Stereochemically controlled synthesis of 1,8-dioxaspiro[4.5]decanes and 1-oxa-8-thiaspiro[4.5]decanes by phenylsulfanyl migration

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Single enantiomers and diastereoisomers of 2- and 3-alkyl-3-phenylsulfanyl-1,8-dioxa- and 1-oxa-8-thiaspiro-[4.5]decanes can be prepared in good yield by acid-catalysed phenylsulfanyl (PhS-) migration. Either the *syn*- or *anti*-stereochemistry can be controlled by aldol reactions or by reduction of hydroxy-ketones.

The synthesis of some constitutional isomers of dioxaspiro-[4.5]decanes is much easier than others. For example, where there are two oxygen atoms that form an acetal, such as **1**[1] and **2**,[2] these compounds are well known and easy to synthesise. For other positional isomers, such as the 1,8-dioxaspiro compounds like **3**, very little is known, especially about the stereochemistry, though the corresponding lactone such as **4**; X = O has been made (Chart 1).[3–5] However, there are some reports that similar

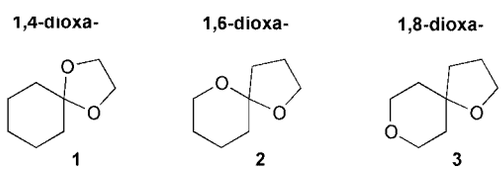


Chart 1

substituted 1,7- and 1,8-dioxaspiro compounds have herbicidal activity.[6] By comparison, the 1-oxa-8-thiaspiro[4.5]decane system is almost unknown, though similar lactones such as **4**; X = S have been reported (Chart 2).[3]

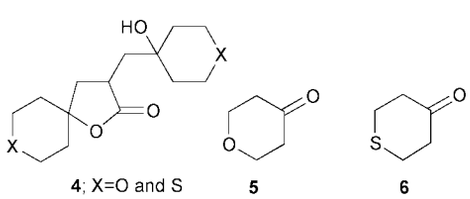
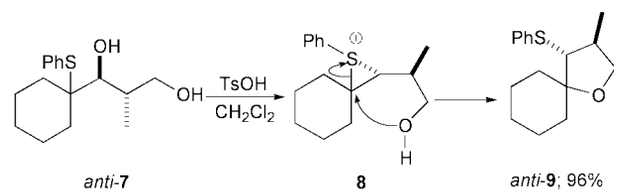
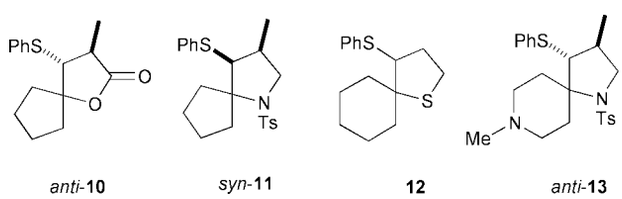


Chart 2

We have previously reported the synthesis of spirocyclic tetrahydrofurans (THFs) like *anti*-**9**,[7] lactones *anti*-**10**,[7] pyrrolidines *syn*-**11**[8] and thiolane **12** (Scheme 1).[9] For example, treatment of the diol *anti*-**7** with catalytic toluene-*p*-sulfonic acid (TsOH) in CH_2Cl_2 gives the episulfonium ion **8** which is captured intramolecularly at the more substituted end to give the spirocyclic tetrahydrofuran *anti*-**9** in essentially quantitative yield.[7] We have also shown that enantiomerically pure THFs and pyrrolidines like *anti*-**9** and *syn*-**11** can be synthesised efficiently using this procedure.[10] This type of 1,2-PhS migration occurs stereospecifically with no loss of enantiomeric or diastereoisomeric purity, with inversion of configuration at the migratory terminus and origin.[11] The majority of these spirocycles have one carbocyclic and one heterocyclic ring (O, N and S),[7,12] this was primarily because we used commercially





Scheme 1

available ketones as the precursors.[7] However, there are a few examples where piperidine based ketones have been used giving 1,8-diazospiro[4.5]decanes such as *anti*-**13**.[8]

We now report a succinct route to the synthesis of single diastereoisomers and enantiomers of substituted 1,8-dioxa and 1-oxa-8-thiaspiro[4.5]decanes using a similar strategy to construct the spirocyclic C(1)–O(5) bond. From related chemistry developed within our laboratory,[7] we chose to use the known ketones **5** and **6** as the starting materials.[13–15]

