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SYNTHESIS AND PROPERTIES OF SOME *O*-[2,2-BIS(ALKYLTHIO)ETHYL]-GLYCOLALDEHYDES*

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ABSTRACT

O-[2,2-Bis(alkylthio)ethyl]glycoaldehydes (**1a–e**; alkyl = Et, Pr, Pr^i, Bu^t, and $-CH_2-$, respectively) have been prepared from the corresponding *O*-[2,2-bis(alkylthio)ethyl]glycolaldehyde dimethyl acetals (**2a–e**) by acid hydrolysis. In anhydrous 1,4-dioxane in the presence of $BF_3 \cdot (Et_2O)_2$, **1a–c** were partially transformed into glycolaldehyde bis(dialkyl dithioacetals), **1d** afforded *trans*-2,6-bis(*tert*-butylthio)-1,4-dioxane and 3,5-bis(*tert*-butylthio)-1,4-oxathiane, and **1e** did not react. The acetals **2a–e** were prepared from the appropriate glycolaldehyde dialkyl dithioacetal by *O*-alkylation with bromoacetaldehyde dimethyl acetal.

INTRODUCTION

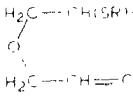
Diglycolaldehyde (2,2′-oxybisacetaldehyde, **7**) in acid media reacts with alcohols and thiols to give mainly acyclic derivatives, namely, diglycolaldehyde bis(dialkyl acetals) and bis(dialkyl dithioacetals), but small proportions of 2,6-dialkoxy-1,4-dioxane and 2,6-bis(alkylthio)-1,4-dioxane were also obtained[1,2]. Although the *O*-(2,2-dialkoxyethyl)glycolaldehydes were transformed into 2,6-dialkoxy-1,4-dioxanes in good yields[3] in the presence of $BF_3 \cdot (Et_2O)_2$, the diglycolaldehyde bis(dialkyl dithioacetals) generally gave[4] 1,1,2-tris(alkylthio)ethanes (**11**).

We now report on the preparation of *O*-[2,2-bis(alkylthio)ethyl]glycolaldehydes (**1a–e**), and on their transformations in the presence of $BF_3 \cdot (Et_2O)_2$.

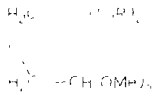
RESULTS AND DISCUSSION

O-[2,2-Bis(alkylthio)ethyl]glycolaldehydes (**1a–e**; alkyl = Et, Pr, Pr^i, Bu^t, and $-CH_2-$, respectively) were obtained in good yields by treatment of the corresponding dimethyl acetals (**2a–e**) with aqueous 1,4-dioxane containing a small proportion of conc. sulfuric acid. In the hydrolysis of **2d**, 3,5-bis(*tert*-butylthio)-1,4-oxathiane[2] (**5**) was a by-product, and this may be related to the tendency of diglycolaldehyde (**7**) and its derivatives to react with 2-methyl-2-propanethiol in acid media[2,4],

*Derivatives of Diglycolaldehyde, Part XVIII. For Part XVII, see ref. 3.



1a R = Et
1b R = Pr
1c R = Pr^i
1d R = Bu^t
1e R = CH_2



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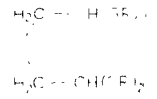
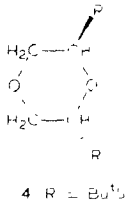
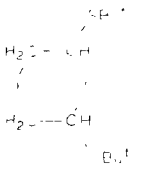
2b R = Pr
2c R = Pr^i
2d R = Bu^t
2e R = H



3a R = Et
3b R = Pr
3c R = Pr^i
3d R = Bu^t
3e R = H



4 R = Bu^{t}S
9 R = Bu^{t}SO$_2$



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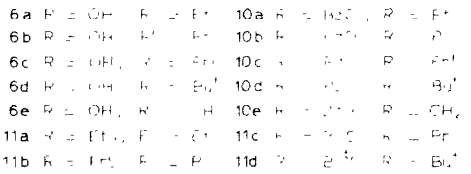
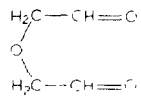


6a R = OH, R' = Et
6b R = OH, R' = Pr
6c R = OH, R' = Pr^i
6d R = OH, R' = Bu^t
6e R = OH, R' = H
10a R = H_2C=, R' = Et
10b R = H_2C=, R' = Pr
10c R = H_2C=, R' = Pr^i
10d R = H_2C=, R' = Bu^t
10e R = H_2C=, R' = CH_2
11a R = EtS, R' = Et
11c R = PrS, R' = Pr^i
11b R = PrS, R' = Pr
11d R = BuS, R' = Bu^t



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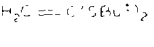

