181. *Extrusion of Sulphur. Part IV.* Effect of Substituents in 11-Phenyldibenzo*[b,f]-1 : 4-*thiazepine.*

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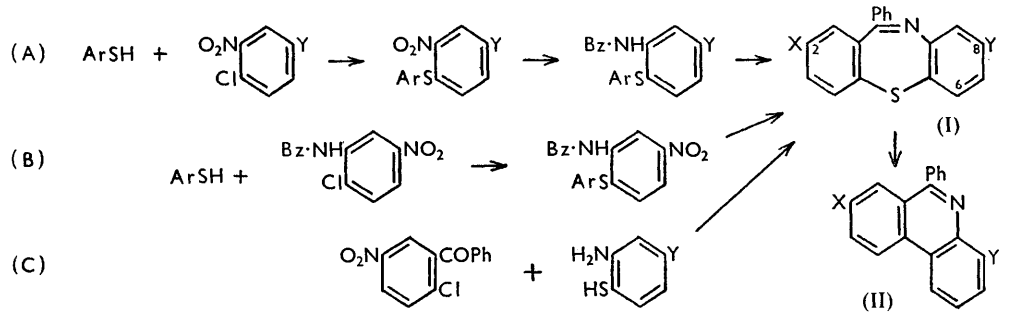
11-Phenyldibenzo[*b,f*]-1 : 4-thiazepines variously substituted in the 2- and/or 8-position are synthesised and the effects of these substituents on extrusion of sulphur are examined.

In Part III * it was shown that 11-phenyldibenzo[*b,f*]-1 : 4-thiazepine (I; X = Y = H) is convertible into 9-phenylphenanthridine (II; X = Y = H) in high yield. Derivatives of the thiazepine are preparable in some variety by syntheses (A),[1] (B),[2] and (C),[3] thus providing an opportunity to examine the effect of substituents on extrusion of sulphur from this type of compound. Since substitution *para* to the sulphur atom is likely to be the most significant and free from steric complications, attention here is restricted to compounds of the general formula (I). Table 1 shows the range and sources of the



thiazepines examined, and Table 2 contains their percentage conversions into corresponding phenanthridines by standardised treatment with copper in quinoline (b. p. 238°) and in diethyl phthalate (b. p. 296°).

Table 1. 11-*Phenyldibenzo*[b,f]-1 : 4-*thiazepines* (I).

	Subst.		Method/			Found (%)			Required (%)		
(I)	X	Y	Source	M. p.	Formula	C	H	N	C	H	N
a	H	H	A	118° [1]	$C_{19}H_{13}NS$	—	—	—	—	—	—
b	H	Cl	A	150	$C_{19}H_{12}NClS$	71·1	4·0	4·3	70·9	3·7	4·4
c	Cl	H	A	134	,,	71·2	3·5	4·6	,,	,,	,,
d	H	Me	A	127	$C_{20}H_{15}NS$	79·8	4·6	4·5	79·7	5·0	4·6
e	Me	H	A	164	,,	79·6	4·7	4·6	,,	,,	,,
f	H	MeO	A	159	$C_{20}H_{15}ONS$	75·4	4·6	4·0	75·7	4·8	4·4
g	MeO	H	A	140	,,	75·8	4·9	4·5	,,	,,	,,
h	H	HO	If	255	$C_{19}H_{13}ONS$	75·2	4·1	—	75·2	4·3	—
i	HO	H	Ig	304	,,	75·1	4·4	—	,,	,,	—
j	H	NO_2	B	187	$C_{19}H_{12}O_2N_2S$	68·5	3·8	8·6	68·7	3·6	8·4
k	NO_2	H	C	159 [3]	,,	—	—	—	—	—	—
l	Cl	Cl	A	152	$C_{19}H_{11}NCl_2S$	64·3	3·4	4·0	64·0	3·1	3·9
m	Me	Cl	A	147	$C_{20}H_{14}NClS$	71·5	4·2	4·2	71·5	4·2	4·2
n	Me	NO_2	B	185	$C_{20}H_{14}O_2N_2S$	69·2	3·8	8·0	69·4	4·1	8·1
o	NO_2	Me	C	177	,,	69·5	4·2	8·1	,,	,,	,,
p	MeO	NO_2	B	138	$C_{20}H_{14}O_3N_2S$	66·5	3·9	7·8	66·3	3·9	7·7

Although the conversion figures shown in Table 2 are usually repeatable within narrow limits they must be regarded as qualitative because accurate temperature control was difficult and the ranging properties of the products introduced unequal errors during

* Part III, *J.*, 1958, 1588.

