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Citation: FUCHS, C. ... et al., 2013. Studies on the double alkylation of 2,2-disubstituted-1,3-dithiacycloalkane-S-oxides: synthesis of tertiary thiol derivatives. RSC Advances, 3, pp.21911-21918.

Metadata Record: https://dspace.lboro.ac.uk/2134/15468

Version: Accepted for publication

Publisher: © Royal Society of Chemistry

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Studies on the Double Alkylation of 2,2-Disubstituted-1,3-Dithiacycloalkane-S-oxides: Synthesis of Tertiary Thiol Derivatives

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Received (in XXX, XXX) Xth XXXXXXXXX 20XX, Accepted Xth XXXXXXXXX 20XX
DOI: 10.1039/b000000x

Di-alkylation of 2,2-dimethyl-1,3-dithiacycloalkane-S-oxides has been achieved allowing the synthesis of two tertiary thiol centres. The diastereoisomers of the mono-alkylated products have been shown to react at different rates. The X-ray crystal structures of three substituted dithiane-S-oxides have been determined, and the conversion of the dialkylated products into cyclic disulfide derivatives of tertiary thiols (1,2-dithiolanes) has been achieved by treatment with acid.

Introduction

As part of an investigation into the synthesis of polysulfide natural products we required a method to generate a tertiary thiol group which would allow synthesis of tertiary di- and tri-sulfide derivatives. There are relatively few methods1 for synthesising tertiary thiols, so we wished to study the sequential alkylation of cyclic dithioketal monosulfoxides 1 (Scheme 1) to allow controlled introduction of two substituents adjacent to a sulfur atom. Monoalkylation of a cyclic dithioketal monosulfoxide has been used in an elegant synthesis of lipoic acid,2 and we wished to explore if further alkylation of this type of sulfoxide system could be employed to form a tertiary sulfoxide 3 which would generate the cyclic disulfide 5 on hydrolysis, and dehydration of the presumed mercaptosulfenic acid 4. The disulfide would then have potential for ring expansion to a trisulfide 6 for example by mono-oxidation and treatment with bis-trimethylsilyl sulfide.3

Use of a chiral auxiliary, and changing the sequence of introduction of substituents, should allow both enantiomers of the tertiary thiol to be produced. A series of experiments was therefore carried out to test if this was a viable approach to generate tertiary thiols protected as their cyclic disulfides.

Results and Discussion

Several cyclic dithioketals were prepared (Scheme 2) from either benzophenone or acetone as possible substrates for oxidation and alkylation. The 5-, 6- and 7-membered compounds derived from benzophenone 9a,4,5 9b,6 9c,7 were prepared in moderate to good yield by known methodology. The benzophenone derived 1,3-dithianes were chosen as they possess no aliphatic signals from the ketone moiety in the NMR spectra, and the derivatives were expected to be crystalline.

The dithiane 8a was prepared in good yield, but no pure product from the reaction of acetone and butane-1,4-dithiol in the presence of TiCl4 could be obtained. Dithiepane 8b could not be isolated, possibly due to slow closure of the seven-membered ring and formation of oligomers or polymers. The dithiepane 8b may not crystallise as well as the corresponding diphenyl compound 9b rendering separation from oligomeric or polymeric by-products difficult.
Scheme 2: Preparation of cyclic dithioketals employed.

The 14-membered dimer 10 (Figure 2) did however crystallise in low yield from the crude oily product after a prolonged period (16 months), and the structure was confirmed by X-ray crystallography (Figure 3). The dimer 10 was shown by $^1$H NMR spectroscopy to convert in CDCl$_3$ to a similar compound (which could be either monomer 8b or linear polymer) with a half-life time of about 1 day. The chemical shift of the methyl group changed from $\delta = 1.60$ in 10 to $\delta = 1.63$ in the new compound, but the structure could not be determined with certainty. The X-ray crystal structure was also obtained for the 1,3-dithiepane 9c and is shown in Figure 4.

Figure 2: Structures of 1,3-dithiepane 9c and 14-membered cyclic bis-dithioketal 10.

