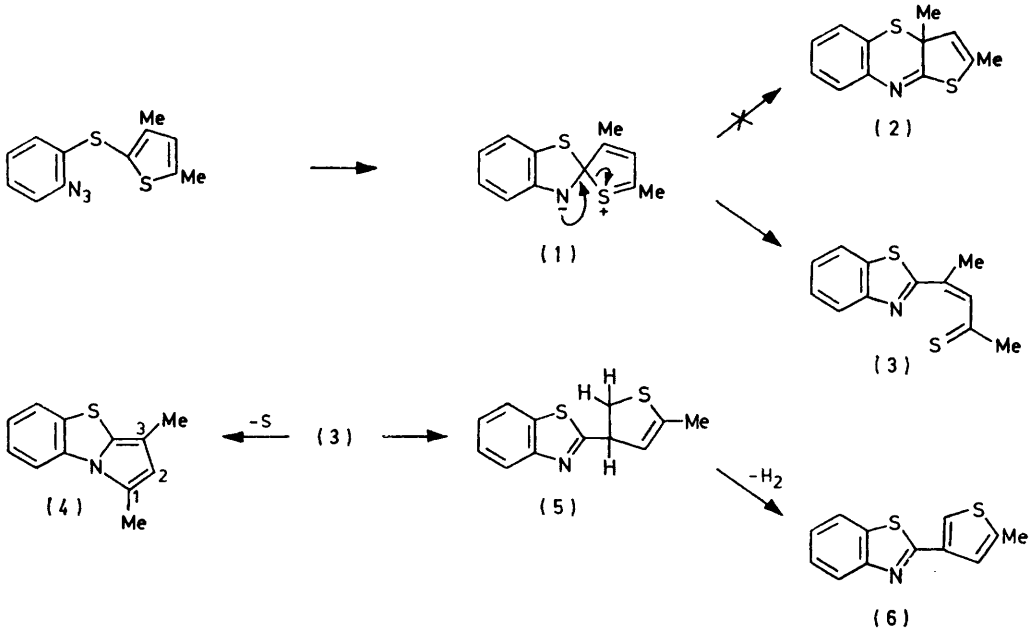
Competitive Cyclisation of Singlet and Triplet Nitrenes. Part 7.[1] Reaction Pathways of 2-Azidophenyl Benzothienyl Azides

By **David G. Hawkins, Otto Meth-Cohn,* and Hans Suschitzky,** The Ramage Laboratories, Department of Chemistry and Applied Chemistry, University of Salford, Salford M5 4WT

The thermal decomposition of 2-azidophenyl 2-(3-methylbenzo[*b*]thienyl) sulphide (7b) and 2-azidophenyl 3-(2-methylbenzo[*b*]thienyl) sulphide (8) proceeds efficiently by way of a spiro-benzothiazoline (9) or (10) giving benzothiopheno-benzothiazines (11) and (16) in both cases. From the former azide were also isolated two 2-benzothiophenylbenzothiazoles (12) and (13). The reactions do not proceed well in the absence of methyl substituents. 2-Azidophenyl 3-(2,5-dimethylthienyl) sulphide (19) surprisingly gave 2-methylbenzothiazole on thermolysis. These various reaction pathways have been rationalised by comparison with those of the related thienyl sulphides.

THE formation of phenothiazine from 2-azidophenyl phenyl sulphides has been thoroughly investigated.[2] The reaction was shown to involve initial formation of a spiro-intermediate by attack of a nitrene (singlet or triplet [3]) at the *ipso* position followed by *S*-rearrangement. In part 6 of this series [1] we demonstrated that while an analogous initial mode of nitrene attack was observed when 2-azidophenyl thienyl sulphides were decomposed, the spiro-intermediate (1) rearranged quite differently (*e.g.* Scheme 1), no phenothiazine-type product (2) being formed. Ready stabilisation was achieved instead, by ring-opening of (1) to give the benzothiazole thioketone (3). This reactive system was further stabilised by cyclisation at nitrogen with subsequent loss of sulphur [giving the pyrrolobenzothiazole (4)] or by ring-closure at a methyl group with subsequent loss of hydrogen [yielding the 2-thienylbenzothiazole (6)].