[1] Brodrick, Nicholson, and Short, *J.*, 1954, 3857.
[2] This paper.
[3] Jarrett and Loudon, Part II, *J.*, 1957, 3818.

isolation. For instance, as control experiments showed, the phenanthridine may usually be separated from the reaction mixture by precipitation as the picrate, but this is slow and incomplete for 7-hydroxy-9-phenylphenanthridine or when a nitro-substituent is present: in these cases modified procedures were necessary (see Experimental section). The hydroxythiazepines (Ih) and Ii) were also the most sensitive of the compounds examined, and particularly with the latter isomer the incidence of side-reactions was apparent from the unusual deepening of colour during conversion.

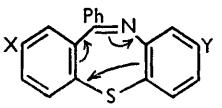
The highest yields recorded in Table 2 are not necessarily the best attainable but

TABLE 2. *Conversion* (%) *of thiazepines* (I) *into phenanthridines* (II).

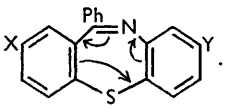
			240°	300°		
I	X	Y	60 min.	10 min.	15 min.	30 min.
a	H	H	Nil	57	73	86
b	H	Cl	—	61	73	81
c	Cl	H	—	56	71	84
d	H	Me	38	80	85	86
e	Me	H	—	51	—	83
f	H	MeO	79	82	—	82
g	MeO	H	10	77	85	88
h	H	HO	76	75	—	—
i	HO	H	Nil	(52)	—	—
j	H	NO_2	—	Nil	—	15 †
k	NO_2	H	30	79	—	—
l	Cl	Cl	—	65	77	83
m	Me	Cl	—	61	79	86
n	Me	NO_2	—	Nil	—	20 †
o	NO_2	Me	60	88	—	—
p	MeO	NO_2	9	60 †	—	—

† Obtained by fractional crystallisation of the bases (see p. 888).

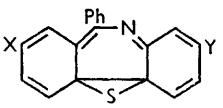
clearly show the scope and value of the method for preparing phenanthridines of this substitution pattern. At the higher temperature variation of the substituent X is seen to be less significant than variation of the substituent Y. The latter, as an electron-donating group, promotes the reaction (d, f, h) but as an electron-restraining group retards it (j, n): on the other hand, X can promote the reaction either as a strongly donor group (g) or as an acceptor group (k). However, at the lower temperature substituent X promotes the reaction more effectively when it is an acceptor group (k, o) than when it is a donor group (g, i). In a reaction at this temperature Brodrick, Nicholson, and Short, who used cuprous salts as catalysts, also failed to detect extrusion of sulphur from the parent thiazepine (Ia) and record only meagre yields of phenanthridines from the thiazepines (I; X = Y = Br or CN).



(III)



(IV)



(V)

The experimental results can be interpreted in terms of the two principal pathways, leading to an intermediate (V) and indicated in formulæ (III) and (IV), by which the carbon atoms initially linked through sulphur become directly linked. Each of the pathways will be affected in a readily accountable manner by the nature of the substituents X and Y, and subsidiary pathways could conceivably be opened by conjugation between these substituents, but the main course is clearly that represented in (III). This predominates at the lower temperature and is perhaps supplemented by course (IV) at the higher temperature. For the subsequent extrusion of sulphur from the intermediate (V) there is analogy in the pyrolysis of arylated ethylene sulphides, a reaction which yields

the corresponding ethylene and is facilitated by the presence of copper:[4] moreover, episulphides are the postulated intermediates in a number of allied reactions[5] which also lead to extrusion of sulphur.

It is noteworthy that in nitrobenzene–phosphoryl chloride the thiazepine (I; X = H, Y = OMe), during the final stage of its preparation (method A), yielded a considerable quantity of 2-methoxy-9-phenylphenanthridine (II; X = H, Y = OMe). On the other hand, attempts to effect extrusion from thiazepines in phosphoric or hydrochloric acid, or from the hydroxythiazepine (Ih) in boiling 2N-sodium hydroxide were unsuccessful.

