The Reductive Fission of Methyl Sulphides, 1,3-Dithiolans, and a 1,3-Oxathiolan by Sodium in Liquid Ammonia

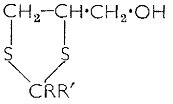
By E. D. Brown, S. M. Iqbal, and L. N. Owen

The fact that 2,3-dimercaptopropanol can be regenerated from its *SS*-methylene derivative, but not from its *SS*-isopropylidene derivative, by sodium in liquid ammonia, is explained by the difference in stability of the respective intermediate alkylthio-derivatives. In a series of 2-(alkylthio)ethanols, only the methylthio-compound is cleaved. The isopropylidene derivatives of cyclohexane-*trans*-1,2-dithiol, 2-mercaptocyclohexanol, and propane-1,2-dithiol give, respectively, *trans*-2-(isopropylthio)cyclohexanethiol, *trans*-2-isopropoxycyclohexanethiol, and a mixture of 2-(isopropylthio)propane-1-thiol and 1-(isopropylthio)propane-2-thiol. In contrast to the last example, the partial cleavage of the isopropylidene derivative of 2,3-dimercaptopropanol occurs only in one direction, to give 2-isopropylthio-3-mercaptopropanol.

The rates of alkaline hydrolysis have been measured for some acetates containing alkylthio- or methoxy-groups. 2-(Alkylthio)ethanols are slowly converted into 1,2-bisalkylthioethanes when boiled with dilute hydrochloric acid.

PROTECTION of a thiol group as its *S*-benzyl derivative and eventual regeneration by reductive fission with sodium in liquid ammonia is a technique which has been extensively used, particularly in peptide synthesis,[1] but comparatively little is known about the susceptibility of other *S*-alkyl groups towards removal under these conditions. Aryl ethyl sulphides are cleaved to give aryl thiols [2] and the *S*-methyl group can similarly be removed from 5-methyl-2-methylthiohistidine; [3] it has also been claimed that diethyl sulphide [4] and dipropyl sulphide [4,5] are reduced to ethanethiol and propanethiol, respectively, but the products were not adequately analysed or characterised. The cleavage of sulphides by alkali metals in methylamine (and other amines) has received some attention.[6]

The regeneration of 2,3-dimercaptopropanol from its benzylidene derivative (I) by treatment with sodium and liquid ammonia [7,8] presumably proceeds through a mono-*S*-benzyl derivative (II) or (III), which then undergoes further reduction. We now find that the methylene derivative (IV) behaves similarly, showing that the intermediate mono-*S*-methyl compound (V) or (VI) must also be susceptible to cleavage. In marked contrast to these results is the earlier observation [8] that the isopropylidene derivative (VII) is



(I; R = H, R′ = Ph)
(IV; R = R′ = H)
(VII; R = R′ = Me)

$CH_2(SR)\cdot CH(SH)\cdot CH_2\cdot OH$
(II; R = PhCH$_2$)
(V; R = Me)
(VIII; R = Pr^i)

$CH_2(SH)\cdot CH(SR)\cdot CH_2\cdot OH$
(III; R = PhCH$_2$)
(VI; R = Me)
(IX; R = Pr^i)

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[6] W. E. Truce, D. P. Tate, and D. N. Burdge, *J. Amer. Chem. Soc.*, 1960, **82**, 2872; W. E. Truce and J. J. Breiter, *ibid.*, 1962, **84**, 1621.

