REACTIONS OF α,β-UNSATURATED ACYL ISOTHIOCYANATES WITH PHENYLHYDRAZINE

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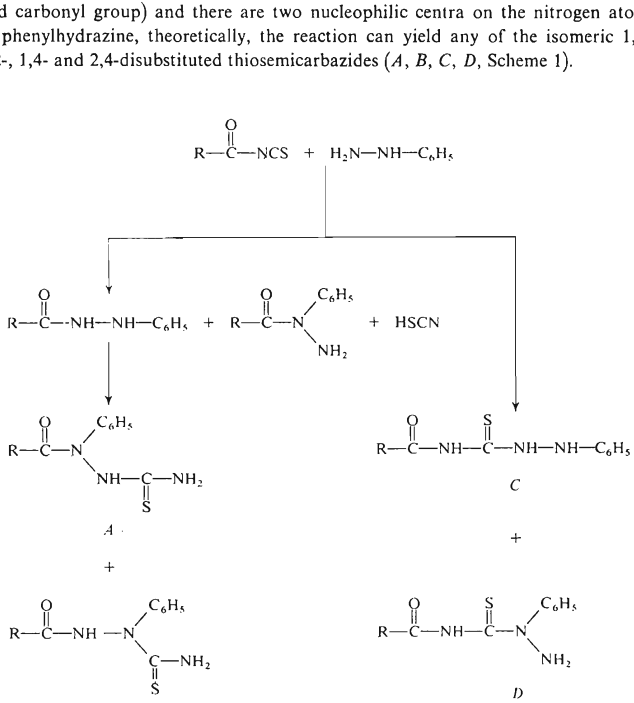
3-(2-Furyl)propenoyl isothiocyanate or 3-phenylpropenoyl isothiocyanate react with phenylhydrazine to give an isomeric mixture of 1,4- and 2,4-disubstituted thiosemicarbazides which cyclize under alkaline conditions to the corresponding 1,3-disubstituted Δ^3-1,2,4-triazoline-5--thiones and 1,5-disubstituted 3-mercapto-1,2,4-triazoles, respectively. The structure of the prepared substances was confirmed by independent syntheses. Methylation of isomeric triazoles as well as methylation followed by cyclization of the corresponding thiosemicarbazides afforded, respectively, 1,5-disubstituted 3-methylthio-1,2,4-triazoles and 1,3-disubstituted 5-methylthio--1,2,4-triazoles. The structure of the synthesized products is discussed on the basis of their IR, ^{1}H-NMR and mass spectra.

Several works on reactions of acyl isothiocyanates with hydrazines have been described in the literature. The reaction of benzoyl isothiocyanate with phenylhydrazine was first described by Dixon[1] and Johnson and Menge[2]. While Dixon[1] isolated 1--phenyl-4-benzoyl thiosemicarbazide as the main product, the authors of the other work[2] were able to resolve the crude product into three crystalline substances, namely 1-phenyl-4-benzoylthiosemicarbazide, 1,3-diphenyl-5-mercapto-1,2,4-triazole and 1,5--diphenyl-3-mercapto-1,2,4-triazole. It has been shown by Durant[3] that benzoyl isothiocyanate reacts with methylhydrazine to a 1,2-disubstituted thiosemicarbazide which cyclizes to the corresponding triazolinethione. When reactions of phenylhydrazine with α,β-unsaturated aryl isothiocyanates, namely 3-ethoxypropenoyl- and 3--methoxy-2-methylpropenoyl isothiocyanates[4], 4-chloro-2-butenoyl isothiocyanate[5] and 3-(1-naphtyl)propenoyl isothiocyanate[6], were studied 1,4-disubstituted thiosemicarbazides were the primary products. The latter compounds cyclized either spontaneously[5] or on heating under alkaline conditions[4,6] to give the corresponding 1,5-disubstituted 1,2,4-triazoline-3-thiones. In the above-mentioned conversions of isothiocyanates with phenylhydrazine the formation of 2,4-disubstituted thiosemicarbazides or their cyclization products was not observed.

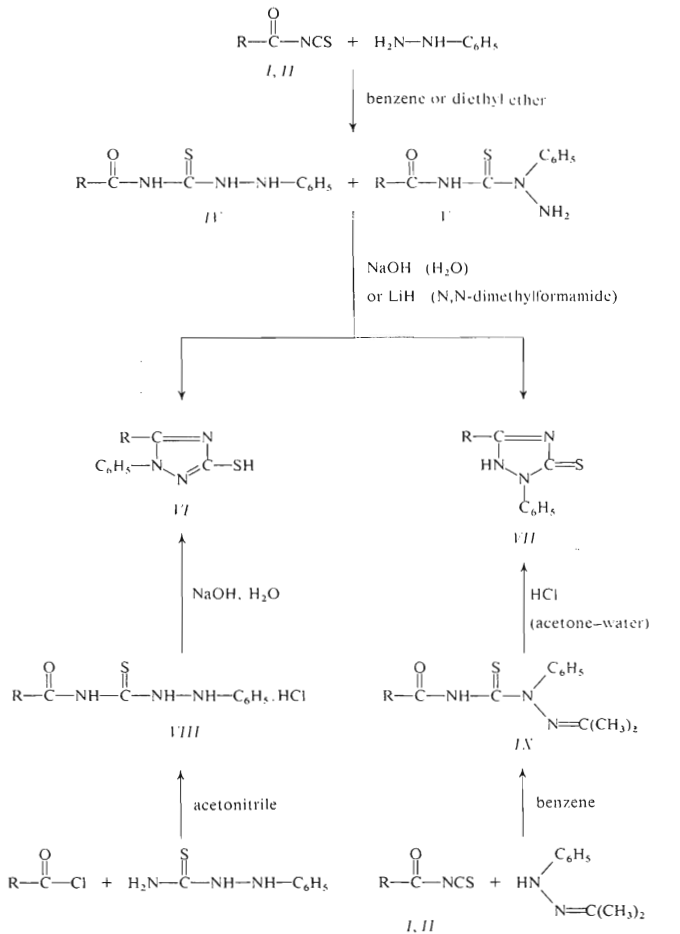
In the present work, with the aim to test the possibility of the formation of the corresponding isomeric thiosemicarbazides and their cyclization products, our attention has been focussed on the reactions of 3-(2-furyl)propenoyl isothiocyanate

