299. *Cyclisation of Some Thiobenzamido-compounds.*

By Alexander Lawson and C. E. Searle.

N-Thiobenzoylsarcosine and *N*-ethyl-*N*-thiobenzoylglycine undergo ring closure in hot acid anhydrides, to give meso-ionic compounds (IV). Thiobenzamidoacetaldehyde diethyl acetal has been cyclised to the ethoxythiazoline (VI) and the thiazole (VII). Thiobenzoyl-semicarbazide and -thiosemicarbazide are cyclised to the hydroxy- (IX) or mercapto-thiadiazole (XII) or the aminothiadiazole (X), depending on the conditions.

In continuation of earlier work [1] on the preparation of α-thioacylamino-acids and their ring closure to thiazol-5-ones, preparation of some new α-thiobenzoyl-amino-acids was attempted by the Holmberg procedure.[2] Cystine reacted normally, though in poor yield, to give *NN'*-di(thiobenzoyl)cystine; the product obtained from ornithine on use of either one or two mols. of (thiobenzoylthio)acetic acid could not however be purified. Arginine gave no product, but with guanidine the reaction mixture, on treatment with bromine, gave a small yield of 3-amino-5-phenyl-1 : 2 : 4-thiadiazole, identical with the product obtained by Goerdeler and Fincke [3] using methyl thionbenzoate as acylating agent, indicating some thiobenzoylation of the guanidino-group. With sarcosine and *N*-ethylglycine, thiobenzoylation proceeded normally, though somewhat slowly in the latter case, but no thiobenzoyl derivative of *N*-phenyl-, *N*-*p*-hydroxyphenyl- or *N*-*o*-carboxyphenylglycine could be isolated.

When thiobenzoylsarcosine (I; R = Me) was heated with acetic anhydride a neutral substance $C_{12}H_{11}O_2NS$ was isolated in 70% yield. Homologous substances were formed from thiobenzoylsarcosine with propionic anhydride, and from *N*-ethyl-*N*-thiobenzoylglycine with acetic anhydride. The compound $C_{12}H_{11}O_2NS$, on hydrolysis with hydrochloric acid, gave sarcosine hydrochloride, hydrogen sulphide, and acetic and benzoic acids, indicating that no group migration had occurred in its formation. The analytical results, and the ready solubility in organic solvents, showed that the compound was not a thiazolium acetate analogous to the type suggested by O'Brien and Niemann [4] to account for the high van't Hoff *i* factor given by benzoylsarcosine in concentrated sulphuric acid. The substance, which is under further investigation, gave a phenylhydrazone and an unstable dinitrophenylhydrazone. It has therefore been designated as ψ-4-acetyl-3-methyl-2-phenylthiazol-5-one (IV; R = R' = Me) and doubtless belongs to the mesoionic class of compounds of which the sydnones [5,6] and anhydro-pyridine- and -quinoline-2-thiolacetic acids [7] are examples. The compound probably arises as a result of the reaction sequence (I)—(IV) in which ring closure of the mixed anhydride (II) is followed by *C*-acylation as in the Dakin and West reaction,[8] but in this case without the decarboxylation that normally takes place with an oxazolone. Such acylation is comparable to the *C*-halogenation of sydnones.[6] It is possible that in the decarboxylative acylation of *N*-alkylated amino-acids such as sarcosine an unstable mesoionic ψ-oxazolone intermediate is involved rather than the oxazolonium cation suggested by Cornforth and Elliot.[9]

Through the kindness of Dr. S. A. Barker and Dr. D. H. Whiffen of the Chemistry

[1] Jepson, Lawson, and Lawton, *J.*, 1955, 1791.
[2] Holmberg, Svedberg Anniversary Vol., Uppsala, 1944, p. 299.
[3] Goerdeler and Fincke, *Chem. Ber.*, 1956, **89**, 1033.
[4] O'Brien and Niemann, *J. Amer. Chem. Soc.*, 1950, **72**, 5348.
[5] Earl and Mackney, *J.*, 1935, 899.
[6] Baker, Ollis, and Poole, *J.*, 1950, 1542.
[7] Duffin and Kendall, *J.*, 1951, 734.
[8] Dakin and West, *J. Biol. Chem.*, 1928, **78**, 91.
[9] Cornforth and Elliot, *Science*, 1950, **112**, 534.