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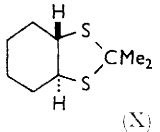
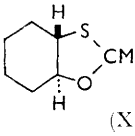
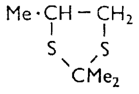
reduced only to a monothiol (VIII) or (IX), and it was therefore desirable to examine some further examples of isopropylidene derivatives. 2,2-Dimethyl-*trans*-4,5-cyclohexano-1,3-dithiolan (X),[9] 2,2-dimethyl-*trans*-4,5-cyclohexano-1,3-oxathiolan (XI),[10] and 2,2,4-trimethyl-1,3-dithiolan (XII) were therefore treated with sodium and liquid ammonia; they gave, respectively, *trans*-2-isopropylthiocyclohexanethiol (XIII), *trans*-2-isopropoxycyclohexanethiol (XIV), and (as will be shown below) a mixture of the two thiols (XV) and (XVI). These observations confirm the stability of the isopropylthio group under these conditions. Further evidence that the nature of the alkyl group has a decisive effect on the ease of fission was provided by the behaviour of the series of 2-*S*-(alkylthio)ethanols (XVII). 2-(Methylthio)ethanol gave 2-mercaptoethanol, 2-(ethylthio)ethanol was essentially unchanged, the recovered material containing only a trace of thiol, and 2-(isopropylthio)ethanol was quite unaffected. 1,2-Bismethylthioethane (XVIII) was completely reduced to ethane-1,2-dithiol.


(X)


(XI)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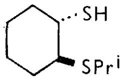
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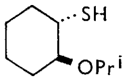
(XIV)

$\text{Me·CH(SH)·CH}_2\text{·SPr}^i$
(XV)

$\text{Me·CH(SPr}^i\text{)·CH}_2\text{·SH}$
(XVI)

$\text{RS·CH}_2\text{·CH}_2\text{·OH}$
(XVII)

$\text{CH}_2\text{(SMe)·CH}_2\text{·SMe}$
(XVIII)

On the basis of the usual mechanism for reductive fission with sodium and liquid ammonia,[11] if the reaction takes place the initial fragments from a sulphide RSR′ would be the alkyl carbanion R^- and the thiol anion $R'S^-$ (or *vice versa*). The special lability of the methyl and the benzyl sulphides is therefore due to the relatively good stabilities of the methyl and the benzyl carbanions, which require less energy for their formation than would be necessary for an ethyl or an isopropyl carbanion; this also accounts for the actual direction of fission of the sulphide. Similar considerations apply to the unsymmetrical isopropylidene derivatives. The oxathiolan (XI) undergoes preferential fission of the $\text{Me}_2\text{C–S}$ bond because the developing negative charge is accommodated better by the resulting thiol anion than by oxygen. From a consideration of the order of acidities $\text{RCH}_2\text{·SH} > \text{R}_2\text{CH·SH} > \text{R}_3\text{C·SH}$, the primary thiol (XVI) should be formed from the dithiolan (XII) more readily than the isomer (XV) but the difference in the stabilities of the intermediates is evidently insufficient for the one to be produced exclusively. With the dithiolan (VII), however, the additional negative charge which will be present throughout on the oxygen atom is enough to inhibit the formation of the secondary thiol, so that the primary compound (IX) is the sole product.

TABLE 1

Chemical shifts * (τ-values) (*J* in c./sec.)

Compound	$\text{CH}_2\text{·OAc}$	CH·SAc	$\text{CH}_2\text{·SAc}$	CH·S	$\text{CH}_2\text{·S}$	$\text{CH}_3\text{·CO·S}$	$\text{CH}_3\text{·CO·O}$	CH_2	CH_3
(XIX)		6·20m	6·90d (*J* 6·0)			7·70 7·75			8·70d (*J* 7·0)
(XX)			7·11t (*J* 7·0)			7·71		8·20q (*J* 7·0)	
(XXI)	5·86d (*J* 6·0)	6·21m	6·80d (*J* 5·5) 6·86d (*J* 7·0)			7·69	7·98		
(XXII)	5·89t (*J* 7·0)			7·01m	7·35t (*J* 7·0)		7·98		8·75d (*J* 7·0)
(XXIII)	5·90m		†	†		7·70	7·98		8·73d (*J* 7·0)

* Abbreviations: d doublet, t triplet, q quintet, m multiplet. † Overlapping signals (total, 4 protons) at *ca.* τ 7·0.