(*I*) and 3-phenylpropenoyl isothiocyanate (*II*) with phenylhydrazine. Since two electrophilic centra are present in acyl isothiocyanates (at the carbon atoms of the NCS and carbonyl group) and there are two nucleophilic centra on the nitrogen atoms in phenylhydrazine, theoretically, the reaction can yield any of the isomeric 1,1-, 1,2-, 1,4- and 2,4-disubstituted thiosemicarbazides (*A*, *B*, *C*, *D*, Scheme 1).



SCHEME 1

Our reaction was performed in benzene, ether and ethanol, and the isolated crude product contained two isomeric thiosemicarbazides in a ratio of 4 : 1 (benzene, ether) or 5 : 6 (ethanol) which could not be separated by either crystallization or chromatography. In order to prove the structure of the formed thiosemicarbazides, 1-[3-(2-furylpropenoyl]-2-phenylhydrazonium chloride (*III*) was prepared by a reaction of 3-(2-furyl)propenoyl chloride with phenylhydrazine. In contrast to 1-ben-



R = 2-furyl—CH=CH (*a*), C_6H_5—CH=CH (*b*)

SCHEME 2

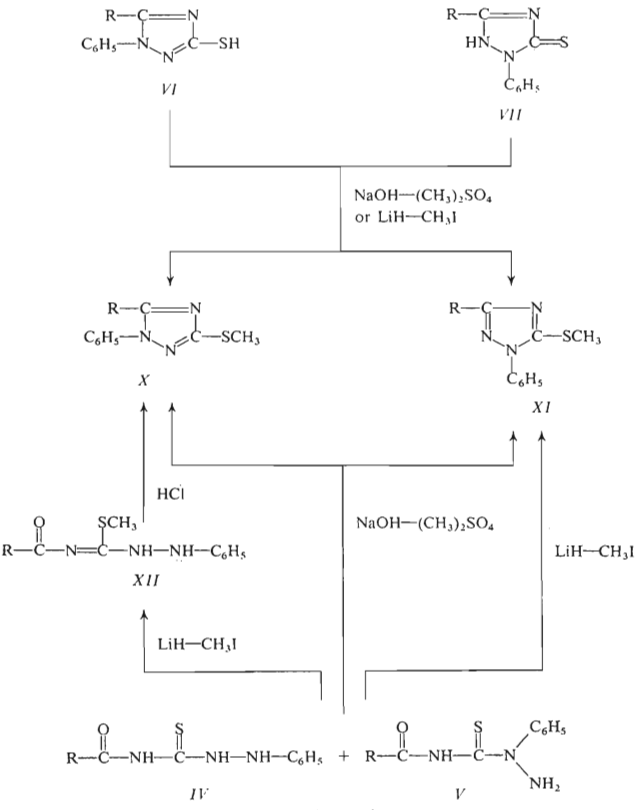
zoyl-2-methylhydrazonium chloride[3], compound *III* does not react in ethanol with NaSCN to form the corresponding 1,2-disubstituted thiosemicarbazide which led us to assume that in our reaction a mixture of 1,4- and 2,4-disubstituted thiosemicarbazides had been formed. While in the case of (2-furyl)propenoyl derivatives both isomeric thiosemicarbazides *IVa* and *Va* are stable, as shown by identical elemental analyses of the substances before and after crystallization, phenylpropenoyl derivatives *IVb* and *Vb* cyclize during crystallization from benzene or ethanol. The product of cyclization of *Vb* is 1,3-disubstituted 1,2,4-triazoline-3-thione (*VIIb*).

When the mixture of thiosemicarbazides was treated with NaOH or LiH a crude product was obtained consisting of a mixture of 1,5-disubstituted 3-mercapto-1,2,4-triazole (*VI*) and 1,3-disubstituted Δ^3-1,2,4-triazoline-5-thione (*VII*), and the ratio of the isomers corresponded to the amount of the related thiosemicarbazides (Scheme 2). Pure compounds *VI* and *VII* were obtained from the crude product by crystallization from ethanol and their structure was confirmed by an independent synthesis (Scheme 2). Reactions of (2-furyl)propenoyl and phenylpropenoyl chloride with 1-phenylthiosemicarbazide gave the corresponding 1,4-disubstituted thiosemicarbazonium chlorides *VIII* and these were cyclized under alkaline conditions to 1,5-disubstituted triazoles *VI*. The addition reactions of acetone phenylhydrazone with isothiocyanates *I* and *II* gave addition products *IX* which, by hydrolysis under acidic conditions, cyclize immediately to 1,3-disubstituted triazolines *VII*. The physico-chemical constants of thus obtained substances were identical to those shown by the reaction products of isothiocyanates *I* and *II* with phenylhydrazine.

