251. *Compounds related to Thiosemicarbazide. Part II.* 1-*Benzoylthiosemicarbazides.*

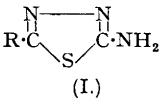
By Eric Hoggarth.

Preparations of 1-benzoylthiosemicarbazides are described, and the constitution of these compounds established by dehydration experiments with a variety of reagents. Evidence is adduced to show that, after initial substitution at position 1, thiosemicarbazide is attacked by benzoyl chlorides in pyridine at both positions 2 and 4. A convenient preparation of 3-phenyl-1 : 2 : 4-triazole-5-thiols (Part I) is afforded by dehydration of 1-benzoylthiosemicarbazides under alkaline conditions.

1-Benzoyl derivatives of 4-aryl- and 4-alkyl-thiosemicarbazides have been prepared by reaction of benzoylhydrazide with aryl and alkyl *iso*thiocyanates (Marckwald and Bott, *Ber.*, 1896, **29**, 2914; Oates and Young, *J.*, 1901, **79**, 659). Both Fehrenbach and Stolle (*J. pr. Chem.*, 1929, **122**, 289) and De (*J. Indian Chem. Soc.*, 1930, **7**, 651) mention 1-benzoylthiosemicarbazide itself, but neither describe its preparation nor characterise it. Fromm (*Annalen*, **1926**, **447**, 259) reported that attempts to benzoylate thiosemicarbazide directly in pyridine or under the Schotten–Baumann conditions resulted in simultaneous elimination of water to give a cyclised product. The inference that 1-benzoylthiosemicarbazides not carrying alkyl or aryl groups are, like the corresponding unsubstituted 4-benzoylthiosemicarbazides (Part I), unstable, has proved to be incorrect.

1-*Benzoylthiosemicarbazide* (II; R = Ph) has been prepared (*a*) by reaction of benzoylhydrazide with ammonium thiocyanate, (*b*) by cautiously heating thiosemicarbazide with the theoretical amount of benzoyl chloride, and (*c*) by benzoylation in ice-cold pyridine. The last route is by far the most convenient but gives in addition to the main product a small quantity of 1 : 4-dibenzoylthiosemicarbazide. 1-p-*Chlorobenzoyl*-, 1-p-*methoxybenzoyl*- and 1-p-*nitrobenzoylthiosemicarbazides* were also prepared by the latter route, as were the 1-benzoyl and 1-p-*methoxy*-

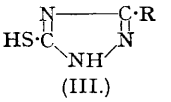
benzoyl derivatives of 4-phenyl-, 4-methyl-, 2 : 4-*dimethyl*-, and 4 : 4-*dimethyl*-thiosemicarbazides. The 4-phenyl- and 4-methyl-thiosemicarbazide derivatives were identical with the compounds obtained by the method of Marckwald and Bott (*loc. cit.*). Primarily, these compounds were prepared in order to study their dehydration reactions, and such studies have established that the benzoyl group is, as expected, in position 1. All dehydrations with the *acidic* reagents described here gave as one of the products (and often as the only product) a 2-amino-5-aryl-1 : 3 : 4-thiadiazole (I). Such sompounds could only arise from 1-benzoylthiosemicarbazides (II) which could (theoretically) give, in addition, 3-aryl-1 : 2 : 4-triazole-5-thiols (III). On the other hand, 4-benzoylthiosemicarbazides (IV) can give rise to (only) the triazoles (III).



(I.)

$R{\cdot}CO{\cdot}NH{\cdot}NH{\cdot}CS{\cdot}NH_2$

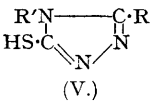
(II.)



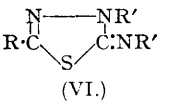
(III.)

$H_2N{\cdot}NH{\cdot}CS{\cdot}NH{\cdot}COR$

(IV.)



(V.)



(VI.)

