Butadiene Sulphone Chemistry. Part I. Addition Reactions

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Butadiene sulphone [2,5-dihydrothiophen dioxide (I)] and 2,3-dihydrothiophen dioxide (II) undergo addition reactions with hydrazine and with substituted hydrazines; either the *NN*- or the *NN'*-disubstituted hydrazine is formed, depending on the nature of the original substituent and on the reaction conditions. The *NN'*-compounds are readily oxidised to azo-compounds. The dihydrothiophen dioxides and substituted analogues also undergo the Michael reaction with donors such as malonic or cyanoacetic ester, benzyl cyanide, nitroparaffins, and acetophenone, and under special conditions with acetoacetic ester. Some further reactions of the adducts are described, including Nef reactions of the nitroalkyl derivatives (XV) which give acyltetrahydrothiophen dioxides. Addition of hydrogen cyanide occurs less readily than does the Michael addition. Hydriodic acid, but not hydrobromic acid, adds to 2,3-dihydrothiophen dioxide, and action of halogens in moderately concentrated nitric acid affords nitrate esters of halogenohydrins from which the halogenohydrins are readily formed by mild hydrolysis. Ammonium hydrogen sulphite readily adds to 2,3-dihydrothiophen dioxides to give the 3-sulphonic acid salts, which undergo the usual reactions.

BUTADIENE sulphone [2,5-dihydrothiophen dioxide (I)] undergoes addition reactions.[1] In general, these are catalysed by alkali, which also catalyses [2] the isomerisation of 2,5- to 2,3-dihydrothiophen dioxide (II); the conjugated olefinic sulphone system of which, like that of vinyl sulphones, accepts substances with active hydrogen groups.

The addition of alcohols, phenols, amines, and thiols has been reported; we record here the properties of some such adducts and their derivatives which have not previously been described. More recently the addition of hydrazine [3] and of malonic ester [4] has been reported. We had independently found these two and similar reactions to proceed,[5] and since our work goes beyond

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[1] B.P. 489,974/1938; J. Böeseken and E. de R. van Zuydewijn, *Proc. Acad. Sci. Amsterdam*, 1936, **39**, 31; H. J. Backer and J. Strating, *Rec. Trav. chim* 1943, **62**, 815; R. E. Benson and T. L. Cairns, *J. Amer. Chem. Soc.*, 1948, **70**, 2115; R. Adams and V. V. Jones, *ibid.*, 1949, **71**, 3826; M. T. Leffler and W. D. Krueger, *ibid.*, p. 370; W. J. Bailey and E. W. Cummins, *ibid.*, 1954, **76**, 1932.

[2] E. Eigenberger, *J. prakt. Chem.*, 1931, **129**, 318; **131**, 289; H. J. Backer, J. Strating, and A. J. Zuithoff, *Rec. Trav. chim.*, 1936, **55**, 761; E. de R. van Zuydewijn, *ibid.*, 1937, **56**, 1059; 1938, **57**, 445; W. J. Bailey and E. W. Cummins, *J. Amer. Chem. Soc.*, 1954, **76**, 1932.

[3] B. Loev, *J. Org. Chem.*, 1961, **26**, 4394; B.P. 861,138.

[4] H. E. Faith, M. P. Kautsky, and B. E. Abreu, *J. Org. Chem.*, 1962, **27**, 2889.

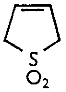
[5] Cf. B.P. application 7453/59, 43,908/59, etc.

that published so far, we report it, with minimal description of overlapping experimentation.

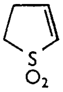
Hydrazine, used for convenience as the hydrate, adds readily to 2,5-dihydrothiophen dioxide (I) at 60° and reacts exothermically with 2,3-dihydrothiophen dioxide (II). The two products are identical and they are therefore the 3-hydrazinotetrahydrothiophen dioxide (III; R = H). Hydrazine also adds to substituted dihydrothiophen dioxides. 3-Methyl-2,5- and 4-methyl-2,3-dihydrothiophen dioxide give the same hydrazine adduct, necessarily 3-hydrazino-3-methyltetrahydrothiophen dioxide. 3-Hydroxy-2,3-dihydrothiophen dioxide gives 3-hydrazino-4-hydroxytetrahydrothiophen dioxide, also obtained from 3,4-epoxy- and from 3-bromo-4-hydroxytetrahydrothiophen dioxide by substitution. 3-Bromo-2,3-dihydrothiophen dioxide with an excess of hydrazine gives 3,4-dihydrazinotetrahydrothiophen dioxide, obtained similarly from the 3,4-dibromo-compound. Other hydrazinotetrahydrothiophen dioxides, prepared from 3-bromo-4-hydroxy- or from 3,4-epoxytetrahydrothiophen dioxides are *NN'*-di- and *N*-phenyl-*N'N'*-di-(4-hydroxy-3-tetrahydrothienyl)hydrazine di-*S*-dioxide, and *N*-phenyl-*N'*-(4-hydroxy-3-tetrahydrothienyl)hydrazine dioxide.

The polar sulphone group does not prevent the hydrazino-group reacting in the usual way and several cyclic derivatives of hydrazinotetrahydrothiophen dioxide with 1,3-dicarbonyl compounds and α,β-unsaturated carbonyl compounds have been prepared.

Substituted hydrazines also add to 2,5-dihydrothiophen dioxide and, more readily, to 2,3-dihydrothiophen dioxide to yield either the *NN'*- or the *NN*-product [(III) or (IV)]. The two structures are readily distinguished since the *NN*-compounds (IV) react with carbonyl compounds to give hydrazones; moreover, on oxidation the *NN'*-compounds give azo-compounds.



(I)



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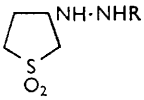

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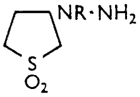

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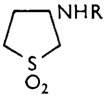

(V)

Methylhydrazine with 2,3-dihydrothiophen dioxide affords the unsymmetrically substituted product (IV; R = Me), which is also obtained from 3-methylamino-tetrahydrothiophen dioxide by nitrosation and reduction.

3-Hydrazinotetrahydrothiophen dioxide with butadiene sulphone in the presence of alkali or with 2,3-dihydrothiophen dioxide gives the symmetrical hydrazine (III; R = 3-tetrahydrothienyl dioxide); for comparison, the *NN*-di-3-tetrahydrothienylhydrazine di-*S*-dioxide (IV; R = 3-tetrahydrothienyl dioxide) was prepared from the amine (V; R = 3-tetrahydrothienyl dioxide) by nitrosation and reduction.

From phenylhydrazine both types of isomer may be obtained. Reaction with 2,3-dihydrothiophen dioxide (II) gives a product (43%) formulated as the *NN'*-disubstituted hydrazine (III; R = Ph) because of its lack of reactivity towards aldehydes, its oxidation to the corresponding azo-compound, and its u.v. spectrum. With 2,5-dihydrothiophen dioxide (I) in the presence of alkaline catalysts, the product, obtained in quantitative yield, was formulated as the *NN*-disubstituted hydrazine (IV; R = Ph), because of its u.v. spectrum and the fact that it gives hydrazones with 2,4-dinitro- and *p*-dimethylamino-benzaldehyde. *m*-Chlorophenylhydrazine, analogously, gave (III; R = *m*-Cl·C_6H_4) from (II) and the isomer (IV; R = *m*-Cl·C_6H_4) from (I). The ^1H n.m.r. spectra of the isomers confirmed their formulations; the assignments (Table 1) followed from the splitting pattern and expected chemical shifts. Each compound gave rise to a one-proton quintuplet expected for a 3-substituted tetrahydrothiophen dioxide, and that isomer of a pair with the rings closest showed the lower chemical shifts for the ring protons. The unsymmetrically substituted hydrazines (IV) would be expected to be the stronger bases and indeed these have the higher chemical shifts for the *N*-protons. Alternative structures, including those of 2-substituted tetrahydrothiophens and products from rearrangement of the hydrazines (III), are excluded by the ^1H n.m.r. results.

TABLE 1

Proton magnetic resonance results
[for *ca.* 5% solutions in (*a*) $CDCl_3$ and (*b*) pyridine]

τ (III)	τ (IV)	Intensity	Multiplicity * (*J* in c./sec.)	Assignment
R = Ph				
(*a*) 2·6—3·35	(*a*) 2·5—3·2	5	c	Ph
5·63	6·47 ‡	2	s	NH
6·08	5·47	1	qi (5, 7·5) †	3-CH
6·85	6·73	2	d	2-CH_2
6·87	6·82	2	t	5-CH_2
7·67	7·50	2	*ca.* q, c	4-CH_2
R = *m*-Cl·C_6H_4				
(*b*)	(*a*) 2·6—3·3	4	c	C_6H_4
4·78	6·43	2	s	NH
5·99	5·35	1	qi (5, 7·5) †	3-CH
6·4—7·15	6·4—7·15	4	c	2- and 5-CH_2
7·5—7·95	7·2—7·8	2	c (each) *ca.* q	4-CH_2

* c = Complex, s = singlet, qi = quintuplet, d = doublet, t = triplet, q = quartet. † Respectively. ‡ Similar values in pyridine.

The phenylhydrazine derivatives have been more extensively investigated because of the interesting biological activity [6] of the symmetrical isomer (III; R = Ph), and a number of substituted 3-phenylhydrazino-tetrahydrothiophen dioxides have been synthesised (Table 2). The unsaturated analogue, 3-phenylhydrazino-2,3-dihydrothiophen dioxide, was obtained from 3,4-dichlorotetrahydrothiophen dioxide and phenylhydrazine; the position of the olefinic link was confirmed by

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[6] E. Evans and D. T. Saggers, *Nature*, 1962, **195**, 619.

the u.v. spectrum. On mild oxidation it gives the conjugated 4-phenylazo-2,3-dihydrothiophen dioxide.

Other nitrogenous substances also add; thus benzotriazole with 2,5-dihydrothiophen dioxide and alkali, or after prolonged reaction with 2,3-dihydrothiophen dioxide (II) at room temperature gave 1-(3-tetrahydrothienyl)benzotriazole dioxide (VI), but with (II) and boiling aqueous alkali it rapidly gave the 2-isomer (VII; X = H); the products were differentiated by their u.v. spectra.[7] Tetrachlorobenzotriazole and 2,3-dihydrothiophen dioxide with a little alkali at room temperature gave 4,5,6,7-tetrachloro-2-(3-tetrahydrothienyl)benzotriazole dioxide (VII; X = Cl). That the substitution in the tetrahydrothiophen dioxide ring was at the 3-position as in (VII) was confirmed in this case by the ^{1}H n.m.r. spectrum (pyridine), which approximated to a first-order pattern. At τ 3·80 there was a quintuplet from the proton at the position of substitution; only 3-substitution is consistent with this splitting. Moreover, there was a doublet at τ 5·72 from an adjacent methylene, necessarily that at the 2-position. At higher field there were two other methylene signals, a triplet at τ 6·82 from the 5-group, and an approximation to a quartet at 6·34 from the 4-methylene (J = 6·5 c./sec.).

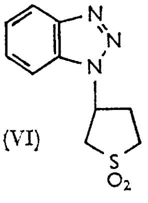
TABLE 2

Substituted 3-(N'-phenylhydrazino)tetrahydrothiophen dioxides

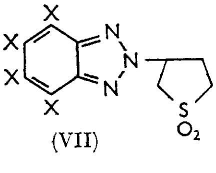
(III) R =	M. p.	Mol. formula	Analysis (%) Found Cl	Found N	Found S	Required Cl	Required N	Required S
m-Me·C_6H_4	85°	$C_{11}H_{16}N_2O_2S$		11·3	13·3		11·65	13·35
o-Cl·C_6H_4	123	$C_{10}H_{13}ClN_2O_2S$	13·7	10·5	12·3	13·6	10·75	12·35
m-Cl·C_6H_4 [a]	130		13·7	10·6	12·3			
2,3-Cl_2·C_6H_3	125	$C_{10}H_{12}Cl_2N_2O_2S$	24·1	9·4	10·8	24·0	9·5	10·85
2,4-Cl_2·C_6H_3	117		23·8	9·5	10·9			
2,5-Cl_2·C_6H_3	132		24·0	9·6	10·8			
3,4-Cl_2·C_6H_3	124		24·1	9·4	10·8			
2,4-$(NO_2)_2$·C_6H_3 [b]	184	$C_{10}H_{12}N_4O_6S$		18·2	10·1		17·7	10·15

[a] Found: C, 45·9; H, 5·2. Required: C, 46·05; H, 5·05. [b] Found: C, 38·1; H, 4·0. Required: C, 37·95; H, 3·8.

We have also prepared O-3-tetrahydrothienylhydroxylamine dioxide (VIII), indirectly, by addition of acetoxime to 2,5-dihydrothiophen dioxide and hydrolysis of the oxime adduct (IX; R¹ = R² = Me). Benzaldehyde oxime reacts analogously to give (IX; R¹ = H, R² = Ph), which can be hydrolysed to (VIII).



(VI)



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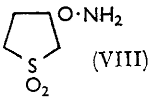

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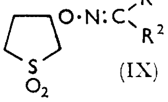

(IX)

Both 2,3- and 2,5-dihydrothiophen dioxide act as acceptors in the Michael reaction;[4] $\alpha\beta$-unsaturated sulphones are among the least reactive systems in this reaction.[8] Generally, in this cyclic system the $\alpha\beta$-unsaturated sulphone reacts much more readily than the $\beta\gamma$-unsaturated isomer and it may be assumed that isomerisation of the latter precedes the Michael reaction. The products from both isomers are identical and therefore 3-substituted (see Table 3). Although carbon–tetrahydrothiophen dioxide bonds have previously been produced by free-radical reactions,[9] and by normal malonic ester synthesis,[10] the Michael reaction is more convenient.