Methylation of cyclic products *VI* and *VII* with dimethyl sulphate or methyl iodide afforded 1,5-disubstituted 3-methylthio-1,2,4-triazoles (*X*) and 1,3-disubstituted 5-methylthio-1,2,4-triazoles (*XI*), respectively (Scheme 3). When the crude product containing a mixture of 1,4- and 2,4-disubstituted thiosemicarbazides was methylated with dimethyl sulphate the corresponding S-methylated triazole *X* and *XI* were formed quantitatively and in the same ratio as the non-methylated cyclic products *VI* and *VII*. Based on the chemical shifts of methyl protons found in ^{1}H-NMR spectra of *X* and *XI* the relative abundance of 1,4- and 1,2-disubstituted thiosemicarbazides in the crude product could be also determined.

When methylation of a mixture of thiosemicarbazides was performed with methyl iodide and lithium hydride, in the case of 1,4-disubstituted thiosemicarbazides also their S-methylated derivatives *XII* were isolated. On heating or treatment with an acid these substances give cyclic products *X* (Scheme 3).

The proposed structures of the synthesized compounds were confirmed by IR, ^{1}H-NMR and mass spectra. The IR spectra of cyclic products *VI*, *VII*, *X* and *XI* showing ν(C=C) and thioamide absorption bands, respectively, at 1638–1652 and 1500–1510 cm^{-1}, contain no carbonyl absorption bands. In the spectra of compounds *VI* the ν(SH) absorption bands appear at 2595 cm^{-1} and, therefore, it can be assumed that SH groups in these substances are in their tautomeric form. On the

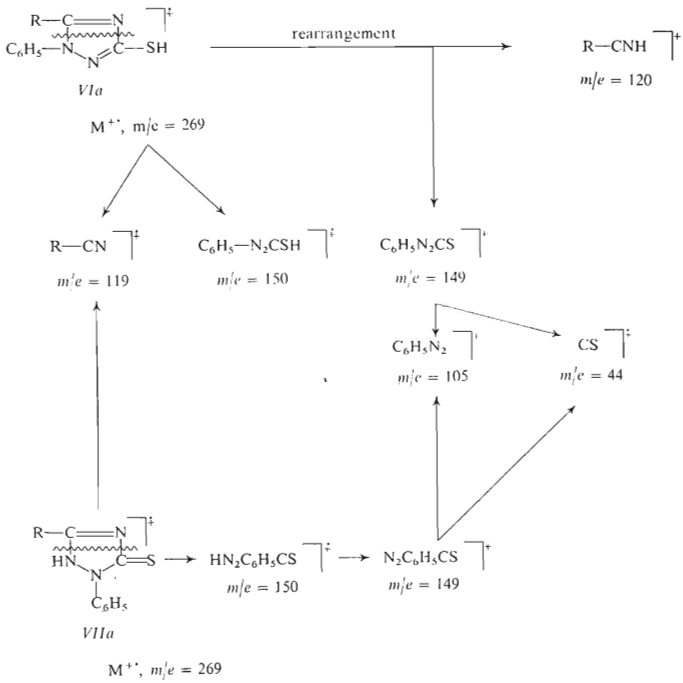


R = 2-furyl—CH=CH (*a*), C_6H_5—CH=CH (*b*)

SCHEME 3

other hand, the spectra of isomeric 1,3-disubstituted triazolines *VII* show ν(NH) bands at 3445 cm^{-1} indicating thione form of these substances. The ^{1}H-NMR spectra of cyclic products *VI*, *VII*, *X* and *XI* show two doublets of *trans* ethylenic protons at δ 6·63–7·10 and 7·25–7·86 ppm (J_{AB} = 16 Hz). The signals of methyl groups in *X* and *XI* are present at δ_{SCH_3} 2·62–2·76 ppm.

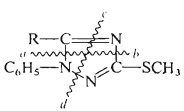
Furan derivatives show doublets of protons at the position 5 of the furan ring at δ 7·35–7·54 ppm ($J_{5,4}$ = 2 Hz); doublets and quartets of protons at the position 3



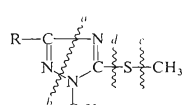
SCHEME 4

and 4 of the furan ring appear at δ 6·50–6·76 ppm ($J_{3,4}$ = 4 Hz) and δ 6·46 to 6·53 ppm ($J_{4,5}$ = 2 Hz, $J_{3,4}$ = 4 Hz), respectively.

The structure of cyclic products follows also from mass spectra of selected substances *VIa*, *VIIa*, *Xa* and *XIa*. High intensity of molecular ion peaks suggests pronounced stability of these substances. The spectra of the non-methylated compounds *VIa* and *VIIa* (Scheme 4) show analogous fragment peaks, except for the intense peak at *m/e* 120 (96%) in the spectrum of *VIa*, not present in the spectrum of *VIIa*. It indicates that in the fragmentation of *VIa* a transfer of the proton from the atom of sulphur to the atom of nitrogen occurs, followed by a cleavage of the ring to give rise to ions $[2\text{-furyl-CH=CH—CHN}]^+$. The mentioned process was confirmed by the spectrum of $[C_3—S^2H]$1-phenyl-5-(2-furyl)vinyl-3-mercapto-1,2,4-triazole (*XIII*). It follows from the relative intensities of molecular ion peaks that the achieved degree of deuteration was 61%. Apart from the molecular ion peak at *m/e* 270 the presence of deuterium was noticeable also by the presence of peaks at *m/e* 121 and 151.