1-Benzoyl-, 1-*p*-methoxybenzoyl-, and 1-*p*-nitrobenzoyl-thiosemicarbazide were dehydrated by phosphoric acid to give thiadiazoles (I; R = Ph, *p*-MeO·C_6H_4, or *p*-ClC_6H_4) and no triazole was detected. From the *p*-methoxybenzoyl compound, *p*-methoxybenzoic acid, arising presumably by simultaneous hydrolysis, was also found. The results were similar with 1-benzoyl-, 1-*p*-methoxybenzoyl-4-methyl-, -2 : 4-dimethyl-, and -4 : 4-dimethyl-thiosemicarbazide. Similar reactions were effected with sulphuric acid, but from the methoxybenzoyl compounds the product was water-soluble, owing apparently to sulphonation. The constitutions of the thiadiazoles follow from their basic properties and stability towards desulphurisation by hydrogen peroxide and Raney nickel catalyst. Under these conditions the sulphur atom of the triazole-thiols is removed (Part I). In a number of cases the thiadiazoles were also synthesised for comparison by a route used by Young and Eyre (*J.*, 1901, **79**, 54) for 2-amino-5-phenyl-1 : 3 : 4-thiadiazole. Fromm (*loc. cit.*) considered that the compound described by Young and Eyre as 2-amino-5-phenyl-1 : 3 : 4-thiadiazole was really 3-phenyl-1 : 2 : 4-triazole-5-thiol, his main reason being the failure of the compound to show the usual reaction of a primary amine with an *iso*thiocyanate. This conclusion must be regarded as erroneous. The dehydration of 1-benzoyl-4-phenylthiosemicarbazide with phosphoric acid differed from all preceding cases in that both aminothiadiazole and triazole-thiol were formed. 1 : 4-Dibenzoylthiosemicarbazide gave 2-benzamido-5-phenyl-1 : 3 : 4-thiadiazole only.

Marckwald and Bott (*loc. cit.*) reported that when 1-benzoyl-4-phenylthiosemicarbazide was dehydrated with acetyl chloride the product was 2-phenylamino-5-phenyl-1 : 3 : 4-thiadiazole, whilst with benzoyl chloride as dehydrating agent they obtained 3 : 4-diphenyl-4 : 1 : 2-triazole-5-thiol (V; R = R′ = Ph). Reinvestigation has shown that, in fact, both give a mixture of thiadiazole and triazole, although the predominating isomer in each instance is that isolated by the earlier authors. Application of benzoyl and acetyl chlorides to the dehydration of other 1-benzoylthiosemicarbazides has given results which, allowing for simultaneous acetylation or benzoylation, do not differ greatly from those recorded for phosphoric acid. Dehydration of 1-benzoyl-4-methylthiosemicarbazide with benzoyl chloride gave a small amount of 3-phenyl-4-methyl-4 : 1 : 2-triazole-5-thiol (V; R = Ph, R′ = Me) which could not be detected amongst the products of dehydration by other reagents. In the main, however, the products of such acidic cyclisations are determined by the substituents of the benzoylthiosemicarbazide molecule and are only to a small degree affected by the reagent used for dehydration.

In marked contrast to the foregoing, if 1-benzoylthiosemicarbazides are boiled with an alcoholic solution of sodium ethoxide, piperidine, or other strong base the elimination of water which takes place under such *alkaline* conditions occurs with exclusive formation of the triazole-thiols (III). In the representative examples studied, the yield of thiol approached the theoretical, and this is the most satisfactory method of preparing these compounds.

The isolation of a small amount of 1 : 4-dibenzoylthiosemicarbazide from the reaction of benzoyl chloride with thiosemicarbazide in pyridine suggested that the dibenzoyl compound might be most conveniently prepared by reaction of 1-benzoylthiosemicarbazide with benzoyl chloride under the same conditions. 1 : 4-Dibenzoylthiosemicarbazide was isolated, but there was also formed much 1 : 2-dibenzoylhydrazine. This seems to indicate that benzoyl chloride attacks position 2 of 1-benzoylthiosemicarbazide as well as position 4, and that 1 : 2-dibenzoyl-

thiosemicarbazide is decomposed, probably during isolation. 1 : 2-Di-*p*-chlorobenzoyl- and 1 : 2-di-*p*-nitrobenzoyl-hydrazine were isolated as by-products in the preparation of the corresponding 1-benzoylthiosemicarbazides and presumably arise in the same way. Corresponding by-products were not found in the other benzoylation reactions, but as those dibenzoylhydrazines detected are very insoluble and were isolated only in small amounts, failure may be due simply to different relative solubilities.

Experimental.

1-*Benzoylthiosemicarbazide* (II; R = Ph).—(*a*) Benzoylhydrazide (6·8 g.) was dissolved in alcoholic hydrogen chloride solution (50 c.c.) and evaporated under reduced pressure, the residue dried by evaporation of several small amounts of alcohol and heated under reflux for 18 hours with a solution of dry ammonium thiocyanate (4·0 g.) in alcohol (200 c.c.). Ammonium chloride was filtered off, the solvent removed under reduced pressure, and the residue crystallised several times from water, giving colourless leaflets (1·1 g.), m. p. 196° (decomp.) (Found : S, 16·3. $C_8H_9ON_3S$ requires S, 16·4%), of the *thiosemicarbazide*.