Figure 3. X-ray structure of 10. The molecule lies on a centre of symmetry.

Figure 4. X-ray structure of dithiepane 9c. One of two similar molecules in the asymmetric unit.

The 6-membered dithioketals 8a and 9b were easily oxidised to the mono-sulfoxide with methanolic sodium periodate, hydrogen peroxide in acetic acid or best with hydrogen peroxide in methanol with a catalytic amount of HCl. Initial experiments with 2,2-dimethyl-1,3-dithiane-1-oxide 11 (Scheme 3) proved the viability of the double alkylation strategy and subsequent conversion to a cyclic disulfide.

Scheme 3: Double alkylation of sulfoxide 11

Thus treatment of 11 with n-butyllithium followed by addition of methyl iodide afforded monoalkylated sulfoxide 12 in 70% yield as a mixture of diastereoisomers (ratio ~ 3:2 by $^1$H NMR spectroscopy). Further deprotonation and methylation then gave a 73% yield of the dimethylated sulfoxide 13 which, pleasingly, could be converted in high yield (84%), to the dimethyl 1,2-dithiolane 14 by treatment with acid. Reaction with hydrochloric acid in acetonitrile at room temperature was found to give the best results; hydrochloric acid in methanol gave lower yields,
while HCl in ether\textsuperscript{14} or toluene returned only the starting sulfoxide.

When the deprotonation was carried out using n-BuLi, small amounts of impurities containing an n-butyl group were observed that were difficult to separate. This was witnessed by the presence of a triplet with $\delta = 0.97$ in the $^1$H NMR spectrum, which did not disappear after purification by chromatography. In related reactions,\textsuperscript{13,14} it was found that use of methyllithium instead of n-butyllithium as base gave higher yields and cleaner compounds. Thus methyllithium was investigated as a base to see if other substituents could be introduced by alkylation. This proved to be the case, and methyllithium as base gave similar yields of purer products. However, we were unable to isolate the benzyl adduct 19 (Scheme 4) on treatment of 12 (a mixture of diastereoisomers) with 1.5 equivalents of methyllithium, and subsequent addition of excess benzyl bromide. Surprisingly, a low yield (9\%) of the dimethylated sulfoxide 13 was obtained, together with 1,2-diphenylethane (38\%) and a 30\% recovery of the starting sulfoxide isolated as a crystalline single diastereoisomer 12a.

The formation of 13 can be explained by a metal-halogen exchange between the excess methyllithium and benzyl bromide with subsequent methylation of the anion of 12 by the resulting methyl bromide. Coupling between the benzyl lithium formed and the benzyl bromide present would then form 1,2-diphenylethane 15. The reaction between the anion of 12 and benzyl bromide must be slow as no evidence for the formation of any benzylated product 19 was obtained. Similarly the 2,2-diphenyl 1,3-dithiane-1-oxide 16\textsuperscript{10} (Scheme 5) could not be alkylated with benzyl bromide in an attempt to generate 17 (n-BuLi used as base); a complex mixture was obtained and no pure substance or starting material could be isolated. The presence of a bulky axial phenyl substituent may have blocked approach of the electrophile preventing alkylation, and the anion must have then degraded by other pathways leading to consumption of the starting material.

Introduction of benzyl as first substituent was successful with sulfoxide 11 (Scheme 6), after lithiation with n-butyllithium, forming 18 as a mixture of diastereoisomers. Subsequent deprotonation with methyllithium and treatment with methyl iodide revealed, however, that only one of the diastereoisomers of 18 was methylated with the other diastereoisomer being recovered in pure form. Neither 18 nor 19 are solid, so no assignment of stereochemistry by X-ray crystallography was possible. Both the mono- and di-alkylated dithiane oxides 18 and 19 were smoothly converted into the 1,2-dithiolanes 20 and 21 respectively by treatment with aqueous hydrochloric acid in acetonitrile, again illustrating the viability of the approach. It was observed that the diastereoisomers of 18 are cleaved at different rates, with the ratio changing from initially 43:57 to 93:7 when the reaction was followed by $^1$H NMR spectroscopy. The diastereomer that is cleaved faster is the one that failed to alkylate, but we were unable to determine the relative stereochemistry of the compound.