Xa



XIa

R = 2-furyl—CH=CH

SCHEME 5

The disintegration of molecular ions of S-methyltriazoles *Xa* and *XIa* (Scheme 5) can occur *via* cleavage of *a* and *b* bonds to form ions if the same *m/e* values (119, 164 and 149). By scission of bonds *c* and *d* in *Xa* ions $[R—CNC_6H_5]^+$, represented by peaks at *m/e* 196 not present in the spectrum of *XIa*, are formed which prove unambiguously the structure of the 1,5-disubstituted derivative. The spectrum of 1,3-disubstituted compound *Xa* contains peaks at *m/e* 268 ($[M—CH_3]^+$) and *m/e* 236 ($[M—SCH_3]^+$) reflecting the cleavage of bonds *c* and *d*. The former ion is cleaved further to give ion $[C_6H_5NCS]^+$ (*m/e* 135) which can not be formed in the fragmentation of *Xa*.

EXPERIMENTAL

The IR spectra (800—3 500 cm^{-1}) for solutions in chloroform or compounds in KBr pellets were measured with a double-beam UR-20 (Zeiss) spectrometer calibrated against a polystyrene foil. ^{1}H-NMR spectra (80 MHz) for solutions in chloroform-d, dimethyl sulphoxide-d_6 or acetone-d_6

were recorded with a Tesla BS 487A instrument using tetramethylsilane as the internal standard. Mass spectra (70 eV) were taken with MS 902 (AEI) spectrometer using the direct sample-introduction technique.

trans-3-(2-Furyl)propenoyl isothiocyanate (*I*) was prepared as described[7]. IR Data ($CHCl_3$): ν_{as}(NCS) 1 973 cm^{-1}, ν(C=O) 1 689 cm^{-1}, ν(C=C) 1 629 cm^{-1}, ν (skeletal furan)1 023 cm^{-1}, γ(CH=CH) 973 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$, δ): 7·49 and 6·33 (doublets, —CH=CH—, J_{AB} = 16 Hz). *trans*-Phenylpropenoyl isothiocyanate (*II*) has been described[8].

1-[3-(2-Furyl)propenoyl]-2-phenylhydrazonium Chloride (*III*)

A solution of phenylhydrazine (2·25 g, 0·02M) in benzene (20 ml) was added during 5 min to a stirred and cooled solution of 3-(2-furyl)propenoyl chloride (3·35 g, 0·02M) in benzene (40 ml). The precipitated crystalline material was filtered and washed with n-hexane to give the title product in 80% yield, m.p. 179—181°C. For $C_{13}H_{14}ClN_2O_2$ (265·7) calculated: 58·80% C, 4·93% H, 10·54% N; found: 58·63% C, 5·08% H, 10·70% N. IR Data (KBr): ν(C=O) 1 690 cm^{-1}, ν(C=O) 1 690 cm^{-1} and 1 660 cm^{-1}, ν(C=C) 1 620 cm^{-1}, ν(skeletal furan) 1 020 cm^{-1}.

An attempt to prepare 1-[3-(2-furyl)propenoyl]-2-phenylthiosemicarbazide by refluxing *III* (2·4 g, 0·01M) with NaSCN (0·85 g, 0·01M) in ethanol (100 ml) for 12 h was unsuccessful. On diluting the mixture with water the starting material (free base) precipitated.

Mixtures of 1,4- and 2,4-Disubstituted Thiosemicarbazides (*IVa* and *Va*, and *IVb* and *Vb*)

Phenylhydrazine (3·24 g, 0·03M) in ether or benzene (10 ml) was added dropwise during 5—10 min to a cold solution of 0·03M of 3-(2-furyl)propenoyl isothiocyanate (*I*) or 3-phenylpropenoyl isothiocyanate (*II*) in the same solvent (50 ml). The precipitate formed within a few minutes was filtered, washed with 10 ml of the respective solvent and dried, to give from *I* a 4 : 1 mixture of 1-phenyl-4-[3-(2-furyl)propenoyl]thiosemicarbazide (*IVa*) and 2-phenyl-4-[3-(2-furyl)propenoyl] thiosemicarbazide (*Va*) in 84% yield, m.p. 150—153°C (from benzene). For $C_{14}H_{13}N_3O_2S$ (287·3) calculated: 58·52% C; 4·56% H; 14·65% N; found: 58·39% C; 4·65% H; 14·82% N. IR Data ($CHCl_3$): $\nu(NH)_{free}$ 3412 cm^{-1}, $\nu(NH)_{assoc}$ 3250 cm^{-1}, ν(C=O) 1 697 cm^{-1}, ν(C=C) 1 626 cm^{-1}, ν(NHCS) 1 508 cm^{-1}, ν(skeletal furan) 1 021 cm^{-1}, γ(CH=CH) 970 cm^{-1}.