(*b*) Finely powdered thiosemicarbazide (9·1 g.) and benzoyl chloride (14 g.) were mixed ice-cold and cautiously warmed. When the vigorous reaction subsided, the solid was broken up, boiled with alcohol (100 c.c.), filtered hot from a small amount of insoluble material, and allowed to crystallise. The solid which separated was crystallised several times from water, giving colourless leaflets (0·95 g.), m. p. 198° (decomp.) (Found : C, 49·7; H, 4·5. $C_8H_9ON_3S$ requires C, 49·3; H, 4·6%). The material insoluble in water crystallised from alcohol in colourless square plates (0·3 g.), m. p. 223°, identical with 2-amino-5-phenyl-1 : 3 : 4-thiadiazole (see later). A further quantity of 1-benzoylthiosemicarbazide was obtained by diluting the original alcoholic mother-liquor with light petroleum (b. p. 60—80°) and crystallising the precipitate several times from water, giving colourless leaflets (1·7 g.), m. p. 194—196° (decomp.) (Found : C, 49·1; H, 4·4%).

(*c*) Powdered thiosemicarbazide (9·1 g.) was suspended in dry pyridine (100 c.c.) cooled to −5°, and benzoyl chloride (14·0 g.) added dropwise below 0° (0·5 hour). After 12 hours' stirring during which room temperature was attained, water (500 c.c.) was added, the pyridine removed under reduced pressure, and the oily precipitate rubbed until hard, collected, and added to boiling water (300 c.c.). The liquid was filtered (charcoal) and allowed to cool, giving colourless leaflets (12·1 g.), m. p. 196—198° (decomp.). The oily material insoluble in water was crystallised twice from alcohol, giving flat needles (0·5 g.), m. p. 174° not depressed by admixture with 1 : 4-dibenzoylthiosemicarbazide prepared as described by Fehrenbach and Stolle (*J. pr. Chem.*, 1929, **122**, 289) (Found : C, 60·7; H, 4·4; N, 14·1. Calc. for $C_{15}H_{13}O_2N_3S$: C, 60·3; H, 4·3; N, 14·1%).