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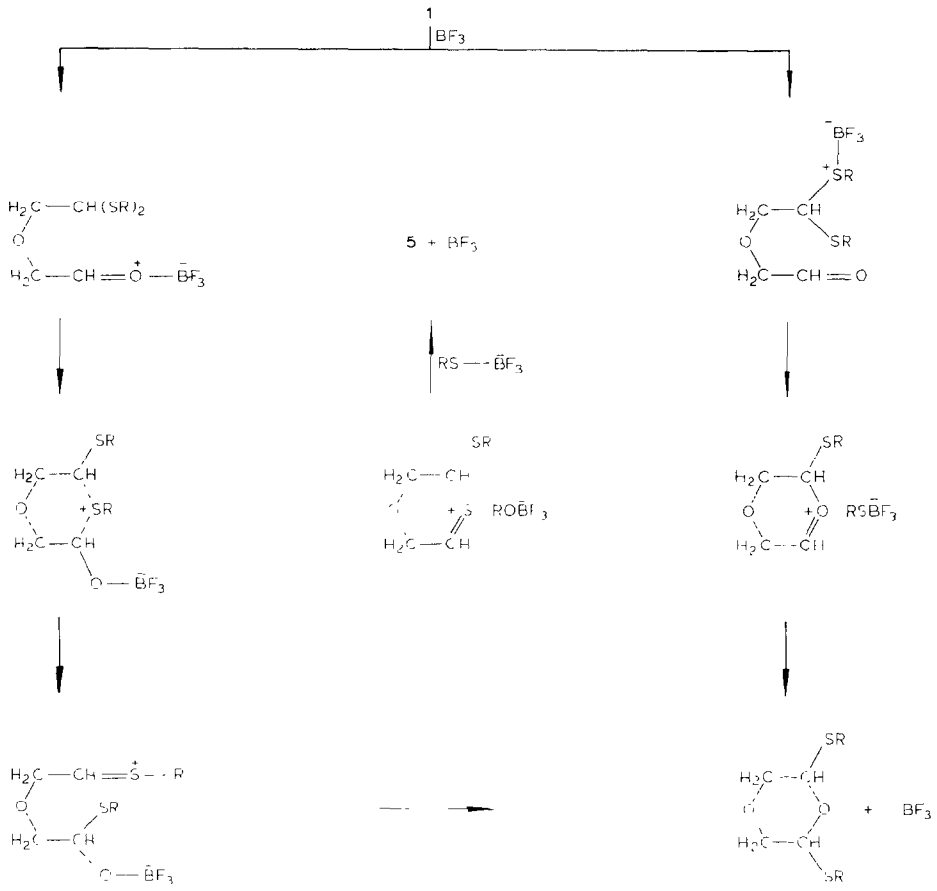
to give sulfur-heterocyclic compounds. As expected[1], the aldehydes **1a–e** showed a marked tendency to hydrate.

Whereas *O*-(1,3-dithiolan-2-ylmethyl)glycolaldehyde (**1e**) was stable in the presence of $BF_3 \cdot (Et_2O)_2$, the aldehydes **1a–c** gave the corresponding diglycolaldehyde bis(dialkyl dithioacetal), namely, **3a** (Et) 26.5%, **3b** (Pr) 44.7%, and **3c** (Pr^i) 28.6%. Although, in these reactions, diglycolaldehyde (**7**) must be formed in addition to **3a–c**, it was probably transformed into tarry products. On the other hand, *O*-[2,2-bis(*tert*-butylthio)ethyl]glycolaldehyde (**1d**) partially reacted to give 3,5-bis(*tert*-butylthio)-1,4-oxathiane (**5**, 42.4%) and *trans*-2,6-bis(*tert*-butylthio)-1,4-dioxane (**4**, 13.6%), which were isolated by column chromatography. Compound **5** is a known compound[2], and the i.r. spectrum of **4** was similar to those reported[2] for *trans*-2,6-bis(alkylthio)-1,4-dioxanes; in its ^{1}H-n.m.r. spectrum, the signals at δ 5.22 (dd, 1 H, J 5.5 and 3.4 Hz), 3.81 (dd, 1 H, J 11.8 and 3.4 Hz), and 3.48 (dd, 1 H, J 11.8 and 5.5 Hz) indicated the *trans* configuration. Oxidation of **4** with hydrogen peroxide gave *trans*-2,6-bis(*tert*-butylsulfonyl)-1,4-dioxane (**9**), which gave spectral data (i.r. and ^{1}H-n.m.r.) similar to those reported for other *trans*-2,6-bis(alkylsulfonyl)-1,4-dioxanes[8]. As diglycolaldehyde bis(di-*tert*-butyl dithioacetal) (**3d**) was not detected (t.l.c.) in the reaction of **1d** with $BF_3 \cdot (Et_2O)_2$ and since **3d** reacts slowly under these conditions[4] to give 3,5-bis(*tert*-butylthio)-1,4-oxathiane (**5**), it appears that trans-thioacetalation did not occur. The formation of 1,4-dioxane and 1,4-oxathiane derivatives in this reaction of **1d** may be ascribed to the easy formation of *tert*-butyl



Scheme 1

cation and to the release of steric strain when the *tert*-butyl cation or the *tert*-butylthio group is lost (see Scheme 1).

The dimethyl acetals **2a–e** were obtained by reacting bromoacetaldehyde dimethyl acetal and the appropriate sodium 2,2-bis(alkylthio)ethoxide; their yields decreased (69→33.7%) as the bulk of the alkylthio group increased. With sodium 2,2-bis(*tert*-butylthio)ethoxide, ketene di-*tert*-butyl dithioacetal (**8**) was obtained, in addition to **2d**, and could have been formed through a β-elimination process. It was shown that **8** was not formed solely from sodium 2,2-bis(*tert*-butylthio)ethoxide, but could be obtained from 2-methoxy-1,1-bis(*tert*-butylthio)ethane and 2-ethylthio-1,1-bis(*tert*-butylthio)ethane in yields of 86.4 and 35%, respectively. Monosaccharide dialkyl dithioacetal derivatives[5,6] undergo this type of reaction which is assumed to involve an E1cB mechanism[7].