The 4 : 1 mixture of 1-phenyl-4-(3-phenylpropenoyl)thiosemicarbazide (*IVb*) and 2-phenyl-4--(3-phenylpropenoyl)thiosemicarbazide (*Vb*), obtained from *II* in a yield of 91%, melted at 159 to 161°C (from chloroform–light petroleum at room temperature). For $C_{16}H_{15}N_3OS$ (297·4) calculated: 64·15% C; 5·08% H; 14·14% N; found: 64·28% C, 4·89% H, 14·35% N. IR Data ($CHCl_3$): $\nu(NH)_{free}$ 3416 cm^{-1}, $\nu(NH)_{assoc}$ 3253 cm^{-1}, ν(C=O) 1 681 cm^{-1}, ν(C=C)1 628 cm^{-1}, ν(NHCS) 1 508 cm^{-1}, γ(CH=CH) 980 cm^{-1}.

1,5-Disubstituted 3-Mercapto-1,2,4-triazoles (*VIa* and *VIb*)

A) A 4 : 1 mixture of thiosemicarbazides *IV* and *V* (5 mM) was added during 5 min to a stirred suspension of LiH (0·037 g, 5 mM) in dimethylformamide (30 ml) cooled with tap water. The stirring was continued until clear solution was formed (~30 min) and dilute (2 : 1) hydrochloric acid was added dropwise, which resulted in the formation of a yellow precipitate. Water was added (40—50 ml) and after 1 h the product was filtered, washed with water and dried.

B) A solution of thiosemicarbazides *IV* and *V* (5 mM) in 2 M-NaOH (10 ml) was heated to boiling and, after cooling, aqueous HCl (1 : 5) was added until the solution was acidic (litmus). The formed precipitate was filtered, washed with water and dried.

C) 1,4-Disubstituted thiosemicarbazonium chloride *VIII* a or *VIIIb* (1·5 mM) was heated to boiling in 1M-NaOH (20 ml) until almost all material dissolved and the mixture was filtered. The product precipitated on addition of aqueous HCl (1 : 1). Compounds *VIa* and *VIb* were obtained in 80% yield.

Two crystallizations of the crude product, obtained by either method *A* or *B*, from ethanol gave pure *VIa* or *VIb* while compounds *VIIa* and *VIIb* remained in the mother liquor.

1-*Phenyl*-5-(2-*furyl*)*vinyl*-3-*mercapto*-1,2,4-*triazole* (VIa): yield, 60·4% of yellow needles, m.p. 167—169°C (dec.). For $C_{14}H_{11}N_3OS$ (269·0) calculated: 62·43% C, 4·11% H, 15·60% N; found: 62·56% C, 4·21% H, 15·48% N. IR Data ($CHCl_3$): ν(SH) 2595 cm^{-1}, ν(C=C) 1639 cm^{-1}, ν(N=C—S) 1508 cm^{-1}, ν(skeletal furan) 1021 cm^{-1}, γ(CH=CH) 963 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 7·64 and 6·63 (doublets, —CH=CH—, J_{AB} = 16 Hz); 7·50 (singlet, C_6H_5). Mass spectral data [fragment ion, *m/e* (%)]: $[M - CO]^+$, 241 (100); $[M - CHO]^+$, 240 (58); $[M - C_2OH]^+$, 228 (61); $[M - CHO - S]^+$, 208 (51); [2-furyl—CH=CH—CNH]$^+$, 149 (100); M^{2+}, 134·5 (24); [2-furyl—CH=CH—CNH]$^+$, 120 (96); [2-furyl—CH=CH—CN]$^+$, 119 (28); $[C_6H_5N_2]^+$, 105 (71); $[C_6H_5N]^+$, 91 (100); $[C_6H_5]^+$, 77 (100); $[C_5H_6]^+$, 65 (82); $[C_5H_4]^+$, 64 (100); $[C_4H_3]^+$, 51 (100); $[CS]^+$, 44 (83); $[C_2OH]^+$, 41 (82); $[C_3H_3]^+$, 39 (72); $[S]^+$, 28 (100).

1-*Phenyl*-5-*phenylvinyl*-3-*mercapto*-1,2,4-*triazole* (VIb): yield, 58% of yellow needles, m.p. 148—150°C. For $C_{16}H_{13}N_3S$ (279·4) calculated: 68·78% C, 4·68% H, 15·04% N; found: 68·59% C, 4·70% H, 15·26% N. IR Data ($CHCl_3$): ν(SH) 2595 cm^{-1}, ν(C=C) 1641 cm^{-1}, γ(CH=CH) 974 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 6·75 and 7·86 (doublets, —CH=CH—, J_{AB} = 16 Hz); 7·34 and 7·49 (multiplets, C_6H_5).

1,3-Disubstituted Δ^3-1,2,4-Triazoline-5-thiones (*VIIa*, *VIIb*)

For method *A* and *B* see preceding section. *C*) 4-Substituted acetone 2-phenylthiosemicarbazone *IXa* or *IXb* (1·5 mM) was dissolved in acetone (15 ml), heated to boiling and aqueous HCl (1 : 1, 10 ml) was added dropwise and with stirring. The product that precipitated on addition of water was filtered and dried, yield 85%.

Three recrystallizations of crude products obtained by method *A* or *B* [from chloroform–light petroleum (1 : 5)], or from the concentrated mother liquor after *VIa* and *VIb* had been removed by crystallization (from a little ethanol) gave pure *VIIa* and *VIIb* in a form of needles.