The following compounds were prepared in very good yield by method (*c*) from the corresponding thiosemicarbazides. 1-p-*Chlorobenzoylthiosemicarbazide* (II; R = *p*-ClC_6H_4) crystallised in colourless glistening needles, m. p. 218—220°, from aqueous alcohol (Found : C, 42·0; H, 3·2; S, 13·9. $C_8H_8ON_3ClS$ requires C, 41·8; H, 3·5; S, 13·9%); a residue insoluble in aqueous alcohol, crystallised from 2-ethoxyethanol, gave colourless leaflets of 1 : 2-di-*p*-chlorobenzoylhydrazine, m. p. 292° not depressed by admixture with a specimen prepared as described by Stolle (*Ber.*, 1912, **45**, 280) (Found : Cl, 22·5. Calc. for $C_{14}H_{10}O_2N_2Cl_2$: Cl, 22·9%). 1-p-*Methoxybenzoylthiosemicarbazide* (II; R = *p*-MeO·C_6H_4) crystallised in small regular prisms or needles, m. p. 236° (decomp.), from 2-ethoxyethanol (Found : C, 48·0; H, 4·7; N, 18·4. $C_9H_{11}O_2N_3S$ requires C, 48·0; H, 4·9; N, 18·7%). 1-p-*Nitrobenzoylthiosemicarbazide* (II; R = *p*-NO_2·C_6H_4) crystallised in colourless needles, m. p. 219° (decomp.), from *n*-propyl alcohol (Found : C, 40·0; H, 3·3; S, 13·3. $C_8H_8O_3N_4S$ requires C, 40·0; H, 3·3; S, 13·4%); on concentration of the mother-liquors from the initial crystallisation, a solid separated which on crystallisation from 2-ethoxyethanol gave yellow leaflets of 1 : 2-di-*p*-nitrobenzoylhydrazine, m. p. 289° not depressed by this compound as prepared by the method of Curtius and Trachmann (*J. pr. Chem.*, 1895, **51**, 178) (Found : C, 51·2; H, 3·0; N, 17·0. Calc. for $C_{14}H_{10}O_6N_4$: C, 50·9; H, 3·0; N, 17·0%). 1-Benzoyl-4-phenylthiosemicarbazide crystallised in fine colourless needles, m. p. 166°, from alcohol, identical with a specimen prepared as described by Marckwald and Bott (*loc. cit.*) (Found : C, 61·8; H, 5·0. Calc. for $C_{14}H_{13}ON_3S$: C, 62·0; H, 4·8%). 1-p-*Methoxybenzoyl*-4-*phenylthiosemicarbazide* crystallised from alcohol in colourless hair-like needles, m. p. 184°, from alcohol (Found : C, 60·1; H, 4·9. $C_{15}H_{15}O_2N_3S$ requires C, 59·8; H, 5·0%). 1-Benzoyl-4-methylthiosemicarbazide crystallised in colourless silky needles, m. p. 195°, from alcohol, identical with a specimen prepared as described by Young and Oates (*loc. cit.*) (Found : C, 51·3; H, 5·0. Calc. for $C_9H_{11}ON_3S$: C, 51·7; H, 5·3%). 1-*Benzoyl*-4-iso-*propylthiosemicarbazide* crystallised in colourless needles, m. p. 175°, from alcohol (Found : C, 55·5; H, 6·4; S, 13·5. $C_{11}H_{15}ON_3S$ requires C, 55·7; H, 6·3; S, 13·5%). 1-p-*Methoxybenzoyl*-4-*methylthiosemicarbazide* crystallised in colourless needles, m. p. 210°, from 2-ethoxyethanol (Found : C, 50·6; H, 5·3. $C_{10}H_{13}O_2N_3S$ requires C, 50·3; H, 5·4%). 1-*Benzoyl*-2 : 4-*dimethylthiosemicarbazide* crystallised in colourless needles, m. p. 193° (decomp.), from aqueous alcohol (Found : C, 53·8; H, 5·6; S, 14·3. $C_{10}H_{13}ON_3S$ requires C, 53·8; H, 5·8; S, 14·4%). 1-p-*Methoxybenzoyl*-2 : 4-*dimethylthiosemicarbazide* crystallised in felted colourless needles, m. p. 192° (decomp.), from alcohol (Found : C, 52·2; H, 6·1; S, 12·9. $C_{11}H_{15}O_2N_3S$ requires C, 52·2; H, 5·9; S, 12·7%). 1-*Benzoyl*-4 : 4-*dimethylthiosemicarbazide* crystallised in colourless needles, m. p. 170°, from alcohol (Found : C, 54·0; H, 5·9; S, 14·3. $C_{10}H_{13}ON_3S$ requires C, 53·8; H, 5·8; S, 14·4%). 1-p-*Methoxybenzoyl*-4 : 4-*dimethylthiosemicarbazide* crystallised in colourless needles, m. p. 167°, from alcohol (Found : C, 52·2; H, 6·0; S, 12·8. $C_{11}H_{15}O_2N_3S$ requires C, 52·2; H, 5·9; S, 12·7%).

2-*Amino*-5-*phenyl*-1 : 3 : 4-*thiadiazole* (I; R = Ph).—1-Benzoylthiosemicarbazide (2·0 g.) was added to syrupy phosphoric acid (10 c.c.) stirred in an oil-bath at 120° during 10 minutes, stirring was continued 30 minutes, and the acid solution cooled and diluted with ice and water to 100 c.c. (there was no insoluble material, indicating complete absence of the triazole-thiol). The precipitate formed by adding excess

of ammonia solution was crystallised from aqueous alcohol, giving colourless square plates (1·0 g.), m. p. 224°, identical with 2-amino-5-phenyl-1 : 3 : 4-thiadiazole prepared by oxidation of benzaldehyde thiosemicarbazone (Young and Eyre, *loc. cit.*) (Found : C, 53·9; H, 4·1. Calc. for $C_8H_7N_3S$: C, 54·1; H, 4·0%). An exactly similar result was obtained by using sulphuric acid (20·0 c.c.) and water (2·0 c.c.) in place of the phosphoric acid. This compound (0·9 g.) in boiling acetic acid (15·0 c.c.) was treated with " perhydrol " (5·0 c.c.), and boiling continued for 20 minutes. The precipitate formed on diluting the product with water and making it alkaline, was collected and crystallised from aqueous alcohol, giving unchanged thiadiazole (0·5 g.), m. p. 224° (Found : S, 18·1. Calc. for $C_8H_7N_3S$: S, 18·1%). The compound (1·8 g.) was also boiled in alcohol (25 c.c.) with Raney nickel catalyst (5·0 g.) for 6 hours and recovered unchanged (1·1 g.), m. p. 224° (Found : S, 18·6%).