Results and discussion

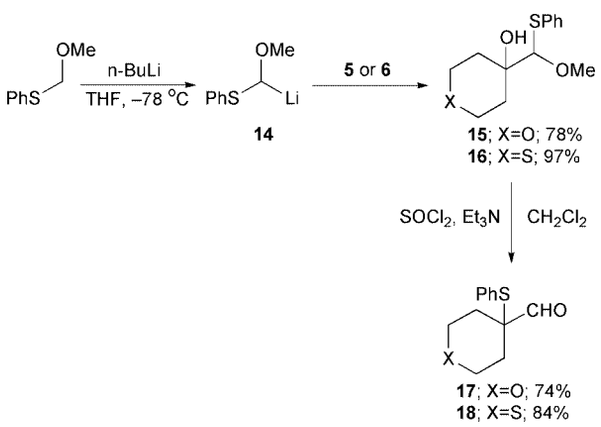
The first step was to prepare the 2-PhS-aldehydes **17**; X = O and **18**; X = S by the methodology developed by de Groot and Jansen.[16–18] Formation of the lithiated sulfide **14** (by addition of *n*-BuLi to methoxymethylphenyl sulfide in THF at −78 °C), followed by the addition of the ketones **5** and **6** gave the alcohols **15**; X = O and **16**; X = S in excellent yield. Rearrangement under our modified conditions[7] ($SOCl_2$, Et_3N in CH_2Cl_2) gave the required aldehydes **17**; X = O and **18**; X = S in high yield (Scheme 2). This reaction works essentially as well as for the previously reported hydrocarbon and amine systems (**15**–**18**; where X = CH_2 and NMe).[7,8]

The diol **22** and **23** stereochemistry was controlled by the reliable *anti*- and *syn*-stereoselective aldol reactions developed by Heathcock *et al.*[19–20] and Masamune and co-workers[21] respectively (Scheme 3). Generation of the lithium (*E*)-enolate of Heathcock's ester (2,6-dimethylphenyl propionate)[19] and the boron (*Z*)-enolate of Masamune's ester (*S*-phenyl thiopropion-

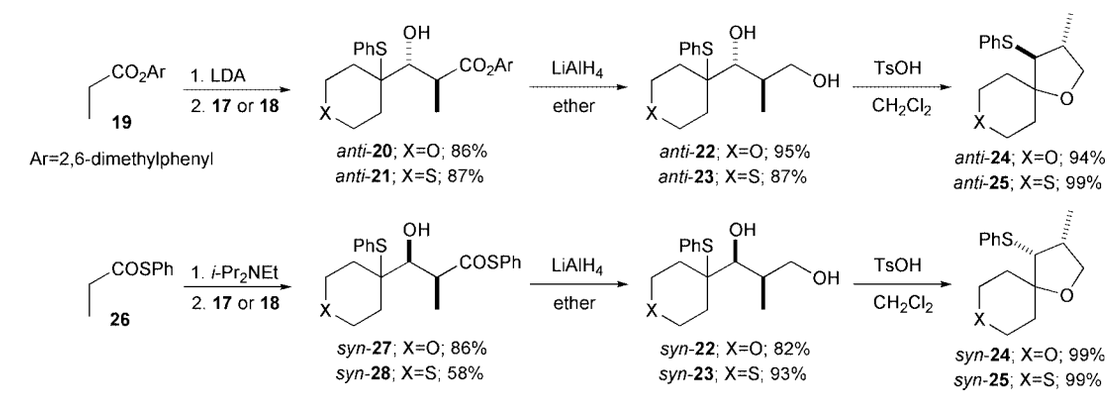
ate)[20] and addition to the 2-*RS* aldehydes **17** and **18** gave predictable *syn*- and *anti*-aldols **20**, **21**, **27** and **28** in excellent yield. Reduction of these with $LiAlH_4$ gave the *syn*- and *anti*-diols **22** and **23**. Acid-catalysed rearrangement with TsOH in refluxing CH_2Cl_2 proceeded smoothly to give stereospecifically the ethers *anti*-**24**, *syn*-**24**, *anti*-**25** and *syn*-**25** in near quantitative yield. It appears that the presence of the additional oxygen and sulfur atoms in the six membered rings has little or no effect on the rearrangement steps to form the 2-PhS aldehyde **17** and **18**, nor in the cyclisation to form the spirocyclic compound **24** and **25**. However, the rearrangement of the thiane-containing diols such as *anti*-**23** proceeded at least one order of magnitude faster than that of the tetrahydropyran-containing diols like *anti*-**22**, presumably due to the additional ether linkage in the starting diol disfavouring episulfonium ion formation. We have observed similar effects with amine analogues.[8]