2,5-Dihydrothiophen dioxide reacts with diethyl malonate in presence of two equivalents of sodium in an excess of ethanol to give the product (X; R¹ = R² = CO_2Et), acid hydrolysis of which gives 3-carboxymethyltetrahydrothiophen dioxide (X; R¹ = H, R² = CO_2H). The physical properties of some esters of this acid are listed in Table 4. Ethyl and t-butyl cyanoacetate also react with 2,5-dihydrothiophen dioxide under conditions similar to those used for diethyl malonate. Less reactive donors, however, do not add; for instance, when diethyl methylmalonate is used, the competing addition of ethanol becomes predominant; the major product is 3-ethoxytetrahydrothiophen dioxide. For the addition of diethyl methylmalonate a catalytic amount of sodium ethoxide in benzene at room temperature may be used; the structure of the addition product was confirmed by methylating the adduct of diethylmalonate and dihydrothiophen dioxide. This agrees with the work of Faith *et al.*[4] on the phenyl analogue.

Alkali also catalyses the addition of benzyl cyanide; increased yields of the adduct (X; R¹ = Ph, R² = CN) are obtained in the presence of a strongly basic ion exchange resin. If benzyl cyanide is not present in excess the primary adduct, 3-(1-cyanobenzyl)tetrahydrothiophen dioxide (X; R¹ = Ph, R² = CN) reacts with a

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[7] F. Krollpfeiffer, H. Pötz, and A. Rosenberg, *Ber.*, 1938, **71**, 596; H. Specker and H. Gawrosch, *ibid.*, 1942, **75**, 1338; R. H. Wiley, N. R. Smith, M. Johnson, and J. Moffat, *J. Amer. Chem. Soc.*, 1954, **76**, 4933.

[8] E. D. Bergmann, D. Ginsburg, and R. Pappo, *Org. Reactions*, 1959, **10**, 179.

[9] M. S. Kharasch, M. Freiman, and W. H. Urry, *J. Org. Chem.*, 1948, **13**, 570; see also B.P. 651,931.

[10] H. J. Backer and Th. A. H. Blaas, *Rec. Trav. chim.*, 1942, **61**, 785.

TABLE 3

Michael reactions—general

No.	Acceptor (dihydrothiophen dioxide)	Donor	Method	Yield (%)	M. p.	B. p.
1	2,5-	Diethyl malonate	A	85[a, b]	63—64° (EtOH)	166—170°/0·4 mm.
2	2,3-	Diethyl malonate	A	90		
3	3-Methyl-2,5-	Diethyl malonate	A	14	73—75 (Et_2O)	
4	2,4-Dimethyl-2,5-	Diethyl malonate	A	Trace[c]		172—173/0·4
5	2,5-	Diethyl methyl malonate	B	35[d]	62 (MeOH)	
6	2,5-	Benzyl cyanide	B	23[e]	153—154 (Et_2O-C_6H_6)	
7	2,3-	Benzyl cyanide	C	47		
8	2,5-	Ethyl cyanoacetate	A	66[f]		224/1·5
9	3-Methyl-2,5-	Ethyl cyanoacetate	A	59	120—121[g] (Et_2O)	
10	4-Methyl-2,3-	Ethyl cyanoacetate	A	54		
11	2,5-	t-Butyl cyanoacetate[h]	A	79[i]		
12	2,3-	Ethyl acetoacetate	C	26[j]	103	200—220/2·0
13	2,5-	Acetophenone	A	50[k]	135—136 (EtOH)	

		Analysis (%)							
		Found				Required			
No.	Molecular formula	C	H	N	S	C	H	N	S
1	$C_{11}H_{18}O_6S$ *	47·2	6·3		11·4	47·5	6·5		11·5
3	$C_{12}H_{20}O_6S$				10·8				10·95
4	$C_{13}H_{22}O_6S$	50·2	7·6		11·6	50·95	7·2		10·5
5	$C_{12}H_{20}O_6S$	49·5	7·1		11·0	49·3	6·9		10·9
6	$C_{12}H_{13}NO_2S$	61·1	5·9		13·8	61·25	5·6		13·6
8	$C_9H_{13}NO_4S$			5·9	13·7			6·05	13·9
9	$C_{10}H_{15}NO_4S$			5·9	12·9			5·7	13·1
11	$C_{11}H_{12}NO_4S$			5·7	12·9			5·5	12·6
12	$C_{10}H_{16}O_5S$	48·2	6·7		12·8	48·4	6·5		12·9
13	$C_{12}H_{14}O_3S$	60·5	5·9	—	13·45	60·5	6·4		13·1

[a] Faith *et al.*[4] give m. p. 65—66°; 66% yield. [b] *Diamide* (from H_2O) had m. p. 259° (decomp.) (Found: N, 12·3; S, 14·6. $C_7H_{12}N_2O_4S$ requires N, 12·7; S, 14·5%). [c] Crude product could not be purified satisfactorily. [d] Also prepared from 3-diethoxycarbonylmethyltetrahydrothiophen dioxide (X; $R^1 = R^2 = CO_2Et$) by refluxing with sodium–ethanol and methyl iodide. [e] The aqueous phase, after benzene extraction, slowly deposited a solid, m. p. 272°; its analysis corresponded to that for the bis-*compound* (XI) (Found: C, 54·5; H, 5·4; N, 3·9; S, 17·8. $C_{16}H_{14}NO_4S_2$ requires C, 54·4; H, 5·4; N, 3·95; S, 18·1%). [f] *Amide* (from EtOH) had m. p. 144—146° (Found: N, 13·8; S, 15·9. $C_7H_{10}N_2O_3S$ requires N, 13·85; S, 15·85%). [g] M. p. (from MeOH) 106—108°. [h] Prepared by method of W. F. Beech and H. A. Piggott, *J. Chem. Soc.*, 1955, 423. [i] Product after evaporation of solvent and excess of reactants. [j] Faith *et al.*[4] give m. p. 103—105° (61% yield) with powdered sodium in benzene. [k] $\lambda_{max.}$ 244, 280, and 325 mμ (inflexion) (ε 12,500, 1600, and 75); 2,4-dinitrophenylhydrazone, m. p. 235°.

* Known compound.

TABLE 4

Esters of 3-carboxymethyltetrahydrothiophen dioxide (X; $R^1 = H, R^2 = CO_2H$)

				Analysis (%)					
				Found			Required		
Ester	Yield (%)	B. p./mm. (m. p.)	Mol. formula	C	H	S	C	H	S
Methyl	69[a]	(65°)	$C_7H_{12}O_4S$	44·2	6·6	16·6	43·7	6·3	16·7
Ethyl *	86[b] 80[a]	236/15[d, h]	$C_8H_{14}O_4S$	46·5	7·0	15·3	46·6	6·8	15·5
n-Butyl	91[b]	185—190/2[g]	$C_{10}H_{18}O_2S$	50·9	7·8	13·5	51·3	7·75	13·7
Isobutyl	94[b]	200—208/0·6[e]	$C_{10}H_{18}O_2S$	51·0	7·9	13·6	51·3	7·75	13·7
2-Ethylhexyl	66[c] 85[b]	170—180/0·025[e]	$C_{14}H_{26}O_4S$			11·1			11·0
3,5,5-Trimethylhexyl	74[c]	172—175/0·01[f]	$C_{15}H_{28}O_4S$	59·0	9·0	10·5	59·2	9·3	10·5
Lauryl	80[c]	(44—46)	$C_{18}H_{34}O_4S$			9·0			9·25
Stearyl	78[c]	(62—64)	$C_{24}H_{46}O_4S$			7·75			7·45
3-Tetrahydrothienyl dioxide...	71[b]	(119—120)	$C_{10}H_{16}O_6S_2$	40·45	5·6	21·35	40·5	5·4	21·6

[a] Hydrogen chloride gas as catalyst, in excess of the alcohol. [b] Toluene-*p*-sulphonic acid as catalyst; water produced was removed by azeotropic distillation with toluene. [c] Conc. sulphuric acid as catalyst, method as (*b*). [d] n_D^{20} 1·4798. [e] n_D^{18} 1·4756. [f] n_D^{18} 1·4730; d_4^{20} 1·092. [g] n_D^{20} 1·4760. [h] Faith *et al.*[13] give b. p. 184—187°/5 mm. for this ester prepared in 87% yield by method (*a*).

* Known compound.

second molecule of dihydrothiophen dioxide, to give the bis-compound (XI).

Alkyldihydrothiophen dioxides also function as acceptors in the Michael reaction. 4-Methyl-2,3- and 3-methyl-2,5-dihydrothiophen dioxide with ethyl cyanoacetate give the same product, accordingly assumed to have structure (XII; R = CN).

Analogously, diethyl malonate, with 3-methyl-2,5-dihydrothiophen dioxide, gives a good yield of, presumably, (XII; R = CO_2Et). From the addition of diethyl malonate to 2,4-dimethyl-2,5-dihydrothiophen dioxide, however, only a small quantity of discoloured oil can be isolated, possibly containing the impure homologues of (XII).

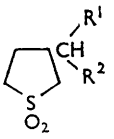
TABLE 5

Michael reactions—nitroparaffins

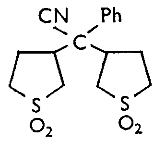
No.	Acceptor (dihydrothiophen dioxide)	Donor	Yield (%)	M. p.
1	2,3-	Nitromethane	68	111—113° (MeOH)
2	2,3- (in excess)	Nitromethane [a]	53	208—211 (H_2O–HOAc)
3	2,3-	Nitroethane	61·5	104·5—105 (MeOH)
4	2,3-	2-Nitropropane	82	74—77 (MeOH)
5	2,3-	1-Nitropropane	82	72 (MeOH)
6	3-Hydroxy-2,3-	Nitroethane	83 [b]	121—123 (H_2O)
7	3-Acetoxy-2,3-	Nitroethane	20·5 [c]	124—126 (EtOAc)
8	3-Ethoxycarbonylmethyl-2,3-	Nitroethane	97	54—56 (H_2O–EtOH)

		Analysis (%)							
		Found				Required			
No.	Molecular formula	C	H	N	S	C	H	N	S
1	$C_5H_9NO_4S$	33·1	5·5	7·8	18·1	33·5	5·0	7·8	17·9
2	$C_9H_{15}NO_6S_2$	35·8	5·4	4·8	21·5	36·35	5·1	4·7	21·6
3	$C_6H_{11}NO_4S$	37·0	5·8	7·0	16·5	37·3	5·7	7·25	16·6
4	$C_7H_{13}NO_4S$	40·7	6·6	6·8	15·7	40·6	6·3	6·8	15·5
5	$C_7H_{13}NO_4S$			6·8	15·8			6·8	15·5
6	$C_6H_{11}NO_5S$	34·8	5·4	6·9	15·0	34·4	5·3	6·7	15·3
7	$C_8H_{13}NO_6S$	38·6	5·5	5·5	12·6	38·2	5·2	5·6	12·75
8	$C_{10}H_{17}NO_6S$	43·3	6·3	5·3	11·6	43·0	6·1	5·0	11·5

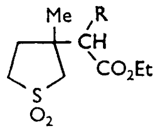
[a] A deficiency of nitromethane was used, to give the bis-adduct (XVI; R = H). [b] Product obtained as an oil, which crystallised after a long time. [c] Based on 74·5% conversion.



(X)



(XI)



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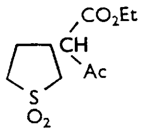

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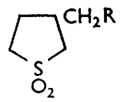

(XIV)

Other donors examined include ethyl acetoacetate, which in the presence of sodium hydroxide or ethoxide gives intractable products; in the presence of Amberlite IRA-400 (OH^- form) it adds to 2,3-dihydrothiophen dioxide to give ethyl 3-oxo-2-(3-tetrahydrothienyl)-butyrate dioxide[4] (XIII). Although acetophenone adds to 2,5-dihydrothiophen dioxide to give 3-phenacyltetrahydrothiophen dioxide (XIV; R = Bz), acetone and acetonitrile do not add. Thus the claim[11] that 3-(2-oxopropyl)tetrahydrothiophen dioxide (XIV; R = Ac) can be made in one step from 2,5-dihydrothiophen dioxide and acetone cannot be confirmed, and the product we isolate is, in fact, 2,3-dihydrothiophen dioxide. The products (XIV; R = Ac or CN) desired from these additions are obtainable indirectly from (XIII) by hydrolysis and from the adduct (X; R^1 = CN, R^2 = CO_2Bu^t) of t-butyl cyanoacetate by pyrolysis.

Acetylacetone, malononitrile, cyanoacetamide, cyanoacetohydrazide, and 2-methylpyridine appear not to add to 2,3-dihydrothiophen dioxide.

Michael addition donors to which we have paid more detailed attention are the nitroparaffins (see Table 5). These add to 2,3-dihydrothiophen dioxide in alcoholic solution to give the 3-nitroalkyltetrahydrothiophen dioxides (XV). The yield of product depends on the proportions of reactants and on the solvent. Ethanol appears to be by far the best solvent and Amberlite IRA-400, in the hydroxy-form, a suitable catalyst. With a deficiency of nitroalkane the bis-adduct (XVI) is readily obtained.

Substituted dihydrothiophen dioxides, such as 3-acetoxy- and 3-ethoxycarbonylmethyl-2,3-dihydrothiophen dioxide also react, but the free 3-carboxymethyl-2,3-dihydrothiophen dioxide under these conditions forms the lactone (XVII) of 3-carboxymethyl-4-hydroxytetrahydrothiophen dioxide.

The adducts (XV) undergo the expected reactions. On hydrogenation they afford aminoalkyltetrahydrothiophen dioxides (XVIII) (Table 6) and by the Nef reaction the corresponding ketones (XIX) (Table 7).

The conditions used for adding nitroalkanes to 2,3-di-

[11] S. Beesley, J. A. John, and J. G. N. Drewitt, B.P. 745,896.

hydrothiophen dioxide are suitable (though no solvent is necessary) for the addition of hydrogen cyanide and give 3-cyanotetrahydrothiophen dioxide (previously described[4,12]). Hydrolysis gives the known 3-carboxytetrahydrothiophen dioxide[4] (XX) identical with that obtained by oxidation of 3-formyltetrahydrothiophen dioxide[4] (XIX; R = H), the product of the Nef reaction of 3-nitromethyltetrahydrothiophen dioxide (XV; R = H). The physical properties of a number of esters of 3-carboxytetrahydrothiophen dioxide (XX) are given in Table 8. Hydrogen cyanide adds only with difficulty to substituted 2,3-dihydrothiophen dioxides, *e.g.*, the 3-acetoxy- or the 3-hydroxy-compound.

