of an additional IHB between the proton of the N(4)H bond and the C=N nitrogen atom as shown in Scheme 1.The lower field position of the N(4)H signal for the predominant stereoisomer (8.17 versus 7.65 ppm, Table 3) also indicates the formation of such a bond.

When a solution of compound **12** is held its ^{1}H NMR spectrum gradually changes and shows a second set of resonance signals corresponding to a stereoisomer with an (*E*)-configuration relative to the C=N bond. The signals for the N(2)H protons are found at 10.84 and 10.57 ppm (Table 3). Most likely this is a question of the (*E*,*E*')- and (*E*,*Z*')-hydrazone structures (*E*,*E*'-**12**) and (*E*,*Z*'-**12**). After some time the spectrum stops changing and becomes an equilibrium including all four of the indicated stereoisomers of compound **12**: (*Z*,*E*') (49), (*Z*,*Z*') (22), (*E*,*E*') (20), and (*E*,*Z*') (9%). The shift of the equilibrium towards the (*Z*,*E*')- and (*Z*,*Z*')-stereoisomers may again be connected to formation of a chelating IHB. The (*E*')-configured structure predominates amongst the geometric isomers.

In the basically dipolar solvent DMSO-d_6 a five-component ring-chain equilibrium is established in which the set of hydrazone stereoisomers conflicts with a cyclic 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thione form **12B** (Tables 3 and 4). When equilibrium is achieved its fraction is 42%. It should be noted that, in the ^{13}C NMR spectrum, the resonance signal for the carbon atom at position 5 of the heterocycle (as for compound **11**) is found in the region 80-85 ppm (82.69 ppm, Table 4) [13]. Within the linear hydrazone forms there occurs a redistribution of stereoisomers and the isomer with an (*E*)-configuration predominates. This is associated with the much higher polarity of the (*E*)-configured isomers (*E*,*E*')-**12** and (*E*,*Z*')-**12** which implies a more marked nonspecific solvation by the dipolar solvent and also additional stabilization of these forms thanks to formation of intermolecular hydrogen bonds between the DMSO and the N(2)H bond.

By treatment of phenylglyoxal hydrate with 1,1-dimethylthiocarbohydrazide in methanol the reaction product **12A** separates as the hydrazone with an (*E*)-configuration. The ^{1}H NMR spectrum of the compound in $CDCl_3$ immediately after solution showed two sets of signals for the two stereoisomers (*E*,*E*')-**12** and (*E*,*Z*')-**12**. When held, an equilibrium was established in the solution involving four isomers having the same quantitative composition as achieved with a sample separated after carrying out the reaction in chloroform.

Hence variation of the conditions for carrying out the reaction of phenylglyoxal hydrate with 1,1-dimethylthiocarbohydrazide can give two modifications of the condensation product of the hydrazone structure with (*Z*)- and (*E*)-configurations. In solutions a partial configurational change occurs to give a multicomponent ring-chain equilibrium.