2-*Amino*-5-p-*methoxyphenyl*-1 : 3 : 4-*thiadiazole* (I; R = *p*-MeO·C_6H_4).—(*a*) 1-*p*-Methoxybenzoylthiosemicarbazide (2·3 g.) was treated with phosphoric acid as described above. After dilution of the reaction liquid with water, the solid was collected and washed. This material was free from sulphur and crystallised from water in colourless needles (0·3 g.), m. p. 181° not depressed by admixture with *p*-methoxybenzoic acid. The acid filtrate was basified with ammonia, and the precipitate collected and crystallised from alcohol, giving colourless prisms of the *thiadiazole* (0·6 g.), m. p. 190° (Found : C, 52·4; H, 4·2. $C_9H_9ON_3S$ requires C, 52·2; H, 4·4%). (*b*) The same compound was obtained by oxidation of *p*-methoxybenzaldehyde thiosemicarbazone as described by Young and Eyre for the benzaldehyde compound; m. p. 190° (Found : C, 52·3; H, 4·4%).

2-*Amino*-5-p-*nitrophenyl*-1 : 3 : 4-*thiadiazole* (I; R = *p*-NO_2·C_6H_4).—This *compound* formed golden yellow prisms, m. p. 254°, from 2-ethoxyethanol (using either phosphoric or sulphuric acid) (Found : C, 43·1; H, 2·8. $C_8H_6O_2N_4S$ requires C, 43·1; H, 2·7%). The acid solution after dilution was neutralised with potassium hydrogen carbonate, as the product is unstable in the presence of strong alkali.

The following compounds were obtained, usually by the action of phosphoric acid on the corresponding benzoylthiosemicarbazides. 2-Methylamino-5-phenyl-1 : 3 : 4-thiadiazole crystallised in large colourless prisms, m. p. 183°, from alcohol (using either phosphoric or sulphuric acid) (Found : C, 56·4; H, 4·7. Calc. for $C_9H_9N_3S$: C, 56·5; H, 4·7%). Young and Eyre (*loc. cit.*) obtained this compound by oxidation of the corresponding thiosemicarbazone and give m. p. 183°. 2-*Methylamino*-5-p-*methoxyphenyl*-1 : 3 : 4-*thiadiazole* crystallised in colourless needles, m. p. 150°, from alcohol (*p*-methoxybenzoic acid also isolated) (Found : C, 54·3; H, 4·9. $C_{10}H_{11}ON_3S$ requires C, 54·3; H, 5·0%). 2-*Methylimino*-5-*phenyl*-3-*methyl*-2 : 3-*dihydro*-1 : 3 : 4-*thiadiazole* (VI; R = Ph, R′ = Me) was obtained as a colourless oil, b. p. 120—122°/1·0 mm., $n_D^{25°}$ 1·6340 (Found : C, 58·2; H, 5·7; S, 15·4. $C_{10}H_{11}N_3S$ requires C, 58·5; H, 5·4; S, 15·6%); the *picrate* crystallised from alcohol–2-ethoxyethanol in greenish-yellow hexagonal plates, m. p. 208° (Found : C, 44·0; H, 3·4; S, 7·7. $C_{10}H_{11}N_3S,C_6H_3O_7N_3$ requires C, 44·2; H, 3·2; S, 7·4%). 2-*Methylimino*-5-p-*methoxyphenyl*-3-*methyl*-2 : 3-*dihydro*-1 : 3 : 4-*thiadiazole* (VI; R = *p*-MeO·C_6H_4, R′ = Me) crystallised in colourless leaflets, m. p. 112°, from alcohol (Found : C, 56·0; H, 5·7. $C_{11}H_{13}ON_3S$ requires C, 56·2; H, 5·5%). 2-*Dimethylamino*-5-*phenyl*-1 : 3 : 4-*thiadiazole* crystallised in large colourless needles, m. p. 98°, from light petroleum (b. p. 60—80°) with a little benzene (Found : C, 58·5; H, 5·2; S, 15·2. $C_{10}H_{11}N_3S$ requires C, 58·5; H, 5·4; S, 15·6%).

2-*Dimethylamino*-5-p-*methoxyphenyl*-1 : 3 : 4-*thiadiazole*.—(*a*) This *compound*, obtained as above, crystallised in large pointed colourless needles, from alcohol, m. p. 124° (Found : C, 56·1; H, 5·4; N, 17·5. $C_{11}H_{13}ON_3S$ requires C, 56·2; H, 5·5; N, 17·9%).