TABLE 6

Products from hydrogenation of 3-nitroalkyltetrahydrothiophen dioxides

No.	Substituent 4-	Substituent 3-	Yield (%)	Isolated as
1	H	CH_2NH_2	66	Hydrochloride, m. p. 242—244°. Oxalate, m. p. 140—141
2	H	$CHMe{\cdot}NH_2$	39	Hydrochloride, m. p. 229—232
3	H	$CMe_2{\cdot}NH_2$	90	Oxalate, m. p. 185—187 (decomp.)
4	H	$CHEt{\cdot}NH_2$	90	Oxalate, m. p. 192—194 (decomp.)
5	OH	$CHMe{\cdot}NH_2$	23	Oxalate, m. p. 228—230

		Analysis of salt (%)									
		Found					Required				
No.	Molecular formula	C	H	Cl	N	S	C	H	Cl	N	S
1	$C_5H_{12}ClNO_2S$	31·7	6·9	19·5	7·1	17·2	32·3	6·5	19·1	7·5	17·3
	$C_5H_{11}NO_2S,\frac{1}{2}C_2H_2O_4$	37·1	6·1		6·8	16·5	37·1	6·2		7·2	16·5
2	$C_6H_{14}ClNO_2S$	36·5	7·2	17·8	6·9	16·0	36·1	7·0	17·75	7·0	16·1
3	$C_7H_{15}NO_2S,\frac{1}{2}C_2H_2O_4$	43·3	7·3		6·3	14·6	43·2	7·3		6·3	14·4
4	$C_7H_{15}NO_2S,\frac{1}{2}C_2H_2O_4$				6·3	14·6				6·3	14·4
5	$C_6H_{13}NO_3S,\frac{1}{2}C_2H_2O_4$				6·2	13·9				6·25	14·3

TABLE 7

Products from Nef reactions on 3-nitroalkyltetrahydrothiophen dioxides

No.	Substituent 3-CO–	Substituent 4-	Yield (%)	M. p. (b. p.)	Characterised as
1	H	H	60—90[a]	(160—170°/2·5 mm.)	Dinitrophenylhydrazone, m. p. 196—198°; diethyl acetal, b. p. 135—138°/0·6 mm.
2	3-Tetrahydrothienyl dioxide	H	47[b]	213—214	
3	Me	H	66	58—59	Dinitrophenylhydrazone, m. p. 185—186°; azine, m. p. 149—151°
4	Et	H	90	48·5—50	Dinitrophenylhydrazone, m. p. 136° (decomp.)
5	Me	$CH_2{\cdot}CO_2Et$	70	30—33	Dinitrophenylhydrazone, m. p. 157—160°

		Analysis (%)					
		Found			Required		
No.	Molecular formula	C	H	S	C	H	S
1	$C_5H_8O_3S$						
2	$C_9H_{14}O_5S_2$	40·2	5·0	24·4	40·6	5·3	24·1
3	$C_6H_{10}O_3S$	44·6	6·4	20·2	44·5	6·2	19·8
4	$C_7H_{12}O_3S$	47·7	6·8	18·1	47·7	6·8	18·2
5	$C_{10}H_{16}O_5S$	48·6	6·5	12·6	48·4	6·5	12·9

[a] Pure product could not be obtained (see Experimental section). [b] Precipitated from reaction solution.

TABLE 8

Esters of 3-carboxytetrahydrothiophen dioxide

				Analysis (%)					
				Found			Required		
Ester	Yield (%)	B. p./mm.	Mol. formula	C	H	S	C	H	S
Methyl	71	148—150°/0·5	$C_6H_{10}O_4S$	40·9	6·1	17·8	40·4	5·7	18·0
Ethyl	94	146—150/0·25	$C_7H_{12}O_4S$	43·3	6·5	16·3	43·7	6·3	16·7
Isobutyl[a]	56	178—180/2	$C_9H_{16}O_4S$	49·4	7·6	14·6	49·1	7·3	14·6
2-Ethylhexyl	40	178—180/0·25	$C_{13}H_{24}O_4S$			11·6	56·5	8·7	11·6
3,5,5-Trimethylhexyl	80	188—190/0·5	$C_{14}H_{26}O_4S$	58·1	9·0	11·0	57·9	9·0	11·0
Lauryl[b]	60	232—234/1	$C_{17}H_{32}O_4S$	61·7	10·1	9·8	61·4	9·7	9·6

[a] M. p. 41—42°. [b] M. p. 37—38°.

Simple acid catalysed additions to the dihydrothiophen dioxide system do not proceed readily. We report,

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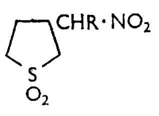
[12] P. Kurtz, *Annalen*, 1951, **572**, 23.

therefore, both the direct addition of hydriodic acid which gives 3-iodotetrahydrothiophen dioxide, whereas neither hydrochloric nor hydrobromic acid reacts,[4] and the formation under acidic conditions of nitrate esters (XXI) and (XXII) of the halogenohydrins of the dihydrothiophen dioxides (I) and (II), respectively. These esters are readily hydrolysed to the halogenohydrins themselves and provide a convenient source for these substances free from the dihalides which may otherwise contaminate them. Previously, the halogenohydrins had been prepared from the dihydrothiophen dioxide by direct halogenation in aqueous solution,[13] by hydrolysis of the corresponding acetates,[14] or by use of *N*-halides.[15] The nitrate esters of the halogenohydrins are colourless solids, some of which are stable for long periods at room temperature; the three halogenohydrins derived from 2,3-dihydrothiophen dioxide are much more water-soluble and also lower-melting than those derived from the 2,5-isomer. The structure (XXII) assigned to the α-halogenohydrins is based on the reduction of the nitrate ester of the bromohydrin with the zinc–copper couple in ethanol to 3-hydroxytetrahydrothiophen dioxide, benzoylation of which gives the known 3-benzoyloxytetrahydrothiophen dioxide.[16] 3-Methyl-2,5-, 2,4-dimethyl-2,5-, and 3,4-dimethyl-2,5-dihydrothiophen dioxide react analogously.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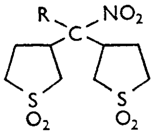
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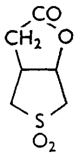
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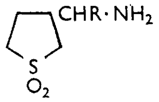
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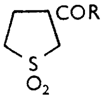
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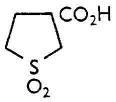
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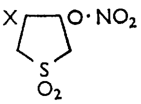
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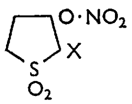
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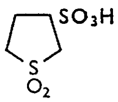
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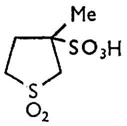
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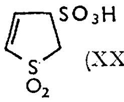

(XXV)

Reaction of 2,3-dihydrothiophen dioxide with aqueous ammonium hydrogen sulphite at atmospheric pressure gives the ammonium salt of 3-sulphotetrahydrothiophen dioxide (XXIII) (85—95%), from which the free acid can be obtained. 2,5-Dihydrothiophen dioxide reacts only sluggishly and with low yield. This is not surprising since hydrogen sulphites add only with difficuly to isolated olefinic bonds, but add readily to bonds conjugated with carbonyl groups.[17]

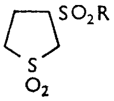
Analogously, 4-methyl-2,3-dihydrothiophen dioxide gives the corresponding acid (XXIV). 3-Bromo-2,3-dihydrothiophen dioxide also reacts, but with dehydrobromination, to give the salt of 3-sulpho-2,3-dihydrothiophen dioxide (XXV).

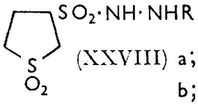
Reaction of the ammonium salt of 3-sulphotetrahydrothiophen dioxide (XXIII) with thionyl chloride and dimethylformamide[18] gives the sulphonyl chloride (85%) which undergoes the expected reactions. Thus it reacts with ammonia to give the sulphonamide (XXVI), with aniline to give the anilide (XXVII), with alcohols to give esters,[19] the physical properties of a number of which are given in Table 9, and with phenylhydrazine to give the hydrazide (XXVIIIa). Reaction with hydrazine in tetrahydrofuran gives a crystalline solid, presumably the hydrazide (XXVIIIb), which was stable only at low temperatures; when warmed to room temperature it rapidly decomposed.

TABLE 9

Esters of 3-sulphotetrahydrothiophen dioxide

			Analysis (%)					
			Found			Required		
Ester	Yield (%)	M. p.	C	H	S	C	H	S
Isobutyl	35	76—77°	37·3	6·2	25·0	37·5	6·3	25·0
n-Nonyl	11	77—78	47·3	8·0	19·3	47·8	8·0	19·6
3,5,5-Trimethylhexyl	60	62—63	47·4	8·1	19·6	47·8	8·0	19·6
n-Decyl	69	83—84	49·3	8·3	18·3	49·4	8·3	18·8
n-Undecyl ...	50	88—90	50·0	8·9	18·0	50·8	8·5	18·1
n-Dodecyl ...	65	82—83	51·8	9·3	16·9	52·1	8·75	17·4
Phenyl.........	16	84—85	43·6	4·8	23·2	43·5	4·4	23·2


(XXVI) R = NH_2
(XXVII) R = NHPh


(XXVIII) a; R = Ph
b; R = H

EXPERIMENTAL

Ultraviolet spectra were determined with a Perkin-Elmer 137 u.v. spectrophotometer and infrared spectra with a Perkin-Elmer 137 Infracord. The ^1H n.m.r. spectra were measured with a Perkin-Elmer R10 spectrophotometer at 60 Mc./sec. Molecular weights were determined cryoscopically with phenol as solvent.

Preparation of Simple Addition Products

Derivaties of 3-*Aminotetrahydrothiophen Dioxide*.—With 5-nitro-2-furaldehyde the amine gave the Schiff's base 3-(5-

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[13] R. C. Morris, E. C. Shokal, and J. L. Van Winkle, U.S.P. 2,460,233; H. J. Backer and Th. A. H. Blaas, *Rec. Trav. chim.*, 1942, **61**, 785; M. Prochazka and V. Horak, *Chem. Listy*, 1958, **52**, 1768.

[14] H. J. Backer and J. Strating, *Rec. Trav. chim.*, 1934, **53**, 525.

[15] H. J. Backer, W. Stevens, and N. Dost, *Rec. Trav. chim.*, 1948, **67**, 451.

[16] H. J. Backer and J. Strating, *Rec. Trav. chim.*, 1943, **62**, 815; cf. E. de R. van Zuydewijn, *ibid.*, 1938, **57**, 445.

[17] M. Morton and H. Landfield, *J. Amer. Chem. Soc.*, 1952, **74**, 3523.

[18] H. H. Bosshard, R. Mory, M. Schmid, and H. Zollinger, *Helv. Chim. Acta*, 1959, **42**, 1653.

[19] R. S. Tipson, *J. Org. Chem.*, 1944, **9**, 235.

nitrofurfurylidenamino)tetrahydrothiophen dioxide, a pale cream solid, m. p. 139—140° (decomp.) (from ethyl acetate) (Found: N, 10·7; S, 12·5. $C_9H_{10}N_2O_5S$ requires N, 10·85; S, 12·4%), $\lambda_{max.}$ (ethyl acetate) 322 mμ (ε 17,000). With benzoyl chloride in presence of sodium hydroxide the amine gave 3-*benzamidotetrahydrothiophen dioxide* (V; R = Bz), m. p. 178° (from ethanol) (Found: N, 5·6; S, 14·0. $C_{11}H_{13}NO_3S$ requires N, 5·9; S, 13·4%). Analogously prepared, 3-(N-*methylbenzamido*)*tetrahydrothiophen dioxide* had m. p. 157° (Found: C, 56·9; H, 6·2; N, 5·2. $C_{12}H_{15}NO_3S$ requires C, 56·9; H, 5·95; N, 5·55%). Slow addition of ethyl chloroformate (1 equiv.) to the amine in water gave a suspension which cleared when heated to 70°; 3-*ethoxyformamidotetrahydrothiophen dioxide* (V; R = CO_2Et), m. p. 96°, crystallised from the cooled solution (Found: N, 7·0; S, 15·5. $C_7H_{13}NO_4S$ requires N, 6·8; S, 15·5%). A solution of the amine hydrochloride warmed with sodium cyanate gave 3-*ureidotetrahydrothiophen dioxide* (V; R = $CO{\cdot}NH_2$), m. p. 191° (from ethanol) (Found: C, 33·2; H, 5·8; N, 15·3; S, 18·5. $C_5H_{10}N_2O_3S$ requires C, 33·7; H, 5·7; N, 15·7; S, 18·0%).

Quartenary Derivatives of Amines.— N-(3-*Tetrahydrothienyl*)*piperidine dioxide methiodide*. 2,5-Dihydrothiophen dioxide (12 g.) and piperidine (8·7 g.) were kept at 65° for 12 hr., excess of amine was removed under reduced pressure, and the non-crystalline residue was treated with methyl iodide at 100° for 5 min. Addition of ethanol afforded the *methiodide*, m. p. 181—182° (from acetic acid) (Found: I, 36·8. $C_{10}H_{20}INO_2S$ requires I, 36·8%). N-(3-*Tetrahydrothienyl*)*morpholine dioxide methiodide*, prepared analogously had m. p. 204—205° (from 80% acetic acid) (Found: I, 36·1. $C_9H_{18}INO_3S$ requires I, 36·5%). 3-*Dimethylaminotetrahydrothiophen dioxide methiodide*, prepared analogously had m. p. 219° (decomp.) (Found: C, 27·4; H, 5·6; I, 42·1; N, 4·7; S, 10·1. $C_7H_{16}INO_2S$ requires C, 27·55; H, 5·3; I, 41·6; N, 4·6; S, 10·5%). The *methochloride* had m. p. 205° (decomp.) (Found: C, 38·8; H, 7·9; Cl, 16·3; S, 14·6. $C_7H_{16}ClNO_2S$ requires C, 39·35; H, 7·55; Cl, 16·6; S, 15·0%). The *ethobromide* had m. p. 178° (Found: Br, 29·5; N, 5·0; S, 11·8. $C_8H_{18}BrNO_2S$ requires Br, 29·35; N, 5·15; S, 11·8%).