The glycolaldehyde dialkyl dithioacetals **6a–e** were obtained from *O*-benzoylglycolaldehyde[9] by two procedures. Reaction in conc. hydrochloric acid with thiols gave *O*-benzoylglycolaldehyde dialkyl dithioacetals (**10a–e**), but only the diethyl

TABLE I

YIELDS[a] OF GLYCOLALDEHYDE DIALKYL DITHIOACETALS AND 1,1,2-TRIS(ALKYLTHIO)ETHANES

Thiol	*$HOCH_2CH(SR)_2$ (%)*	*$RS\text{-}CH_2CH(SR)_2$ (%)*
$HSCH_2CH_2SH$	**6e** (70.1)[b]	
EtSH	**6a** (54.6)[b]	
PrSH	**6b** (40.2)[b]	
Pr^{i}SH	**6c** (32.1)[b]	
Bu^{t}SH	**6d** (25.9)[b]	
EtSH	**6a** (66.0)[c,d]	**11a** (0.49)
PrSH	**6b** (60.5)[c]	**11b** (0.51)
Pr^{i}SH	**6c** (55.6)[c]	**11c** (2.24)
Bu^{t}SH	**6d** (48.6)[c]	**11d** (9.82)

[a]From *O*-benzoylglycolaldehyde. [b]After reaction of the aldehyde with thiols and treatment of the distilled products with KOH. [c]After conversion of the aldehyde into glycolaldehyde diethyl acetal and subsequent reaction with thiols. [d]Has been prepared[10] (57.8%) from glycolaldehyde.

(**10a**) and 1,3-dithiolan-2-yl (**10e**) derivatives were obtained pure by distillation. The other derivatives (**10b–d**) were contaminated with olefinic by-products, as shown by ^{1}H-n.m.r. spectroscopy. Although both pure and impure products variously gave **6a–e** on treatment with aqueous potassium hydroxide, the overall yields decreased as the α-branching in the alkylthio groups increased (Table I).

In the second procedure, *O*-benzoylglycolaldehyde was transformed into glycolaldehyde diethyl acetal (67%), and then treated with conc. hydrochloric acid and the thiol. The overall yields for **6a–d** were higher than in the first procedure (Table I), but small proportions of 1,1,2-tris(alkylthio)ethanes[4] (**11a–d**) were also formed, which were removed by column chromatography. *O*-Benzoylglycolaldehyde dipropyl, di-isopropyl, and di-*tert*-butyl dithioacetals (**10b–d**) were prepared by benzoylation of their dithioacetals (**6b–d**).

EXPERIMENTAL

General methods. — Organic solutions were dried over anhydrous Na_2SO_4. Solvents were evaporated under diminished pressure at <40°. Column chromatography was carried out on Silica gel 60 (Merck, 70–230 mesh, ASTM). Melting points (uncorrected) were obtained with an Electrothermal melting-point apparatus. U.v. spectra were recorded with a Perkin–Elmer 124 spectrometer. I.r. spectra were recorded for films on NaCl or KBr discs with a Pye–Unicam SP 1000 spectrometer. ^{1}H-N.m.r. spectra were recorded for solutions in various solvents (internal Me_4Si) with a Perkin–Elmer–Hitachi R-20 B spectrometer. Chemical shifts are given on the δ scale, and couplings in Hz.

O-Benzoylglycolaldehyde[9] (69%), b.p. 104–105°/2 mmHg, was prepared from 1-*O*-benzoylglycerol by periodate oxidation. 1,1-Diethoxy-2-methoxyethane[11]

(43.8%), b.p. 144–148°/710 mmHg, was obtained from bromoacetaldehyde diethyl acetal and sodium methoxide.

O-[*2,2-Bis(alkylthio)ethyl*]*glycolaldehydes* (**1a–e**). — A mixture of the appropriate acetal **2**, 1,4-dioxane, water, and conc. sulfuric acid was boiled under reflux for 1 h, sodium hydrogencarbonate (0.5 g) was added, the mixture was partially concentrated and then extracted with ether (4 × 40 mL), and the combined extracts were dried, filtered, and concentrated to dryness.

(*a*) O-[*2,2-Bis(ethylthio)ethyl*]*glycolaldehyde* (**1a**). Compound **2a** (5.8 g), 1,4-dioxane (30 mL), water (25 mL), and sulfuric acid (0.25 mL) were mixed. Distillation of the crude product gave **1a** (3.8 g, 80%), b.p. 94–97°/0.6 mmHg; ν_{max} 2805, 2700, 1740, 1260, 1130, and 968 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 9.62 (t, 1 H, *J* 0.8 Hz), 4.07 (d, 2 H, *J* 0.8 Hz), 3.95–3.45 (m, 3 H), 2.63 (q, 4 H, *J* 7 Hz), and 1.20 (t, 6 H, *J* 7 Hz) (Found: C, 46.2; H, 7.8. $C_8H_{16}O_2S_2$ calc.: C, 46.1; H, 7.6%).