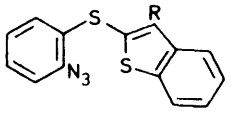
SCHEME 1

We now report the thermolysis of the corresponding 2-azidophenyl benzothienyl sulphides (7) and (8). Fusion of the benzene ring might be expected to markedly change the reactivity of the corresponding spiro-intermediates (9) and (10), since in the first case benzothiazole formation would be at the expense of aromaticity in the benzothienyl benzenoid ring and in the second case would involve an unlikely C–C bond breakage.

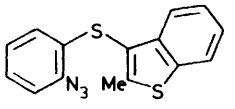
The thermolyses were best effected in hot bromobenzene or *o*-dichlorobenzene under nitrogen. The remarkable thermal stability of the azides in this series [*e.g.* some azide (7a and 8) was recovered after 4 h at 180 °C] speaks against the possibility of concerted addition of the azide moiety to the benzothienyl double bond, and in favour of a nitrene-mediated pathway. While the parent 2-benzothienyl azide (7a) decomposed yielding a deep green solution, the 3-methyl derivative (7b) and its isomer (8) reacted extremely cleanly, evidencing the ready formation of the spiro-intermediates (9) and (10).

Decomposition of 2-(2-*Azidophenyl*) 3-*Methylbenzo*[b]-*thienyl Sulphide* (7b).—The pale straw-coloured reaction

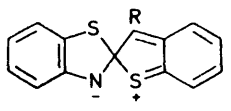
mixture from thermolysis in bromobenzene or *o*-dichlorobenzene gave four products in high overall yield. The first product (41%) was obtained as a yellow oil which showed no prominent absorptions in its i.r. spectrum but had a high-field methyl singlet (δ, 1.45,



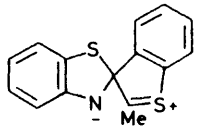
(7) a ; R = H
b ; R = Me



(8)

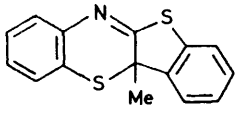


(9)



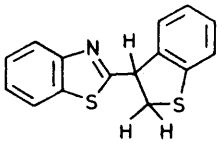
(10)

shifted by 1.00 p.p.m. compared to the starting azide) and signals due to eight shielded aromatic protons in its n.m.r. spectrum, indicating that the methyl group was attached to sp^3 rather than sp^2 carbon. Its mass spectrum confirmed the empirical formula $C_{15}H_{11}NS_2$ and showed prominent losses of H, SH, and methyl followed by sulphur from the molecular ion. Taken together these data support the benzothienobenzothiazine structure (11), a benzologue of (2) and the product expected by analogy with the 2-azidodiphenyl sulphide thermolyses.

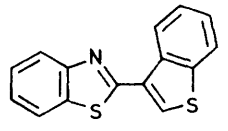


(11)

The second product (42%), another yellow oil, again showed no significant infrared absorptions but lacked a methyl resonance in its n.m.r. spectrum. Instead an aliphatic ABX system was evident. The ultraviolet spectrum was characteristic of a benzothiazole chromophore while the mass spectrum indicated an isomer of the first product but which fragmented significantly by breaking in half giving an ion of *m/e* 135 due to a benzothiazolium cation. The assignment of the structure as 2-(2,3-dihydrobenzothien-3-yl)benzothiazole (12) was