The structures of the products from the unsymmetrical dithiolans are based on the nuclear magnetic resonance spectra of the acetyl derivatives (which are more readily interpreted than the spectra of the free thiols). To provide data with which comparison could be made, the spectra of the model compounds (XIX)—(XXII) were recorded; these are included in Table 1. The positions and intensities of the signals from the acetyl derivative (XXIII) are in good agreement with that structure, and there is no indication of the presence of the isomeric secondary thiolacetate (XXIV) which would have given a signal at *ca.* τ 6·3 (CH·SAc), weaker resonances at *ca.* τ 7·0 (only CH·S; no $\text{CH}_2\text{·SAc}$), and stronger resonances at *ca.* τ 7·7 ($\text{CH}_2\text{·SPr}^i$ in addition to S·CO·CH_3). The acetyl derivative of the reduction product from 2,2,4-trimethyl-1,3-dithiolan (XII) showed a doublet (*J* = 6·5 c./sec.) at τ 8·71 (6H; CMe_2), and a doublet (*J* = 6·5 c./sec.) at τ 8·67 (3H; terminal Me), but the signal for the S·CO·CH_3 protons, although of correct intensity, appeared as two sharp peaks at τ 7·75 and 7·70. There is no reason to invoke spin–spin splitting in such a case, and the simplest explanation is that two

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[9] S. M. Iqbal and L. N. Owen, *J. Chem. Soc.*, 1960, 1030.

[10] M. Kyaw and L. N. Owen, *J. Chem. Soc.*, 1965, 1298.

[11] A. J. Birch, *Quart. Rev.*, 1950, **4**, 69.

acetylthio groups are present, in different environments; the line positions are in fact identical with those of the pair of acetylthio groups in 1,2-bisacetylthiopropane (XIX). Furthermore, the remaining four protons gave rise to a multiplicity of signals extending over the region τ 6·2—7·6, which is also compatible with a mixture of the two acetyl derivatives (XXV) and (XXVI).

$CH_3{\cdot}CH(SAc){\cdot}CH_2{\cdot}SAc$ (XIX)

$CH_2(SAc){\cdot}CH_2{\cdot}CH_2{\cdot}SAc$ (XX)

$CH_2(SAc){\cdot}CH(SAc){\cdot}CH_2{\cdot}OAc$ (XXI)

$CH_2(SPr^i){\cdot}CH_2{\cdot}OAc$ (XXII)

$CH_2(SAc){\cdot}CH(SPr^i){\cdot}CH_2OAc$ (XXIII)

$CH_2(SPr^i){\cdot}CH(SAc){\cdot}CH_2{\cdot}OAc$ (XXIV)

$CH_3{\cdot}CH(SPr^i){\cdot}CH_2{\cdot}SAc$ (XXV)

$CH_3{\cdot}CH(SAc){\cdot}CH_2{\cdot}SPr^i$ (XXVI)

It is interesting that the two methylene protons in the $CH_2{\cdot}SAc$ group of 2,3-bisacetylthiopropyl acetate (XXI) appear not as a simple doublet but as an unsymmetrical quartet (*i.e.*, a pair of doublets); they are therefore non-equivalent. A similar result has been recorded[12] for the methylene group in 1,2-dichloropropane and for the terminal methylene group in 1,2-dibromobutane. The multiplicity of the methylene protons in the $CH_2{\cdot}OAc$ group of compound (XXIII) suggests that they, too, are non-equivalent.