1-*Phenyl*-3-(2-*furyl*)*vinyl*-Δ^3-1,2,4-*triazoline*-5-*thione* (VIIa): yield, 15%; m.p. 231—233°C. For $C_{14}H_{11}N_3OS$ (269·0) calculated: 62·43% C; 4·11% H, 15·60% N; found: 62·27% C, 4·09% H, 15·42% N. IR Data ($CHCl_3$): ν(NH) 3445 cm^{-1}, ν(C=C) 1640 cm^{-1}, ν(N—C=S) 1500 cm^{-1}, ν(skeletal furan) 1020 cm^{-1}, γ(CH=CH) 958 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$–dimethyl sulphoxide-d_6): 7·95 and 7·45 (multiplets, C_6H_5); 7·34 and 6·66 (doublets, —CH=CH—, J_{AB} = 16 Hz). Mass spectral data [fragment ion, *m/e* (%)]: $(M - CO]^+$, 241 (100); $[M - CHO]^+$, 240 (75); $[M - C_2OH]^+$, 228 (15); [M -2furyl—CH=CH—CN]$^+$, 150 (18); $[M - 2furyl—CH=CH—H]$, 149 (48); $[M]^{2+}$, 134·5 (15); [2-furyl—CH=CH—CN]$^+$, 119 (75): $[C_6H_5N_2]^+$, 105 (47); $[C_6H_5N]^+$, 91 (100); $[C_6H_5]^+$, 77 (100); $[C_5H_5]^+$ 65 (57); $[C_5H_4]$ 51 (69); $[CS]^+$, 44 (19); $[C_2OH]^+$, 41 (63); $[C_3H_3]^+$, 39 (100); $[CO]^+$, 28 (73).

1-*Phenyl*-3-*phenylvinyl*-Δ^3-1,2,4-*triazoline*-5-*thione* (VIIb): yield, 15%; m.p. 221—222°C. For $C_{16}H_{13}N_3S$ (279·4) calculated: 68·78% C, 4·68% H, 15·04% N; found: 68·71% C, 4·87% H, 14·80% N. IR Data ($CHCl_3$): ν(NH) 3446 cm^{-1}, ν(C=C) 1625 cm^{-1}, ν(N—C=S) 1503 cm^{-1}, γ(CH=CH) 969 cm^{-1}. ^{1}H-NMR Data (dimethyl sulphoxide-d_6): 7·25 (doublet, one of —CH= =CH— protons, J_{AB} = 16 Hz); 7·67 and 8·19 (multiplets, C_6H_5, one of —CH=CH— protons).

1,4-Disubstituted Thiosemicarbazonium Chlorides (*VIIIa*, *VIIIb*)

A solution of 3-(2-furyl)propenoyl chloride or 3-phenylpropenoyl chloride (3·3 mM) in acetonitrile (5 ml) was added to 1-phenylthiosemicarbazide (3·3 mM) in boiling acetonitrile and heated under reflux for 30 min. After cooling, the crystalline product that had separated during these operations was filtered and dried.

1-*Phenyl*-4-[3-(2-*furyl*)*propenoyl*)]*thiosemicarbazonium chloride* (VIIIa): yield, 90%; m.p. 251 to 253°C (from dimethylformamide–water). For $C_{14}H_{14}ClN_2O_2S$ (323·8) calculated: 51·89% C, 4·52% H, 12·97% N; found: 51·66% C, 4·42% H, 13·12% N. IR Data (KBr): ν(C=O) 1 673 cm^{-1}, ν(C=C) 1 629 cm^{-1}, ν(NHCS) 1 500 cm^{-1}, ν(skeletal furan) 1035) cm^{-1}, γ(CH=CH) 973) cm^{-1}.

1-*Phenyl*-4-(3-*phenylpropenoyl*)*thiosemicarbazonium chloride* (VIIIb): yield, 96%; m.p. 241 to 242°C. For $C_{16}H_{16}N_3OS$ (333·8) calculated: 57·56% C, 4·83% H, 12·59% N; found: 57·41% C, 4·64% H, 12·81% N. IR Data (KBr): ν(C=O) 1676 cm^{-1}, ν(C=C) 1 622 cm^{-1}, ν(NHCS) 1 498 cm^{-1}, γ(CH=CH) 981 cm^{-1}.

4-Substituted Acetone 2-Phenylthiosemicarbazones (*IXa*, *IXb*)

A mixture of the corresponding isothiocyanate (0·027M) and acetone phenylhydrazone (0·027M) in benzene (30 ml) was heated under reflux for 1 h. After concentration to one third of the original volume, the product was precipitated by an addition of ten volumes of light petroleum, filtered and dried.

Acetone 2-*phenyl*-4-[3-(2-*furyl*)*propenoyl*]*thiosemicarbazone* (IXa): yield, 75%; m.p. 145–147°C (dec., from acetone–water). For $C_{17}H_{17}N_3O_2S$ (327·4) calculated: 62·39% C, 5·23% H, 12·83% N; found: 62·58% C, 5·08% H, 12·66% N. IR Data ($CHCl_3$): ν(C=O) 1 673 cm^{-1}, ν(C=C) 1612 cm^{-1}, ν(NHCS) 1 500 cm^{-1}, ν(skeletal furan) 1021 cm^{-1}, γ(CH=CH) 966 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 1·72 (singlet, $-CH_3$), 4·97 (singlet, —NH—), 7·37 and 7·65 (doublets, —CH=CH—, J_{AB} = 16 Hz), 7·32 and 7·87 (multiplets, $-C_6H_5$).