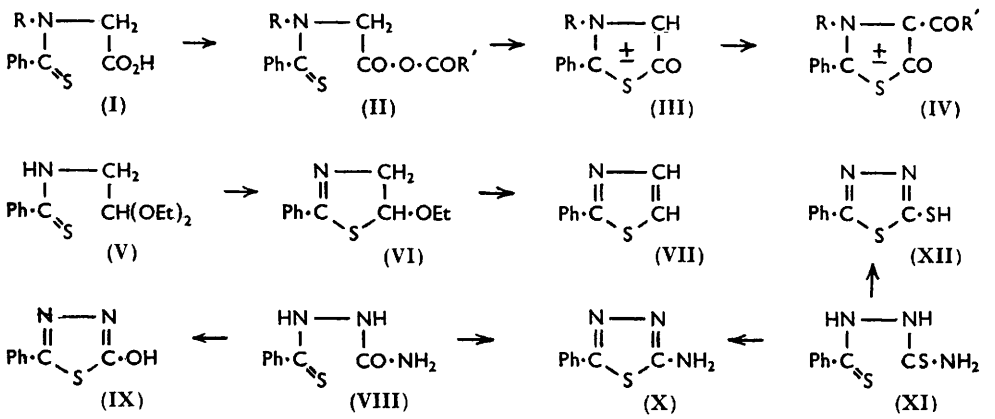
Department, University of Birmingham, the infrared spectrum of ψ-4-acetyl-3-methyl-2-phenylthiazole-5-one (IV; R = R′ = Me) has been examined. The highly conjugated nature of the carbonyl group in position 4, suspected because of the difficulty of preparing the usual ketonic derivatives, is confirmed by the large displacement of the carbonyl absorption from 1725—1705 cm.$^{-1}$ in saturated aliphatic ketones to 1644 cm.$^{-1}$ in this substance.

Attempts to open the ring in the compound (IV; R = R′ = Me) resulted in gross decomposition. Though resistant to catalytic hydrogenation at atmospheric pressure and unaffected by ammonia in dioxan at 100° (in contrast to thiazolones), the substance reacted with benzylamine and aniline with loss of the sulphur to give unidentified crystalline products.

2-Thiobenzamidoethanol and 3-thiobenzamidopropanol, prepared from the amino-alcohols, were readily dehydrated to 2-phenylthiazoline and 5 : 6-dihydro-2-phenyl-1 : 3-thiazine.

Thiobenzamidoacetaldehyde diethyl acetal (V), prepared readily from aminoacetal, lost one mol. of ethanol under mild dehydrative conditions, giving 5-ethoxy-2-phenylthiazoline (VI), and a second mol. under more vigorous conditions, giving 2-phenylthiazole (VII).

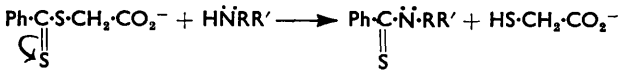
1-Thiobenzoylsemicarbazide (VIII), when heated alone or with hot concentrated hydrochloric or polyphosphoric acid, gave 2-hydroxy-5-phenyl-1 : 3 : 4-thiadiazole (IX) by elimination of ammonia; with acetic anhydride the corresponding acetyl derivative was obtained; with acetyl chloride, on the other hand, cyclisation took place with loss of water to give 2-amino-5-phenyl-1 : 3 : 4-thiadiazole (X), prepared by Young and Eyre [10] by oxidation of benzylidenethiosemicarbazone with ferric chloride. Cyclisation of 1-thiobenzoylthiosemicarbazide (XI) likewise could proceed by alternative routes: loss of hydrogen sulphide to give (X) or loss of ammonia to give 2-mercapto-5-phenyl-1 : 3 : 4-thiadiazole (XII).