TABLE 5. Characterictics of Compounds **2-9** and **11-17**

Compound	Empirical formula	Found, % / Calculated, %			mp, °C	Yield, %
		C	H	N		
2	$C_8H_{16}N_4OS$	44.42 / 44.28	7.46 / 7.56	25.90 / 25.99	Oil	31
3	$C_{11}H_{14}N_4OS$	52.78 / 52.86	5.64 / 5.54	22.38 / 22.50	130-131	62
4	$C_9H_{14}N_4O_2S$	44.61 / 44.56	5.82 / 5.74	23.12 / 23.20	118-119	72
5	$C_5H_8N_4S$	38.45 / 38.33	5.16 / 5.24	35.87 / 35.77	90-91	22
6	$C_8H_{14}N_4S$	48.46 / 48.52	7.12 / 7.20	28.25 / 28.40	98-99	65
7	$C_{11}H_{12}N_4S$	56.87 / 56.75	5.21 / 5.24	24.12 / 24.20	Oil	38
8	$C_7H_{12}N_4S$	45.63 / 45.76	6.56 / 6.44	30.41 / 30.50	124-125	69
9	$C_8H_{14}N_4S$	48.46 / 48.36	7.12 / 7.14	28.25 / 28.30	94-95	60
11	$C_9H_{10}N_4OS$	48.63 / 48.66	4.53 / 4.44	25.21 / 25.30	148-149	72
(*Z*)-**12A**	$C_{11}H_{14}N_4OS$	52.78 / 52.86	5.64 / 5.69	22.38 / 22.30	178-179	70
(*E*)-**12A**	$C_{11}H_{14}N_4OS$	52.78 / 52.89	5.64 / 5.54	22.38 / 22.29	146-147	64
13	$C_{15}H_{14}N_4OS$	60.38 / 60.46	4.73 / 4.79	18.78 / 18.66	176-178	21
14	$C_{17}H_{18}N_4OS$	62.55 / 62.56	5.56 / 5.48	17.16 / 17.30	177-179	58
15	$C_{16}H_{16}N_4OS$	61.52 / 61.63	5.16 / 5.22	17.93 / 17.85	180-181	33
16	$C_{17}H_{18}N_4OS$	62.55 / 62.46	5.56 / 5.49	17.16 / 17.30	115-117	34
17	$C_{18}H_{20}N_4OS$	63.50 / 63.59	5.92 / 5.84	16.46 / 16.35	189-190	54

Reaction of benzil with thiocarbohydrazide and 1,1-dimethylthiocarbohydrazide in benzene gives compounds **13** and **14** (R^2 = Ph, Tables 2-4) having many structural similarities with compounds prepared by reaction with phenylglyoxal hydrate.

The reaction of thiocarbohydrazide with benzil is complicated by the fact that, in benzene solution, the reaction mixture forms a precipitate which most likely exists as an oligomer. It is poorly soluble in various solvents and shows only aromatic proton signals in the ^{1}H NMR spectrum. The mother liquor shows the presence of a low yield (15-20%) of the 4-amino-5-hydroxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**13**).

Alcohols have been used as solvent in the formation of the corresponding derivatives **15** and **16** (Tables 2 and 3). The 5-alkoxy-4,5-dihydro-2H-[1,2,4]triazine structure of these compounds has been confirmed from the NMR spectroscopic data (in particular, in the ^{13}C NMR spectrum a signal for the C(5) atom is seen at 87-89 ppm) and also in the mass spectra (*m/z* 312 $[M]^+$ and 326 $[M]^+$ respectively) which is markedly similar to the corresponding data for the 5-alkoxy derivatives formed by reacting benzil with thiosemicarbazide [8]. When compounds **15** and **16** are held for several days in DMSO their hydrolysis products accumulate, i.e. 5-hydroxy-4,5-dihydro-2H-[1,2,4]triazine-3-thione **13** together with methanol or ethanol respectively.

Reaction of benzil with 1,1-dimethylthiocarbohydrazide in benzene with different variants of the synthesis does not go to completion as indicated by the ^{1}H NMR spectra of the crystalline materials separated from the reaction mixture. The reaction product at the unsubstituted amino group (molar ratio 1:1, compound **14**) occurs partially as a precipitate (about 35%) and the rest was separated from the mother liquor by TLC (23%).

In solution in $CDCl_3$ the product of condensation occurs as an equilibrium involving four hydrazone structure stereoisomers **14A**: (*Z*,*E*')-, (*Z*,*Z*')-, (*E*,*E*')- and (*E*,*Z*)- and also the cyclic tautomer 4-dimethylamino-5-hydroxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**14B**). When changing to DMSO-d_6 as solvent the equilibrium is fully shifted to the cyclic form **14B**. The ^{13}C NMR spectrum (Table 4) of the cyclic form shows the presence of a signal at 85.04 due to the carbon atom at position 5 of the heterocycle and the ^1H NMR spectrum a signal at 6.47 ppm which can be assigned to the proton of the OH bond (Table 3).