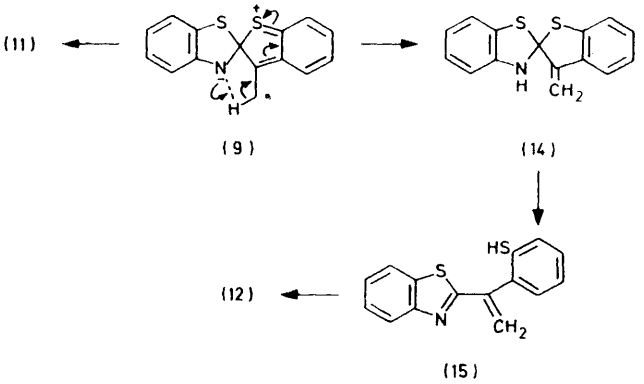
(12)



(13)

further supported by its dehydrogenation to the benzothiophen (13) with triphenylmethyl perchlorate. This benzothiophen was unambiguously synthesised by the condensation of *o*-aminothiophenol with benzothiophen-3-carboxylic acid in polyphosphoric acid. Indeed, the third product (5%) proved to be the benzothiophen (13), the fourth being a small amount of the amine (10%) corresponding to the starting azide (7b).

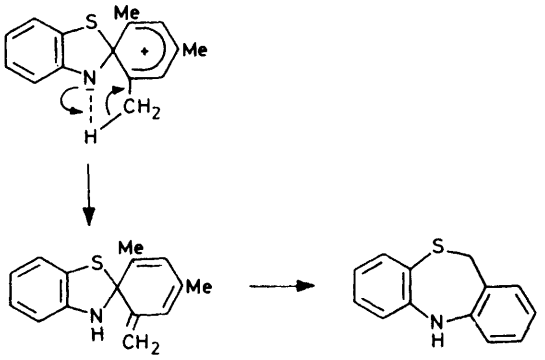
Surprisingly the spiro-intermediate (9) still shows a considerable tendency to react by benzothiazole formation and C–S (thienyl) bond-breakage, despite the apparent higher energy barrier to this pathway compared to the phenothiazine-type rearrangement route leading to (11). One is thus led to consider that the spiro-intermediate (9) is re-aromatised to the isomer (14) prior to ring–chain tautomerism to (15) and subsequent cyclisation to (12) (Scheme 2). This hydrogen abstraction is related to that proposed by Cadogan and his group [2] for a stage in the decomposition of 2-azidophenyl mesityl sulphide (Scheme 3). This route to the benzothienylbenzothiazole would also explain why no indolo-



SCHEME 2

benzothiazole [the 1,2-benzologue of (4)] is formed in this case unlike the thiophen series (Scheme 1).

Another notable feature of this reaction is the isolation of the dihydrobenzothiophen (12), as well as its aro-

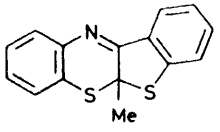


SCHEME 3

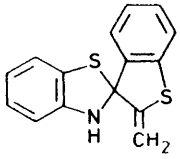
matised analogue. That this was not the case with 2-azidophenyl-3,5-dimethylthiophen [in which only the aromatised thienylbenzothiazole (6) was isolated (Scheme 1)] underscores the considerably greater aromaticity of the unfused thiophen ring over that in the benzothiophen. From our previous experience,[4] a significant degree of dehydrogenation arises from the triplet nitrene abstracting two vicinal hydrogens from

dihydroaromatic compounds, which accounts also for some of the amine regularly formed in such situations.

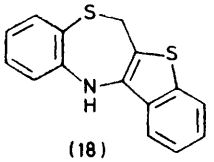
Decomposition of 2-*Azidophenyl* 3-(2-*Methylbenzo*[b]-*thienyl*) *Sulphide* (8).—This azide again reacted cleanly and quantitatively yielding one product as a yellow oil. The product proved to be an isomer of (11) and its closely similar spectral properties (see Experimental section) argue strongly for the structure (16), that expected from a phenothiazine-type rearrangement from the spiro-intermediate (10). In this case, the alternative pathway of hydrogen abstraction to give (17) and rearrangement, possibly to give (18) (*cf.* Scheme 3), was not observed.