(*b*) O-[*2,2-Bis(propylthio)ethyl*]*glycolaldehyde* (**1b**). Compound **2b** (3.9 g), 1,4-dioxane (30 mL), water (25 mL), and sulfuric acid (0.25 mL) were mixed. Distillation of the crude product gave **1b** (2.7 g, 82.7%), b.p. 94–96°/0.4 mmHg; ν_{max} 2700, 1740, 1240, 1125, and 970 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 9.62 (t, 1 H, *J* 0.8 Hz), 4.07 (d, 2 H, *J* 0.8 Hz), 3.74 (m, 3 H), 2.58 (m, 4 H), 1.50 (m, 4 H), and 0.95 (t, 6 H, *J* 6.9 Hz) (Found: C, 50.6; H, 8.3. $C_{10}H_{20}O_2S_2$ calc.: C, 50.8; H, 8.5%).

(*c*) O-[*2,2-Bis(isopropylthio)ethyl*]*glycolaldehyde* (**1c**). Compound **2c** (1.88 g), 1,4-dioxane (15 mL), water (15 mL), and sulfuric acid (0.25 mL) were mixed. Distillation of the crude product gave **1c** (1.32 g, 84%), b.p. 84–86°/0.4 mmHg; ν_{max} 2820, 2705, 1738, 1240, 1126, and 970 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 9.63 (t, 1 H, *J* 0.8 Hz), 4.07 (d, 2 H, *J* 0.8 Hz), 4.0–3.62 (m, 3 H), 2.13 (septet, 2 H, *J* 6.7 Hz), and 1.26 (d, 12 H, *J* 6.7 Hz) (Found: C, 51.0; H, 8.7. $C_{10}H_{20}O_2S_2$ calc.: C, 50.8; H, 8.5%).

(*d*) O-[*2,2-Bis*(tert-*butylthio)ethyl*]*glycolaldehyde* (**1d**). Compound **2d** (2.84 g), 1,4-dioxane (30 mL), water (20 mL), and sulfuric acid (0.25 mL) were mixed. Distillation of the crude product gave a mixture (1.8 g), b.p. 85–87°/0.1 mmHg, which, on chromatography (4:1 hexane–ether), gave, first, 3,5-bis(*tert*-butylthio)-1,4-oxathiane (**5**, 0.06 g), which was identified by comparison with an authentic sample[2]. Eluted second was **1d** (1.68 g, 69.4%), which, after distillation, had ν_{max} 2800, 2700, 1742, 1268, 1154–1120, and 970 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 9.78 (t, 1 H, *J* 0.8 Hz), 4.20 (d, 2 H, *J* 0.8 Hz), 4.11–3.6 (m, 3 H), and 1.39 (s, 18 H) (Found: C, 54.2; H, 9.4. $C_{12}H_{24}O_2S_2$ calc.: C, 54.5; H, 9.2%).

(*e*) O-(*1,3-Dithiolan-2-ylmethyl*)*glycolaldehyde* (**1e**). Compound **2e** (6.7 g), 1,4-dioxane (35 mL), water (30 mL), and sulfuric acid (0.25 mL) were mixed. Extraction with chloroform (4 × 20 mL) and distillation of the crude product gave **1e** (4.10 g, 83.6%), b.p. 110–112°/0.4 mmHg; ν_{max} 1735, 1240, 1142, 1120, and 970 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 9.59 (t, 1 H, *J* 0.8 Hz), 4.54 (t, 1 H, *J* 7 Hz), 4.07 (d, 2 H, *J* 0.8 Hz), 3.52 (d, 2 H, *J* 7 Hz), and 3.11 (s, 4 H) (Found: C, 40.6; H, 5.4. $C_6H_{10}O_2S_2$ calc.: C, 40.4; H, 5.6%).

Reaction of O-[*2,2-bis(alkylthio)ethyl*]*glycolaldehyde* (**1a–e**) *in the presence of boron trifluoride etherate*. — The appropriate aldehyde (**1a–e**) in 1,4-dioxane (8 mL)

was treated with boron trifluoride etherate (0.25 mL) at room temperature. The mixture was basified (aqueous 10% K_2CO_3), and extracted with ether (3 × 15 mL), and the combined extracts were dried, filtered, and concentrated to dryness.

(*a*) Compound **1a** (0.3 g) was treated for 1 day. Column chromatography (4:1 hexane–ether) of the crude product gave, first, diglycolaldehyde bis(diethyl dithioacetal)[2] (**3a**; 0.06 g, 26.5%), and then **1a** (0.02 g).

(*b*) Compound **1b** (0.33 g) was treated for 2 days. Column chromatography (4:1 hexane–ether) of the crude product gave, first, diglycolaldehyde bis(dipropyl dithioacetal)[2] (**3b**; 0.115 g, 44.7%), and then **1b** (0.018 g).

(*c*) Compound **1c** (0.447 g) was treated for 2 days. Column chromatography (4:1 hexane–ether) of the crude product gave, first, diglycolaldehyde bis(di-isopropyl dithioacetal)[2] (**3c**; 0.1 g, 28.6%), and then **1c** (0.04 g).