The availability of the alkylthioethanols provided an opportunity to measure the rates of alkaline hydrolysis of their acetates, to discover what influence is exerted by a neighbouring sulphur atom. 2-Mercaptoethyl acetate and some methoxy compounds were also studied. Table 2 shows that the presence of a neighbouring mercapto, alkylthio, or methoxy group increases the rate relative to ethyl acetate, the methoxy group having the most influence, but the general effect is only small. This is in contrast to the considerable acceleration brought about by the hydroxyl group in 2-hydroxyethyl acetate.[13]

TABLE 2

Rates of hydrolysis of acetates by 0·05N-sodium hydroxide in 50% aqueous acetone at 0°

	10^2k (l. mole^{-1} sec.$^{-1}$)
EtOAc	1·20
$CH_2(SMe){\cdot}CH_2{\cdot}OAc$	1·23
$CH_2(SEt){\cdot}CH_2{\cdot}OAc$	1·30
$CH_2(SPr^i){\cdot}CH_2{\cdot}OAc$	1·50
$CH_2(SMe){\cdot}CH(SMe){\cdot}CH_2{\cdot}OAc$	2·43
$CH_2(SH){\cdot}CH_2{\cdot}OAc$	1·33
$CH_2(OMe){\cdot}CH_2{\cdot}OAc$	1·96
$CH_2(OMe){\cdot}CH(OMe){\cdot}CH_2{\cdot}OAc$	3·92

When 2-(methylthio)ethanol (XVII; R = Me) is boiled with dilute aqueous hydrochloric acid it is slowly converted into 1,2-bismethylthioethane (XVIII).[14] It has now been shown that intermolecular transfer of the alkylthio group also occurs with the ethyl, isopropyl, and the t-butyl analogues (XVII; R = Et, Pr^i, and Bu^t) to give the corresponding 1,2-bisalkylthioethanes, isolated as the crystalline disulphones.

EXPERIMENTAL

Nuclear magnetic resonance (n.m.r.) spectra were recorded in carbon tetrachloride, with tetramethylsilane as internal standard, on a Varian A-60 instrument on permanent loan to Professor D. H. R. Barton, F.R.S., from the Wellcome Trustees.

Model Compounds for N.m.r. Spectra.—1,2-Bisacetylthiopropane,[14] 1,3-bisacetylthiopropane,[15] and 2,3-bisacetylthiopropyl acetate[16] were prepared as previously described. 2-(Isopropylthio)ethyl acetate is reported below.

Acetates for Kinetic Experiments.—2,3-Bismethylthiopropyl acetate,[14] 2-mercaptoethyl acetate,[17] and 2-methoxyethyl acetate[18] were prepared according to the references cited. The 2-(alkylthio)ethyl acetates are described below.

2,3-Dimethoxypropyl acetate was synthesised by a route which for the first three stages exactly followed the procedures used by Fischer and Sowden[19] for the corresponding optically active compounds. Inactive 1,2-*O*-isopropylideneglycerol was converted *via* the 3-*O*-benzyl ether, b. p. 154°/12 mm., n_D^{24} 1·4929 (lit.,[19] b. p. 95—97°/0·3 mm., n_D^{16} 1·4970), into benzyl 2,3-dihydroxypropyl ether, b. p. 126—127°/0·8 mm., n_D^{20} 1·5321 (lit.,[19] b. p. 138—139°/0·33 mm., n_D^{16} 1·5342), and thence into benzyl 2,3-dimethoxypropyl ether, b. p. 144—145°/16 mm., n_D^{23} 1·4927 (lit.,[19] b. p. 147—148°/13 mm., n_D^{17} 1·4932); the constants quoted from the literature refer to the optically active forms. The last compound (9·3 g.) in ethanol (50 c.c.) was shaken with 5% palladium–charcoal (0·5 g.) and hydrogen until absorption of the gas ceased. Distillation of the filtered solution then afforded 2,3-dimethoxypropanol (4·5 g.), b. p. 70°/13 mm., n_D^{19} 1·4247 (lit.,[20] b. p. 180°, n_D^{15} 1·4249), which was heated with acetic anhydride (10 g.) and pyridine (3 g.) on a steam-bath for 5 hr. The cooled mixture was then stirred with water and extracted with ether to give 2,3-dimethoxypropyl acetate (5·0 g.), b. p. 96°/23 mm., n_D^{22} 1·4517 (lit.,[20] b. p. 195°, n_D^{25} 1·414) (Found: C, 51·6; H, 8·9. Calc. for $C_7H_{14}O_4$: C, 51·8; H, 8·7%).