Rates of reaction of (thiobenzoylthio)acetic acid with different amino-compounds vary greatly. In the absence of steric hindrance of the approach of the amino-nitrogen atom to the thion-carbon atom of the (thiobenzoylthio)acetic acid, the ease of reaction depends largely on the electronegativity of the amino-nitrogen atom. However, reaction occurred very slowly or not at all with 2-amino-2-methylpropanol and 2-amino-2-methylpropane-1 : 3-diol in which the amino-group is attached to a quaternary carbon atom, and this is attributed to steric factors, which prevent close approach of the reacting groups. Similar considerations presumably apply in the case of α-amino*iso*butyric acid, which was found by Jepson *et al.*[1] to be very resistant to thiobenzoylation. Thiobenzoylation occurred

[10] Young and Eyre, *J.*, 1901, 54.

rapidly with two amino-alcohols (2-aminoethanol and 3-aminopropanol) in which those steric relations do not occur.



Owing to the exceptional rapidity with which it is thiobenzoylated morpholine may be used to test for the presence of unchanged (thiobenzoylthio)acetic acid in a reaction mixture, or to remove it before liberation of a thiobenzamido-acid by acidification.

When thiobenzoylation is slow it is accompanied by side reactions which result in small yields. In such cases some benzaldehyde was usually observed as a by-product, and the mixture remained dark. Hydrogen sulphide was sometimes evolved. It is possible that thiobenzoylation with methyl thionbenzoate,[1] although slower and less convenient, would be more satisfactory with the less reactive amino-compounds.

The action of silver nitrate on new thiobenzoyl derivatives in aqueous alcohol was examined. Silver sulphide was usually formed rapidly in the cold when the group ·CS·NH· was present, although thiobenzoyl-cystine, -semicarbazide, and -thiosemicarbazide did not react appreciably until the mixture was heated. The presence of hydrogen on the nitrogen atom adjacent to the thion group is not essential, however, since thiobenzoyl-sarcosine reacted readily in the cold. Thiobenzoyl-piperidine and -morpholine reacted only slowly at 100°, which may indicate initial hydrolysis.

Experimental

Thiobenzoylation of Amino-acids.—(Thiobenzoylthio)acetic acid, m. p. 125—126°, was prepared by Crawhall and Elliot's method [11] in yields up to 53%. The alkaline solution obtained after addition of sodium chloroacetate and refluxing usually gave a crystalline product when acidified at 0° with hydrochloric acid, and extraction from a benzene solution into alkali was thus avoided. On the larger scale used in the present work crystallisation from chloroform–light petroleum (b. p. 100—120°) rather than from benzene–light petroleum was preferred.

Thiobenzoylation was carried out by the Holmberg procedure.[2] Of the amino-acids whose thiobenzoylation had not been already reported, only sarcosine gave a good yield of its thiobenzoyl derivative. Cystine reacted slowly with (thiobenzoylthio)acetic acid, a little hydrogen sulphide being evolved. After 3 weeks the pale red solution was neutralised with hydrochloric acid, yielding a dark oil which was extracted with ether. Crystallisation from benzene–light petroleum of the oil after removal of the ether gave needles of NN'-*dithiobenzoylcystine*, m. p. 117—118° (Found: C, 58·0; H, 4·5. $C_{20}H_{20}O_4N_2S_2$ requires C, 57·7; H, 4·8%). With aqueous-ethanolic silver nitrate, silver sulphide was formed on warming only.

Thiobenzoylation of arginine was very slow. A marked smell of benzaldehyde was observed and a positive test was obtained with 2 : 4-dinitrophenylhydrazine. No solid product was isolated on acidification or after treatment with acetic anhydride at 100°. With an excess of guanidine hydrochloride reaction was also slow. Treatment of the red supernatant solution with bromine gave a little 3-amino-5-phenyl-1 : 2 : 4-thiadiazole, m. p. 132—134°, alone or mixed with a specimen prepared by Dr. F. Kurzer from guanidine and methyl thionbenzoate by Goerdeler and Fincke's method.[3]

Thiobenzoylsarcosine.—A solution containing (thiobenzoylthio)acetic acid (2·1 g., 1 mol.), sarcosine (1·0 g., 1·1 mol.), and sodium hydroxide (0·8 g., 2 mol.) in 25 ml. of water was set aside at room temperature for 4 days. The light red cloudy solution, smelling of benzaldehyde, was filtered, chilled, and acidified with hydrochloric acid. The crude oil soon solidified. Its solution in chloroform was washed with water and evaporated to small bulk. Addition of light petroleum gave *thiobenzoylsarcosine* (1·46 g., 70%), pale yellow tablets (from ethyl acetate–light petroleum), m. p. 152—153° (decomp.) when inserted at 130° (Found: C, 57·8; H, 5·2; N, 6·7. $C_{10}H_{11}O_2NS$ requires C, 57·4; H, 5·3; N, 6·7%).