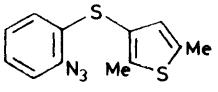
(16)



(17)



(18)



(19)

Decomposition of Other 2-*Azidophenyl Sulphides.*—As already mentioned, the parent 2-azidophenyl benzothienyl sulphide (7a) decomposed giving a deep green solution which on work-up yielded a green polymer and unstable products difficult to purify. (Other workers [5] have decomposed this same azide in xylene solution to give the corresponding amine, in low yield, this solvent being very prone to hydrogen abstraction.[6]) Curiously, the same problem was observed with the 2-azidophenyl thienyl sulphides and it would seem that either the unsubstituted products are unstable or that different pathways are followed. Two impure products apart from the polymer were isolated, which from accurate mass measurement contained $C_{14}H_9NS_2$ and $C_{13}H_8NS_2$, respectively, and for which other limited spectroscopic data were available, but we are uncertain as to the exact nature of these compounds.

In order to test the use of methyl groups in stabilising products in this type of reaction we also examined the azide (19), the parent system of which also gave only a highly-coloured polymer on thermolysis.[1] Thermolysis in bromobenzene resulted in a dark brown solution from which was emitted quantities of hydrogen sulphide. Work-up gave, surprisingly, 2-methylbenzothiazole (30%) together with the ubiquitous amine (19; NH_2 in place of N_3, 44% yield). We have no idea as to the origin of the benzothiazole except to suggest a spiro-intermediate once again as a first step.

EXPERIMENTAL

The general conditions are as described in Part 5.[7] N.m.r. spectra were obtained for solutions in $CDCl_3$ with tetramethylsilane as internal standard. Solutions were dried with anhydrous magnesium sulphate. Light petroleum refers to the fraction of b.p. 60—80°.

Preparation of the Azides (7, 8, *and* 19).—(a) 2-*Azidophenyl* 2-*benzo*[b]*thienyl sulphide* (7a). This was prepared according to our published method,[5] m.p. 74—75° (decomp.) [lit.,[5] 76—78° (decomp.)].

(b) 2-*Azidophenyl* 2-(3-*methylbenzo*[b]*thienyl*) *sulphide* (7b). By the same method 3-methylbenzothiophen [8] gave: i, 2-*nitrophenyl* 2-(3-*methylbenzo*[b]*thienyl*) *sulphide* (59%) as yellow needles, m.p. 144—145° (from ethanol) (Found: C, 58.95; H, 3.7; N, 5.6. $C_{15}H_{11}NO_2S_2$ requires C, 58.8; H, 3.7; N, 4.65%), $\nu_{max.}$ (Nujol) 1 510 and 1 330 cm^{-1} (NO_2), δ 2.44 (s, Me), 6.91—8.22 (m, aromatic); ii, 2-*aminophenyl* 2-(3-*methylbenzo*[b]*thienyl*) *sulphide* (56%) as a pale straw oil, b.p. 184—190° at 0.3 mmHg (Found: C, 66.76; H, 4.67; N, 5.26. $C_{15}H_{13}NS_2$ requires C, 66.38; H, 4.83; N, 5.16%), $\nu_{max.}$ (liquid film) 3 450 and 3 350 cm^{-1} (NH_2), δ 2.39 (s, Me), 4.08 (br s, NH_2), and 6.47—7.55 (m, aromatic); and iii, 2-*azidophenyl* 2-(3-*methylbenzo*[b]*thienyl*) *sulphide* (7b) (80%) as colourless prisms, m.p. 115—116° (from chloroform) (Found: C, 60.05; H, 3.75; N, 14.35. $C_{15}H_{11}N_3S_2$ requires C, 60.6; H, 3.75; N, 14.15%), $\nu_{max.}$ (Nujol) 2 150 and 2 100 cm^{-1} (N_3).