(*b*) 4 : 4-Dimethylthiosemicarbazide (Jensen, *J. pr. Chem.*, 1941, **159**, 189) (11·9 g.) and *p*-methoxybenzaldehyde (13·6 g.) were heated gently in alcohol (50 c.c.) for 18 hours. The solid which separated was crystallised from alcohol, giving yellow leaflets of the *thiosemicarbazone* (8·6 g.), m. p. 130° (Found : C, 53·3; H, 6·4. $C_{11}H_{15}ON_3S$ requires C, 55·7; H, 6·3%). This compound was oxidised as described by Young and Eyre (*loc. cit.*), giving the same thiadiazole as in (*a*), m. p. 124° (Found : C, 55·9; H, 5·2%).

2-*Benzamido*-5-*phenyl*-1 : 3 : 4-*thiadiazole*.—1 : 4-Dibenzoylthiosemicarbazide (3·0 g.) and syrupy phosphoric acid (10 c.c.) gave this compound, which crystallised from 2-ethoxyethanol in silky needles (2·4 g.) m. p. 235° (Found : S, 11·3. Calc. for $C_{15}H_{11}ON_3S$: S, 11·4%). The compound was boiled with concentrated hydrochloric acid and 2-ethoxyethanol for 12 hours, giving 2-amino-5-phenyl-1 : 3 : 4-thiadiazole, which crystallised from aqueous alcohol in small rectangular plates, m. p. 224° not depressed by this compound as prepared above (Found : C, 54·1; H, 3·7%).

Dehydration of 1-*Benzoyl*-4-*phenylthiosemicarbazide*.—(*a*) The benzoyl compound (2·7 g.) was dehydrated in the usual way with phosphoric acid (10 c.c.), and after dilution with ice and water (250 c.c.) the mixture was made alkaline with concentrated sodium hydroxide solution. The solid was collected and crystallised from alcohol, giving long colourless needles (1·0 g.), m. p. 198°, of 2-phenylamino-5-phenyl-1 : 3 : 4-thiadiazole (Young and Eyre obtained this compound by oxidation of the corresponding thiosemicarbazone and gave m. p. 199°) (Found : C, 66·3; H, 4·4. Calc. for $C_{14}H_{11}N_3S$: C, 66·4; H, 4·3%). The original alkaline filtrate was acidified, and the precipitate crystallised from alcohol, giving long colourless needles of 3 : 4-diphenyl-4 : 1 : 2-triazole-5-thiol (0·5 g.), m. p. 282° (Marckwald and Bott give m. p. 187°; a misprint for 287°?) (Found : C, 66·4; H, 4·2; S, 13·1. Calc. for $C_{14}H_{11}N_3S$: C, 66·4; H, 4·3; S, 12·7%). When the above triazole (1·2 g.) was oxidised with " perhydrol " (5·0 c.c.) in boiling acetic acid (15 c.c.), 3 : 4-diphenyl-4 : 1 : 2-triazole was formed, which crystallised from light petroleum (b. p. 60—80°) in colourless needles (0·5 g.), m. p. 136° (Marckwald and Bott give m. p. 142°) (Found : C, 76·2; H, 5·0. Calc. for $C_{14}H_{11}N_3$: C, 76·0; H, 5·0%). When the thiadiazole (1·2 g.) was treated with " perhydrol " in the same way, unchanged starting material was recovered (0·75 g.), m. p. 198° (Found : S, 12·9%).

(*b*) The benzoyl compound (5·4 g.) and acetyl chloride (3·1 g.) were mixed ice-cold. A vigorous reaction took place, and after 5 minutes' warming on the water-bath, water (250 c.c.) was added. Concentrated sodium hydroxide solution was added to alkalinity, and the solid collected and crystallised from alcohol, giving the thiadiazole (2·2 g.), m. p. 200° (Found : S, 12·8. Calc. for $C_{14}H_{11}N_3S$: S, 12·7%). The alkaline filtrate was made acid with concentrated hydrochloric acid, and the triazole collected and crystallised from alcohol (0·25 g., m. p. 282°) (Found : S, 12·4%).