The absolute stereochemistry of similar diols *anti*- and *syn*-**31** was controlled by using Evans' reliable phenylalanine-derived oxazolinone **29** as the chiral auxiliary,[22] primarily because of our previous experience with related carbocyclic systems (Scheme 4).[10] Addition of the boron (*Z*)-enolate to the aldehyde **17** gave a single diastereoisomer of the *syn*-aldol[23] *syn*, *anti*-**30**, and, in the presence of the Lewis acid Et_2AlCl (according to Heathcock)[24,25] gave a single diastereoisomeric *anti*-aldol **30**. Removal of the chiral auxiliary was simply and efficiently achieved by the addition of $LiBH_4$ with one equivalent of water in THF (under Pennings conditions),[26] giving the diols *syn*- and *anti*-**31** respectively in near quantitative yield. Treatment of these diols *syn*- and *anti*-**31** under our usual acid-catalysed conditions gave the enantiomerically pure spirocyclic ethers *syn*- and *anti*-**32** in a similar high yield to that obtained in the racemic series. The rearrangement occurred with no loss of diastereoisomeric or enantiomeric purity. The enantiomeric excess was near perfect (>98%)—determined by ^1H and ^{19}F NMR analysis of the corresponding Mosher's esters (derived from the *syn*- and *anti*-diol **31**)[27]—while those of the THF's were determined by ^1H NMR in the presence of the chiral shift reagent Eu(hfc)$_3$ and by comparison with the racemic series *syn*- and *anti*-**24**.[28] The C(2,3) *anti*- and *syn*-stereochemistry of the aldol products **30** was confirmed by subsequent cyclisation to the THFs (determined by a 500 MHz NOESY spectrum on *anti*-**24**). The absolute stereochemistry at the hydroxy position (C-3) is assumed from previous work including that on the carbocyclic compounds in our laboratory under identical conditions.[10]

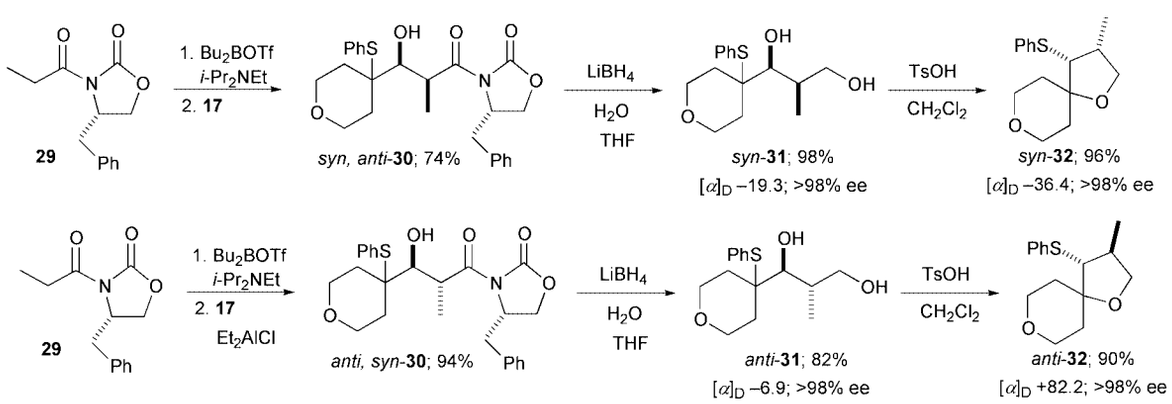
We next studied the effect of a secondary and tertiary alcohol as potential nucleophiles for the episulfonium ions like **8**. In previous cases with a primary alcohol as a nucleophile and a secondary alcohol as a leaving group as in diol *anti*-**7**, the reaction may be controlled by preferential loss of the protonated secondary alcohol to give THF *anti*-**9** (Scheme 1). With two secondary alcohols, as in *syn*- and *anti*-diols **44** and **46**, which protonated secondary alcohol would be lost is uncertain. One could be lost with [1,2]-SPh participation or the other with [1,4]-SPh participation, which we believe is possible since simple data[29] have suggested that both [1,2]-SR participation for an acyclic system was as efficient as [1,4]-SR participation.