Figure 5: X-ray crystal structure of sulfoxide 12a.
Scheme 6: Double alkylation of sulfoxide 11 and 1,2-dithiolane formation.

We then investigated alkylation of the dithiane derived from menthone as a chiral auxiliary (Scheme 7). The dithioacetal 22 formed from menthone and 1,3-propanedithiol on oxidation with NaIO₄ in methanol gave only the sulfoxide 23 as a single diastereoisomer, the structure being confirmed by X-ray crystallography (Figure 6).

Scheme 7: Alkylation of menthone derived sulfoxide 23.

Alkylation was found to be completely diastereoselective for both methyl iodide and benzyl bromide, yielding only 24a or 24b respectively when methyllithium was employed as base. The structures of the two alkylation products 24a and 24b were established by single crystal X-ray diffraction and are shown in Figures 7 and 8.

Figure 7: X-ray crystal structure of methylated sulfoxide 24a.
Figure 8: X-ray crystal structure of benzylated sulfoxide 24b. Hydrogen atoms omitted for clarity. One of two similar molecules in the asymmetric unit.

The benzylated product 24b could be cleanly converted to the dithiolane 20a, which was shown to be the pure S-enantiomer by chiral HPLC, conditions having been established to separate the racemic product 20 generated from 18 (Scheme 6). It was not possible to effect a second alkylation with methyllithium as base and methyl iodide as alkylating agent, 24b being recovered unchanged in 69% yield, and no evidence for the formation of 25 was obtained. This may have been due to the axial methylene group of the menthyl auxiliary group blocking approach of the electrophile.

Conclusions

In conclusion, we have shown that it is possible in two cases so far, to effect di-alkylation of dithioketal-S-oxides, and that the diastereoisomers of the mono-alkylated products react at different rates. We have determined the X-ray crystal structures of a cyclic dithiane and three substituted dithiane-S-oxides, and shown that the dialkylated products can be converted into cyclic disulfide derivatives of tertiary thiols on treatment with aqueous hydrochloric acid in acetonitrile. Further studies on increasing the range of alkylating agents, and applying the method to natural product synthesis are in progress.

Acknowledgements

We thank Mr J.A Daley for performing CHN analyses, and Mr E. Simpson for help with electronic plots of NMR spectra. We thank Loughborough University for financial support, and the EPSRC National Mass Spectrometry Service at Swansea for mass spectra.

Experimental Section

Reactions involving sodium hydride, n-butyl- or methyllithium were performed in oven-dried glassware (150 °C overnight) under an atmosphere of nitrogen. Tetrahydrofuran and diethyl ether were distilled from Na/Ph2CO immediately before use. Petrol, methanol, and dichloromethane were distilled, while all other solvents were used as received unless otherwise stated. Column chromatography was performed on silica-gel 60 with gradient elution using petrol:ethyl acetate mixtures. Thin layer chromatography was performed on silica-gel 60, and the visualizing method is quoted. Chiral HPLC was performed using a Eurocel 01 5µm column, 250 x 4.6 mm with pre-column, and UV detection. 1H and 13C NMR spectra were recorded at 400 MHz and 100 MHz respectively on Bruker DPX 400MHz or Bruker Advance 400MHz instruments using CDCl3 as solvent and TMS as standard unless otherwise stated. Chemical shifts are reported as δH or δC in ppm relative to TMS. Assignments were assisted by COSY, DEPT, HMBC and HMQC analysis. For 1H spectra coupling patterns are reported as s, d, t, q or m with coupling constants, J, in hertz. For 13C spectra the term in brackets indicates the proton attachment based on the DEPT-135 experiment.