3-(1-*Naphthalenethio*)*tetrahydrothiophen Dioxide.*—2,5-Dihydrothiophen dioxide (12 g.), 1-naphthalenethiol (14 ml.), and potassium hydroxide (6 g.) in water (50 ml.) when kept for 3 days afforded crystals of the *naphthalenethio-derivative* (15 g.), m. p. 111° (from ethanol) (Found: C, 59·9; H, 4·85; S, 22·4. $C_{14}H_{14}O_2S_2$ requires C, 60·5; H, 5·05; S, 23·0%).

Preparation of 3-*Hydrazinotetrahydrothiophen Dioxides and related Substances*

3-*Hydrazinotetrahydrothiophen Dioxide* (III; R = H).—A mixture of hydrazine hydrate (64% hydrazine) (250 ml.) and technical 2,5-dihydrothiophen dioxide (150 g.) was warmed at 60° for 5 hr.; the excess of hydrazine was then removed on the steam-bath under reduced pressure. The viscous, slightly discoloured hydrazino-derivative (188 g.) decomposed when distillation was attempted, but in methanol with concentrated hydrochloric acid gave the hydrochloride, m. p. 186° (from aqueous ethanol) (Found: N, 15·3; S, 17·3. Calc. for $C_4H_{10}N_2O_2S,HCl$: N, 15·0; S, 17·5%). (Loev[3] gives m. p. 191—192°; 96% yield of crude base from 95% hydrazine.) Other salts, similarly prepared, were the oxalate, m. p. 160° (decomp.), and the nitrate, m. p. 130°. With benzoyl chloride in aqueous alcoholic sodium hydroxide, 3-hydrazinotetrahydrothiophen dioxide afforded the benzoyl derivative, m. p. 184—185°, insoluble in water.

Alternatively, when 2,3-dihydrothiophen dioxide (II) (15 g.) was added to hydrazine hydrate (25 ml.) the solid rapidly dissolved with a rise in temperature to about 60°. After 2 hr. more at 60° the excess of hydrazine was removed and the residue (20 ml.) was converted into the oxalate, m. p. 160° (decomp.), identical with that obtained from 2,5-dihydrothiophen dioxide.

3-*Hydrazino*-3-*methyltetrahydrothiophen Dioxide.*—(*a*) Isoprene sulphone (66 g.) and hydrazine hydrate (100 ml.) were kept at 70° for 20 hr. The solution was then freed from unchanged material at 160°/20 mm. The residual hydrazino-derivative (76 g.), was a viscous liquid.

(*b*) 4-Methyl-2,3-dihydrothiophen dioxide (5 g.) and hydrazine hydrate analogously gave a similar product (6 g.). The two products gave the following identical salts (mixed m. p.): *nitrate*, m. p. 135—137° (decomp.) (Found: C, 26·5; H, 6·2; N, 18·5; S, 14·1. $C_5H_{12}N_2O_2S,HNO_3$ requires C, 26·4; H, 5·8; N, 18·5; S, 14·1%); *picrate*, m. p. 134° (decomp.) (Found: N, 17·8; S, 8·1. $C_5H_{12}N_2O_2S,C_6H_3N_3O_7$ requires N, 17·8; S, 8·15%); *oxalate*, m. p. 150—151° (decomp.) (Found: S, 15·4. $2C_5H_{12}N_2O_2S,C_2H_2O_4$ requires S, 15·3%); *sulphate*, m. p. 194° (decomp.); and *hydrochloride*, m. p. 189—190° (decomp.). The red *hydrazone* with 5-nitro-2-furaldehyde, had m. p. 104—105° (from ethyl acetate–light petroleum) (Found: N, 14·4; S, 11·0. $C_{10}H_{13}N_3O_5S$ requires N, 14·6; S, 11·2%), $\lambda_{max.}$ (ethyl acetate) 274 and 395 mμ (ε 10,000 and 18,000).

3-*Hydrazino*-4-*hydroxytetrahydrothiophen Dioxide.*—(*a*) 3-Bromo-4-hydroxytetrahydrothiophen dioxide (5 g.) and hydrazine hydrate (10 ml.) were set aside at room temperature for 1 week. Excess of hydrazine was removed by vacuum distillation and the residual water-soluble solid gave the *hydrazino-compound*, m. p. 144° (decomp.) (Found: S, 19·3. $C_4H_{10}N_2O_3S$ requires S, 19·3%). The *p-nitrobenzaldehyde derivative* had m. p. 193—194° (from ethanol) (Found: N, 13·9; S, 10·7. $C_{11}H_{13}N_3O_5S$ requires N, 14·05; S, 10·7%). With excess of boiling acetic anhydride it gave the NNO-*triacetyl derivative*, m. p. 245° (from ethanol) (Found: N, 9·4; S, 10·7. $C_{10}H_{16}N_2O_6S$ requires N, 9·6; S, 10·95%). The red *hydrazone* with 5-nitro-2-furaldehyde had m. p. 154—155° (from ethyl acetate–light petroleum) (Found: N, 14·2; S, 11·1. $C_9H_{11}N_3O_6S$ requires N, 14·5; S, 11·1%), $\lambda_{max.}$ (ethyl acetate) 274 and 397·5 mμ (ε 11,000 and 17,500).

(*b*) 3,4-Epoxytetrahydrothiophen dioxide (25 g.) and anhydrous hydrazine (20 ml.) were boiled in methanol for 1 hr. to give a homogeneous mixture which when cooled deposited the hydrazino-compound (26 g.), m. p. 140—143° (decomp.).

(*c*) Hydrazine hydrate (20 ml.) and 3-hydroxy-2,3-dihydrothiophen dioxide (13·4 g.) reacted exothermically; the solution was evaporated under vacuum and the hydrazino-compound was deposited; the pure product (13·5 g.) had m. p. 140° (decomp.).

NN′-*Di*-(4-*hydroxy*-3-*tetrahydrothienyl*)*hydrazine Di*-S-*dioxide.*—A solution of 3-hydrazino-4-hydroxytetrahydrothiophen dioxide (50 g.) and 3,4-epoxytetrahydrothiophen dioxide (45 g.) in methanol was boiled for 26 hr. and cooled. First, unchanged epoxy-compound crystallised (m. p. 155—158°) and later, from the mother-liquors, the *ditetrahydrothienyl compound*, m. p. 232—233° (decomp.) (from aqueous ethanol) (Found: C, 31·85; H, 5·6; N, 9·35; S, 21·6. $C_8H_{16}N_2O_6S$ requires C, 32·0; H, 5·4; N, 9·3; S, 21·4%).

3,4-*Dihydrazinotetrahydrothiophen Dioxide*.—(*a*) 3-Bromo-2,3-dihydrothiophen dioxide (6 g.), was dissolved in hydrazine hydrate (50 ml.) at 25—30° and set aside overnight. Vacuum evaporation and addition of concentrated hydrochloric acid (10 ml.) and ethanol (20 ml.) to the residue gave 3,4-*dihydrazinotetrahydrothiophen dioxide dihydrochloride*, m. p. 216° (decomp.) (from aqueous ethanol) (Found: N, 21·7; S, 12·7; Cl, 28·7. $C_4H_{12}N_4O_2S,2HCl$ requires N, 22·1; S, 12·65; Cl, 28·0%). With alcoholic *p*-nitrobenzaldehyde the *bis-hydrazone* was produced, m. p. 188° (Found: C, 48·4; H, 4·1; N, 18·2; S, 7·4. $C_{18}H_{18}N_6O_6S$ requires C, 48·45; H, 4·05; N, 18·8; S, 7·2%).

(*b*) Similarly, 3,4-dibromotetrahydrothiophen dioxide (20 g.) and hydrazine hydrate (50 ml.) gave 3,4-dihydrazinotetrahydrothiophen dioxide as a mass of hard crystals which were not purified, but identified as the bis-*p*-nitrobenzaldehyde dihydrazone, m. p. 186—188°.

3-*Hydroxy*-4-N′-*phenylhydrazinotetrahydrothiophen Dioxide*.—3-Bromo-4-hydroxytetrahydrothiophen dioxide (107·5 g.), phenylhydrazine (216 g.), and ethanol (400 ml.) were heated under reflux for 12 hr. The mixture was cooled and filtered and the filtrate evaporated *in vacuo*. The brown residue was washed with ether, treated with an excess of sodium hydroxide, again washed with ether, and extracted with chloroform. Evaporation of the extract gave a discoloured viscous liquid that crystallised from ethanol–ether; the readily oxidised plates of the *phenylhydrazino-compound* (10 g.) had m. p. 140—141° (decomp.) (Found: S, 13·0. $C_{10}H_{14}N_2O_3S$ requires S, 13·2%).

N-*Phenyl*-N′N′-*di*-(4-*hydroxy*-3-*tetrahydrothienyl*)*hydrazine Di*-S-*dioxide*.—3,4-Epoxytetrahydrothiophen dioxide (13·4 g.), phenylhydrazine (12 g.), and phenol (9·4 g.) were heated on a steam-bath for 1 hr. The epoxide slowly dissolved. The mixture was kept at room temperature for several days. The dark red viscous liquid was triturated with ether and crystallised from ethanol. The *trisubstituted hydrazine* (10·7 g.) had m. p. 107—108° (Found: C, 45·2; H, 5·1; N, 7·7; S, 16·6. $C_{14}H_{20}N_2O_6S_2$ requires C, 44·7; H, 5·3; N, 7·45; S, 17·0%).

3-N-*Methylhydrazinotetrahydrothiophen Dioxide* (IV; R = Me).—(a) *By direct addition*. A solution of methylhydrazine sulphate (28·6 g.), sodium hydroxide (16 g.), and 2,3-dihydrothiophen dioxide (12·8 g.) in water (100 ml.) was boiled for 3 hr. and then evaporated to half volume. Dilution with ten volumes of ethanol and decantation separated the sodium sulphate and the addition of concentrated hydrochloric acid then gave 3-N-*methylhydrazinotetrahydrothiophen dioxide hydrochloride* (17·5 g.), m. p. 190° (from aqueous ethanol) (Found: N, 13·9; S, 15·9; Cl, 17·1. $C_5H_{12}N_2O_2S,HCl$ requires N, 13·95; S, 16·0; Cl, 17·65%). With benzaldehyde in aqueous acetic acid it readily gave the *benzaldehyde hydrazone*, m. p. 102° (from aqueous methanol) (Found: N, 10·9; S, 12·6. $C_{12}H_{16}N_2O_2S$ requires N, 11·1; S, 12·7%). The orange-red *hydrazone* with 5-nitro-2-furaldehyde had m. p. 165° (from ethyl acetate–light petroleum) (Found: N, 14·0; S, 11·25. $C_{10}H_{13}N_3O_5S$ requires N, 14·6; S, 11·2%), $\lambda_{max.}$ (ethyl acetate) 277 and 410 mμ (ε 10,500 and 20,000).

(b) *Indirectly*. Addition of 20% aqueous sodium nitrite (100 ml.) to a solution of 3-methylaminotetrahydrothiophen dioxide hydrochloride (50 g.), m. p. 184°, in 2·5N-hydrochloric acid (350 ml.) at 5° gave, almost immediately, a precipitate of 3-(methylnitrosoamino)tetrahydrothiophen dioxide (73%), m. p. 106—107° (Horak and Prochazka [20] give m. p. 104—105°). Zinc dust (25 g.) was added slowly to a solution of this nitroso-compound (15 g.) in 50% aqueous acetic acid (250 ml.) and the mixture was heated for 30 min. at 100° and then filtered. Benzaldehyde was added to the filtrate, and the benzaldehyde *N*-methyl-*N*-(3-tetrahydrothienyl)hydrazone dioxide (62%) was isolated.

3-N′N′-*Dimethylhydrazinotetrahydrothiophen Dioxide*.—*NN*-Dimethylhydrazine (36 g.) was added to 2,3-dihydrothiophen dioxide (17·7 g.) in water (15 ml.) and the mixture was kept at 60° for 30 hr. Excess of dimethylhydrazine was removed on the steam-bath under reduced pressure, and the residue was converted into 3-N′N′-*dimethylhydrazinotetrahydrothiophen dioxide hydrochloride*, m. p. 202—203° (from aqueous ethanol) (Found: C, 33·8; H, 7·0; N, 12·9; S, 15·1. $C_6H_{14}N_2O_2S,HCl$ requires C, 33·55; H, 7·05; N, 13·05; S, 14·95%). The same material was obtained in the presence of traces of potassium hydroxide from butadiene sulphone.

3,3′-*Hydrazotetrahydrothiophen Dioxide* (III; R = 3-tetrahydrothienyl dioxide).—A solution of 3-hydrazinotetrahydrothiophen dioxide (62·5 g.) and 2,3-dihydrothiophen dioxide (24 g.) was refluxed for 3 hr. in water (30 ml.). The *hydrazo-compound* (47 g.) crystallised from the cooled solution, m. p. 187—188° (from acetic acid) (Found: C, 35·7; H, 6·6; N, 10·45; S, 23·8. $C_8H_{16}N_2O_4S_2$ requires C, 35·8; H, 6·0; N, 10·45; S, 23·9%). The hydrochloride had m. p. 217° (decomp.). No reaction was observed with benzaldehyde in dilute acetic acid.

Addition of sodium nitrite (1·3 g.) in water (30 ml.) to a solution at 0° of this hydrazo-compound (5 g.) in N-hydrochloric acid (200 ml.) gave N-*nitroso*-3,3′-*hydrazotetrahydrothiophen dioxide* (4·7 g.), m. p. 132—136° (from just warm aqueous ethanol) (decomp.) (Found: N, 13·8; S, 21·4. $C_8H_{15}N_3O_5S_2$ requires N, 14·15; S, 21·6%). When heated in solvents the nitroso-compound decomposed.