(*d*) Compound **1d** (0.736 g) was treated for 25 days. Column chromatography (10:1 hexane–ether) gave, first, 3,5-bis(*tert*-butylthio)-1,4-oxathiane[2] (**5**; 0.22 g, 42.4%), and then *trans*-2,6-bis(*tert*-butylthio)-1,4-dioxane (**4**; 0.1 g, 13.6%); ν_{max} 1386, 1363, 1206, 1158, 1116, 1088, 1044, 980, 882, 867, and 838 cm^{-1}; ^1H-N.m.r. data ($CDCl_3$): δ 5.22 (dd, 1 H, *J* 5.5 and 3.4 Hz), 3.81 (dd, 1 H, *J* 11.8 and 3.4 Hz), 3.48 (dd, 1 H, *J* 11.8 and 5.5 Hz), and 1.38 (s, 9 H) (Found: C, 56.7; H, 5.5. $C_{12}H_{24}O_2S_2$ calc.: C, 56.6; H, 5.5%). Eluted third was **1d** (0.11 g).

A mixture of **4** (0.07 g), acetic acid (1 mL), acetic anhydride (0.5 mL), and aqueous 30% hydrogen peroxide was left at room temperature for 14 days, and then concentrated to dryness. A small amount of ethanol was added to the residue, yielding *trans*-2,6-bis(*tert*-butylsulfonyl)-1,4-dioxane (**9**; 0.055 g, 63.2%), m.p. 157–158°; ν_{max} 1300, 1285, 1136, 1115, 1090, 985, 950, 890, 850, and 794 cm^{-1}; ^1H-N.m.r. data ($CDCl_3$): δ 5.40 (dd, 1 H, *J* 5.3 and 4.5 Hz), 4.23 (dd, 1 H, *J* 12 and 5.3 Hz), 3.93 (dd, 1 H, *J* 12 and 4.5 Hz), and 1.40 (s, 9 H) (Found: C, 43.8; H, 7.3. $C_{12}H_{24}O_6S_2$ calc.: C, 43.9; H, 7.4%).

(*e*) Compound **1e** did not react; after 4 days, 81.6% was recovered.

O-[*2,2-Bis(alkylthio)ethyl*]*glycolaldehyde dimethyl acetal* (**2a–e**). – Sodium hydride was added to the appropriate glycolaldehyde dialkyl dithioacetal (**6a–e**) in xylene (25 mL), and the mixture was boiled under reflux until the hydride disappeared. After cooling, bromoacetaldehyde dimethyl acetal was added, the mixture was boiled under reflux, and the solid materials were collected and washed with several portions of ether. The filtrate and washings were combined and concentrated to dryness.

The following materials and reaction times were used:

Starting material (g)	*Xylene (mL)*	*NaH (g)*	*Bromoacetaldehyde dimethyl acetal (g)*	*Time (h)*
6a (5)	25	0.75	7.7	30
6b (6.18)	25	0.79	8.17	40
6c (5)	25	0.63	7.53	40
6d (8.5)	30	0.95	15.0	168
6e (9.04)	70	1.64	18.0	40

(*a*) O-[*2,2-Bis(ethylthio)ethyl*]*glycolaldehyde dimethyl acetal* (**2a**). Distillation of the crude product gave **2a** (5.26 g, 69%), b.p. 90–93°/0.1 mmHg; ν_{max} 1378, 1265, 1200, 1115, 1080, 975, and 958 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 4.42 (t, 1 H, *J* 5.5 Hz), 3.70 (m, 3 H), 3.47 (d, 2 H, *J* 5.5 Hz), 3.30 (s, 6 H), 2.64 (q, 4 H, *J* 7 Hz), and 1.20 (t, 6 H, *J* 7 Hz) (Found: C, 47.4; H, 8.7. $C_{10}H_{22}O_3S_2$ calc.: C, 47.2; H, 8.7%).

(*b*) O-[*2,2-Bis(propylthio)ethyl*]*glycolaldehyde dimethyl acetal* (**2b**). Distillation of the crude product gave **2b** (5 g, 55.6%), b.p. 104–106°/0.2 mmHg; ν_{max} 1374, 1200, 1120, 1075, 980, and 958 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 4.41 (t, 1 H, *J* 5.4 Hz), 3.67 (m, 3 H), 3.46 (d, 2 H, *J* 5.4 Hz), 3.29 (s, 6 H), 2.57 (m, 4 H), 1.50 (m, 4 H), and 0.95 (t, 6 H, *J* 6.8 Hz) (Found: C, 51.2; H, 9.3. $C_{12}H_{26}O_3S_2$ calc.: C, 51.0; H, 9.3%).

(*c*) O-[*2,2-Bis(isopropylthio)ethyl*]*glycolaldehyde dimethyl acetal* (**2c**). Distillation of the crude product gave a liquid (4.6 g), b.p. 90–92°/0.1 mmHg, column chromatography (3:1 hexane–ether) of which gave **2c** (2.86 g, 39.3%), b.p. 90–92°/0.5 mmHg; ν_{max} 1378, 1240, 1197, 1120, 1070, 980, and 952 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 4.40 (t, 1 H, *J* 5.4 Hz), 4.01–3.57 (m, 3 H), 3.47 (d, 2 H, *J* 5.4 Hz), 3.30 (s, 6 H), 3.10 (m, 2 H), and 1.15 (d, 12 H, *J* 6.7 Hz) (Found: C, 51.1; H, 9.3. $C_{12}H_{26}O_3S_2$ calc.: C, 51.0; H, 9.3%).