IR-spectra were recorded on a Perkin Elmer Paragon 1000 FT-IR spectrometer or on a PerkinElmer Spectrum 65 FT-IR spectrometer, for neat liquids, and as Nujol-mulls, or KBr discs for solids, with wavenumbers reported in cm⁻¹. HRMS was carried out using a Thermo Scientific Orbitrap Exactive with Advion Triversa Nanomate, or by the EPSRC National Mass Spectrometry Service Centre in Swansea. Melting points were measured on a Stuart Scientific Melting Point apparatus SMP3 and are uncorrected. Elemental Analyses were determined on a Perkin-Elmer 2400 analyser.

2,2-Diphenyl-1,3-dithiolane 9a

Benzophenone (1.88 g, 10.3 mmol) and 1,2-ethanediethiol (1.30 g, 13.8 mmol) were dissolved in CH2Cl2 (12 ml). The solution was stirred at room temperature and aluminium trichloride (0.51 g, 3.7 mmol) was added. The mixture turned yellow and boiled. After 30 min aq. HCl (5 ml, 2 M) was added. The organic layer was separated, washed with water, dried and rotary evaporated to give a white solid (2.58 g, 100%), m.p. 102-103 ºC (lit.6: 104-105 ºC). Recrystallisation from CH2Cl2/petrol gave pure crystalline product (2.07 g, 8.0 mmol, 78%, m.p. 102-103 ºC (lit.6: 104-105 ºC).
2,2-Diphenyl-1,3-dithiane was prepared as above from benzophenone (1.91 g, 10.5 mmol) and 1,3-propanedithiol (1.31 g, 12 mmol). Crude product was obtained as a white solid (2.84 g, 99%). Recrystallisation from CH₂Cl₂/petrol gave pure crystalline product (1.66 g, 6 mmol, 58%, m.p. 109-110 ºC). ¹H NMR (400 MHz, CDCl₃) δ = 1.95-2.05 (m, 2H, SCH₂CH₂), 2.74-2.83 (m, 4H, SCH₂), 7.20-7.30 (m, 2H), 7.30-7.40 (m, 4H), 7.65-7.75 (m, 4H).

13C NMR (100 MHz, CDCl₃) δC = 24.5 (CH₂), 29.4 (CH₂), 62.8 (Cq), 127.6 (CH), 128.4 (CH), 129.3 (CH), 142.5 (Cq).

2,2-Diphenyl-1,3-dithiepane 9c
2,2-Diphenyl-1,3-dithiepane was prepared as above from benzophenone (1.87 g, 10.3 mmol) and 1,4-butanedithiol (1.54 g, 12.6 mmol). The crude product (3.03 g) was an oil that showed no signals for thiol or carbonyl in the IR spectrum, but was impure by NMR spectroscopy. The oil solidified on standing and crystallisation from CH₂Cl₂ at -20 ºC yielded product (472 mg, 1.7 mmol, 16%) with minor impurities. The substance recovered from the mother liquor was subjected to chromatography (40 g silica, 97:3 petrol:EtOAc, 40 ml fore-run, fractions 15 ml). Fractions 6 and 7 deposited crystals. Fractions 5-9 afforded pure compound (469 mg, 1.6 mmol, 16%) and material with minor impurities (228 mg, 0.83 mmol, 8%). Combined yield 40%.

Rf (97:3 petrol:EtOAc) 0.53 [UV254 quenched]. m.p. 106-108 ºC (from petrol/EtOAc).

¹H NMR (400 MHz, CDCl₃) δ = 1.95-2.10 (m, 4H, SCH₂CH₂), 2.90-3.05 (m, 4H, SCH₂), 7.18-7.26 (m, 2H), 7.26-7.35 (m, 4H), 7.50-7.60 (m, 4H).

13C NMR (100 MHz, CDCl₃) δC = 31.2 (CH₂), 31.4 (CH₂), 70.2 (Cq), 127.2 (CH), 128.1 (CH), 128.2 (CH), 145.1 (Cq).