Scheme 2



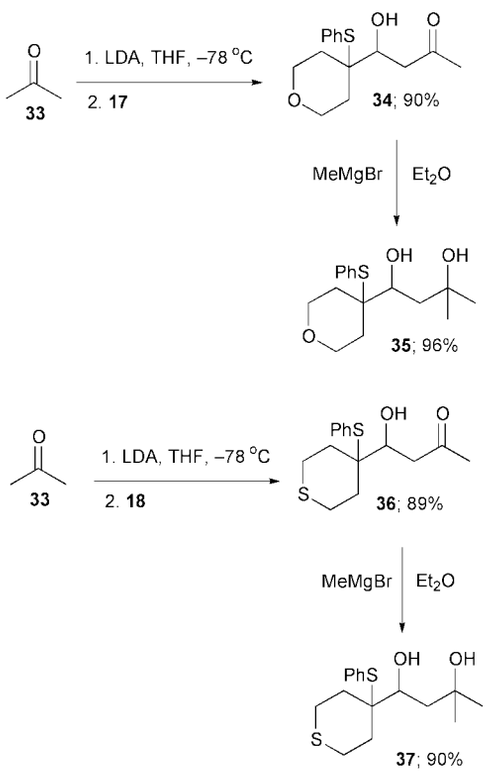
Scheme 3



Scheme 4

In the case of diols (*e.g.*, **37**) with a tertiary alcohol as a potential nucleophile, preferential loss of the protonated tertiary alcohol might be expected over the secondary alcohols since such elimination processes are well known.

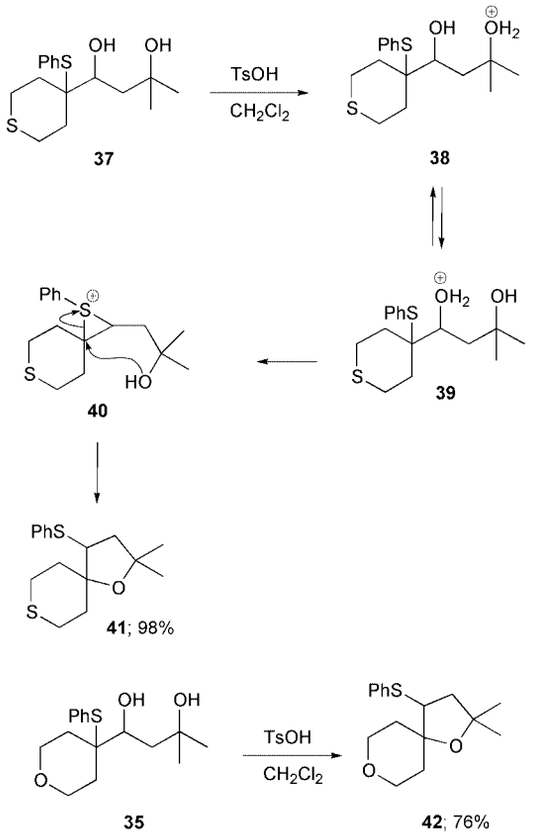
We synthesised the tertiary alcohols **35** and **37**, which were simpler to make because of the absence of stereochemistry, by the addition of MeMgBr to the 1,3-hydroxyketone **34** and **36** (synthesised by the addition of the lithium enolate of acetone **33** to the aldehydes **17** and **18**). These reactions occurred cleanly without enolisation of the ketone (*e.g.* **34**) giving the tertiary alcohol in excellent yield (Scheme 5).



Scheme 5

Acid-catalysed rearrangement of these diols **35** and **37** under our usual conditions (TsOH in CH_2Cl_2) gave surprisingly the THFs **41** and **42** in near quantitative yield. By thin layer chromatography (TLC), no other intermediates were formed and the rearrangement occurred smoothly and was as efficient as previous cases with a primary alcohol as a nucleophile. Presumably, proton transfer between the tertiary and secondary alcohol in **38** and **39** was rapid, and the stereospecific elimination of the protonated secondary alcohol **39** by [1,2]-SPh participation was evidently preferred. It is even more remarkable that competing protonation and decomposition of the tertiary alcohol (*e.g.* **38**) does not occur in refluxing toluene-*p*-sulfonic acid in CH_2Cl_2, instead [1,2]-SPh participation to form the episulfonium ion and cyclisation **40** occurs efficiently giving the structurally unusual di-tertiary alkyl ethers such as **41** (Scheme 6). However, under prolonged reflux, the 1,8-dioxaspirodecanes such as **42** decomposes whereas the 1-oxa-8-thiaspirodecanes **41** are stable. This is presumably the main cause of the lower yield of **42**.