(*d*) O-[*2,2-Bis*(tert-*butylthio)ethyl*]*glycolaldehyde dimethyl acetal* (**2d**). Distillation of the crude product gave impure ketene di-*tert*-butyl dithioacetal (**8**, 2.78 g), b.p. 105–110°/15 mmHg; **6d** (1.24 g), b.p. 74–76°/0.5 mmHg; and then impure **2d** (4.52 g), b.p. 108–110°/0.5 mmHg.

Column chromatography (hexane) yielded pure **8** (1.45 g), which was identified by comparison with an authentic sample (see below), and pure **2d** (4 g, 33.7%), b.p. 107–109°/0.5 mmHg; ν_{max} 1358, 1153, 1112, 1067, 972, and 948 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 5.51 (t, 1 H, *J* 5.3 Hz), 4.12–3.52 (m, 5 H), 3.41 (s, 6 H), and 1.37 (s, 18 H) (Found: C, 54.2; H, 9.8. $C_{14}H_{30}O_3S_2$ calc.: C, 54.1; H, 9.7%).

(*e*) O-(*1,3-Dithiolan-2-ylmethyl*)*glycolaldehyde dimethyl acetal* (**2e**). Distillation of the crude product gave **2e** (10 g, 67.1%), b.p. 106–110°/0.3 mmHg; ν_{max} 1455, 1200, 1118, 1082, 980, and 958 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 4.48 (m, 2 H), 3.49 (m, 4 H), 3.20 (s, 6 H), and 3.10 (s, 4 H) (Found: C, 43.0; H, 7.2. $C_8H_{16}O_3S_2$ calc.: C, 42.8; H, 7.2%).

Glycolaldehyde dialkyl dithioacetals (**6a–e**). — (*a*) *From glycolaldehyde diethyl acetal.* A stirred mixture of the acetal (4.5 g) in the appropriate ice-cold thiol (14 mL) was treated with conc. hydrochloric acid (6 mL) at room temperature for 30 min. After aqueous potassium hydroxide (15 g in 15 mL) had been added, the mixture was extracted with ether (3 × 30 mL), and the combined extracts were dried, filtered, and concentrated to dryness.

(*b*) *From* O-*benzoylglycolaldehyde.* The aldehyde (20 g) in ice-cold, conc. hydrochloric acid (30 mL) was treated with the appropriate thiol. The mixture was stirred at room temperature for 30 min, or 1 h when 2-methyl-2-propanethiol was used. Ether (150 mL) and cold water (50 mL) were added; in the preparation of **6e**, chloroform (130 mL) and water (25 mL) were used. The aqueous solutions were

discarded, and the organic layer was treated with aqueous 30% sodium hydroxide (60 mL) and then with water (50 mL), dried, filtered, and concentrated to dryness. The crude product was distilled, and a solution of the residue in ethanol (10 g in 80 mL) was treated with aqueous potassium hydroxide (5 g in 20 mL) at room temperature for 12 h. The mixture was concentrated and extracted with ether (4 × 50 mL), and then the combined extracts were dried, filtered, and concentrated to dryness.

Glycolaldehyde diethyl dithioacetal (**6a**). — (*a*) *From glycolaldehyde diethyl acetal.* Column chromatography (50:1 hexane–ether) of the crude product gave, first, 1,1,2-tris(ethylthio)ethane[4] (**11a**; 0.05 g, 0.73%); and then **6a** (5.5 g, 98.6%), b.p. 70–73°/0.4 mmHg: ν_{max} 3365, 1373, 1072, 1050, 1010, and 972 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 3.84–3.30 (m, 3 H), 2.60 (q, 5 H, *J* 7.2 Hz; one proton exchangeable with D_2O), and 1.20 (t, 6 H, *J* 7.2 Hz) (Found: C, 43.2; H, 8.4; S, 38.3. $C_6H_{14}OS_2$ calc.: C, 43.3; H, 8.5; S, 38.5%).

(*b*) *From O-benzoylglycolaldehyde.* Ethanethiol (30 mL) was used. Distillation of the crude product gave *O*-benzoylglycolaldehyde diethyl dithioacetal (**10a**; 25.4 g, 77.6%), b.p. 140–143°/0.4 mmHg; ν_{max} 1725, 1607, 1587, 1265, 1116, 1073, and 714 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 8.0 (m, 2 H), 7.4 (m, 3 H), 4.48–3.9 (m, 3 H), 2.68 (q, 4 H, *J* 7 Hz), and 1.26 (t, 6 H, *J* 7 Hz) (Found: C, 57.7; H, 6.6; S, 23.9. $C_{13}H_{18}O_2S_2$ calc.: C, 57.7; H, 6.7; S, 23.7%). After saponification and distillation, **6a** (4.33 g, 70.4%) was obtained; b.p. 70–73°/0.4 mmHg.