2,2,9,9-Tetramethyl-1,3,8,10-tetrathiacyclotetradecane 10
Acetone (0.76 g, 13 mmol) and 1,4-butanedithiol (1.32 g, 11 mmol) were dissolved in CH₂Cl₂ (5 ml) and stirred at 0 ºC. TiCl₄ (1.0 ml, 1.0 M solution in CH₂Cl₂) was added. The mixture turned white and turbid. After stirring overnight the mixture was washed with NaOH (aq) (2 M, 1 ml) and brine (1 ml). The dichloromethane layer was dried over MgSO₄. Evaporation yielded a clear colourless oil (1.57 g), which turned into a white jelly. Attempted kugelrohr distillation yielded no identifiable products. After 16 months crystals were deposited (86 mg, 0.53 mmol, 4.9%). Single crystal X-ray analysis showed these to be the dimer. ¹H NMR spectroscopy in CDCl₃ showed the dimer to rapidly convert into another compound of similar structure (δ = 1.60 to 1.63 for the methyl signal).

m.p. 144-147 ºC.

¹H NMR (400 MHz, CDCl₃) δ = 1.60 (s, 12H), 1.90-2.00 (m, 4H), 2.75-2.85 (m, 4H).

13C NMR (100 MHz, CDCl₃) δC = 29.0 (CH₂), 32.0 (CH₂), 33.4 (CH₃), 54.4 (Cq).

2,2,6-Trimethyl-1,3-dithiane-1-oxides 12/12a
2,2-Dimethyldithiane-1-oxide (0.51 g, 3.1 mmol) was dissolved in THF (6 ml) and the solution stirred at -78 ºC. n-Butyllithium solution (2.0 ml, 2.0 M in hexanes, 4.0 mmol) was added dropwise. After 15 min methyl iodide (0.25 ml, 4.0 mmol) was added. After a further 45 min, the reaction mixture was quenched by addition of ammonium chloride (0.5 ml sat. aq. solution) and warmed to room temperature. Water (15 ml) was added and the mixture extracted with dichloromethane (3 x 15 ml). The combined organic phases were washed with brine, dried over MgSO₄ and concentrated. Chromatography, eluting with CHCl₃:MeOH (24:1), gave a 3:2 mixture of diastereoisomers as a clear yellow liquid (0.39 mg, 70%), which partially crystallised. Mixture of diastereomers: m.p. slightly above room temperature.

¹H NMR (400 MHz, CDCl₃) δ = 1.33 (d, J = 7 Hz, 3H, CH₃-6, major isomer) + 1.41 (d, J = 7 Hz, 3H, CH₃-6, minor isomer), 1.47 + 1.59 (2 x s, 2 x 3H, CH₂-2, major isomer), 1.53 + 1.65 (2 x s, 2 x 3H, CH₂-2, minor isomer), 1.58-1.67 (m, 1H, H-5, both isomers), 1.95-2.12 (m, 1H, H-5, both isomers), 2.30-2.40 (m, 1H, H-4, minor isomer), 2.51 (app dt, J = 14, 3 Hz, 1H, H-4, major isomer), 2.60-2.76 (m, 1H, H-6, both isomers), 2.82-2.98 (m, 1H, H-4, both isomers).

¹C NMR (100 MHz, CDCl₃) δC = 16.0 (CH₃), 16.6 (CH₃), 17.9 (CH₃), 21.7 (CH₃), 22.5 (CH₃), 25.3 (CH₂), 25.4 (CH₂), 25.7
Z-2,2-Dimethyl-6-methyl-1,3-dithiane-1-oxide 12a (the diastereoisomer that failed to alkylate; oxygen axial, methyl equatorial): m.p. 102-103 ºC (from Et2O).

1H NMR (400 MHz, CDCl3) δ H = 1.34 (d, J = 7 Hz, 3H, CH3-6), 1.50 (s, 3H, CH3-2), 1.57 (s, 3H, CH3-2), 1.52-1.68 (m, 1H, H-5), 2.02-2.15 (m, 1H, H-5), 2.52 (app dt, J = 14, 3 Hz, 1H, H-4), 2.53-2.65 (m, 1H, H-6), 2.89 (ddd, J = 15, 13, 2 Hz, 1H, H-4).

13C NMR (100 MHz, CDCl3) δ C = 18.1 (CH3), 22.0 (CH2), 22.7 (CH3), 25.6 (CH2), 26.1 (CH3), 46.5 (CH), 58.7 (Cq).