2-(*Alkylthio*)*ethanols*.—(i) 2-(Methylthio)ethanol was prepared[14] by methylation of 2-mercaptoethanol.

(ii) After the reaction of sodium (11·5 g.) with ethanol (250 c.c.) was complete, ethanethiol (31 g.) was added and the mixture was boiled under reflux during the gradual addition of ethylene chlorohydrin (40 g.) (1 hr.) and for a further 30 min. The solution was then concentrated, filtered to remove sodium chloride, and distilled to give 2-(ethylthio)ethanol (37 g.), b. p. 80°/20 mm., n_D^{18} 1·4878 (lit.,[21] b. p. 35°/0·12 mm., n_D^{25} 1·4853). The 3,5-*dinitrobenzoate* crystallised from aqueous ethanol in plates, m. p. 78—79° (Found: C, 44·0; H, 4·0. $C_{11}H_{12}N_2O_6S$ requires C, 43·8; H, 4·0%).

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[12] N. M. R. Spectra Catalog, Varian Associates, California, 1962, No. 30 and 74.

[13] W. Davis and W. C. J. Ross, *J. Chem. Soc.*, 1950, 3056.

[14] P. S. Fitt and L. N. Owen, *J. Chem. Soc.*, 1951, 2250.

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(iii) Propane-2-thiol (40 g.) was similarly converted into 2-(isopropylthio)ethanol (45 g.), b. p. 96°/24 mm., n_D^{20} 1·4795 (lit.,[21] b. p. 42—46°/1·5 mm., n_D^{25} 1·4775). The 3,5-*dinitrobenzoate*, plates from aqueous ethanol, had m. p. 76—77° (Found: C, 45·9; H, 4·5; O, 30·5. $C_{12}H_{14}N_2O_6S$ requires C, 45·8; H, 4·5; O, 30·3%).

(iv) A stream of ethylene oxide was passed through a rapidly stirred mixture of freshly distilled 1,1-dimethylethanethiol (21·5 g.) and 15% aqueous sodium hydroxide (30 c.c.) at 30—40° under nitrogen, the flask being weighed from time to time until 20% excess of the calculated amount was absorbed. Stirring was maintained for 14 hr. at room temperature and the organic layer was then taken up in ether, washed with dilute hydrochloric acid and with water, dried, and distilled to give 2-(*t-butylthio*)*ethanol* (29 g.), b. p. 73°/6 mm., n_D^{18} 1·4780 (Found: C, 53·9; H, 10·6; S, 23·6. $C_6H_{14}OS$ requires C, 53·7; H, 10·5; S, 23·9%). The 3,5-*dinitrobenzoate*, after crystallisation from aqueous ethanol, had m. p. 71—72° (Found: C, 47·1; H, 5·1. $C_{13}H_{16}N_2O_6S$ requires C, 47·5; H, 4·9%).

2-(*Alkylthio*)*ethyl Acetates*.—The 2-(alkylthio)ethanol, mixed with twice its weight of pyridine, was treated with a 20% excess of acetic anhydride for 24 hr. at room temperature. The mixture was then poured into water and the product isolated by extraction with ether.

2-(Methylthio)ethyl acetate (yield, 88%) had b. p. 71°/15 mm., n_D^{25} 1·4600 (lit.,[22] b. p. 79—80°/21 mm., n_D^{30} 1·4583); 2-(ethylthio)ethyl acetate (84%), b. p. 85°/16 mm., n_D^{18} 1·4614 (lit.,[13] b. p. 90°/4 mm.); 2-(*isopropylthio*)*ethyl acetate* (80%), b. p. 99°/22 mm., n_D^{21} 1·4570 (Found: C, 51·9; H, 8·7; S, 19·8. $C_7H_{14}O_2S$ requires C, 51·8; H, 8·7; S, 19·8%); and 2-(*t-butylthio*)*ethyl acetate* (85%), b. p. 43°/0·5 mm., n_D^{20} 1·4580 (Found: C, 54·5; H, 9·3; S, 17·8. $C_8H_{16}O_2S$ requires C, 54·5; H, 9·1; S, 18·2%).