Slow addition of 3,3′-*hydrazotetrahydrothiophen dioxide* (7 g.) to 16% aqueous sodium hypochlorite (50 ml.) at 0—5° afforded 3,3′-*azotetrahydrothiophen dioxide*, m. p. 169—170° (from water) (Found: N, 10·3; S, 24·2. $C_8H_{14}N_2O_4S_2$ requires N, 10·5; S, 24·1%), $\lambda_{max.}$ (chloroform) 362 mμ (ε 19).

NN-*Di*-(3-*tetrahydrothienyl*)*hydrazine Di*-S-*dioxide* (IV; R = 3-tetrahydrothienyl Dioxide).—2,3-Dihydrothiophen dioxide (100 g.), when boiled for 1·5 hr. with aqueous 3-aminotetrahydrothiophen dioxide [1] (500 ml.; 70% w/v) and left to cool overnight, gave *di*-(3-*tetrahydrothienyl*)*amine di*-S-*dioxide* (*ca.* 75 g.), m. p. 132° (from aqueous acetone or glacial acetic acid) (Found: C, 37·5; H, 6·1; S, 25·2. $C_8H_{15}NO_4S_2$ requires C, 37·9; H, 5·95; S, 25·3%). The *acetyl derivative* had m. p. 228—229° (from aqueous ethanol) (Found: C, 40·8; H, 5·9; N, 4·75; S, 21·7. $C_{10}H_{17}NO_5S_2$ requires C, 40·65; H, 5·8; N, 4·75; S, 21·7%). The hydrochloride had m. p. 263° (decomp.) and the nitrate m. p. 216° (decomp.). The amine (25 g.) in 50% aqueous acetic acid (300 ml.) was nitrosated with sodium nitrite (10 g.) at 50° for 10 min. The cooled solution gave N-*nitrosodi*-(3-*tetrahydrothienyl*)*amine di*-S-*dioxide* (9·5 g.), m. p. 167—168° (from aqueous ethanol) (Found: C, 34·2; H, 5·1; N, 9·7; S, 23·1. $C_8H_{14}N_2O_5S_2$ requires C, 34·0; H, 5·0; N, 9·95; S, 22·7%), reduction of which with zinc dust in 50% acetic acid afforded *NN*-di-(3-tetrahydrothienyl)hydrazine di-*S*-dioxide, isolated as the *benzaldehyde*

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[20] V. Horak and M. Prochazka, *Chem. and Ind.*, 1961, 472.

derivative, m. p. 216° (Found: C, 49·7; H, 5·8; N, 7·8; S, 17·8. $C_{15}H_{20}N_2O_4S_2$ requires C, 50·55; H, 5·65; N, 7·85; S, 18·0%).

3-N′-*Phenylhydrazinotetrahydrothiophen Dioxide* (III; R = Ph).—A clear solution of phenylhydrazine (45 ml.) and 2,3-dihydrothiophen dioxide (24 g.) in water (30 ml.) was boiled for 3 hr. Addition of methanol (25 ml.) slowly gave the crystalline *phenylhydrazino-derivative* (20 g.), m. p. 106—108° (from aqueous methanol) (Found: C, 53·7; H, 5·4; N, 12·7; S, 14·1. $C_{10}H_{14}N_2O_2S$ requires C, 53·1; H, 6·2; N, 12·4; S, 14·15%), $\lambda_{\max.}$ (95% ethanol) 206, 241, and 286 mμ (ε 12,500, 11,950, and 2200). It gave no well-defined crystalline product with benzaldehyde in 50% aqueous acetic acid. The *hydrochloride* had m. p. 186° (decomp.) (Found: N, 10·65; S, 12·4; Cl, 13·4. $C_{10}H_{14}N_2O_2S$,HCl requires N, 10·65; S, 12·2; Cl, 13·5%), $\lambda_{\max.}$ (0·1N-HCl) 225 and 273 mμ (ε 6700 and 970).

N-*Phenyl*-N-3-*tetrahydrothienylhydrazine Dioxide* (IV; R = Ph).—A mixture of pure 2,5-dihydrothiophen dioxide (59 g.), phenylhydrazine (59 g.), and 40% sodium hydroxide (0·6 g.; 0·01 equiv.) was kept at 60° for some hours; when it had set solid it was recrystallised from ethanol to give the *disubstituted hydrazine* (96%), m. p. 119—120° (Found: C, 53·1; H, 6·4; N, 12·4; S, 14·2. $C_{10}H_{14}N_2O_2S$ requires C, 53·1; H, 6·2; N, 12·4; S, 14·15%), $\lambda_{\max.}$ (95% ethanol) 206, 248, and 287 mμ (ε 13,000, 13,100 and 1650). The hydrochloride had m. p. 184—186°, $\lambda_{\max.}$ (0·1N-HCl) 230infl and 260 (ill-defined) mμ (ε *ca.* 2000 and 460). This hydrazine did not give a solid hydrazone with benzaldehyde, but with 2,4-dinitrobenzaldehyde it gave a *hydrazone*, m. p. 179—182° (from ethanol) (Found: C, 50·4; H, 4·1; N, 14·15; S, 7·75. $C_{17}H_{16}N_4O_6S$ requires C, 50·5; H, 3·9; N, 13·85; S, 7·9%), and with *p*-dimethylaminobenzaldehyde a *hydrazone*, m. p. 100—102° (from 80% aqueous ethanol) (Found: C, 63·8; H, 6·7; N, 11·7; S, 8·9. $C_{19}H_{23}N_3O_2S$ requires C, 63·8; H, 6·5; N, 11·7; S, 9·0%).

N-m-*Chlorophenyl*-N-3-*tetrahydrothienylhydrazine Dioxide* (IV; R = *m*-Cl·C_6H_4).—2,5-Dihydrothiophen dioxide (6 g.) and *m*-chlorophenylhydrazine (8 g.) were heated at 60° for 24 hr. The brown tar obtained gave the *product* (50%), m. p. 98—99° (from ethyl acetate–light petroleum) (Found: C, 46·3; H, 5·2; Cl, 13·8; N, 10·8; S, 12·3. $C_{10}H_{13}ClN_2O_2S$ requires C, 46·1; H, 5·0; Cl, 13·6; N, 10·7; S, 12·3%).

3-N′-*Phenylhydrazino*-2,3-*dihydrothiophen Dioxide*.—3,4-Dichlorotetrahydrothiophen dioxide (142 g.), m. p. 123°, was added during 20 min. to a stirred mixture of phenylhydrazine (165 ml.) and 3% aqueous sodium hydroxide (2 l.). After 2 hr. the product was collected, washed, dried, and recrystallised from alcohol. The *phenylhydrazino-compound* (66%) had m. p. 139—140° (Found: C, 53·6; H, 5·5; N, 12·4; S, 14·4. $C_{10}H_{12}N_2O_2S$ requires C, 53·55; H, 5·4; N, 12·5; S, 14·3%), $\lambda_{\max.}$ (alcohol) 245 and 283 mμ (ε 13,500 and 2100) almost identical with those of (III; R = Ph). Oxidation of the phenylhydrazino-compound (5 g.) in acetic acid (25 ml.) with hydrogen peroxide (10 ml.; 100 vol.) gave, within 3 hr., the yellow 4-*phenylazo*-2,3-*dihydrothiophen dioxide*, m. p. 192° (decomp.) (from alcohol) (Found: N, 12·3; S, 14·3. $C_{10}H_{10}N_2O_2S$ requires N, 12·6; S, 14·4%), $\lambda_{\max.}$ (95% ethanol) 204, 249, 288, 298, and 353 mμ (ε 7250, 11,500, 3500, 3500, and 21,500), different from 3-phenylazotetrahydrothiophen dioxide * [$\lambda_{\max.}$ 216, 271, and 396 mμ (ε 10,000, 9800, and 200)].

1-(3-*Tetrahydrothienyl*)*benzotriazole Dioxide* (VI).—Technical 2,5-dihydrothiophen dioxide (118 g.) and benzotriazole (119 g.) were briefly warmed in 6·5% aqueous potassium hydroxide (1 l.) and set aside for 14 days. The crystalline *benzotriazole* (VI) (33 g.) was collected and washed with water, and gave needles, m. p. 160° (from aqueous ethanol) (Found: N, 17·4; S, 13·5. $C_{10}H_{11}N_3O_2S$ requires N, 17·7; S, 13·5%), $\lambda_{\max.}$ 209, 255, and 283 mμ (ε 11,000, 6500, and 4800). When boiled with mixed concentrated nitric (58 ml.) and hydrochloric (175 ml.) acids for 5 min. this substance afforded, from the cooled solution, 4,5,6,7-*tetrachloro*-1-(3-*tetrahydrothienyl*)*benzotriazole dioxide*, m. p. 212—213° (from acetic acid) (Found: Cl, 38·3; N, 11·3; S, 8·6. $C_{10}H_7Cl_4N_3O_2S$ requires Cl, 37·8; N, 11·2; S, 8·55%), $\lambda_{\max.}$ 217, 266infl., and 305 mμ (ε 38,000, 8000, and 5500).

2-(3-*Tetrahydrothienyl*)*benzotriazole Dioxide* (VII).—When boiled for 2 hr., a solution of benzotriazole (12 g.) and 2,3-dihydrothiophen dioxide (12 g.) in 0·5% aqueous potassium hydroxide (100 ml.) gave an oil that crystallised when cool to give the *benzotriazole* (VII) (12 g.), m. p. 135° (from ethanol) (Found: C, 50·7; H, 5·0; N, 17·6; S, 13·5. $C_{10}H_{11}N_3O_2S$ requires C, 50·7; H, 4·7; N, 17·7; S, 13·5%), $\lambda_{\max.}$ 211, 263, and 279 mμ (ε 12,500, 6300, and 8000). The corresponding tetrachloro-compound was obtained when a mixture of 2,3-dihydrothiophen dioxide (5 g.), 4,5,6,7-tetrachlorobenzotriazole (5 g.), and water (50 ml.) was kept overnight with sufficient potassium hydroxide to give a clear solution initially. 4,5,6,7-*Tetrachloro*-2-(3-*tetrahydrothienyl*)*benzotriazole dioxide* (5 g.) separated overnight, m. p. 203—204° (from acetic acid) (Found: Cl, 38·3. $C_{10}H_7Cl_4N_3O_2S$ requires Cl, 37·8%), $\lambda_{\max.}$ 215, 266, and 305 mμ (ε 35,000, 8200, and 5500). Mixed m. p. with the isomeric 1-(3-tetrahydrothienyl) dioxide (m. p. 212—213°), 185—195°.

Reactions of 3-*Hydrazinotetrahydrothiophen Dioxide*

3-Hydrazinotetrahydrothiophen dioxide with acetone gave the hydrazone, m. p. 87—88° (from n-propanol). It readily formed salts, recrystallisable from ethanol: picrate, m. p. 134—136°; hydrochloride, m. p. 153—155°; nitrate, m. p. 124—125°.

The *mono-hydrazone* with benzil had m. p. 123—125° (from methanol) (Found: C, 62·4; H, 5·5; N, 8·0; S, 9·4. $C_{18}H_{18}N_2O_3S$ requires C, 63·15; H, 5·3; N, 8·2; S, 9·35%). The red *hydrazone* with 5-nitro-2-furaldehyde had m. p. 126—129° (decomp.) (from acetic acid) (Found: C, 39·6; H, 4·5; N, 14·6; S, 12·0. $C_9H_{11}N_3O_5S$ requires C, 39·6; H, 4·0; N, 15·4; S, 11·7%), $\lambda_{\max.}$ (ethyl acetate) 274 and 392 mμ (ε 9800 and 16,000).

3-Hydrazinotetrahydrothiophen dioxide (7·5 g.) with benzenesulphonyl chloride (9 g.) (added dropwise) in aqueous sodium hydroxide below 5° gave the benzenesulphonohydrazide which crystallised slowly from the acidified mixture, m. p. 146—147° (decomp.). The analogous *isonicotinoyl hydrazide* had m. p. 150° (from ethanol) (Found: C, 47·1; H, 5·5; N, 16·4; S, 12·6. $C_{10}H_{13}N_3O_3S$ requires C, 47·0; H, 5·1; N, 16·45; S, 12·55%), hydrochloride described by Loev.[3]

3-Hydrazinotetrahydrothiophen dioxide hydrochloride with maleic anhydride in boiling water gave the sparingly soluble cyclic N-(3-*tetrahydrothienyl*)*maleic hydrazide dioxide*, m. p. 274—275° (Found: C, 42·0; H, 4·7; N, 12·3; S, 14·0. $C_8H_{10}N_2O_4S$ requires C, 41·7; H, 4·4; N, 12·2; S, 13·9%).

3-Hydrazinotetrahydrothiophen dioxide (15 g.) with ethyl

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* First prepared from (III; R = Ph) by D. Hughes and G. T. Newbold at Chesterford Park Research Station.

cyanoacetate (11·3 g.) at 100°, for 3 hr. gave 2-*cyano*-N′-3-*tetrahydrothienylacetohydrazide dioxide* (13 g.), m. p. 146—148° (from methanol) (Found: C, 38·7; H, 5·5; N, 19·0; S, 14·6. $C_7H_{11}N_3O_3S$ requires C, 38·7; H, 5·7; N, 19·35; S, 14·75%).

3-Hydrazinotetrahydrothiophen dioxide hydrochloride (10 g.) was kept with sodium cyanate (3·5 g.) in water (100 ml.) at room temperature for 3 hr. The solution was evaporated to dryness, and the residue extracted with hot ethanol. The liquid, when cooled, afforded 1-(3-*tetrahydrothienyl*)*semicarbazide* S-*dioxide*, m. p. 165° (from aqueous ethanol) (Found: N, 21·3; S, 16·9. $C_5H_{11}N_3O_3S$ requires N, 21·75; S, 16·6%). Analogously prepared 1-(3-*tetrahydrothienyl*)*thiosemicarbazide dioxide* had m. p. 132° (Found: N, 19·1; S, 30·4. $C_5H_{11}N_3O_2S_2$ requires N, 20·05; S, 30·65%). The latter with acetone in dilute acetic acid gave the thiosemicarbazone, m. p. 181° (decomp.).