Experimental

2-Nitrodiaryl Sulphides.—The 2-nitrodiaryl sulphides described in Table 3 were prepared by dropwise addition of 30% aqueous sodium hydroxide (1·1 mol.) to a solution of the appropriate thiophenol (1·1 mol.) and *o*-chloronitrobenzene (1 mol.) in ethanol (500 c.c.), the whole being heated thereafter for 30 min. under reflux and the product crystallised from methanol or ethanol.

Table 3. 4- *and/or* 4′-*Substituted* 2-*nitrodiphenyl sulphides.*

Cross ref.	Subst. 4′	Subst. 4	M. p.	Formula	Found (%) C	Found (%) H	Found (%) N	Required (%) C	Required (%) H	Required (%) N
a	H	H	79° [6]	$C_{12}H_9O_2NS$	—	—	—	—	—	—
b	H	Cl	84 [7]	$C_{12}H_8O_2NSCl$	—	—	—	—	—	—
c	Cl	H	97	,,	54·1	3·2	5·7	54·2	3·0	5·3
d	H	Me	72	$C_{13}H_{11}O_2NS$	63·7	4·3	5·8	63·7	4·5	5·7
e	Me	H	89 [8]	,,	—	—	—	—	—	—
f	H	MeO	Oil *	$C_{13}H_{11}O_3NS$	—	—	—	—	—	—
g	MeO	H	94	,,	59·5	3·9	5·6	59·8	4·2	5·3
l	Cl	Cl	158 [7]	$C_{12}H_7O_2NSCl_2$	—	—	—	—	—	—
m	Me	Cl	121 [9]	$C_{13}H_{10}O_2NSCl$	—	—	—	—	—	—

* The oil was used as such and was characterised by oxidation with hydrogen peroxide in acetic acid to the corresponding *sulphone*, m. p. 105° (Found: C, 53·3; H, 3·8; N, 4·8. $C_{13}H_{11}O_5NS$ requires C, 53·2; H, 3·9; N, 4·8%).

2-Benzamidodiaryl Sulphides.—2-Nitrodiaryl sulphides were reduced[6] to the amines which were isolated as crude hydrochlorides and these were treated with benzoyl chloride at room temperature for 2—3 hr. in dry pyridine. After addition of dilute sulphuric acid and recovery from alkali-washed and dried ethereal extracts, all except the last three benzamido-compounds described in Table 4 were thus obtained. The last three compounds were prepared by the

Table 4. 4- *and/or* 4′-*Substituted* 2-*benzamidodiphenyl sulphides.*

Cross-ref.	Subst. 4′	Subst. 4	M. p.	Formula	Found (%) C	Found (%) H	Found (%) N	Required (%) C	Required (%) H	Required (%) N
a	H	H	67° [1]	$C_{19}H_{15}ONS$	—	—	—	—	—	—
b	H	Cl	81	$C_{19}H_{14}ONSCl$	67·1	4·5	4·3	67·2	4·1	4·1
c	Cl	H	102	,,	67·1	4·7	4·2	,,	,,	,,
d	H	Me	91	$C_{20}H_{17}ONS$	74·9	5·5	4·5	75·2	5·4	4·4
e	Me	H	94	,,	75·1	5·1	4·2	,,	,,	,,
f	H	MeO	61	$C_{20}H_{17}O_2NS$	71·9	5·3	4·2	71·6	5·1	4·2
g	MeO	H	78	,,	71·3	4·9	4·1	,,	,,	,,
l	Cl	Cl	110	$C_{19}H_{13}ONSCl_2$	61·2	3·7	4·0	61·0	3·5	3·7
m	Me	Cl	85	$C_{20}H_{16}ONSCl$	67·5	4·5	4·0	67·9	4·5	4·0
j	H	NO_2	115	$C_{19}H_{14}O_3N_2S$	65·2	4·0	8·3	65·1	4·0	8·0
n	Me	NO_2	125	$C_{20}H_{16}O_3N_2S$	65·6	4·3	7·9	65·9	4·4	7·7
o	MeO	NO_2	142	$C_{20}H_{16}O_4N_2S$	63·2	4·1	7·6	63·1	4·2	7·4

procedure for 2-nitrodiaryl sulphides but by using 2-chloro-5-nitrobenzanilide (suspension) in place of the chloronitrobenzene.