4-*Hydroxymethyl*-1,3-*dithiolan* (IV).—2,3-Dimercaptopropanol (18·6 g.) was added to a stirred mixture of 30% formalin (25 c.c.) and dioxan (25 c.c.). Sulphuric acid (0·1 g.) was added, and the solution was heated on the steam-bath under nitrogen for 6 hr., a test for thiol then being negative. Concentration under reduced pressure, and extraction with chloroform afforded the *methylene derivative* (8·7 g.), b. p. 124°/6 mm., n_D^{17} 1·5932 (Found: C, 35·5; H, 6·0. $C_4H_8OS_2$ requires C, 35·3; H, 5·9%). This was characterised as the *phenylurethane*, m. p. 94—96° (from aqueous ethanol) (Found: C, 51·7; H, 5·2; S, 25·2. $C_{11}H_{13}NO_2S_2$ requires C, 51·7; H, 5·1; S, 25·1%).

2,2,4-*Trimethyl*-1,3-*dithiolan* (XII).—A solution of propane-1,2-dithiol[9] (7·8 g.) and sulphuric acid (0·2 g.) in acetone (150 c.c.) was set aside overnight, then concentrated to an oil which was taken up in chloroform, washed with aqueous sodium hydroxide and with water, dried, and distilled to give the *isopropylidene derivative* (5·9 g.), b. p. 77—79°/25 mm., n_D^{20} 1·5208 (Found: C, 48·5; H, 8·3. $C_6H_{12}S_2$ requires C, 48·6; H, 8·2%).

Reduction of Dithiolans with Sodium in Liquid Ammonia.—(i) To a stirred solution of 4-hydroxymethyl-1,3-dithiolan (5·1 g.) and ethanol (1 c.c.) in liquid ammonia (100 c.c.), sodium (5·1 g.) was added in small pieces. The blue solution was stirred for 2 hr., then the excess of sodium was decomposed by the addition of ammonium chloride, and the ammonia was allowed to evaporate. The residue was dissolved in water, acidified with hydrochloric acid, and extracted with ether (3 × 40 c.c.) to give 2,3-dimercaptopropanol (2·8 g.), b. p. 100°/0·1 mm., n_D^{19} 1·5715 (Found: thiol-S, 50·4. Calc. for $C_3H_8OS_2$: thiol-S, 51·6%).

(ii) 2,2-Dimethyl-*trans*-4,5-cyclohexano-1,3-dithiolan[9] (2·7 g.) on similar treatment gave trans-2-(*isopropylthio*)-*cyclohexanethiol* (1·2 g.), b. p. 89—92°/0·4 mm., n_D^{23} 1·5229 (Found: C, 56·5; H, 9·5; S, 33·3; thiol-S, 16·6. $C_9H_{18}S_2$ requires C, 56·7; H, 9·5; S, 33·7; thiol-S, 16·9%). It was characterised by reaction with chloro-2,4-dinitrobenzene in alkaline ethanol to give 2,4-*dinitrophenyl* trans-2-(*isopropylthio*)*cyclohexyl sulphide*, m. p. 97° (from ethanol) (Found: C, 51·1; H, 5·5; N, 8·1. $C_{15}H_{20}N_2O_4S_2$ requires C, 50·6; H, 5·6; N, 7·9%).

(iii) 2,2-Dimethyl-*trans*-4,5-cyclohexano-1,3-oxathiolan[10] (2·1 g.) gave trans-2-*isopropoxycyclohexanethiol* (0·6 g.), b. p. 49°/0·04 mm., n_D^{22} 1·4731 (Found: C, 61·7; H, 10·4; S, 18·7; thiol-S, 18·0. $C_9H_{18}OS$ requires C, 62·0; H, 10·4; S, 18·4%).