N-*Ethyl*-N-*thiobenzoylglycine.*—Thiobenzoylation of *N*-ethylglycine occurred much less readily than with sarcosine. After 5 days, the solution, which was still dark red but gave no

[11] Crawhall and Elliot, *J.*, 1951, 2071.

product with morpholine, was filtered, chilled, and acidified. The resultant oil was extracted with chloroform, washed with water, dried, and evaporated. The residue gave N-*ethyl*-N-*thiobenzoylglycine*, thick blades (26%), m. p. 136—137°, from ethyl acetate–light petroleum (Found: C, 59·5; H, 5·9. $C_{11}H_{13}O_2NS$ requires C, 59·2; H, 5·8%). With *N*-*p*-hydroxyphenylglycine only a gum was obtained.

Reaction of Thiobenzoylsarcosine and N-*Ethyl*-N-*thiobenzoylglycine with Acid Anhydrides.*—Thiobenzoylsarcosine (1·0 g.) was warmed on the steam-bath with acetic anhydride (15 c.c.), rapidly darkening. After 1 hr. the excess of anhydride was removed under reduced pressure, then xylene was twice added and removed similarly. The dark residue of *ψ*-4-*acetyl*-3-*methyl*-2-*phenylthiazol*-5-*one* (77%) crystallised from aqueous ethanol (charcoal), then from chloroform or ethyl acetate–light petroleum as a light yellow solid, m. p. 134—135° [Found: C, 61·6; H, 4·8; N, 5·9; S, 14·1%; *M* (Rast), 232. $C_{12}H_{11}O_2NS$ requires C, 61·7; H, 4·7; N, 6·0; S, 13·7%; *M*, 233] $\lambda_{max.}$ 2440, 2800, 3570 Å (ε 10,240, 9900, 11,020) in EtOH.

If the temperature was raised to 140° and air replaced by nitrogen, the same product was obtained in 69% yield. In the presence of 3-methylpyridine (10 ml.) some carbon dioxide was evolved but only the above compound (22%) was isolated.

A homologous substance was obtained by treating thiobenzoylsarcosine similarly with propionic anhydride. The mass remaining after removal of the anhydride was extracted several times with light petroleum (b. p. 80—100°). *ψ*-4-*Propionyl*-3-*methyl*-2-*phenylthiazol*-5-*one*, yellow needles, had m. p. 109—110° (61%) (Found: C, 63·0; H, 5·05. $C_{13}H_{13}O_2NS$ requires C, 63·2; H, 5·25%).

When *N*-ethyl-*N*-thiobenzoylglycine in acetic anhydride was heated at 100° the mixture darkened slowly. The *ψ*-4-*acetyl*-3-*ethyl*-2-*phenylthiazol*-5-*one*, isolated as above, crystallised from aqueous ethanol as pale yellow prismatic needles, m. p. 104—105° (Found: C, 63·0; H, 5·2. $C_{13}H_{13}O_2NS$ requires C, 63·2; H, 5·25%).

Reactions of ψ-4-Acetyl-3-methyl-2-phenylthiazolone.—The compound dissolved readily in ethyl acetate and chloroform, and sparingly in ether and light petroleum. It was insoluble in cold dilute acids and bases. The *phenylhydrazone*, prepared in aqueous acetic acid, had m. p. 218° (prismatic needles from ethanol) (Found: C, 66·5; H, 5·2. $C_{18}H_{17}ON_3S$ requires C, 66·8; H, 5·3%). A sparingly soluble 2:4-dinitrophenylhydrazone, prepared in ethanol containing a drop of sulphuric acid, decomposed on recrystallisation.

(a) *With bases.* Attempts to remove the acetyl group by alkaline hydrolysis gave no isolable product. The compound was recovered unchanged after being heated with ammonia in dioxan at 100° (cf. thiazolones [1]).