[4] Staudinger and Siegwart, *Helv. Chim. Acta*, 1920, **3**, 833. Schönberg, *Ber.*, 1925, **58**, 1793; Schönberg and Vargha, *Annalen*, 1930, **483**, 176.

[5] Parham and Traynelis, *J. Amer. Chem. Soc.*, 1954, **76**, 4960; 1955, **77**, 68; Knott, *J.*, 1955, 916 *et seq.* Moore and Porter, *J.*, 1958, 2062; Schönberg, *J. Org. Chem.*, 1958, **23**, 104; cf. Huisgen and Appl, *Chem. Ber.*, 1958, **91**, 12.

[6] Roberts and Turner, *J.*, 1926, 1208.

[7] Loudon and Shulman, *J.*, 1938, 1618.

[8] Gilman and Broadbent, *J. Amer. Chem. Soc.*, 1947, **69**, 2053.

[9] Loudon and Robson, *J.*, 1937, 242.

11-*Phenyldibenzo*[b,f]-1 : 4-*thiazepines*.—*Methods* A *and* B, *Table* 1. The 2-benzamidodiaryl sulphide (1 mol.), phosphoryl chloride (4 mol.), and pure nitrobenzene (13 mol.) were heated under reflux for 4 hr. After removal of volatile materials at 0·1 mm. and trituration of the residue with dilute sodium hydroxide the thiazepine was recovered in benzene. By-products were obtained in two cases: (i) The usual trituration of the crude product from 2-benzamido-4-methoxydiphenyl sulphide gave a considerable quantity of a yellow solid which was insoluble in benzene. This solid, after being heated for 30 min. with dilute aqueous sodium hydroxide, yielded 2-methoxy-9-phenylphenanthridine (Table 5) which was recovered in hot benzene: alternatively a hot solution of the original solid in dilute sulphuric acid gave as yellow needles, m. p. 283° (decomp.), the *sulphate* of the same base (Found: C, 62·5; H, 4·25; N, 3·8. $C_{20}H_{16}ON,HSO_4$ requires C, 62·7; H, 4·5; N, 3·65%). (ii) The benzene extract of the crude product from 2-benzamido-4′-methoxy-4-nitrodiphenyl sulphide afforded a small first crop of 5-nitro-2-phenylbenzothiazole, m. p. 138° (from ethanol) (Found: C, 61·1; H, 2·9; N, 10·6. Calc. for $C_{13}H_8O_2N_2S$: C, 61·0; H, 3·15; N, 10·9%). This compound is apparently formed by scission of the diaryl sulphide and cyclisation of the resultant 2-benzamido-4-nitrothiophenol (or its equivalent): the mechanism was not examined.

Method C, *Table* 1. To a solution of 4 : 4′-dimethyl-2 : 2′-dinitrodiphenyl disulphide in glacial acetic acid at 100° successive additions of concentrated hydrochloric acid and zinc dust were made until the solution was colourless. The hot filtered solution was then added to twice its volume of water containing sodium acetate equivalent to the mineral acid used. The resultant zinc salt was dried and dissolved in concentrated hydrochloric acid from which 2-*amino*-4-*methylthiophenol hydrochloride* crystallised; it had m. p. 189° (decomp.) (Found: C, 47·6; H, 5·5; N, 7·8. C_7H_9NS,HCl requires C, 47·9; H, 5·7; N, 8·0%). It was condensed with 2-chloro-5-nitrobenzophenone as described for the lower homologue.

2- and 8-Hydroxythiazepine (Ii, Ih, Table 1) were obtained by demethylating 2- and 8-methoxythiazepine with hydrobromic acid in acetic acid (3 hr. under reflux).