(c) 2-*Azidophenyl* 3-(2-*methylbenzo*[b]*thienyl*) *sulphide* (8). To a refluxing, magnetically stirred suspension of copper(I) oxide (3.6 g), potassium hydroxide (3.4 g, 0.06 mol), and *o*-aminothiophenol (7.88 g, 0.06 mol) in dimethylformamide (50 ml) was added 2-methyl-3-bromobenzothiophen [9] (10.19 g, 0.045 mol) under nitrogen. Reflux was maintained for 36 h and the mixture poured onto ice–6N-hydrochloric acid. The solution was filtered through Celite and basified with sodium hydroxide–water (40% w/v). The solution was then extracted with dichloromethane and the extracts dried and evaporated. Chromatography on alumina with diethyl ether–light petroleum (1 : 6 v/v) as eluant gave 2-*aminophenyl* 3-(2-*methylbenzo*[b]*thienyl*) *sulphide* (1.58 g, 13%) as pale prisms, m.p. 89—90° [from light petroleum (b.p. 40—60°)] (Found: M^+, 271.048 9. $C_{15}H_{13}NS_2$ requires M, 271.049 0), $\nu_{max.}$ (Nujol) 3 420 and 3 340 cm^{-1} (NH_2), δ 2.70 (s, Me), 4.12 (br s, NH_2), and 6.5—8.0 (m, aromatic). The amine was converted as above into the corresponding *azide* (96%) giving pale prisms, m.p. 89—90° [from light petroleum (b.p. 40—60°)] (Found: M^+, 297.039 3. $C_{15}H_{11}N_3S_2$ requires M, 297.039 5), $\nu_{max.}$ (Nujol) 2 120 and 2 090 cm^{-1} (N_3), δ 2.53 (s, Me) and 6.47—7.67 (m, aromatic).

(d) 2-*Azidophenyl* 3-(2,5-*dimethylthienyl*) *sulphide* (19). Using the method described in (c), 3-bromo-2,5-dimethylthiophen (12.0 g, 0.063 mol), on heating with the same reagent for 36 h under reflux, gave 2-*aminophenyl* 3-(2,5-*dimethylthienyl*) *sulphide* (2.42 g, 16%) as a pale straw-coloured oil, b.p. 114—120° at 0.3 mmHg (Kugelrohr) (Found: C, 61.3; H, 5.4; N, 5.9. $C_{12}H_{13}NS_2$ requires C, 61.25; H, 5.55; N, 5.95%), $\nu_{max.}$ (liquid film) 3 450 and 3 360 cm^{-1} (NH_2), δ 2.41 (s, Me), 2.32 (s, Me), 4.15 (br s, NH_2), and 6.4—7.3 (m, aromatic). Treatment as before gave the corresponding *azide* (2.29 g, 85%) as pale prisms, m.p. 69—70° [from light petroleum (b.p. 40—60°)] (Found: M^+, 261.039 6. $C_{12}H_{11}N_3O_2$ requires M, 261.039 6), $\nu_{max.}$ (Nujol) 2 120 and 2 090 cm^{-1} (N_3), δ 2.40 (s, Me) and 6.57—7.07 (m, aromatic).

Decomposition of the Azides.—The azide (2.0 g) in a small volume of the solvent was added to the refluxing solvent under nitrogen so as to make a 1% w/v solution. This solution was then heated for 2½—4 h, the reaction being

monitored by the disappearance of the azide absorption in the infrared solution spectrum. The resulting solution was evaporated *in vacuo* and chromatographed on alumina, giving products as follows.

(a) *From 2-azidophenyl 2-benzo*[b]*thienyl sulphide* (7a). The decomposition was conducted in bromobenzene solution. Elution with diethyl ether–light petroleum (1 : 4 v/v) gave a brown powder (0.13 g) having a mass-spectral molecular weight of 242. Elution with a 1 : 1 v/v mixture of the same solvents gave a red solid (0.62 g) (M^+ 255). Elution with diethyl ether and finally with methanol gave a green polymer.