Glycolaldehyde dipropyl dithioacetal (**6b**). — (*a*) *From glycolaldehyde diethyl acetal.* Distillation of the crude product gave a mixture (5.95 g), b.p. 140–143°/14 mmHg, column chromatography (7:1 hexane–ether) of which gave, first, 1,1,2-tris(propylthio)ethane[4] (**11b**; 0.065 g, 0.76%); and then **6b** (5.88 g, 90.3%): ν_{max} 3420, 1378, 1055, 1020, and 780 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 3.9–3.4 (m, 3 H), 2.6 (m, 4 H), 2.3 (bs, 1 H; proton exchangeable with D_2O), 1.62 (m, 4 H), and 1.0 (t, 6 H, *J* 6.8 Hz) (Found: C, 49.5; H, 9.2; S, 32.8. $C_8H_{18}OS_2$ calc.: C, 49.4; H, 9.3; S, 33.0%).

A solution of **6b** (1.4 g) in pyridine (4 mL) was treated conventionally with benzoyl chloride (1 mL), to give *O*-benzoylglycolaldehyde dipropyl dithioacetal (**10b**; 1.8 g, 83.6%), b.p. 142–144°/0.5 mmHg: ν_{max} 1723, 1602, 1585, 1268, 1175, 1109, 1065, and 703 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 8.0 (m, 2 H), 7.4 (m, 3 H), 4.5–3.9 (m, 3 H), 2.65 (m, 4 H), 1.55 (m, 4 H), and 1.0 (t, 6 H, *J* 6.8 Hz) (Found: C, 60.2; H, 7.4. $C_{15}H_{22}O_2S_2$ calc.: C, 60.3; H, 7.4%).

(*b*) *From O-benzoylglycolaldehyde.* Propanethiol (36 mL) was used. Distillation of the crude product gave impure **10b** (27.12 g), b.p. 140–145°/0.5 mmHg. After saponification and distillation, **6b** (3.51 g) was obtained; b.p. 93–96°/1 mmHg.

Glycoaldehyde di-isopropyl dithioacetal (**6c**). — (*a*) *From glycolaldehyde diethyl acetal.* Distillation of the crude product gave a mixture (5.72 g), b.p. 120–122°/14 mmHg, column chromatography (7:1 hexane–ether) of which gave, first, 1,1,2-tris(isopropylthio)ethane[4] (**11c**; 0.284 g, 3.3%); and then **6c** (5.43 g, 83%): ν_{max} 3410, 1378, 1363, 1047, 1010, and 760 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 4.0–3.5 (m,

3 H), 3.11 (septet, 2 H, *J* 7 Hz), 2.9 (bs, 1 H; proton exchangeable with D_2O), and 1.30 (d, 12 H, *J* 7 Hz) (Found: C, 49.3; H, 9.4. $C_8H_{18}OS_2$ calc.: C, 49.4; H, 9.3%).

A solution of **6c** (1.12 g) in pyridine (4 mL) was treated conventionally with benzoyl chloride (1 mL), to give *O*-benzoylglycolaldehyde di-isopropyl dithioacetal (**10c**; 1.42 g, 82.5%), b.p. 140–142°/0.4 mmHg; ν_{max} 1727, 1605, 1587, 1380, 1367, 1260, 1180, 1157, 1110, 1070, and 707 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 8.0 (m, 2 H), 7.4 (m, 3 H), 4.6–4.0 (m, 3 H), 3.2 (septet, 2 H, *J* 7 Hz), 1.3 (d, 6 H, *J* 7 Hz), and 1.28 (d, 6 H, *J* 7 Hz) (Found: C, 60.5; H, 7.5. $C_{15}H_{22}O_2S_2$ calc.: C, 60.3; H, 7.4%).

(*b*) *From* O-*benzoylglycolaldehyde*. 2-Propanethiol (36 mL) was used. Distillation of the crude product gave impure **10c** (22.0 g), b.p. 135–140°/1 mmHg. After saponification and distillation, **6c** (3.45 g) was obtained; b.p. 70–74°/0.6 mmHg.

*Glycolaldehyde di-*tert*-butyl dithioacetal* (**6d**). — (*a*) *From glycolaldehyde diethyl acetal*. Column chromatography (10:1 hexane–ether) of the crude product gave, first, 1,1,2-tris(*tert*-butylthio)ethane[4] (**11d**; 1.45 g, 14.6%); and then **6d** (5.4 g, 72.6%), m.p. 57–58°; ν_{max} 3450, 1380, 1360, 1154, 1045, 1020, and 765 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 4.0–3.4 (m, 3 H), 2.48 (bt, 1 H; proton exchangeable with (D_2O), and 1.38 (s, 18 H) (Found: C, 53.8; H, 10.1. $C_{10}H_{22}OS_2$ calc.: C, 54.0; H, 10.0%).

A solution of **6d** (0.36 g) in pyridine (4 mL) was treated conventionally with benzoyl chloride (0.5 mL). Column chromatography (10:1 hexane–ether) of the product gave *O*-benzoylglycolaldehyde di-*tert*-butyl dithioacetal (**10d**; 0.47 g, 89%); ν_{max} 1720, 1600, 1580, 1360, 1265, 1095, and 694 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 8.2 (m, 2 H), 7.5 (m, 3 H), 4.4 (m, 3 H), and 1.38 (s, 18 H) (Found: C, 62.6; H, 8.1. $C_{17}H_{26}O_2S_2$ calc.: C, 62.5; H, 8.0%).