When the substance (0·5 g.) was heated with benzylamine (2 ml.) the mixture became dark green at about 90° and evolved hydrogen sulphide and a garlic-like odour. After 0·5 hr. at 130° the whole was poured into iced water. The sticky solid gave, from ethyl acetate–light petroleum, an unidentified sulphur-free *substance* (0·23 g.) as colourless needles, m. p. 168—169° (Found: C, 74·9; H, 6·5; N, 11·4. $C_{15}H_{16}ON_2$ requires C, 75·0; H, 6·7; N, 11·7%). The acetyl group was removed during the reaction, since the 4-propionyl analogue gave the same substance.

A similar yield was obtained by refluxing the reactants in water until no more hydrogen sulphide was evolved (6 hr.); but carrying out the reaction in boiling xylene under nitrogen gave a less easily purified product.

With aniline, hydrogen sulphide was not evolved until 130—140°, the solution becoming green at 150—160°. After 1 hr. at 160—170° the mixture was poured into dilute hydrochloric acid, the resulting sticky solid being washed and dried in chloroform. The *product* crystallised as stout needles, m. p. 250—252° (decomp.), from ethyl acetate–light petroleum. Analysis agreed with the simple replacement of S by N·C_6H_5 (38%) (Found: C, 74·1; H, 5·4. $C_{18}H_{16}O_2N_2$ requires C, 74·0; H, 5·5%). Refluxing in xylene for 2·5 hr. under nitrogen gave the same compound (59%). This substance was more basic than that obtained from benzylamine. Treatment of a chilled solution in dilute hydrochloric acid with sodium nitrite caused separation of another substance as needles, m. p. 194—195°, from aqueous methanol or ethyl acetate–light petroleum (Found: C, 68·6; H, 4·6%).

(b) *With acid.* Warming the thiazolone gently in concentrated hydrochloric acid gave a pale yellow solution, which after 3 hr. at 100° yielded benzoic acid. Evaporation of the filtrate under reduced pressure gave sarcosine hydrochloride, m. p. (after precipitation with dry ether from absolute ethanol) 166—169°, mixed m. p. 166—170°.

Thiobenzamido-alcohols and -acetals and Their Cyclisation.—2-Thiobenzamidoethanol, formed rapidly in 81% yield on addition of a slight excess of 2-aminoethanol to aqueous sodium (thiobenzoylthio)acetate at room temperature, had m. p. 93—94° (from chloroform–light petroleum) (Goldberg and Kelly [12] give m. p. 96°) (Found: C, 59·7; H, 6·1. Calc. for $C_9H_{11}ONS$: C, 59·8; H, 6·1%).

Ring-closure to 2-phenylthiazoline occurred readily. The picrate, tablets from ethyl acetate, had m. p. 172—173·5° (Gabriel and Leupold [13] gave m. p. 173—174°) (Found: C, 45·7; H, 3·2. Calc. for $C_{15}H_{12}O_7N_4S$: C, 45·9; H, 3·1%). Cyclisation was carried out by gently warming the compound with phosphoric oxide (yield 75%), heating it with polyphosphoric acid on the steam-bath for 1 hr. (67%), or storage overnight in cold concentrated hydrochloric acid (77%), the mixture in each case being added to excess of water and extracted with ether after basification.

Attempted dehydration of 2-thiobenzamidoethanol by acetic anhydride at 100° gave *2-thiobenzamidoethyl acetate* as a red oil which from ether–light petroleum gave light yellow prismatic rods, m. p. 67—68° (65%) (Found: C, 59·2; H, 5·8. $C_{11}H_{13}O_2NS$ requires C, 59·3; H, 6·0%). The *benzoate* (53%) was obtained by using benzoyl chloride in 3-methylpyridine at 0° and had m. p. 125—126° (from chloroform–light petroleum) (Found: C, 67·4; H, 5·3. $C_{16}H_{15}O_2NS$ requires C, 66·9; H, 5·3%).