Cyclic Derivatives from 3-*Hydrazinotetrahydrothiophen Dioxide*.— 3-*Methyl*-5-*pyrazolones*. 3-Hydrazinotetrahydrothiophen dioxide (10 g.) and ethyl acetoacetate (9 ml.) reacted vigorously when warmed; the mixture set to the solid 3-*methyl*-1-(3-*tetrahydrothienyl*)-5-*pyrazolone* S-*dioxide* (42%), m. p. 211—212° (Found: N, 12·8; S, 14·9. $C_8H_{12}N_2O_3S$ requires N, 12·95; S, 14·85%), readily methylated with dimethyl sulphate in methanolic sodium hydroxide; the product, continuously extracted from aqueous solution with chloroform, crystallised slowly when the chloroform had been removed to give 2,3-*dimethyl*-1-(3-*tetrahydrothienyl*)-5-*pyrazolone* S-*dioxide*, m. p. 108—110° (Found: C, 46·8; H, 6·5; N, 12·4; S, 14·1. $C_9H_{14}N_2O_3S$ requires C, 46·95; H, 6·15; N, 12·15; S, 13·9%).

3-*Methyl*-1-(3-*tetrahydrothienyl*)*pyridazinone* S-*Dioxide*.—A solution of 3-hydrazinotetrahydrothiophen dioxide (15 g.) and laevulinic acid (11·6 g.) in ethanol (100 ml.) was boiled for 24 hr., then cooled. The *pyridazinone* (21 g.) crystallised, m. p. 149° (from ethanol) (Found: C, 46·8; H, 5·7; S, 13·95. $C_9H_{14}N_2O_3S$ requires C, 46·95; H, 6·15; S, 13·9%).

3,5-*Dimethyl*-2-(3-*tetrahydrothienyl*)*pyrazole* S-*Dioxide*.—Acetylacetone (11 g.) was added dropwise to 3-hydrazinotetrahydrothiophen dioxide (15 g.). A vigorous exothermic reaction ensued. The mixture was therefore diluted with ethanol (25 ml.); when reaction was complete the solid *pyrazole* (20 g.) was collected, m. p. 109—110° (from ethanol) (Found: C, 50·2; H, 6·5; N, 13·0; S, 14·8. $C_9H_{14}N_2O_2S$ requires C, 50·45; H, 6·6; N, 13·05; S, 14·9%). The base readily formed salts crystallisable from ethanol: hydrochloride, m. p. 204—206°; sulphate, m. p. 195—197°; nitrate, m. p. 124° (decomp.); and picrate, m. p. 155—157°.

3-*Methyl*-2-(3-*tetrahydrothienyl*)*pyrazolidin*-5-*one* S-*Dioxide*.—3-Hydrazinotetrahydrothiophen dioxide (15 g.) was heated with crotonic acid (8·6 g.) at 100° for 30 min. to give a viscous liquid which distilled at up to 220°/0·5 mm. and set to an amber glass (17 g.). The *pyrazolidinone* was microcrystalline, m. p. 122—124° (from ethanol) (Found: C, 43·3; H, 6·3; N, 12·7; S, 14·6. $C_8H_{14}N_2O_3S$ requires C, 44·0; H, 6·45; N, 12·85; S, 14·7%). In alcoholic solution it readily formed a hydrochloride, m. p. 206—208°, and a sulphate, m. p. 258—259° (decomp.). It did not react with 2,4-dinitrophenylhydrazine and gave no solid picrate (in benzene or ethanol).

3-(2-*Dimethylaminoethyl*)-5-*phenyl*-1-(3-*tetrahydrothienyl*)-*pyrazoline Dioxide*.—An alcoholic solution of 5-dimethylamino-1-phenylpent-1-en-3-one hydrochloride (2·5 g.) and 3-hydrazinotetrahydrothiophen dioxide (1·5 g.) containing acetic acid (1·5 ml.) was kept overnight and then evaporated to dryness. The viscous residue gave silky needles (2·0 g.) of the *substituted pyrazoline hydrochloride*, m. p. 98—100° (from ethanol) (Found: C, 54·4; H, 7·4; N, 11·4; S, 8·5; Cl, 9·8. $C_{17}H_{25}N_3O_2S$,HCl requires C, 54·9; H, 7·05; N, 11·3; S, 8·6; Cl, 9·55%).

O-(3-*Tetrahydrothienyl*)*hydroxylamine Dioxide* (VIII).—Hydroxylamine hydrochloride (30 g.) and 2,5-dihydrothiophen dioxide (40 g.) were kept for several days with benzaldehyde (40 ml.) in aqueous sodium hydroxide (28 g. in 130 ml.). The heavy oil which separated initially solidified slowly and gave the *benzaldehyde oxime* (IX; R^1 = H, R^2 = Ph) (40 g.) as needles, m. p. 90° (Found: S, 13·6. $C_{11}H_{13}NO_3S$ requires S, 13·4%). Analogous reactions with acetone instead of benzaldehyde afforded an uncrystallisable oil (IX; $R^1 = R^2$ = Me). Hydrolysis of either the oil or the solid benzaldehyde derivative with concentrated hydrochloric acid (4 vol.) at 100° for 1 hr. and removal of the carbonyl compound by evaporation or extraction with chloroform gave O-(3-*tetrahydrothienyl*)*hydroxylamine dioxide hydrochloride*, m. p. 188° (from alcohol) (Found: C, 25·7; H, 4·8; N, 7·3; S, 16·8; Cl, 18·8. $C_4H_9NO_3S$,HCl requires C, 25·6; H, 5·35; N, 7·45; S, 17·1; Cl, 18·9%). The buff-coloured 5-*nitro*-2-*furaldehyde oxime* had m. p. 106—107° (from dil. acetic acid) (Found: C, 39·9; H, 3·3; N, 9·95; S, 11·5. $C_9H_{10}N_2O_6S$ requires C, 39·4; H, 3·7; N, 10·2; S, 11·7%), $\lambda_{max.}$ (ethyl acetate) 333 mμ (ε 15,000).

Michael Reactions

Method A.—The donor (1 mole) was dissolved in a solution of sodium (1 mole) in ethanol, and the dihydrothiophen dioxide (1 mole) was added slowly, with stirring. The solution was refluxed for 1—5 hr., cooled, and diluted with water containing acetic acid. It was then continuously extracted with ether or dichloromethane and the extract was dried ($MgSO_4$) and evaporated. The residue was purified by recrystallisation or distillation.

Method B.—The dihydrothiophen dioxide (1 mole) and the donor (1 mole) were dissolved in benzene and mixed with a solution of sodium (0·3 mole) in ethanol. The solution was set aside at room temperature for 2—5 days and worked up as in Method A; benzene was used to extract the aqueous phase.

Method C.—Equimolar amounts of donor and the dihydrothiophen dioxide in ethanol were stirred for 15—17 hr. under reflux with Amberlite IRA-400 (OH^-) (80 g. per mole of donor). The resin was then filtered off and washed with hot ethanol. The combined filtrate and washings were either cooled to precipitate the product, or were evaporated and the residue was recrystallised or distilled.

When nitroparaffins were used as donors, 10 moles per mole of dihydrothiophen dioxide were used to minimise formation of the bis-adducts. The products were usually oils, which eventually crystallised.

The bis-adduct (XVI; R = H), prepared from equimolar amounts of nitromethane and 2,3-dihydrothiophen dioxide, precipitated during the reflux period. The resin and product were filtered off and Soxhlet-extracted with water. The aqueous extract was evaporated and the product crystallised out.

The uncrystallisable oily residue obtained from nitroethane and 3-acetoxy-2,3-dihydrothiophen dioxide was dissolved in aqueous ethanol and kept overnight; starting material crystallised out. The filtrate was evaporated and the residue was dissolved in the minimum of aqueous ethanol and set aside for 7 days, during which time the product crystallised.

Preparation of 3-*Ethoxycarbonylmethyl*-2,3-*dihydrothiophen Dioxide*.—To a cooled solution of sodium (46 g.) and diethylmalonate (350 g.) in dry ethanol (1·5 l.) was added 3,4-dibromotetrahydrothiophen dioxide (278 g.) in portions, so that the temperature remained below 20°. The mixture was kept for 115 hr., the solid was collected and the filtrate was evaporated under reduced pressure. The solid was freed from sodium bromide by washing with water. The washings, combined with the original filtrate, were extracted with ether and the extract was dried and evaporated. The residue was distilled *in vacuo* and diethyl malonate (158 g.) was recovered; the residue (67 g.) crystallised. The original solid (207 g.) and this residue afforded 3-*diethoxycarbonylmethyl*-2,3-*dihydrothiophen dioxide* (229 g.), m. p. 74—75° (from ethanol) (Found: C, 47·6; H, 6·1; S, 11·6. $C_{11}H_{16}O_6S$ requires C, 47·8; H, 5·9; S, 11·6%). With hydrazine hydrate in boiling ethanol it gave the *bishydrazide*, m. p. 228—229° (Found: C, 33·9; H, 5·0; N, 22·7; S, 12·85. $C_7H_{12}N_4O_4S$ requires C, 33·9; H, 4·85; N, 22·6; S, 12·9%). When hydrolysed with boiling 15% hydrochloric acid, the substituted malonate (265 g.) gave 3-*carboxymethyl*-2,3-*dihydrothiophen dioxide* (122 g.), m. p. 122—124° (Found: C, 40·5; H, 4·3; S, 18·3%; Equiv., 184. $C_6H_8O_4S$ requires C, 40·9; H, 4·6; S, 18·2%; Equiv., 176). The *ethyl ester*, prepared by the usual azeotropic distillation technique, had b. p. 163°/0·1 mm., n_D^{18} 1·4930.

Lactone of 3-*Carboxymethyl*-4-*hydroxytetrahydrothiophen Dioxide* (XVII).—Attempts to add nitroalkanes to the free acid, 3-carboxymethyl-2,3-dihydrothiophen dioxide were unsuccessful; the product was the *lactone* of 3-carboxymethyl-4-hydroxytetrahydrothiophen dioxide. This lactone could also be obtained by refluxing the acid (4·4 g.) in water (30 ml.) for 24 hr. The residue after evaporation of the water gave the pure lactone (2·9 g., 66%), m. p. 160—162° (from water) (Found: C, 41·0; H, 4·7; S, 18·1%; equiv. 170. $C_6H_8O_4S$ requires C, 40·9; H, 4·55; S, 18·2%; equiv. 176). With hydrazine hydrate (2·5 ml.) the lactone (2·2 g.) exothermically gave the *hydrazide* of 3-carboxymethyl-4-hydroxytetrahydrothiophen dioxide, m. p. 141—142° (from methanol) (Found: C, 34·8; H, 5·9; N, 13·45; S, 15·35. $C_6H_{12}N_2O_4S$ requires C, 34·6; H, 5·8; N, 13·45; S, 15·4%).

Reactions of Michael Adducts

3-*Carboxymethyltetrahydrothiophen Dioxide* (X; $R^1 = H$, $R^2 = CO_2H$).—(*a*) Hydrolysis of 3-diethoxycarbonylmethyltetrahydrothiophen dioxide (X; $R^1 = R^2 = CO_2Et$) (28 g.) with boiling 19% hydrochloric acid (50 ml.) for 2—3 hr. gave the acid (X) (17 g., 96%). m. p. 88·5—89·5° (from ethyl acetate) (Found: C, 40·4; H, 5·5; S, 17·8. Calc. for $C_6H_{10}O_4S$: C, 40·4; H, 5·65; S, 18·0%). (Faith *et al.*[4] give m. p. 88—90°.) The *benzylammonium salt* had m. p. 134—136° (Found: N, 4·6. $C_{13}H_{19}NO_4S$ requires N, 4·9%). The *hydrazide* (prepared from the ethyl ester; cf. Table 4) had m. p. 109—110° (Found: C, 37·65; H, 6·5; N, 14·3; S, 16·9. $C_6H_{12}N_2O_3S$ requires C, 37·5; H, 6·3; N, 14·6; S, 16·7%). The bright yellow condensation product of this hydrazide with 5-nitro-2-furaldehyde had m. p. 189—191° (from dil. acetic acid) (Found: C, 41·6; H, 4·5; N, 13·35; S, 9·85. $C_{11}H_{13}N_3O_6S$ requires C, 41·9; H, 4·2; N, 13·3; S, 10·2%), $\lambda_{max.}$ (0·2% aqueous acetic acid) 261 and 363 mμ (ε 11,500 and 19,500).

(*b*) 3-Cyano(ethoxycarbonyl)methyltetrahydrothiophen dioxide (X; $R^1 = CN$, $R^2 = CO_2Et$) (12 g.) was added to a solution of potassium hydroxide (2·8 g.) in aqueous ethanol (110 ml., 90%); the temperature was kept at 60° for 2 hr. The cooled solution was kept overnight and the ethyl alcohol was removed *in vacuo*; the residue was carefully acidified with dilute hydrochloric acid and the solution exhaustively extracted with ether. Drying and evaporation of the combined ether extracts afforded the acid (*ca.* 1 g.), m. p. and mixed m. p. with product of (*a*) 88—89°.

Under milder conditions with aqueous sodium hydroxide, hydrolysis afforded 3-dicarboxymethyltetrahydrothiophen dioxide, m. p. 155—156° (decomp.) (from ethyl acetate). (Faith *et al.*[4] give m. p. 166°, determined by a special technique.)

3-(1-*Carboxyethyl*)*tetrahydrothiophen Dioxide*.— 3-Diethoxycarbonyl(methyl)methyltetrahydrothiophen dioxide (36 g.) was refluxed for 12 hr. with 20% hydrochloric acid (120 ml.). The solution was evaporated to dryness *in vacuo*, water (100 ml.) was added, and the solution was evaporated again. The residue slowly solidified to a waxy solid (20 g.), purified by extraction with ether to give the *acid* (5·5 g.), m. p. 107—109° (from ethyl acetate) (Found: C, 43·8; H, 6·2%; Equiv., 193. $C_7H_{12}O_4S$ requires C, 43·7; H, 6·3%; Equiv., 192). From the ether washings a second acid was isolated, m. p. 60—62°, probably a different crystalline form of the first. The *benzylamine salt* of the form of m. p. 107—109° had m. p. 145° (Found: N, 4·55. $C_{14}H_{21}NO_4S$ requires N, 4·7%).