Reaction of 1,1-dimethylthiocarbohydrazide with benzil in methanol gives the 4-dimethylamino-5-methoxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**17**) whose structure was confirmed by ^1H and ^{13}C NMR spectroscopy (Tables 2 and 3). Hence the ^{13}C NMR spectrum shows a signal for the carbon at position 5 at 90.69 and a signal for the C=S carbon at 170.81 ppm.

We can conclude that reaction of 1,2-dicarbonyl compounds with thiocarbohydrazide and its substituted analogs depends not only on the structure of the reacting materials but also on the conditions of carrying out the reaction and leads to a rather broad range of condensation products of linear and cyclic structure tending to configurational conversions in solutions with ring-chain conversion in a number of cases.

EXPERIMENTAL

^1H and ^{13}C NMR spectra were obtained on a JEOL JNM-A-500 (500 and 125 MHz respectively) and Bruker AM-300 spectrometer (300 and 75 MHz respectively) using DMSO-d_6 or $CDCl_3$ using HMDS as internal standard at 0.05 ppm. Mass spectra were recorded on a Finnigan MAT 95 mass spectrometer using the EI method (electron ionization energy 70 eV). Elemental analysis was carried out on a Carlo Erba Strumentazione model 1106 analyzer. Monitoring of the reaction course and the purity of the compounds prepared was carried out by TLC on Silufol UV-254 grade plates. The characteristics of the synthesized compounds **1-17** are given in Table 5.

The substituted thiocarbohydrazides were prepared according to the method reported in [14].

Reaction of Thiocarbohydrazide with Diacetyl. A. Thiocarbohydrazide (0.212 g, 2 mmol) and diacetyl (0.17 g, 0.18 ml, 2 mmol) were mixed with cooling in ice. The mixture was allowed to stand for 1 day in a fridge and the precipitate was filtered off.

B. A solution of diacetyl (0.17 g, 0.18 ml, 2 mmol) in water (5 ml) was added to a suspension of thiocarbohydrazide (0.212 g, 2 mmol) in water (10 ml) and heated for 3 h at 80ºC. The mixture was left for 1 day and the precipitate was filtered off.

C. A solution of diacetyl (0.17 g, 0.18 ml, 2 mmol) in methanol (5 ml) was added to a suspension of thiocarbohydrazide (0.212 g, 2 mmol) in methanol (20 ml), stirred at room temperature for 2 days, and the precipitate was filtered off.

According to ^1H NMR spectroscopic data, the mother liquor in all cases contained a mixture of the diacetyl thiocarbonohydrazone (**1**) and 4-amino-6-methyl-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**5**).

Diacetyl Bisthiocarbonohydrazone (4). A solution of diacetyl (0.34 g, 0.35 ml, 4 mmol) in water (5 ml) was added to a suspension of thiocarbohydrazide (0.212 g, 2 mmol) in water (10 ml). The mixture was allowed to stand for 3 days and the precipitate was filtered off and washed with methanol and ether to give compound **4** (0.36 g, 72%).

4-Amino-6-methyl-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (5). A. A suspension of thiocarbohydrazide (0.212 g, 2 mmol) in methanol (10 ml) was mixed with a solution of diacetyl (0.17 g, 0.18 ml, 2 mmol) in methanol (5 ml) with cooling in ice. The mixture was left at this temperature for 1 day and the precipitate was filtered off. The mother liquor was evaporated *in vacuo* and the residue was extracted with hexane (3×20 ml). The extracts were combined, solvent removed *in vacuo*, and the residue was recrystallized from pentane to give compound **5** (0.085 g, 22%).