(iv) 2,2,4-Trimethyl-1,3-dithiolan (2·7 g.) gave a mixture (1·1 g.) of 2-(isopropylthio)propane-1-thiol and 1-(isopropylthio)propane-2-thiol, b. p. 85—87°/25 mm., n_D^{17} 1·5032 (Found: thiol-S, 21·1. Calc. for $C_6H_{12}S_2$: thiol-S, 21·4%). Acetylation with acetic anhydride in pyridine afforded a mixture of the corresponding acetyl derivatives, b. p. 84°/0·7 mm., n_D^{23} 1·5002, $\nu_{max.}$ 1690 cm.$^{-1}$ (SAc) (Found: C, 50·1; H, 8·1; S, 33·3. Calc. for $C_8H_{16}OS_2$: C, 50·0; H, 8·4; S, 33·3%).

3-*Acetylthio*-2-(*isopropylthio*)*propyl Acetate*.—Acetic anhydride (6 g.) was slowly added to a cooled solution of 2-isopropylthio-3-mercaptopropanol[8] (3·8 g.) in pyridine (7 c.c.). Next day, the mixture was concentrated under reduced pressure, and the residue was stirred with water, then extracted with ether. The extract was washed with 2N-hydrochloric acid and with water, then dried and distilled to give the *acetate* (4·8 g.), b. p. 97—98°/0·1 mm., n_D^{21} 1·5004 (Found: C, 48·0; H, 7·3. $C_{10}H_{18}O_3S_2$ requires C, 48·0; H, 7·2%).

Treatment of 2-(*Alkylthio*)*ethanols with Sodium in Liquid Ammonia*.—(i) Sodium (2·6 g.) was added to a stirred solution of 2-(methylthio)ethanol (2·6 g.) in liquid ammonia, and after 2 hr. the mixture was worked up as described above. Distillation of the product gave 2-mercaptoethanol (0·95 g.), b. p. 62°/20 mm., n_D^{20} 1·4642 (Found: thiol-S, 39·0. Calc. for C_2H_6OS: thiol-S, 41·0%).

(ii) Similar treatment of 2-(ethylthio)ethanol (5 g.) gave a product (2·3 g.), b. p. 79—80°/20 mm., n_D^{21} 1·4861, (Found: thiol-S, 0·7%), which had an infrared spectrum almost identical to that of the starting material.

(iii) 2-(Isopropylthio)ethanol (4·4 g.) gave recovered material (2·8 g.), b. p. 88°/20 mm., n_D^{19} 1·4788 (Found: thiol-S, nil), with an unaltered infrared spectrum.

Reduction of 1,2-*Bismethylthioethane with Sodium in Liquid Ammonia*.—Treatment of this compound (2·1 g.) as in the preceding experiments gave ethane-1,2-dithiol (0·9 g.), b. p. 45°/18 mm., n_D^{20} 1·5600 (Found: thiol-S, 67·9. Calc. for $C_2H_6S_2$: thiol-S, 68·2%).

Rates of Alkaline Hydrolysis of Acetates.—Equal volumes of acetone and aqueous sodium hydroxide were mixed to give a stock solution of 0·0508N-sodium hydroxide in 50% aqueous acetone. To 100 c.c. of this, cooled to 0°, and maintained at that temperature, was added the ester (0·002 mole), and a 10 c.c. portion was withdrawn at intervals, added to 0·0510N-hydrochloric acid and back titrated with the stock sodium hydroxide solution (phenolphthalein indicator). The bimolecular rate constants,

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[22] T. Hoshino, K. Yamagishi, and Y. Ichikawa, *Proc. Japan Acad.*, 1953, **29**, 55 (*Chem. Abs.*, 1954, **48**, 5789).

determined graphically in the usual way, are recorded in Table 2.