3-(1-*Carboxybenzyl*)*tetrahydrothiophen Dioxide* (X; $R^1 = Ph$, $R^2 = CO_2H$).—(*a*) 3-(1-Cyanobenzyl)tetrahydrothiophen dioxide (X; $R^1 = Ph$, $R^2 = CN$) (2·35 g.) was refluxed for 4 hr. with concentrated hydrochloric acid (25 ml.). The solid gradually dissolved to give a clear solution and after further heating a solid slowly separated, which gave needles of the carboxybenzyl compound (1·8 g., 71%), m. p. 191—192° (from water) (Found: C, 56·6; H, 5·4; S, 12·5. Calc. for $C_{12}H_{14}O_4S$: C, 56·7; H, 5·55; S, 12·6%). (Faith *et al.*[4] give m. p. 195—196° for this acid, obtained from the phenylmalonate in 45% yield.)

3-*Cyanomethyltetrahydrothiophen Dioxide* (XIV; $R = CN$).—3-t-Butoxycarbonylcyanomethyltetrahydrothiophen dioxide (X; $R^1 = CN$, $R^2 = CO_2Bu^t$) (51·8 g. crude) and toluene-*p*-sulphonic acid (0·8 g., 0·015 mol.) were heated in an oil-bath at 250—270°/40—50 mm. for several hours and then distilled by reducing the pressure. An orange oil (16 g., 50%), collected at 200—210°/0·8—1 mm., eventually solidified and afforded the *cyanomethyl compound* (10 g.), m. p. 117·5—118·5° (from ethanol) (Found: N, 8·7; S, 20·1. $C_6H_9NO_2S$ requires N, 8·8; S, 20·1%).

3-(2-*Oxopropyl*)*tetrahydrothiophen Dioxide* (XIV; $R = Ac$).—(*a*) 3-Acetyl(ethoxycarbonyl)methyltetrahydrothiophen dioxide (XIII) was added to aqueous sodium hydroxide (150 ml., 5%) and kept overnight. Then 50% sulphuric acid (15 ml.) was added dropwise. When the vigorous evolution of carbon dioxide had moderated the solution was warmed gently until gas evolution ceased. The cooled solution was continuously extracted with dichloromethane for 24 hr. The extract was dried and evaporated and the residue was distilled *in vacuo*; it gave a liquid (10 g.), b. p. 170°/0·4 mm., which solidified when cooled and afforded 3-(2-oxopropyl)tetrahydrothiophen dioxide, m. p. 41—43° (from ethanol) (Found: C, 47·8; H, 7·0; S, 18·2. Calc. for $C_7H_{12}O_3S$: C, 47·7; H, 6·9; S, 18·2%). (Faith *et al.*[4] give m. p. 43—44°, but no analysis.)

The 2,4-dinitrophenylhydrazone had m. p. 175° (decomp.). (lit.,[4] 175—176°).

(*b*) 2,5-Dihydrothiophen dioxide (50 g.) was dissolved in acetone (250 ml.) and aqueous benzyltrimethylammonium hydroxide (20 ml., 40%) was added. The solution was refluxed for 2 hr., cooled, and the separated solid was filtered off. It gave 2,5-di-isopropylidene-2,5-dihydrothiophen dioxide (4·5 g.), m. p. 266° (cf. Backer and Strating[1]). The filtrate was heated on a steam-bath *in vacuo*, and the viscous residue on an oil-bath in a high vacuum. After much decomposition a fraction was obtained, b. p. 170°/0·8 mm., which slowly solidified and gave a 2,3-dihydrothiophen dioxide, m. p. 49—51° (from ethanol) (identified by mixed m. p. and i.r. evidence). None of the desired[11] material (XIV; R = Ac) was obtained.

Nef Reactions.—In general a solution of the nitroalkyltetrahydrothiophen dioxide (1 mole) in 1·7N-sodium hydroxide in 18% v/v aqueous ethanol (1 l.) was slowly added to 17N-sulphuric acid (1·6 l.) at −15° with stirring. The blue solution was kept at room temperature until the colour had disappeared and was then continuously extracted with chloroform or dichloromethane. Evaporation of the solvent usually gave an oil which rapidly crystallised.

3-*Formyltetrahydrothiophen Dioxide* (XIX; R = H).—The product from Nef reaction on 3-nitromethyltetrahydrothiophen dioxide was a yellow oil, distillation of which (accompanied by some decomposition) gave an oil, b. p. 160—170°/2·5 mm. Its 2,4-dinitrophenylhydrazone, m. p. 196—198° (Found: C, 40·0; H, 3·8; N, 16·9; S, 9·9. $C_{11}H_{12}N_4O_6S$ requires C, 40·2; H, 3·7; N, 17·1; S, 9·8%), had an analysis consistent with the presence of at least 72% of 3-formyltetrahydrothiophen dioxide. With ethylene glycol the distillate gave the acetal, 2-(3-*tetrahydrothienyl*)-1,3-*dioxolan dioxide*, m. p. 65—66° (Found: C, 43·2; H, 6·5; S, 16·6. $C_7H_{12}O_4S$ requires C, 43·7; H, 6·3; S, 16·7%). Azeotropic distillation of the chloroform extract with ethanol and benzene containing a trace of toluene-*p*-sulphonic acid gave the *diethyl acetal* of 3-formyltetrahydrothiophen dioxide, b. p. 135—138°/0·6 mm., n_D^{19} 1·4719 (Found: C, 48·3; H, 8·0; S, 14·8. $C_9H_{18}O_4S$ requires C, 48·6; H, 8·1; S, 14·4%). The acetal was readily hydrolysed by boiling 3% hydrochloric acid (30 min.) or by 3% mineral acid in 50% aqueous dioxan (at room temperature overnight). Hydrolysis was proved by i.r. spectroscopy, but distillation did not give 3-formyltetrahydrothiophen dioxide of high purity.

Hydrogenation of Nitroalkyltetrahydrothiophen Dioxides.—The nitroalkyltetrahydrothiophen dioxide (25 g.) in ethanol (500 ml.) was hydrogenated over Raney nickel (*ca.* 10 g.) at 50 lb./sq. in. and 50° for 2 hr. The solution was filtered and evaporated *in vacuo*. The amine was isolated as the hydrochloride (by adding conc. hydrochloric acid) or the oxalate (by adding ethanolic oxalic acid).

Lactam of 3-(1-*Aminoethyl*)-4-*carboxymethyltetrahydrothiophen Dioxide*.—Reduction of 3-ethoxycarbonylmethyl-4-(1-nitroethyl)tetrahydrothiophen dioxide gave a crystalline solid (33%), m. p. 249—251° (from methanol). The infrared spectrum and elemental analysis were consistent with it being the *lactam* (Found: C, 47·0; H, 6·5; N, 6·8; S, 15·5. $C_8H_{13}NO_3S$ requires C, 47·3; H, 6·4; N, 6·9; S, 15·8%).

3-*Cyanotetrahydrothiophen Dioxide and Derivatives*

3-*Cyanotetrahydrothiophen Dioxide*.— 2,3-Dihydrothiophen dioxide (118 g.), hydrocyanic acid (54 ml.), and potassium cyanide (1·75 g.) or Amberlite IRA-400 resin (OH^-) (80 g.) were stirred under reflux (at 50°) for 2 hr. The catalyst was neutralised by the addition of glacial acetic acid (2 ml.) or filtered off, and the excess of hydrogen cyanide was removed by passing nitrogen through the apparatus at 50°. The residue was boiled with methanol (250 ml.) and filtered hot. It was then Soxhlet-extracted with methanol for 15 hr. The extracts were combined, treated with charcoal, cooled, and filtered to give 3-cyanotetrahydrothiophen dioxide (53—58 g., 37—40%), m. p. 119—120° (from methanol) (Found: C, 41·3; H, 5·0; N, 9·4; S, 22·5. Calc. for $C_5H_7NO_2S$: C, 41·4; H, 4·8; N, 9·65; S, 22·1%). (Faith *et al.*[4] give m. p. 118—119°; Kurtz[12] gives m. p. 118°.)

3-*Acetoxy*-4-*cyanotetrahydrothiophen Dioxide*.—A solution of 3-hydroxy-2,3-dihydrothiophen dioxide (24 g.) in hydrocyanic acid (20 g.) was stirred under reflux at 40—45° for 2 hr. in the presence of Amberlite IRA-400 (OH^-) (20 g.). Acetic acid (2 g.) was then added and the excess of hydrogen cyanide was removed in a nitrogen stream at 50°. The residue was dissolved in pyridine (minimum), filtered, and acetylated with acetyl chloride (8 g.). Addition of water and concentration of the soution gave 3-*acetoxy*-4-*cyanotetrahydrothiophen dioxide* (3 g.), m. p. 141—143° (from ethanol) (Found: C, 41·4; H, 4·7; N, 7·0; S, 15·5. $C_7H_9NO_4S$ requires C, 41·4; H, 4·4; N, 6·9; S, 15·8%), also obtained in poor yield directly from 3-acetoxy-2,3-dihydrothiophen dioxide and hydrogen cyanide, with potassium cyanide as catalyst.

3-*Carboxytetrahydrothiophen Dioxide*.—(*a*) 3-Cyanotetrahydrothiophen dioxide (145 g.) was refluxed with concentrated hydrochloric acid (350 ml.) for 18 hr. The reaction mixture was cooled to room temperature and the crude acid was filtered off (158 g.). It was boiled with ethyl acetate and the hot solution was filtered to remove ammonium chloride and cooled. 3-Carboxytetrahydrothiophen dioxide (127 g.), m. p. 139—141°, was deposited (Found: C, 36·8; H, 5·1; S, 19·6. Calc. for $C_5H_8O_4S$: C, 36·60 H, 4·9; S, 19·5%). (Faith *et al.*[4] give m. p. 141—142°.) The p-*nitrobenzyl ester* had m. p. 77—78° (Found: C, 47·7; H, 5·0; N, 4·5; S, 10·7. $C_{12}H_{13}NO_6S$ requires C, 48·15; H, 4·3; N, 4·7; S, 10·7%). The *hydrazide* had m. p. 71—72° (from aqueous propan-2-ol) (Found: C, 33·4; H, 6·1; N, 15·3; S, 17·7. $C_5H_{10}N_2O_3S$ requires C, 33·7; H, 5·6; N, 15·7; S, 18·0%). This hydrazide with 5-nitro-2-furaldehyde gave the *substituted hydrazone* as bright yellow prisms, m. p. 231—232° (from dil. acetic acid) (Found: N, 13·85; S, 10·6. $C_{10}H_{11}N_3O_6S$ requires N, 13·95; S, 10·6%), $\lambda_{max.}$ (ethyl acetate) 255 and 363 mμ (ε 11,500 and 15,400).

(*b*) Aqueous potassium permanganate (*ca.* 90 ml.; N) was added in 10 ml. portions to a stirred solution of 3-formyltetrahydrothiophen dioxide (XIX; R = H) (2 g.) in 0·5N-sodium hydroxide (20 ml.). After 1 hr. the solid was collected and washed with 0·5N-sodium hydroxide (2 × 20 ml.). The combined filtrate and washing were freed from cations with Zeo-Karb 225, and evaporated to a yellow oil which partly solidified. Extraction with boiling dichloromethane, followed by evaporation of the solvent gave 3-carboxytetrahydrothiophen dioxide (0·7 g.), m. p. and mixed m. p. 139—141° (from ethyl acetate).

Esters of 3-*Carboxytetrahydrothiophen Dioxide*.—Crude 3-carboxytetrahydrothiophen dioxide (calculated to contain 1 mole of pure acid), the appropriate alcohol (1·5 mole), toluene (250 ml.), and concentrated sulphuric acid (1·5 ml.)

were refluxed through a Dean and Stark still-head, until no more water separated. The solution was filtered hot to remove ammonium salts and the excess of solvent was evaporated off. The residue was dissolved in ethyl acetate and the ammonium salts were filtered off. The ethyl acetate was evaporated off and the residue was either distilled or crystallised. The results are summarised in Table 8.

3-*Hydroxymethyltetrahydrothiophen Dioxide*.—3-Ethoxycarbonyltetrahydrothiophen dioxide (38·4 g.) was dissolved in sodium-dried ether (150 ml.) and stirred. A suspension of lithium aluminium hydride (5·67 g.) in sodium-dried ether (150 ml.) was added dropwise at such a rate as to maintain a continuous reflux (*ca.* 30 min.). The mixture was refluxed for 1 hr. more and then worked up. Evaporation of the chloroform extract gave the *hydroxymethyl compound* as an oil (30 g., 100%), b. p. 184—186°/0·4 mm., n_D^{20} 1·5035 (Found: C, 39·75; H, 6·7; S, 21·65. $C_5H_{10}O_3S$ requires C, 40·0; H, 6·7; S, 21·35%). The *benzoate* had m. p. 92·5—94·5° (from methanol) (Found: C, 56·7; H, 5·7; S, 12·55. $C_{12}H_{14}O_4S$ requires C, 56·7; H, 5·6; S, 12·6%).

Reactions under Acidic Conditions

3-*Iodotetrahydrothiophen Dioxide*.—A mixture of 2,3-dihydrothiophen dioxide (10 g.) and 55% hydriodic acid (50 ml.) was boiled for 1 hr.; the cooled mixture was extracted with dichloromethane and dried, and the solvent was removed to leave the iodo-compound (83%), m. p. 95—96° (Found: I, 51·3. Calc. for $C_4H_7IO_2S$: I, 51·55%). Faith *et al.*[4] prepared this from the bromo-compound and sodium iodide (73%) and give m. p. 96—97°.