Acetone 2-*phenyl*-4-(3-*phenylpropenoyl*)*thiosemicarbazone* (IXb): yield, 88%; m.p. 142–143°C (from ethanol). For $C_{18}H_{19}N_3OS$ (337·4) calculated: 67·58% C, 5·67% H, 12·45% N; found: 67·32% C, 5·91% H, 12·27% N. IR Data ($CHCl_3$): ν(C=O) 1 675 cm^{-1}, ν(NHCS) 1 500 cm^{-1}, γ(CH=CH) 970 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 1·76 (singlet, $-CH_3$), 4·97 (singlet, —NH—), 7·24–7·92 (multiplet, —CH=CH—, $-C_6H_5$).

1,5-Disubstituted 3-Methylthio-1,2,4-triazoles (*Xa*, *Xb*) and 1,3-Disubstituted 5-Methylthio-1,2,4-triazoles (*XIa*, *XIb*)

A) Dimethyl sulphate (0·46 g, 4 mM) was added dropwise and with stirring to a solution of the respective triazole *VI* or triazoline *VII* (3·3 mM). The product was filtered, washed with water, dried, and crystallized from acetone–water. The substances were obtained in 80–90% yields.

B) The respective triazole *VI* or triazoline *VII* (1·6 mM) was added with stirring to a suspension of LiH (0·015 g, 1·6 mM) in dimethylformamide (10 ml). When a clear solution was formed, methyl iodide (0·29 g, 2 mM) was added dropwise, the mixture was stirred for 20 min and then poured into water (10 ml). The precipitate that had separated during 24 h from the cloudy solution was filtered, washed with water, dried and crystallized from acetone–water. Yield, 60–70%.

C) Methylation of a mixture of 1,4- and 2,4-disubstituted thiosemicarbazones *IV*, *V* in the manner described in *A*) gave a mixture of methylated triazoles *X* and *XI* the ratio of which corresponded to that of starting materials.

D) 4-Substituted 1-phenyl-S-methylthiosemicarbazide *XII* was refluxed in a mixture of acetone (15 ml) and concentrated hydrochloric acid (2 ml), or heated at 120 °C in phosphoric acid (84%, 10 ml) for 10 min, or heated without any solvent at 120—140°C for 20 min. Water was added after cooling, the solids filtered, dried and crystallized from acetone–water. The yield of 1,5-disubstituted 3-methylthio-1,2,4-triazoles *X* obtained by the three procedures was 79, 30 and 60%, respectively.

1-*Phenyl*-5-(2-*furyl*)*vinyl*-3-*methylthio*-1,2,4-*triazole* (Xa): m.p. 113—115°C. For $C_{15}H_{13}N_3OS$ (283·2) calculated: 63·62% C, 4·62% H, 14·84% N; found: 63·81% C, 4·56% H, 14·69% N. IR Data ($CHCl_3$): $\nu_{as}(CH_3)$ 2941 cm^{-1}, ν(C=C) 1638 cm^{-1}, ν(N=C—S) 1506 cm^{-1}, ν(skeletal furan) 1019 cm^{-1}, γ(CH=CH) 963 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 2·62 (singlet, —SCH_3), 6·63 and 7·55 (doublets, —CH=CH—, J_{AB} = 16 Hz), 7·48 (singlet, —C_6H_5). Mass spectral data [fragment ion, *m/e* (%)]: [M — CO]$^+$, 255 (44), [M — C_2OH]$^+$, 242 (100), [M — CO — C_2H_2]$^+$, 229 (49), [2-furyl—CH=CH—CNC_6H_5]$^+$, 196 (17), [M — 2-furyl—CH=CH—CN]$^+$, 164 (27), [$C_6H_5N_2CS$]$^+$, 149 (44), [M]$^{2+}$, 141·5 (10), [2-furyl—CH=CH—CN]$^+$, 119 (17), [$C_6H_5N_2$]$^+$, 105 (26), [C_6H_5N]$^+$, 91 (100), [C_6H_5]$^+$, 77 (100), [C_5H_5]$^+$, 65 (47), [C_5H_4]$^+$. 64 (100), [C_4H_3]$^+$, 51 (76), [CS]$^+$, 44 (98), [C_2OH]$^+$, 41 (38), [C_3H_3]$^+$, 39 (57), [CO]$^+$, 28 (98).

1-*Phenyl*-5-(3-*phenylvinyl*)-3-*methylthio*-1,2,4-*triazole* (Xb): m.p. 97—98°C. For $C_{17}H_{15}N_3S$ (293·4) calculated: 69·59% C, 5·15% H; 14·32% N; found: 69·34% C, 4·96% H, 14·25% N. IR Data ($CHCl_3$): $\nu_{as}(CH_3)$ 2945 cm^{-1}, ν(C=C) 1643 cm^{-1}, ν(N=C—S) 1507 cm^{-1}, γ(CH=CH) 976 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 2·66 (singlet, —SCH_3), 6·81 and 7·81 (doublets, —CH=CH—, J_{AB} = 16 Hz), 7·36 and 7·51 (multiplets, —C_6H_5).