3-Aminopropanol was thiobenzoylated less readily than 2-aminoethanol. The red oil which separated was, after 18 hr., dissolved in ether, washed, and dried. Evaporation to small bulk and addition of light petroleum gave *3-thiobenzamidopropanol*, pale yellow leaflets, m. p. 69—70·5° (79%) (Found: C, 61·7; H, 6·7. $C_{10}H_{13}ONS$ requires C, 61·5; H, 6·7%). Its solution in cold concentrated hydrochloric acid, on being kept overnight, diluted, and treated with excess of sodium carbonate, gave 5 : 6-dihydro-2-phenyl-1 : 3-thiazine as an oil. This gave a *picrate*, m. p. 183—185°, from ethanol (Found: C, 47·4; H, 3·4. $C_{16}H_{14}O_7N_4S$ requires C, 47·3; H, 3·45%). The mercuric chloride complex had m. p. 141—143° (Pinkus [14] gave m. p. 140—142°).

Thiobenzoyl derivatives of 2-amino-2-methylpropanol and 2-amino-2-methylpropane-1 : 3-diol could not be prepared by the Holmberg procedure, even by using a considerable excess of the amino-alcohols. The benzaldehyde-like odour always observed in such experiments was in the former case shown to be due to benzaldehyde, identified as the semicarbazone.

On addition of a slight excess of aminoacetaldehyde diethyl acetal to aqueous sodium (thiobenzoylthio)acetate with stirring, *thiobenzamidoacetaldehyde diethyl acetal* (89%) rapidly separated; it had m. p. 69—70° (from ethyl acetate–light petroleum) (Found: C, 61·4; H, 7·65. $C_{13}H_{19}O_2NS$ requires C, 61·7; H, 7·5%). Warming with concentrated hydrochloric acid yielded 5-ethoxy-2-phenylthiazoline as an oil, giving the *picrate*, m. p. 163—164°, from ethanol (95%) (Found: C, 46·5; H, 3·6. $C_{17}H_{16}O_8N_4S$ requires C, 46·8; H, 3·6%). The same base was obtained by ring-closure with polyphosphoric acid at 100° (54%). Ring-closure with polyphosphoric acid at 180° or with hot phosphoric oxide however gave 2-phenylthiazole, also isolated as the picrate, m. p. 123—124° from aqueous ethanol (Hubacher [15] gave m. p. 124—125°). The lower yields (50% and 27% respectively) were probably caused by the high solubility of the picrate in ethanol.

No thiobenzoyl derivative of methylaminoacetaldehyde diethyl acetal could be isolated.

Thiobenzoylsemicarbazides and Their Cyclisation.—Semicarbazide was thiobenzoylated in the usual way, a slight excess of semicarbazide hydrochloride being used. In the presence of only 2 mols. of sodium hydroxide, the product, which was soluble in excess of alkali, separated from the reaction mixture. After 6 hr. at room temperature *1-thiobenzoylsemicarbazide* (68%) was crystallised from ethyl acetate–light petroleum as light yellow leaflets, m. p. 158—159° (Found: C, 49·0; H, 4·6. $C_8H_9ON_3S$ requires C, 49·2; H, 4·6%).

In refluxing concentrated hydrochloric acid 1-thiobenzoylsemicarbazide was quickly converted into *2-hydroxy-5-phenyl-1 : 3 : 4-thiadiazole*, m. p. 146—148° (from ethanol) (64%) (Found: C, 53·9; H, 3·4; N, 15·6. $C_8H_6ON_2S$ requires C, 53·9; H, 3·4; N, 15·7%). The thiadiazole, which was soluble in sodium carbonate, was also obtained by using polyphosphoric acid at 140° (88%) or heating thiobenzoylsemicarbazide alone at 190° (83%).

[12] Goldberg and Kelly, *J.*, 1948, 1919.
[13] Gabriel and Leupold, *Ber.*, 1898, **31**, 2833.
[14] Pinkus, *Ber.*, 1893, **26**, 1077.
[15] Hubacher, *Annalen*, 1890, **259**, 228.