B. Solvent was removed from the mother liquors of the reaction of thiocarbohydrazide with diacetyl by methods A-C to give a solid residue (0.10-0.15 g). The residue was chromatographed on a silica gel column (100 g) using the system ether–hexane (4:3). Evaporation of solvent gave compound **5** (0.02-0.04 g, 5-11%) with R_f 0.45.

Reaction of Diacetyl with 1-Isopropylthiocarbohydrazide. A. 1-Isopropylthiocarbohydrazide (0.296 g, 2 mmol) in chloroform (10 ml) was mixed with a solution of diacetyl (0.18 g, 0.19 ml, 2.1 mmol) in chloroform (5 ml). The mixture was held at room temperature for 1 day and solvent was removed *in vacuo* to give 0.42 g of a mixture of **5-diacetyl isopropylthiocarbonohydrazone (2)** (R_f 0.40, ether–hexane, 4:3) and **4-isopropylamino-6-methyl-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (6)** (R_f 0.95) in a molar ratio of about 1:1 (according to ^{1}H NMR spectroscopic data). When the mixture was held for a week the ratio of reaction products was virtually unchanged. Solvent was removed and the residue was chromatographed on a silica gel column (100 g) in the system ether–hexane (4:3). Removal of solvent gave compound **2** (0.14 g, 31%) and compound **6** (0.19 g, 44%).

Treatment of 1-isopropylthiocarbohydrazide with diacetyl by method A in methanol gave a mixture of hydrazone **2** and methylene **6** which was converted over a week in solution to pure 4-isopropylamino-6-methyl-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**6**).

B. 1-Isopropylthiocarbohydrazide (0.296 g, 2 mmol) was mixed with diacetyl (0.18 g, 0.19 ml, 2.1 mmol). The product was held at room temperature for a week, excess diacetyl was removed *in vacuo* and the residue was recrystallized from hexane to give compound **6** (0.28 g, 65%).

Reaction of Diacetyl with 1-Phenylthiocarbohydrazide. A. A solution of 1-phenylthiocarbohydrazide (0.364 g, 2 mmol) in chloroform (10 ml) was mixed with a solution of diacetyl (0.18 g, 0.19 ml, 2.1 mmol) in chloroform (5 ml). The mixture was held for a week at room temperature. Solvent was removed *in vacuo* to give 0.48 g of a mixture of **diacetyl 5-phenylthiocarbonohydrazone (3)** and **6-methyl-5-methylene-4-phenylamino-4,5-dihydro-2H-[1,2,4]triazine-3-thione (7)** in the molar ratio of about 1:1 (according to ^{1}H NMR spectroscopic data). Chromatography of the reaction mixture on silica gel plates (ether–hexane, 4:3) gave compound **3** (0.21 g, 41%, R_f 0.40) and compound **7** (0.19 g, 38%, R_f 0.60).

B. A solution of 1-phenylthiocarbohydrazide (0.364 g, 2 mmol) in methanol (10 ml) was mixed with a solution of diacetyl (0.18 g, 0.19 ml, 2.1 mmol) in methanol (5 ml) and refluxed for 5 h. Solvent and excess diacetyl were removed *in vacuo* to give, as in the case of the reaction in chloroform, a mixture of diacetyl 5-phenylthiocarbonohydrazone (**3**) and 6-methyl-5-methylene-4-phenylamino-4,5-dihydro-2H-[1,2,4]triazine-3-thione (**7**). The mixture was chromatographed on silica gel plates (ether–hexane, 4:3) to give compound **3** (0.19 g, 37%) and compound **7** (0.16 g, 32%).

C. 1-Phenylthiocarbohydrazide (0.364 g, 2 mmol) was mixed with diacetyl (0.18 g, 0.19 ml, 2.1 mmol). After 1 day the excess diacetyl was removed *in vacuo*. The residue was recrystallized from a mixture of hexane–benzene (1:1) to give compound **3** (0.32 g, 62%).