(*b*) *From* O-*benzoylglycolaldehyde*. 2-Methyl-2-propanethiol (39 mL) was used. Distillation of the crude product gave impure **10d** (14.16 g), b.p. 122–140°/0.6 mmHg. After saponification and distillation, **6d** (4.95 g) was obtained; b.p. 78–80°/0.4 mmHg.

Glycolaldehyde ethylene dithioacetal (**6e**). — (*a*) *From* O-*benzoylglycolaldehyde*. 1,2-Ethanethiol (15 mL) was used. Distillation of the crude product gave *O*-benzoylglycolaldehyde ethylene dithioacetal (**10e**; 21.84 g, 75%), b.p. 142–144°/0.3 mmHg; ν_{max} 1737, 1600, 1580, 1280, 1120, 1070, and 720 cm^{-1}. ^{1}H-N.m.r. data ($CDCl_3$): δ 7.96 (m, 2 H), 7.38 (m, 3 H), 4.9–4.17 (m, 3 H), and 3.1 (s, 4 H) (Found: C, 55.2; H, 5.1. $C_{11}H_{12}O_2S_2$ calc.: C, 54.9; H, 5.0%). After saponification and distillation, **6e** (5.3 g), b.p. 86–88°/1 mmHg, was obtained; ν_{max} 3390, 1374, 1050, 1010, and 846 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 4.38 (t, 1 H, *J* 6.7 Hz), 3.4 (bd, 2 H, *J* 6.7 Hz), 3.06 (s, 4 H), and 2.55 (bs, 1 H; proton exchangeable with D_2O) (Found: C, 35.2; H, 5.9. $C_4H_8OS_2$ calc.: C, 35.3; H, 5.9%).

*Ketene di-*tert*-butyl dithioacetal* (**8**). — A mixture of 1,1-diethoxy-2-methoxyethane[11] (3.2 g), 2-methyl-2-propanethiol (10 mL), and conc. sulfuric acid (0.5 g) was stirred at room temperature for 16 h, basified with aqueous potassium hydroxide, and extracted with ether (3 × 30 mL). The combined extracts were dried, filtered, and concentrated to dryness. Distillation of the residue gave 1,1-bis(*tert*-butylthio)-2-methoxyethane (3.8 g, 74.5%), b.p. 120–122°/14 mmHg; ν_{max} 1360, 1160, and 1110

cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 3.96–3.40 (m, 3 H), 3.31 (s, 3 H), and 1.37 (s, 18 H) (Found: C, 56.0; H, 10.0; S, 27.1. $C_{11}H_{24}OS_2$ calc.: C, 55.8; H, 10.2; S, 27.1%).

A mixture of the foregoing product (3.3 g), 2-methyl-2-propanol (40 mL), and sodium hydride (0.76 g) was boiled under reflux for 24 h and then concentrated. Water (25 mL) was added, the mixture was extracted with ether (2 × 25 mL), and the combined extracts were dried, filtered, and concentrated to dryness. Column chromatography of the residue gave **8** (2.46 g, 86.4%), b.p. 105–108°/14 mmHg; ν_{max} 1575, 1550, 1455, 1364, 1160, 1090, 924, 857, 780, and 755 cm^{-1} λ_{max}^{hexane} 252, 257, and 262 nm (ε 3068, 3068, and 2631). ^{1}H-N.m.r. data (CCl_4): δ 5.80 (s, 1 H) and 1.40 (s, 9 H) (Found: C, 58.9, H, 10.0. $C_{10}H_{20}S_2$ calc.: C, 58.7; H, 9.9%).

Compound **8** (35.8%) was obtained from 1,1-bis(*tert*-butylthio)-2-ethylthioethane after 48 h under conditions similar to those described.

Glycolaldehyde diethyl acetal. — A mixture of *O*-benzoylglycolaldehyde (16 g), ethanol (150 mL), benzene (50 mL), and conc. sulfuric acid (1 g) was boiled under reflux with azeotropic distillation of water for 6 h. Aqueous sodium hydroxide (12 g in 25 mL) and ethanol (25 mL) were added, and the mixture was boiled under reflux for 1 h, concentrated, and extracted with ether (3 × 60 mL). The combined extracts were dried, filtered, and concentrated. Distillation of the residue yielded the acetal (9.14 g, 67%), b.p. 72–74°/14 mmHg; ν_{max} 3415, 1366, 1230, 1126, and 1090–1035 cm^{-1}. ^{1}H-N.m.r. data (CCl_4): δ 4.44 (t, 1 H, J 5.5 Hz), 3.95–3.20 (m, 6 H), 2.32 (bs, 1 H, proton exchangeable with D_2O), and 1.17 (t, 6 H, J 7 Hz) (Found: C, 53.8; H, 10.4. $C_6H_{14}O_3$ calc.: C, 53.7, H, 10.5%).

When water was not removed by azeotropic distillation, 61.5% of the acetal was obtained.

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