(b) *From 2-azidophenyl 2-(3-methylbenzo*[b]*thienyl) sulphide* (7b). The decomposition was conducted in both bromobenzene and *o*-dichlorobenzene solution. Diethyl ether–light petroleum (1 : 9 v/v) eluted first the unchanged azide (0.05 g, 2.5%). Using the same solvents in the proportions 1 : 4 to 1 : 1 gave a yellow oil (1.43 g from bromobenzene and 1.57 g from *o*-dichlorobenzene). This oil was separated on 200 × 200 × 2 mm silica-gel plates using diethyl ether–light petroleum (b.p. 40—60°) (1 : 9) for development. After two elutions the following products were isolated in order of mobility: (i) 2-(2,3-*dihydro*-3-*benzo*[b]*thienyl*)*benzothiazole* (12) (from bromobenzene, 0.72 g, 41%; from *o*-dichlorobenzene, 0.75 g, 42%) as a pale yellow oil, b.p. 154—158° at 0.3 mmHg (Kugelrohr) (Found: C, 67.05; H, 3.85; N, 5.4. $C_{15}H_{11}NS_2$ requires C, 66.9; H, 4.1; N, 5.2%), δ 3.70 and 3.77 (AB portion of an ABX spectrum, J_{AX} 7.7, J_{BX} 7.0, J_{AB} 14.0 Hz, CH_2), 5.10 (t, CH), and 6.8—8.2 (m, aromatic), *m/e* 269 (96%, M^+), 236 (88, M^+ − SH), 135 (50, $M - C_8H_6S$), and 134 (96, $M^+ - 1$, doubly charged), $\lambda_{max.}$ (MeOH) (ε) 235 (24 810), 273 (12 680), and 325 nm (6 620); (ii) 5a-*methylbenzo*[1,4]*thiazino*[3,2-b]-*benzo*[b]*thiophen* (11) (from bromobenzene, 0.48 g, 28%; from *o*-dichlorobenzene, 0.73 g, 41%) as a pale yellow oil, b.p. 140—144 at 0.2 mmHg (Kugelrohr) (Found: C, 66.5; H, 4.15; N, 5.45. $C_{15}H_{11}NS_2$ requires C, 66.9; H, 4.1; N, 5.2%), δ 1.45 (s, Me) and 7.05—7.40 (m, aromatics), *m/e* 269 (96%, M^+), 268 (100, $M^+ - 1$), 254 (84, (M^+ − Me), 236 (44, M^+ − SH), and 222 (11, 254 − S), $\lambda_{max.}$ (MeOH) (ε): 223 (33 300) and 255 nm (19 500); (iii) 2-(3-*benzo*[b]-*thienyl*)*benzothiazole* (13) (0.09 g, 5%) as pale cream crystals, m.p. 91—92° (Found: C, 67.35; H, 3.5; N, 5.45. $C_{15}H_{19}$-NS_2 requires C, 67.4; H, 3.4; N, 5.25%), δ 7.17—7.80 (m, 4 H), 7.75—8.17 (m, 4 H), and 8.00—9.00 (m) (all aromatic), $\lambda_{max.}$ (MeOH) (ε) 220 (40 200) and 325 nm (17 200); and (iv) 2-aminophenyl 2-(3-methylbenzo[*b*]thienyl) sulphide (0.18 g, 10%).

(c) *From 2-azidophenyl 3-(2-methylbenzo*[b]*thienyl) sulphide* (8). Elution with light petroleum gave unchanged azide (0.1 g, 5%). Elution with diethyl ether–light petroleum (1 : 19 v/v) gave 5a-*methylbenzo*[1,4]*thiazino*[2,3-b]-*benzo*[b]*thiophen* (16) (1.70 g, ~100%) (Found: C, 66.67; H, 4.08; N, 5.39. $C_{15}H_{11}NS_2$ requires C, 66.88; H, 4.12; N, 5.20%), δ 1.57 (s, Me), 6.93—7.80 (7 H, m, aromatic), and 8.20—8.30 (1 H, d, aromatic), *m/e* 269 (73%, M^+), 254 (80, M^+ − Me), 236 (100, M^+ − SH), and 222 (254—S), $\lambda_{max.}$ (MeOH) (ε): 215 (23 920) and 250 nm (24 265).