Treatment of thiobenzoylsemicarbazide with acetic anhydride at 100° for 2 hr., followed by dilution with acetone and pouring on ice, gave *2-acetoxy-5-phenyl-1 : 3 : 4-thiadiazole* (75%), m. p. 117—119° (from aqueous ethanol) (Found : C, 54·2; H, 3·5; N, 12·6. $C_{10}H_8O_2N_2S$ requires C, 54·5; H, 3·6; N, 12·7%). The same compound was produced by the action of acetyl chloride on the semicarbazide in 3-methylpyridine, but in the absence of a base acetyl chloride at room temperature gave 2-amino-5-phenyl-1 : 3 : 4-thiadiazole, m. p. 224—225° (oil-bath), 240—241° (block) (from chloroform–light petroleum) (Young and Eyre [10] gave m. p. 222—223°). Mixed with a specimen prepared by their procedure it had m. p. 224—226° (Found : C, 54·0; H, 4·1. Calc. for $C_8H_7N_3S$: C, 54·2; H, 3·95%). When the acetyl chloride mixture was poured on ice a strong smell of benzoyl chloride was observed.

1-*Thiobenzoylthiosemicarbazide* was prepared in the usual way. The bright yellow solid (69%), which was too unstable to be purified by crystallisation or by dissolution in sodium hydrogen carbonate solution, was freed from traces of unchanged (thiobenzoylthio)acetic acid by washing with cold ether (Found : C, 45·8; H, 4·75; N, 20·3. $C_8H_9N_3S_2$ requires C, 45·7; H, 4·3; N, 19·9%). At 125—128° it became colourless with the elimination of hydrogen sulphide, the m. p. recorded being that of the resulting 2-amino-5-phenyl-1 : 3 : 4-thiadiazole (above), which was most conveniently formed by boiling thiobenzoylthiosemicarbazide with water until no more hydrogen sulphide was evolved (63%). It formed a very sparingly soluble *picrate*, felted needles (from aqueous acetone), m. p. 268—271° (decomp.) (block) (Found : C, 41·0; H, 2·5. $C_{14}H_{10}O_7N_6S$ requires C, 41·4; H, 2·5%).

Treating 1-thiobenzoylthiosemicarbazide with cold concentrated hydrochloric acid gave at once a quantitative yield of *2-mercapto-5-phenyl-1 : 3 : 4-thiadiazole*, pale yellow crystals (from aqueous ethanol), m. p. 224—225·5° (block) (Found : C, 49·7; H, 3·3; N, 14·6. $C_8H_6N_2S_2$ requires C, 49·5; H, 3·1; N, 14·4%). This was soluble in aqueous sodium hydroxide and gave a yellow colour with sodium nitroprusside, gave no precipitate with mercuric chloride, and with silver nitrate gave a slight precipitate of a silver salt but no silver sulphide on warming.

Refluxing the thiol with benzyl chloride and sodium hydrogen carbonate in 70% aqueous ethanol for 4 hr. afforded *2-benzylthio-5-phenyl-1 : 3 : 4-thiadiazole*, needles (from aqueous ethanol), m. p. 108—109° (91%) (Found : C, 63·4; H, 4·2. $C_{15}H_{12}N_2S_2$ requires C, 63·4; H, 4·2%).

Thiobenzoylation of Secondary Amines.—Addition of morpholine in slight excess to aqueous sodium (thiobenzoylthio)acetate caused almost instantaneous decolorisation of the solution and precipitation of solid thiobenzoylmorpholine (91%), needles (from aqueous ethanol), m. p. 137—138° (McMillan and King [16] gave m. p. 137—138·5°) (Found : C, 64·1; H, 6·4. Calc. for $C_{11}H_{13}ONS$: C, 63·8; H, 6·3%). The compound was also formed rapidly on addition of morpholine to (thiobenzoylthio)acetic acid in hot water or dissolution of (thiobenzoylthio)-acetic acid in morpholine.

When twice the theoretical amount of piperidine was added to aqueous sodium (thiobenzoylthio)acetate decolorisation soon occurred with the separation of thiobenzoylpiperidine as an oil which later crystallised. The product had m. p. 61—62° after crystallisation from warm ethanol, then ether–light petroleum (Bergmann [17] gave m. p. 63—64°) (Found : C, 70·2; H, 7·2. Calc. for $C_{12}H_{15}NS$: C, 70·25; H, 7·3%).

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8, Hunter Street, London, W.C.1. [*Received, September 28th*, 1956.]

[16] McMillan and King, *J. Amer. Chem. Soc.*, 1948, **70**, 4143.
[17] Bergmann, *Ber.*, 1920, **53**, 979.