Action of Aqueous Hydrochloric Acid on 2-(*Alkylthio*)-*ethanols*.—(i) 2-(Ethylthio)ethanol (5 g.) and 0·7N-hydrochloric acid (100 c.c.) were boiled together under reflux for 24 hr.; an oil gradually separated from the solution. Extraction of the cooled mixture with chloroform gave an oil (4 g.), b. p. 110—120°/2 mm., which contained no thiol and no halogen. To a portion (0·75 g.) of this product dissolved in acetic acid (5 c.c.), 30% hydrogen peroxide (5 c.c.) was cautiously added, and when the reaction ceased the mixture was evaporated on the steam-bath. Trituration of the residue with methanol, and crystallisation from this solvent, gave 1,2-bisethylsulphonylethane as needles (0·3 g.); m. p. 132—133° (lit.,[23] m. p. 132°).

(ii) 2-(Isopropylthio)ethanol (4 g.) under the same conditions gave an oil (3·2 g.), b. p. 78—80°/15 mm., a portion of which was oxidised as before; chromatography of the resulting syrup, in 10% ethanol–benzene on alumina, gave a small yield of 1,2-bisisopropylsulphonylethane, m. p. and mixed m. p. 145—146° (see below).

(iii) Similar treatment of 2-(t-butylthio)ethanol (4 g.) gave an oil (2·9 g.), b. p. 40—45°/1 mm., which on oxidation gave a syrup. This was dissolved in dioxan, filtered to remove some gelatinous material, and recovered by evaporation. Trituration with methanol and recrystallisation from this solvent gave 1,2-bis-t-butylsulphonylethane, m. p. and mixed m. p. 230—232° (see below).

1,2-*Bisisopropylthioethane*.—Ethylene dibromide (2·45 g.) was added dropwise (25 min.) to propane-2-thiol (2·0 g.) in a solution prepared from ethanol (15 c.c.) and sodium (0·65 g.), heated and stirred under reflux. The mixture was boiled for a further 30 min., then cooled, concentrated, filtered from sodium bromide, and distilled to give 1,2-*bisisopropylthioethane* (2·1 g.), b. p. 50°/0·1 mm., n_D^{20} 1·4974 (Found: C, 53·7; H, 10·0. $C_8H_{18}S_2$ requires C, 53·9; H, 10·2%).

1,2-*Bisisopropylsulphonylethane*.—Oxidation of 1,2-bisisopropylthioethane (0·75 g.) in acetic acid (3 c.c.) with 30% hydrogen peroxide (7 c.c.), and evaporation on the steam-bath, gave the *disulphone* (0·52 g.) as plates, m. p. 145—146° (from ethanol), $\nu_{max.}$ 1302, 1127 cm.$^{-1}$ ($-SO_2$) (paraffin mull) (Found: C, 39·6; H, 7·3. $C_8H_{18}O_4S_2$ requires C, 39·7; H, 7·5%).

1,2-*Bis-t-butylthioethane*.—Reaction of ethylene dibromide (3·1 g.) with 1,1-dimethylethanethiol (1·5 g.), as described above for the similar reaction with propane-2-thiol, gave 1,2-*bis-t-butylthioethane* (1·4 g.), b. p. 118—120°/18 mm., n_D^{18} 1·4897 (Found: C, 57·5; H, 10·9; S, 31·0. $C_{10}H_{22}S_2$ requires C, 58·2; H, 10·7; S, 31·1%).

1,2-*Bis-t-butylsulphonylethane*.—Oxidation of the preceding compound by the method described above gave the *disulphone*, needles, m. p. 231—232° (from methanol), $\nu_{max.}$ 1300, 1115 cm.$^{-1}$ ($-SO_2-$) (paraffin mull) (Found: C, 44·6; H, 8·4; S, 23·7. $C_{10}H_{22}O_4S_2$ requires C, 44·4; H, 8·2; S, 23·7%).

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[23] J. C. Saur, *J. Amer. Chem. Soc.*, 1957, **79**, 5314.