(d) *From 2-azidophenyl 3-(2,5-dimethylthienyl) sulphide* (19). Elution with diethyl ether–light petroleum (1 : 9 v/v) gave 2-methylbenzothiazole (0.30 g, 29%) and with diethyl ether–light petroleum (1 : 4 v/v) gave 2-aminophenyl 3-(2,5-dimethylthienyl) sulphide (0.70 g, 39%). Polymeric material was eluted with solvents of increasing polarity, finally using methanol.

Dehydrogenation of 2-(2,3-*Dihydro*-3-*benzo*[b]*thienyl*)*benzothiazole* (12).—To the title compound (0.10 g) in glacial acetic acid (8 ml) and acetic anhydride (1 ml) was added freshly prepared triphenylmethyl perchlorate [10] (0.13 g) and the mixture heated on a water bath for 0.5 h. Water (50 ml) was added and the mixture extracted with ether. The extracts were washed with 2M-sodium hydroxide solution, dried, and evaporated, and the residue was chromatographed on silica. Elution with diethyl ether–light petroleum (1 : 9 v/v) gave white crystals which were further purified on silica thick-layer plates (200 × 200 × 2 mm). Elution with diethyl ether–light petroleum (1 : 19 v/v) gave 2-(3-benzo[*b*]thienyl)benzothiazole (13) (0.10 g, *ca.* 100%), m.p. and mixed m.p. 91—92°.

Synthesis of 2-(3-*Benzo*[b]*thienyl*)*benzothiazole* (13). To 2-aminothiophenol (0.35 g, 0.002 8 mol) and benzothiophen-3-carboxylic acid [11] (0.5 g, 0.002 8 mol) was added polyphosphoric acid (*ca.* 10 g) and the temperature was raised to 259° and maintained at this temperature with stirring for 3 h. The cooled reaction mixture (at *ca.* 100°) was quenched with ice–water and the mixture extracted with ether (2 × 100 ml). The extract was washed with 2M-sodium hydroxide solution (2 × 50 ml) and water, dried, and evaporated. The residue was recrystallised from light petroleum to give the title product (0.35 g, 47%), m.p. and mixed m.p. with the product from above 91—92°. The infrared spectra of the two compounds were superimposable.

We thank the S.R.C. for a research grant (to D. G. H.).

[9/384 *Received*, 9*th March*, 1979]

REFERENCES

[1] Part 6, J. M. Lindley, O. Meth-Cohn, and H. Suschitzky, *J.C.S. Perkin I*, 1978, 1198.
[2] For a review see J. I. G. Cadogan, *Accounts Chem. Research*, 1972, **5**, 303.
[3] I. M. McRobbie, O. Meth-Cohn, and H. Suschitzky, *J. Chem. Res.* (*S*), 1977, 17; (*M*), 1977, 0434.
[4] B. Iddon, O. Meth-Cohn, E. F. V. Scriven, H. Suschitzky, and P. T. Gallagher, *Angew. Chem.*, in the press (review).
[5] B. Iddon, H. Suschitzky, D. S. Taylor, and K. E. Chippendale, *J.C.S. Perkin I*, 1974, 2500.
[6] A. Bertho, *Ber.*, 1934, **57**, 1138.
[7] J. M. Lindley, I. M. McRobbie, O. Meth-Cohn, and H. Suschitzky, *J.C.S. Perkin I*, 1977, 2194.
[8] N. B. Chapman, K. Clarke, and B. Iddon, *J. Chem. Soc.*, 1965, 774.
[9] D. A. Shirley, M. J. Danzig, and F. C. Canter, *J. Amer. Chem. Soc.*, 1953, **75**, 3278.
[10] A. O. Fitton and R. K. Smalley, 'Practical Heterocyclic Chemistry,' Academic Press, London, 1968, p. 100.
[11] R. B. Mitra, K. Rabindran, and B. D. Tilak, *J. Sci. Ind. Res.* (*India*), 1956, **15B**, 627.