(*c*) When benzoyl chloride (5·6 g.) was used in place of acetyl chloride in (*b*) above, the thiadiazole

was isolated as previously (1·0 g.), m. p. 198° (Found : S, 13·1%). The precipitate obtained by acidifying the alkaline solution was stirred for 1 hour with 10% potassium hydrogen carbonate solution (to remove benzoic acid), and the insoluble triazole collected and crystallised from alcohol (1·6 g.), m. p. 284° (Found : S, 13·0%).

Dehydration of 1-*Benzoylthiosemicarbazide.*—(*a*) 1-Benzoylthiosemicarbazide (10·0 g.) and acetyl chloride (8·0 g.) were mixed ice-cold and cautiously heated under reflux. When the vigorous reaction subsided, heating was continued for 15 minutes, and water (200 c.c.) added, followed by 5N-sodium hydroxide solution until the mixture was strongly alkaline. The insoluble material was collected and crystallised from aqueous alcohol, giving colourless plates (1·8 g.), m. p. 224°, of 2-amino-5-phenyl-1 : 3 : 4-thiadiazole. The alkaline solution was precipitated with acid, and the 2-acetamido-5-phenyl-1 : 3 : 4-thiadiazole (7·5 g.), m. p. 278°, collected and boiled with water to extract any 3-phenyl-1 : 2 : 4-triazole-5-thiol. None of the latter compound was found, and the residue was crystallised from 2-ethoxyethanol, giving colourless needles (4·6 g.), m. p. 281—282° (Found : S, 14·6. Calc. for $C_{10}H_9ON_3S$: S, 14·6%). The constitution of this compound was established by hydrolysis. The acetamido-compound (1·0 g.), 2-ethoxyethanol (20 c.c.), and concentrated hydrochloric acid (5 c.c.), refluxed together for 18 hours, gave 2-amino-5-phenyl-1 : 3 : 4-thiadiazole (0·5 g.), m. p. 225° (Found : S, 18·3%).

(*b*) With benzoyl chloride (14·0 g.) in place of acetyl chloride in the above experiment, 2-benzamido-5-phenyl-1 : 3 : 4-thiadiazole (3·9 g.), m. p. 235° (Found : S, 11·3%), and 2-amino-5-phenyl-1 : 3 : 4-thiadiazole (3·2 g.), m. p. 225° (Found : S, 17·9%), were obtained. Benzoic acid (6·5 g.) was separated from the benzamido-compound with potassium hydrogen carbonate solution, but no 3-phenyl-1 : 2 : 4-triazole-5-thiol was found.

Dehydration of 1-*Benzoyl-4-methylthiosemicarbazide.*—(*a*) This compound (2·1 g.) and acetyl chloride (1·6 g.), on reaction together as in (*a*) above, gave 2-methylaminophenyl-1 : 3 : 4-thiadiazole (1·1 g.), m. p. 183° (Found : S, 16·8%). (*b*) The benzoyl compound (10·5 g.) and benzoyl chloride (14·0 g.) on reaction as in (*b*) above gave a mixture ; the portion soluble in N-sodium hydroxide gave 3-phenyl-4-methyl-4 : 1 : 2-triazole-5-thiol (0·55 g.), m. p. 166° not depressed by a specimen prepared as described by Young and Eyre (see below) (Found : S, 16·6. Calc. for $C_9H_9N_3S$: S, 16·8%), and benzoic acid (6·4 g.) separated by potassium hydrogen carbonate ; the residue insoluble in alkali was extracted with N-hydrochloric acid, leaving 2-*benzomethylamido-5-phenyl*-1 : 3 : 4-*thiadiazole*, which crystallised from alcohol in large colourless prisms (5·5 g.), m. p. 135° (Found : C, 65·1 ; H, 4·6 ; S, 11·0. $C_{16}H_{13}ON_3S$ requires C, 65·1 ; H, 4·4 ; S, 10·7%). (The constitution of this compound was confirmed by hydrolysis with acid to 2-methylamino-5-phenyl-1 : 3 : 4-thiadiazole, m. p. 182°, as described above for 2-acetamido-5-phenyl-1 : 3 : 4-thiadiazole.) The acid extract was made alkaline and gave 2-methylamino-5-phenyl-1 : 3 : 4-thiadiazole (1·4 g.), m. p. 182°. When the triazole (0·5 g.) was oxidised with " perhydrol " (2·5 c.c.) in acetic acid (5 c.c.), 3-phenyl-4-methyl-4 : 1 : 2-triazole was obtained, and crystallised from benzene in colourless needles (0·25 g.), m. p. 116° (Found : C, 68·2 ; H, 6·3. Calc. for $C_9H_9N_3$: C, 67·9 ; H, 5·7%). Under the same conditions the thiadiazole was recovered unchanged (0·4 g.), m. p. 183°.