Halogenohydrins of Dihydrothiophen Dioxides from their Nitrate Esters.— 2-*Chloro*-3-*hydroxytetrahydrothiophen dioxide*. 2,3-Dihydrothiophen dioxide (5 g.) was added to 40% aqueous nitric acid (40 ml.) cooled to *ca.* 18°. Moist chlorine was then passed through the stirred solution (below 10°) until saturation was reached. The crystalline *nitrate ester* (6 g.) which separated was collected, m. p. 89° (from ethanol) (Found: C, 22·1; H, 2·45; Cl, 16·3; N, 6·5; S, 15·25. $C_4H_6ClNO_5S$ requires C, 22·3; H, 2·8; Cl, 16·5; N, 6·5; S, 14·85%). In moist air at 80° for 15 hr. it yielded an oil which crystallised from ether–light petroleum or from chloroform. The 2-*chloro*-3-*hydroxytetrahydrothiophen dioxide* so obtained had m. p. 76·5° (Found: C, 27·7; H, 4·2; Cl, 21·0; S, 18·5. $C_4H_7ClO_3S$ requires C, 28·15; H, 4·15; Cl, 20·8; S, 18·8%). With boiling acetic anhydride it gave the 3-acetoxy-derivative, m. p. 87° (from methanol).

2-*Bromo*-3-*hydroxytetrahydrothiophen dioxide*. This was prepared analogously by passing a slow stream of air through a reservoir of bromine covered by water and into an ice-cooled mixture of 2,3-dihydrothiophen dioxide (10 g.) in 40% aqueous nitric acid (100 ml.). The reaction was complete in 3 hr.; the mixture was decanted from traces of 2,3-dibromotetrahydrothiophen dioxide and when cooled yielded the *nitrate* of the monobromo-compound (6·5 g.), as needles, m. p. 96—97° (from ethanol) (Found: C, 18·7; H, 2·3; Br, 29·2; N, 5·4; S, 13·2. $C_4H_6BrNO_5S$ requires C, 18·45; H, 2·3; Br, 30·8; N, 5·4; S, 12·3%). In moist air it yielded 2-*bromo*-3-*hydroxytetrahydrothiophen dioxide*, m. p. 109° (Found: C, 22·1; H, 3·4; Br, 36·6; S, 14·0. $C_4H_7BrO_3S$ requires C, 22·35; H, 3·4; Br, 37·15; S, 14·9%). This bromohydrin was also prepared by passing bromine through aqueous 2,3-dihydrothiophen dioxide in the presence of mercuric oxide. With boiling acetic anhydride it gave the 3-acetoxy-compound, m. p. 87° (from aqueous ethanol) and with ice-cold nitric acid and sulphuric acid it regenerated the nitrate ester, m. p. 96°.

Reduction of this nitrate ester (2·3 g.) with a zinc–copper couple (25 g.) in boiling 95% ethanol (100 ml.) for 6 hr., filtration, and evaporation of the alcohol gave an oil which was benzoylated (benzoyl chloride in aqueous sodium hydroxide). The benzoyl derivative had m. p. 160° (from ethanol), undepressed by admixture with 3-*benzoyloxytetrahydrothiophen dioxide*, m. p. 162° (Found: C, 54·8; H, 4·9; S, 13·3. $C_{11}H_{12}O_4S$ requires C, 55·0; H, 5·05; S, 13·35%), prepared analogously from 3-hydroxytetrahydrothiophen dioxide (Backer and Strating[1]; van Zuydewijn[2]). Mixed m. p. with 3-benzoyloxy-2,3-dihydrothiophen dioxide (m. p. 158—160°) was 148—150°.

3-*Hydroxy*-2-*iodotetrahydrothiophen Dioxide*.— Finely ground iodine (10 g.) and 2,3-dihydrothiophen dioxide (5 g.) were added to 40% aqueous nitric acid (50 ml.) and the mixture was shaken for 18 hr. Decantation from residual iodine, ice-cooling, and filtration yielded the *nitrate* of the iodo-compound, m. p. 58—59° (from 40% aqueous nitric acid) (Found: I, 41·35; N, 4·3. $C_4H_6INO_5S$ requires I, 41·3; N, 4·5%). This ester in moist air gave, in quantitative yield, the *iodo-compound*, m. p. 123—124° (Found: C, 18·3; H, 2·7; S, 12·0. $C_4H_7IO_3S$ requires C, 18·35; H, 2·7; S, 12·25%), converted by boiling acetic anhydride into the acetate, m. p. 75°.

Nitrates of 3,4-*Halogenohydrins*.—These nitrate esters were prepared in a manner analogous to the 2,3-halogenohydrin nitrates. 3-*Chloro*-4-*hydroxytetrahydrothiophen dioxide nitrate* had m. p. 113—114° (from ethanol) (Found: C, 22·4; H, 2·75; Cl, 16·1; N, 6·65. $C_4H_6ClNO_5S$ requires C, 22·3; H, 2·8; Cl, 16·5; N, 6·5%); 3-*bromo*-4-*hydroxytetrahydrothiophen dioxide nitrate* had m. p. 94—95° (Found: C, 18·45; H, 2·0; Br, 28·9; N, 5·7; S, 12·6. $C_4H_6BrNO_5S$ requires C, 18·45; H, 2·3; Br, 30·8; N, 5·4; S, 12·3%); and 3-*hydroxy*-4-*iodotetrahydrothiophen dioxide nitrate* (from methanol or aqueous acetic acid) had m. p. 102—103° (Found: C, 15·45; H, 2·0; I, 41·4; N, 4·3; S, 10·4. $C_4H_6INO_5S$ requires C, 15·6; H, 1·95; I, 41·3; N, 4·55; S, 10·4%). When warmed in moist air at 60—70° or in boiling water these esters yielded the corresponding known[1,2,13,15] halogenohydrins, best crystallised from aqueous ethanol or ethyl acetate–petroleum. Whereas the physical constants of our chlorohydrin and bromohydrin agreed well with the literature values, 3-hydroxy-4-iodotetrahydrothiophen dioxide had m. p. 185—186° (decomp.) (lit.,[21] 180—181°).

Bromohydrins and Bromohydrin Nitrates of Alkyltetrahydrothiophen Dioxides.—Application of the methods described to 3-methyl- and 2,4- and 3,4-dimethyl-2,5-dihydrothiophen dioxide gave, respectively, 3-methyl-2,5-dihydrothiophen dioxide bromohydrin, m. p. 77° (Found: S, 13·8. Calc. for $C_5H_9BrO_3S$: S, 14·0%) (Eigenberger[22] quotes m. p. 67—68° for 3-bromo-4-hydroxy-4-methyltetrahydrothiophen dioxide) through the *nitrate*, m. p. 115° (Found: C, 22·1; H, 3·3; N, 5·1; S, 11·7; Br, 29·0. $C_5H_8BrNO_5S$ requires C, 21·9; H, 2·95; N, 5·1; S, 11·7; Br, 29·15%); 2,4-*dimethyl*-2,5-*dihydrothiophen dioxide bromohydrin*, m. p. 118—119° (Found: Br, 33·0; S, 12·9. $C_6H_{11}BrO_3S$ requires Br, 32·85; S, 13·2%) (this substance is mentioned but not described by Morris and Van

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[21] O. E. Van Lohuizen and H. J. Backer, *Rec. Trav. chim.*, 1949, **68**, 1137.

[22] E. Eigenberger, *J. prakt. Chem.*, 1930, **127**, 307.

Winkle [23]) through the *nitrate*, m. p. 119° (Found: C, 26·2; H, 3·8; Br, 27·3; N, 4·5; S, 10·7. $C_6H_{10}BrNO_5S$ requires C, 25·0; H, 3·5; Br, 27·7; N, 4·85; S, 11·1%); and 3-*bromo*-4-*hydroxy*-3,4-*dimethyltetrahydrothiophen dioxide*, m. p. 149·5—150·5° (Found: Br, 32·1; S, 13·1. $C_6H_{11}BrO_3S$ requires Br, 32·85; S, 13·2%), by exposing the *nitrate*, m. p. 132° (Found: C, 25·7; H, 3·6; Br, 27·7; N, 4·7; S, 11·0. $C_6H_{10}BrNO_5S$ requires C, 25·0; H, 3·5; Br, 27·7; N, 4·85; S, 11·1%), to moist air. With an excess of boiling water the last-named nitrate gave within 30 min. *trans*-3,4-dihydroxy-3,4-dimethyltetrahydrothiophen dioxide, m. p. 176—177° (Found: C, 40·1; H, 7·6; S, 17·7. Calc. for $C_6H_{12}O_4S$: C, 40·0; H, 6·7; S, 17·8%), previously [24] obtained (m. p. 175°) similarly from 3,4-dibromo-3,4-dimethyltetrahydrothiophen dioxide.

3-*Sulphotetrahydrothiophen Dioxide and Related Substances*

Ammonium Salt of 3-*Sulphotetrahydrothiophen Dioxide*.—2,3-Dihydrothiophen dioxide (472 g.) and ammonium sulphite (536 g.) were dissolved in water and kept at room temperature for 24 hr. The solution was then concentrated *in vacuo* and the precipitate was filtered off, washed with ethanol, and dried, to give the 3-*sulphonate* (740 g., 85%), m. p. 274—276° (from aqueous ethanol) (Found: C, 22·1; H, 5·2; N, 6·35; S, 29·2. $C_4H_{11}NO_5S$ requires C, 22·1; H, 5·1; N, 6·45; S, 29·5%). The free acid (79·5 g.) was obtained by passing a solution of the ammonium salt (100 g.) in water (300 ml.) down a column of Zeo-Karb 225 (500 g.; H^+ form) and evaporating the effluent *in vacuo*. The residual oil crystallised to give a deliquescent solid, m. p. 110°.

Ammonium Salt of 3-*Methyl*-3-*sulpho-tetrahydrothiophen Dioxide*.—3-Methyl-2,3-dihydrothiophen dioxide (13·2 g.) dissolved in water (200 ml.), was added to a solution of sulphur dioxide (6·5 g.) in 0·880 ammonia (25 ml.) and kept at room temperature for 3 days. The solution was then continuously extracted with chloroform for 48 hr.; the extract was dried ($MgSO_4$) and evaporated, to give starting material (7·0 g.). The aqueous solution, after extraction, was treated with Zeo-Karb 225 (H^+) and evaporated *in vacuo*. The residual oil was dissolved in ethanol and filtered. Anhydrous ammonia was bubbled through the filtrate and the precipitated solid was filtered off; it gave the 3-*sulphonate* (7·4 g., 69%), m. p. 199—200° (from aqueous ethanol) (Found: N, 6·2; S, 27·2. $C_5H_{13}NO_5S_2$ requires N, 6·1; S, 27·7%).

Ammonium Salt of 3-*Sulpho*-2,3-*dihydrothiophen Dioxide*.—Similarly 3-bromo-2,3-dihydrothiophen dioxide (19·2 g.) gave the 3-*sulphonate* (13·5 g., 63%), m. p. 204—205° (from ethanol) (Found: C, 22·3; H, 4·2; N, 6·4; S, 29·5. $C_4H_9NO_5S_2$ requires C, 22·3; H, 4·2; N, 6·5; S, 29·75%).

Derivatives of 3-*Sulphotetrahydrothiophen Dioxide*

3-*Chlorosulphonyltetrahydrothiophen Dioxide*.—The ammonium salt of 3-sulphotetrahydrothiophen dioxide (200 g.) was refluxed for 30 min. with an excess of thionyl chloride (500 ml.) containing dimethylformamide (10 ml.).[18] The solution was then cooled and poured into ice–water (3 l.). The precipitated *chlorosulphonyl derivative* (150 g., 85%) was filtered off, washed with water, and dried, m. p. 112—113° (from ethyl acetate) (Found: C, 23·2; H, 3·3; Cl, 16·6; S, 29·0. $C_4H_7ClO_4S_2$ requires C, 22·0; H, 3·2; Cl, 16·2; S, 29·3%).

3-*Sulphamoyltetrahydrothiophen Dioxide* (XXVI).—3-Chlorosulphonyltetrahydrothiophen dioxide (21·9 g.) was dissolved in acetone (250 ml.), and 0·880 ammonia (15 g.) was added dropwise with stirring at 20°. The mixture was stirred for 15 min. and then filtered. Evaporation of the filtrate *in vacuo* at 40° gave a yellow oil, which was dissolved in hot water, decolourised with charcoal, and cooled; 3-*sulphamoyltetrahydrothiophen dioxide* (14 g. 68%), m. p. 137—139°, crystallised out (Found: N, 7·0; S, 32·5. $C_4H_9NO_4S_2$ requires N, 7·0; S, 32·2%).

3-*Phenylsulphamoyltetrahydrothiophen Dioxide* (XXVII).—3-Chlorosulphonyltetrahydrothiophen dioxide (15 g.) was added in portions with stirring to a suspension of aniline (2·2 g.) in 2N-sodium hydroxide. The mixture was stirred for 15 min. and then acidified with hydrochloric acid. The precipitate was filtered off, dissolved in dilute sodium hydroxide, and reprecipitated with conc. hydrochloric acid. It gave the *phenylsulphamoyl compound* (1 g., 14%), m. p. 118—119° (from ethyl acetate–light petroleum) (Found: C, 43·5; H, 5·0; N, 5·1; S, 23·5. $C_{10}H_{13}NO_4S_2$ requires C, 43·6; H, 4·8; N, 5·1; S, 23·3%).

3-(N′-*Phenylhydrazinosulphonyl*)*tetrahydrothiophen Dioxide* (XXVIIIa).—Phenylhydrazine (6 g.) was added dropwise at 10—15° to a solution of the sulphonyl chloride in tetrahydrofuran. The precipitate was filtered off and gave the *phenylhydrazide* (5·3 g., 70%), m. p. 137—140° (from ethanol) (Found: C, 41·8; H, 4·8; N, 9·4; S, 22·4. $C_{10}H_{14}N_2O_4S_2$ requires C, 41·4; H, 4·9; N, 9·7; S, 22·1%).

Esters of 3-*Sulphotetrahydrothiophen Dioxide*.—3-Chlorosulphonyltetrahydrothiophen dioxide (1·1 equiv.) reacted at −5° with the alcohol (10 g.) in dry redistilled pyridine according to the method of Tipson.[19] The precipitated esters were filtered off and recrystallised from ethyl acetate. The results are summarised in Table 9.

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[24] H. J. Backer and J. A. Bottema, *Rec. Trav. chim.*, 1932, **51**, 294; E. de R. Van Zuydewijn, *ibid.*, 1938, **57**, 445.