Reaction of Diacetyl with 1,1-Dimethylthiocarbohydrazide. 1,1-Dimethylthiocarbohydrazide (0.268 g, 2 mmol) was mixed with diacetyl (0.8 g, 0.19 ml, 2.1 mmol). After 1 day the excess diacetyl was removed *in vacuo* and the residue was recrystallized from hexane to give **4-Dimethylamino-6-methyl-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (8)** (0.28 g, 69%, R_f 0.60, ether–hexane, 4:3).

Carrying out the reaction in chloroform and methanol also gave only compound **8**.

Reaction of Diacetyl with 1,1,4-Trimethylthiocarbohydrazide. 1,1,4-Trimethylthiocarbohydrazide (0.296 g, 2 mmol) was mixed with diacetyl (0.18 g, 0.19 ml, 2.1 mmol). After 1 day the excess diacetyl was removed *in vacuo* and the residue was recrystallized from hexane to give **2,6-dimethyl-4-dimethylamino-5-methylene-4,5-dihydro-2H-[1,2,4]triazine-3-thione (9)** (0.26 g, 60%, R_f 0.70, ether–hexane, 4:3).

Carrying out the reaction in chloroform or methanol also gave only compound **9**.

4-Amino-5-hydroxy-5-phenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (11). A suspension of thiocarbohydrazide (0.212 g, 2 mmol) in water (10 ml) was mixed with a solution of phenylglyoxal hydrate

(0.304 g, 2 mmol) in water (5 ml) with cooling in ice. The mixture was allowed to stand for 7 days and the precipitate was filtered off and washed with water and ether to give compound **11** (0.32 g, 72%).

Phenylglyoxal 5,5-Dimethylthiocarbonohydrazone (12). A. 1,1-Dimethylthiocarbohydrazide (0.268 g, 2 mmol) was mixed with a solution of phenylglyoxal hydrate (0.304 g, 2 mmol) in chloroform (20 ml) and allowed to stand at room temperature for 1 day. Solvent was evaporated *in vacuo* and the residue was recrystallized from a mixture of hexane and benzene (1:1) to give the **(*Z*)-isomer** of **phenylglyoxal 5,5-dimethylthiocarbonohydrazone (*Z*)-12A** (0.35 g, 70%).

B. 1,1-Dimethylthiocarbohydrazide (0.268 g, 2 mmol) was mixed with a solution of phenylglyoxal hydrate (0.304 g, 2 mmol) in methanol (20 ml) and refluxed for 2 h. Solvent was evaporated *in vacuo* and the residue was washed with a mixture of hexane and benzene (1:1) and ether to give the **(*E*)-isomer** of **phenylglyoxal 5,5-dimethylthiocarbonohydrazone (*E*)-12A** (0.32 g, 64%).

4-Amino-5-hydroxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (13). A solution of thiocarbohydrazide (0.212 g, 2 mmol) and benzil (0.420 g, 2 mmol) in benzene (20 ml) was refluxed for 10 h with the addition of a catalytic amount of trifluoroacetic acid. The precipitate (0.25 g) was separated. The ^{1}H NMR spectroscopic data showed that the compound contained just aromatic proton signals. Solvent was removed from the mother liquor *in vacuo*. The residue was recrystallized from a mixture of benzene–hexane (1:5) to give compound **13** (0.126 g, 21%).

5-Hydroxy-4-dimethylamino-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (14). A solution of 1,1-dimethylthiocarbohydrazide (0.268 g, 2 mmol) and benzil (0.420 g, 2 mmol) in benzene (20 ml) was refluxed for 10 h with the addition of a catalytic amount of trifluoroacetic acid. The precipitate (0.245 g) was separated and washed with benzene and hexane. Solvent was removed from the mother liquor *in vacuo*. The residue was chromatographed on a silica gel column (100 g) using the system benzene–acetone (2:1). Removal of solvent gave a solid residue (0.145 g, R_f 0.45, benzene–acetone, 2:1) which was washed with cold chloroform and benzene to give compound **14** (0.135 g). The overall yield of compound **14** is 0.38 g (58%).