3-*Phenyl*-1 : 2 : 4-*triazole-5-thiol* (III ; R = Ph).—1-Benzoylthiosemicarbazide (3·9 g.) was added to a solution of sodium (1·5 g.) in alcohol (50 c.c.) and the whole gently heated under reflux for 12 hours. After evaporation to dryness under reduced pressure, the residue was dissolved in water (100 c.c.), filtered (charcoal), and acidified with 10% acetic acid. The precipitate was collected, washed, and dried (3·4 g. ; m. p. 240—245°), and crystallised from water in colourless leaflets (2·8 g.), m. p. 256° not depressed by 3-phenyl-1 : 2 : 4-triazole-5-thiol prepared as described in Part I (Found : C, 54·4 ; H, 3·8 ; S, 18·2. Calc. for $C_8H_7N_3S$: C, 54·2 ; H, 4·0 ; S, 18·1%). The same result was obtained by using piperidine (2·5 c.c.) in place of sodium ethoxide, but longer reaction time was necessary with pyridine.

The following were prepared in analogous experiments : all had m. p.s not depressed by the compounds prepared as previously. 3-*p*-Methoxyphenyl-1 : 2 : 4-triazole-5-thiol (III ; R = *p*-MeO·C_6H_4) crystallised in stout needles from aqueous alcohol, m. p. 257° (Found : C, 52·1 ; H, 4·2 ; S, 15·4. Calc. for $C_9H_9ON_3S$: C, 52·2 ; H, 4·35 ; S, 15·5%). 3-*p*-Chlorophenyl-1 : 2 : 4-triazole-5-thiol (III ; R = *p*-C_6H_4Cl) crystallised as a microcrystalline powder from aqueous alcohol, m. p. 296—298° (Found : C, 45·6 ; H, 3·0 ; S, 14·9. Calc. for $C_8H_6N_3ClS$: C, 45·4 ; H, 2·8 ; S, 15·1%). 3-Phenyl-4-methyl-4 : 1 : 2-triazole-5-thiol (V ; R = Ph, R′ = Me) crystallised in flattened needles from alcohol, m. p. 166° (Found : C, 56·3 ; H, 4·6%). 3-*p*-Methoxyphenyl-4-methyl-4 : 1 : 2-triazole-5-thiol (V ; R = *p*-MeO·C_6H_4, R′ = Me) crystallised in long needles from aqueous alcohol, m. p. 176—178° (Found : C, 54·7 ; H, 4·9. $C_{10}H_{11}ON_3S$ requires C, 54·3 ; H, 5·0%). This compound was also obtained, m. p. 176°, by the method of Young and Eyre (*loc. cit.*) by heating 1-*p*-methoxybenzoyl-4-methylthiosemicarbazide at 200° (Found : C, 54·1 ; H, 4·7%). 3 : 4-Diphenyl-4 : 1 : 2-triazole-5-thiol (V ; R = R′ = Ph) crystallised in silky needles from alcohol, m. p. 282° (Found : S, 12·7%).

1 : 4-*Dibenzoylthiosemicarbazide.*—1-Benzoylthiosemicarbazide (3·9 g.) was stirred in pyridine (20 c.c.) and treated with benzoyl chloride (3·8 g.) below 0°. After 12 hours' standing, water (100 c.c.) was added, and the pyridine removed under reduced pressure. The precipitate was collected and ground with N-sodium hydroxide solution (50 c.c.), and the yellow sodium salt was collected, washed with a little water, and ground with N-hydrochloric acid until decolorised. The solid was collected, washed, and crystallised from alcohol, giving 1 : 4-dibenzoylthiosemicarbazide as colourless plates (0·65 g.) ; m. p. 176° (Found : S, 10·6. Calc. for $C_{15}H_{13}O_2N_3S$: S, 10·7%). The original alkaline solution was precipitated with acid, and the flocculent precipitate collected (free from sulphur) and crystallised from water containing a little alcohol, giving long felted needles (1·1 g.), m. p. 236° not depressed by 1 : 2-dibenzoylhydrazine as prepared by the method of Autenrieth and Spiess (*Ber.*, 1901, **34**, 187) (Found : C, 69·8 ; H, 4·6 ; N, 12·0. Calc. for $C_{14}H_{12}O_2N_2$: C, 70·0 ; H, 5·0 ; N, 11·7%).

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