HRMS: calcd. for C7H14NaOS2 [MNa]+ 201.0378; found 201.0377.

6-Benzyl-2,2-dimethyl-1,3-dithiane-1-oxide 18

Sulfoxide 13 (0.51 g, 3.1 mmol) was dissolved in THF (12 ml) and the solution stirred at -75 ºC. Methyl lithium (3.0 ml, 1.5 M in Et2O, 4.5 mmol) was added and the mixture stirred for 1 h. Benzy chloride (0.59 g, 4.7 mmol) was added and the pale yellow green solution was left to warm to room temperature.

Aqueous work-up and chromatography (1:1 petrol:EtOAc + 0.2% MeOH) yielded product (0.59 g, 2.3 mmol, 75%) as a sticky oil consisting of two diastereoisomers (43:57) which did not separate.

Rf (1:1 petrol:EtOAc + 0.2% MeOH) = 0.38 (stains with warm phosphomolybdic acid).

HRMS: Calcd. for C13H18OS2 [MNa]+ 277.0691; found 277.0686.

2,2,6,6-Tetramethyl-1,3-dithiane-1-oxide 13

A solution of sulfoxide 12 (3.2 mixture of diastereoisomers) (0.37 g, 2.1 mmol) in THF (7 ml) was stirred at -78 ºC and treated with n-butyllithium solution (1.0 ml, 2.0 M in hexanes, 2.5 mmol). After 15 min methyl iodide (0.20 ml, 3.2 mmol) was added and the mixture allowed to warm to room temperature. Saturated ammonium chloride solution (0.5 ml) and then water (10 ml) were added. The mixture was extracted with dichloromethane (2 x 10 ml) and the organic extracts dried and evaporated to give a pale yellow oil (0.4 g). Chromatography over silica afforded the product as a clear colourless oil (0.29 g, 73%).

Rf (1:1 petrol:EtOAc) = 0.33 [stains with cold KMnO4 (aq)].


$^{13}$C NMR (100 MHz, CDCl$_3$) δ C = 14.2 (CH$_3$), 19.7 (CH$_3$), 21.9 (SCH$_2$CH$_2$), 28.3 (CH$_3$), 38.8 (SCH$_2$), 46.1 (PhCH$_2$), 58.4 (Cq), 60.0 (Cq), 127.0 (CH), 128.1 (CH), 131.2 (CH), 134.7 (Cq).

HRMS: Calcd. for C$_{14}$H$_{20}$OS$_2$ [MNa]$^+$ 291.0848; found 291.0843.

**(1R,6R,7S,10R)-7-Isopropyl-10-methyl-1,5-dithia-spiro[5.5]undecane-1-oxide 23**

(1R,6R,7S,10R)-7-Isopropyl-10-methyl-1,5-dithia-spiro[5.5]undecane-1-oxide 23 was prepared from menthone and 1,3-propanedithiol followed by treatment with NaIO$_4$ following a literature procedure.$^2$

$^1$H NMR (400 MHz, CDCl$_3$) δ H = 0.88 (d, $J = 6.8$ Hz, 3H), 0.90-1.10 (m, 7H), 1.45-1.65 (m, 2H), 1.65-1.85 (m, 2H), 1.95-2.50 (m, 7H), 2.60-2.75 (m, 1H), 2.80-2.90 (m, 1H), 3.00-3.10 (m, 1H).

$^{13}$C NMR (100 MHz, CDCl$_3$) δ C = 19.3 (CH$_3$), 21.4 (CH$_2$), 22.2 (CH$_2$), 23.5 (CH$_3$), 24.4 (CH$_3$), 25.5 (CH), 27.2 (CH), 30.9 (CH$_3$), 33.7 (CH$_2$), 34.3 (CH$_2$), 36.5 (PhCH$_3$), 44.7 (CH), 57.1 (SCH), 70.1 (Cq), 126.7 (CH), 128.5 (CH), 129.6 (CH), 137.3 (Cq).