1-*Phenyl*-3-(2-*furyl*)*vinyl*-5-*methylthio*-1,2,4-*triazole* (XIa): m.p. 74—76°C. For $C_{15}H_{13}N_3OS$ (283·2) calculated: 63·62% C, 4·62% H, 14·84% N; found: 63·42% C, 4·90% H, 14·60% N. IR Data ($CHCl_3$): $\nu_{as}(CH_3)$ 2945 cm^{-1}, ν(C=C) 1627 cm^{-1}, ν(N=C—S) 1508 cm^{-1}, ν(skeletal furan) 1018 cm^{-1}, γ(CH=CH) 966 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 2·74 (singlet, —CH_3), 6·79 (doublet, one of —CH=CH— protons, J_{AB} = 16 Hz), 7·35—7·60 (multiplet, —C_6H_5, one of —CH=CH— protons). Mass spectral data [fragment ion, *m/e* (%)]: [M — CH_3]$^+$, 268 (9), [M — CO]$^+$, 255 (40), [M — C_2OH]$^+$, 242 (100), [M — CO — C_2H_2]$^+$, 229 (18), [M — 2-furyl—CH=CH—CN]$^+$, 164 (12), [$C_6H_5N_2CS$]$^+$, 149 (22), [M]$^{2+}$, 141·5 (13), [C_6H_5NCS]$^+$, 135 (19), [2-furyl—CH=CH—CN]$^+$, 119 (100), [$C_6H_5N_2$]$^+$, 105 (32), [C_6H_5N]$^+$, 91 (100), [C_6H_5]$^+$, 77 (100), [C_5H_5]$^+$, 65 (76), [C_5H_4]$^+$, 64 (100), [C_4H_3]$^+$, 51 (100), [C_2OH]$^+$, 41 (54), [C_3H_3]$^+$, 39 (91), [CO]$^+$, 28 (35).

1-*Phenyl*-3-*phenylvinyl*-5-*methylthio*-1,2,4-*triazole* (XIb): m.p. 109—110°C. For $C_{17}H_{15}N_3S$ (293·4) calculated: 69·59% C, 5·15% H, 14·39% N; found: 69·46% C, 5·37% H, 14·01% N. IR Data ($CHCl_3$): $\nu_{as}(CH_3)$ 2948 cm^{-1}, ν(C=C) 1652 cm^{-1}, ν(N=C—S) 1509 cm^{-1}, γ(CH=CH) 974 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$): 2·76 (singlet, —SCH_3), 7·10 and 7·66 (doublets, —CH=CH—, J_{AB} = 16 Hz), 7·37 (multiplet, —C_6H_5).

4-Substituted 1-Phenyl-S-methylisothiosemicarbazides (*XIIa*, *XIIb*)

A 4 : 1 mixture of 1,4- and 2,4-disubstituted thiosemicarbazides *IV* and *V* was methylated as described in *B*). Crystallization (thrice) of the crude product from chloroform–light petroleum (1 : 8) at room temperature yielded pure *XII* a or *XIIb*. Concentration of the mother liquor and crystallization of the residue from acetone–water afforded compounds *XIa* or *XIb*.

1-*Phenyl*-4-[3-(2-*furyl*)*propenoyl*]-S-*methylisothiosemicarbazide* (XIIa): yield, 70%; m.p. 138 to 140° (dec.). For $C_{15}H_{15}N_3O_2S$ (301·4) calculated: 59·74% C, 5·01% H, 13·93% N; found-

59·76% C, 5·21% H, 13·80% N. IR Data (KBr): ν(C=O) 1 660 cm^{-1}, ν(C=C) 1 626 cm^{-1}: ν(NHCS) 1 490 cm^{-1}, ν(skeletal furan) 1 034 cm^{-1}, γ(CH=CH) 962 cm^{-1}. ^{1}H-NMR Data ($CDCl_3$–dimethyl sulphoxide-d_6): 2·77 (singlet, —SCH_3), 6·63 and 7·42 (doublets, —CH=CH— J_{AB} = 16 Hz), 7·05 multiplet, —C_6H_5).

1-*Phenyl*-4-(3-*phenylpropenoyl*)-S-*methylisothiosemicarbazide* (XIIb): yield, 72%; m.p. 120 to 122°C (dec.). For $C_{17}H_{17}N_3OS$ (311·4) calculated: 65·57% C, 5·50% H, 13·49% N; found, 65·53% C, 5·37% H, 13·53% N. IR Data ($CHCl_3$): ν(NH) 3 405 cm^{-1}, $\nu_{as}(CH_3)$ 2 945 cm^{-1}, ν(C=O) 1 681 cm^{-1}, ν(C=C) 1 632 cm^{-1}, ν(NHCS) 1 505 cm^{-1}, γ(CH=CH) 980 cm^{-1}. ^{1}H, -NMR Data (acetone-d_6): 2·47 (singlet, —SCH_3), 6·81—7·87 (multiplet, —C_6H_5, —CH=CH—): 8·75 and 9·45 (singlets, —NH—).

[C_3-S^2H]1-Phenyl-5-(2-furyl)vinyl-3-mercapto-1,2,4-triazole (*XIII*)

A mixture of 1,5-disubstituted triazole *VIa* (0·27 g, 1 mM) and ^2H_2O (1·9 g, 100 mM) in acetone-d_6 (8 ml) was heated under reflux for 4 h. The mass spectrum of the product should be taken immediately after concentration lest it might hydrolyze, when allowed to get ito contact with atmospheric moisture, to the original components. The sample can be kept under nitrogen for a few hours.

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