9-*Phenylphenanthridines*.—A small pear-shaped flask, containing the thiazepine (0·001 mole), copper bronze (0·4 g.), and diethyl phthalate (3 c.c.) in an atmosphere of nitrogen, was plunged into a metal-bath regulated at 315°. Thereupon the bath temperature fell to 300° and then slowly rose again. After the stated time (Table 2) the flask was removed, its contents were cooled, transferred, and boiled with benzene, and the resultant suspension was filtered through a pad of charcoal. For the phenanthridines (II, a–h, l, and m; Tables 2 and 5) the filtrate was

TABLE 5. 9-*Phenylphenanthridines* (II).

	Subst.				Found (%)			Required (%)			Picrate
(II)	X	Y	M. p.	Formula	C	H	N	C	H	N	M. p.
a	H	H	105° [1]	$C_{19}H_{13}N$	—	—	—	—	—	—	251°
b	H	Cl	134	$C_{19}H_{12}NCl$	79·1	4·3	4·7	78·7	4·1	4·8	245
c	Cl	H	120 [11]	,,	—	—	—	—	—	—	260
d	H	Me	119 [12]	$C_{20}H_{15}N$	—	—	—	89·2	5·6	—	245
e	Me	H	90	,,	89·3	5·4	—	,,	—	—	280
f	H	MeO	116	$C_{20}H_{15}ON$	84·1	5·5	5·1	84·2	5·3	4·9	260 *
g	MeO	H	Oil [13]	,,	—	—	—	—	—	—	270
h	H	HO	290	$C_{19}H_{13}ON$	83·9	5·0	5·0	84·1	4·8	5·2	295
i	HO	H	266	,,	83·8	4·7	5·2	,,	,,	,,	245 †
j	H	NO_2	223	$C_{19}H_{12}O_2N_2$	76·3	3·8	9·3	76·0	4·0	9·3	215
k	NO_2	H	236 [3]	,,	—	—	—	—	—	—	247
l	Cl	Cl	196	$C_{19}H_{11}NCl_2$	70·4	3·9	4·4	70·4	3·4	4·3	214
m	Me	Cl	179	$C_{20}H_{14}NCl$	79·1	4·6	4·6	79·3	4·6	4·6	232
n	Me	NO_2	228	$C_{20}H_{14}O_2N_2$	76·3	4·9	8·9	76·4	4·5	8·9	209
o	NO_2	Me	229	,,	76·3	4·7	9·0	,,	,,	,,	213
p	MeO	NO_2	213	$C_{20}H_{14}O_3N_2$	72·7	4·0	8·6	72·7	4·3	8·5	231

* Found: C, 60·5; H, 3·7. $C_{26}H_{18}O_8N_4$ requires C, 60·7; H, 3·5%.
† Found: C, 59·4; H, 3·1. $C_{25}H_{16}O_8N_4$ requires C, 60·0; H, 3·2%.

concentrated to 25 c.c. and treated with a saturated solution (4 c.c.) of picric acid in benzene, the picrate being collected after 30 min. and weighed. In the other cases (II, i, j, k, n, o, p) picrate precipitation was incomplete even after 12 hr. and successive crops were obtained by

[10] Fries, Koch, and Stuckenbrock, *Annalen*, 1929, **468**, 201.
[11] Mamalis and Petrow, *J.*, 1950, 703.
[12] Ritchie, *Proc. Roy. Soc. N.S. Wales*, 1945, **78**, 134.
[13] Copp and Walls, *J.*, 1950, 311.

further concentration: alternatively the solvents were removed (120°/0·1 mm.) from the original benzene filtrate, and the resultant bases were fractionally crystallised from ethanol. Phenanthridines (Table 5), liberated from picrates by treatment with alkali, were recovered in benzene.

Reactions in quinoline were similarly conducted (bath-temp. 255°), solvents being removed *in vacuo* from the benzene–quinoline filtrate and the residue, dissolved in benzene, being washed with 1·5N-acetic acid. Phenanthridines—except for the cases (k, o, p, Table 2) where the free bases were fractionally crystallised—were precipitated as picrates, and thereafter unchanged thiazepines were recovered from the alkali-washed benzene mother-liquor.

We thank the Department of Scientific and Industrial Research for a Maintenance Allowance (to R. H. B. G.) and Mr. G. Milmine for help with the preparative work. Microanalyses were by Mr. J. M. L. Cameron and his staff.

THE UNIVERSITY, GLASGOW, W.2. [*Received, November 3rd*, 1958.]