Calcd. for C$_{20}$H$_{30}$OS$_2$ 61.26 %C, 9.55 %H; found 60.97, 9.51.

HRMS: Calcd. for C$_{20}$H$_{30}$OS$_2$ [MNa]$^+$ 297.1312; found 297.1317.

m.p. 161-168 ºC (from CH$_2$Cl$_2$/petrol).

$\nu$ max /cm$^{-1}$ 2965, 2919, 2859, 1452, 1363, 1261, 1115.

**3-Benzyl-1,2-dithiolane 20**

3-Benzyl-1,2-dithiolane was prepared using the method above in 60% isolated yield.

$^1$H NMR (400 MHz, CDCl$_3$) δ H = 1.55 (s, 6H), 2.11 (t, $J = 6.6$ Hz, 2H, SCH$_2$CH$_2$), 3.24 (t, $J = 6.6$ Hz, 2H, SCH$_2$).

$^{13}$C NMR (100 MHz, CDCl$_3$) δ C = 28.2 (CH$_3$), 37.9 (SCH$_2$), 48.6 (CH$_2$), 60.5 (Cq).

$\nu$ max /cm$^{-1}$ 2965, 2919, 2859, 1452, 1363, 1261, 1115.

**3-Benzyl-1,2-dithiolane 20**

3-Benzyl-1,2-dithiolane was prepared using the method above in 60% isolated yield.

$^1$H NMR (400 MHz, CDCl$_3$) δ H = 1.95-2.05 (m, 1H, one of SCH$_2$CH$_2$), 2.30-2.40 (m, 1H, one of SCH$_2$CH$_2$), 2.96 (d, $J = 7.6$ Hz, 2H, PhCH$_2$), 3.05-3.15 (m, 1H, one of SCH$_2$), 3.15-3.25 (m, 1H, one of SCH$_2$), 3.82 (quint, $J = 6.8$ Hz, 1H, SCH), 7.15-7.35 (m, 5H).
13C NMR (100 MHz, CDCl3) δC = 38.4 (SCH2), 39.6 (CH2), 40.9 (PhCH2), 57.5 (CH), 126.7 (CH), 128.5 (CH), 128.8 (CH), 139.5 (Cq). Chiral HPLC: 5.38 min + 5.87 min (chiralcel OD ; 9:1 hexanes:isopropanol ; 1.0ml/min ; detection at 254 nm). The optical rotation could not be determined due to the instability of the product.

3-Methyl-3-benzyl-1,2-dithiolane 21

3-Methyl-3-benzyl-1,2-dithiolane was prepared as above. The reaction was shown to be quantitative by NMR spectroscopy. 

1H NMR (400 MHz, CDCl3) δ = 1.43 (s, 3H), 2.00-2.12 (m, 1H, SCH2CH2), 3.00 (d, J = 13.6 Hz, 1H, one of PhCH2), 3.14 (d, J = 13.6 Hz, 1H, one of PhCH2), 3.26 (td, J = 7.6, 0.6 Hz, 2H), 7.20-7.35 (m, 5H).

13C NMR (100 MHz, CDCl3) δC = 25.2 (CH2), 37.4 (SCH2), 45.8 (PhCH2), 46.6 (SCH2CH2), 65.1 (Cq), 126.7, 128.0, 130.4, 137.9 (Cq).

Crystallography.

For each sample, a crystal was mounted in oil on a glass fibre and fixed in the cold nitrogen stream (150 K) on a Bruker APEX 2 CCD diffractometer equipped with MoKα radiation (λ = 0.71073 Å) and a graphite monochromator. Intensity data were measured by thin-slice ω-scans and corrected for Lp and absorption effects. Data were reduced using the SAINT program. The structures were determined by the direct methods routine in the SHELXS-97 program and refined by full-matrix least-squares methods, on F2, in SHELXL-97. The non-hydrogen atoms were refined with anisotropic thermal parameters. Hydrogen atoms were constrained.

Notes and references

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† Electronic Supplementary Information (ESI) available: NMR spectra and crystallographic data.

See DOI: 10.1039/b000000x/


Notes and references