4-Amino-5-methoxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (15). A solution of thiocarbohydrazide (0.212 g, 2 mmol) and benzil (0.420 g, 2 mmol) in methanol (20 ml) was refluxed for 10 h with the addition of a catalytic amount of trifluoroacetic acid. The precipitate separated (0.15 g) showed only aromatic proton signals in the ^{1}H NMR spectrum. Solvent was removed from the mother liquor *in vacuo*. The residue was dried *in vacuo* at 90ºC and recrystallized from a mixture of benzene–hexane (1:1) to give compound **15** (0.209 g, 33%).

4-Amino-5-ethoxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (16) was obtained from thiocarbohydrazide and benzil in ethanol similarly to compound **15** to give compound **16** (0.218 g, 34%).

4-Dimethylamino-5-methoxy-5,6-diphenyl-4,5-dihydro-2H-[1,2,4]triazine-3-thione (17). A solution of 1,1-dimethylthiocarbohydrazide (0.268 g, 2 mmol) and benzil (0.420 g, 2 mmol) in methanol (20 ml) and refluxed for 10 h with the addition of a catalytic amount of trifluoroacetic acid. Solvent was removed *in vacuo*. The residue was washed with a small volume of cold methanol and recrystallized from a mixture of benzene and hexane (1:1) to give compound **17** (0.37 g, 54%).

REFERENCES

1. V. V. Alekseev, K. N. Zelenin, and S. I. Yakimovich, *Zh. Org. Khim.*, **31**, 937 (1995).
2. P. Ch. Guha and S. Ch. Dey, *J. Indian Chem. Soc.*, **2**, 225 (1925).
3. A. C. Brown, E. C. Pickering, and F. J. Wilson, *J. Chem. Soc.*, 107 (1927).
4. H. R. Wiley, *J. Macromol. Sci. Chem.*, **A25**, 231 (1988).
5. U. K. Pandey, O. P. Pandey, S. R. Sengupta, and S. C. Tripathi, *Polyhedron*, **6**, 1611 (1987).
6. H. D. S. Yadava, S. R. Sengupta, and S. C. Tripathi, *Inorg. Chem. Acta*, **128**, 1 (1987).

7. O. P. Pandey, S. R. Sengupta, and S. C. Tripathi, *Synth. React. Inorg. Metal-Org. Chem.*, **17**, 567 (1987).
8. P. Souzaz, M. A. Mendiola, A. Arguero, V. Fernández, E. Gutiérrez-Puebla, and C. Ruiz-Valero, *Z. Naturforsch.*, **49b**, 263 (1994).
9. P. Souzaz, M. A. Mendiola, A. I. Metesanz, V. Fernández, and A. Arguero, *Transition Met. Chem.*, **20**, 157 (1995).
10. K. N. Zelenin, V. V. Alekseev, K. Pikhlaia, and V. V. Ovcharenko, *Izv. Akad. Nauk, Ser. Khim.,* 197 (2002).
11. K. N. Zelenin and V. V. Alekseev, *Khim. Geterotsikl. Soedin.*, 267 (1993). [*Chem. Heterocycl. Comp.*, **29**, 236 (1993)].
12. K. N. Zelenin, V. V. Alekseev, T. I. Pekhk, and O. B. Kuznetsova, *Khim. Geterotsikl. Soedin.*, 1288 (1989). [*Chem. Heterocycl. Comp.*, **25**, 1080 (1989)].
13. K. N. Zelenin, O. B. Kuznetsova, and V. V. Alekseev, *Khim. Geterotsikl. Soedin.*, 1418 (1992). [*Chem. Heterocycl. Comp.*, **28**, 1211 (1992)].
14. F. C. Brown, Ch. K. Bradsher, B. F. Moser, and Sh. Forrester, *J. Org. Chem.*, **24**, 1056 (1956).