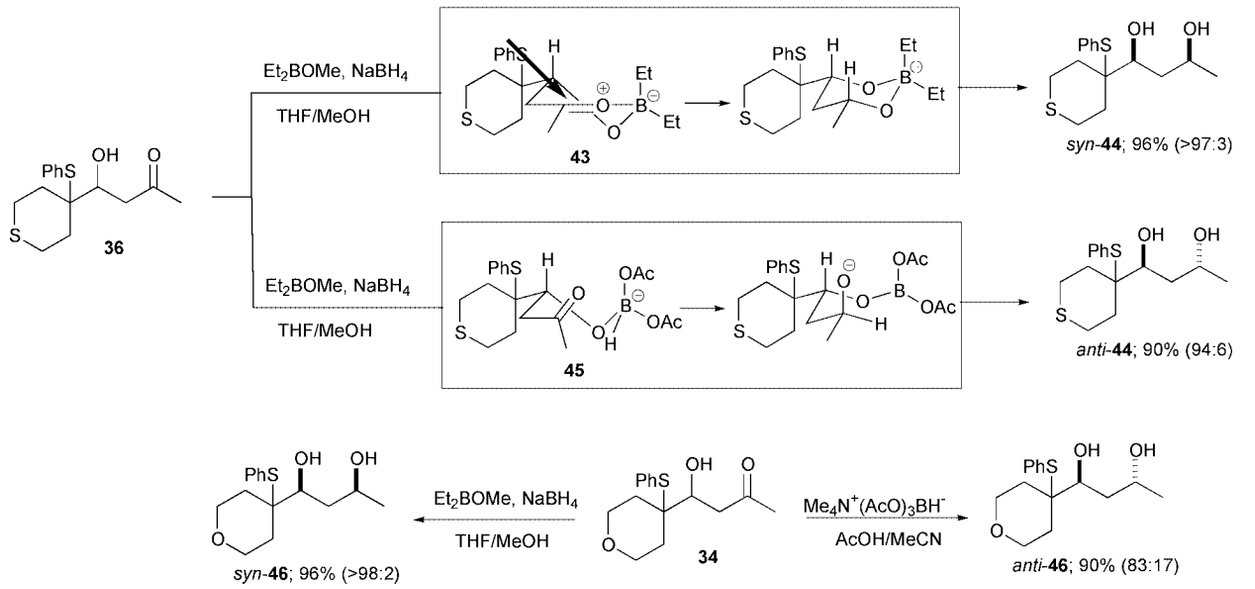
The *syn*- and *anti*-1,3-diols **44** and **46** were synthesised using a stereoselective reduction strategy involving our key intermediate 1,3-hydroxyketones. Access to the *syn*-diols **44** and **46** were achieved using Prasad and co-workers'[30] methodology—reduction of the ketones **34** and **36** with $NaBH_4$ as an external reducing agent in the presence of Et_2BOMe as a chelating agent gave predictably the *syn*-diols as a single diastereoisomer. The reduction occurs by axial hydride addition to the top face of **43** *via* a chair transition state rather than a disfavoured boat transition state, by addition to the bottom face—controlled by the larger R_2CSPh group in the equatorial position. The remaining *anti*-diols **44** and **46** were synthesised using Evans and co-workers'[31] reliable intramolecular hydride delivery reagent: $Me_4N(AcO)_3BH$ (Scheme 7). Addition of the 1,3-hydroxyketones **34** and **36** to a stirred solution of $Me_4N(AcO)_3BH$ in acetic acid at −30 °C for 2 days gave predominately the *anti*-diols **44** and **46** in excellent yield. This reduction proceeds *via* a chair transition state, where the larger methyl group rather than the carbonyl (C=O) group of the ketone in **45** was in a pseudo-equatorial position to avoid the developing 1,3-diaxial interactions. In all cases so far studied,[32] Prasad's *syn*-stereoselective reduction was more efficient than Evans' *anti*-reduction.



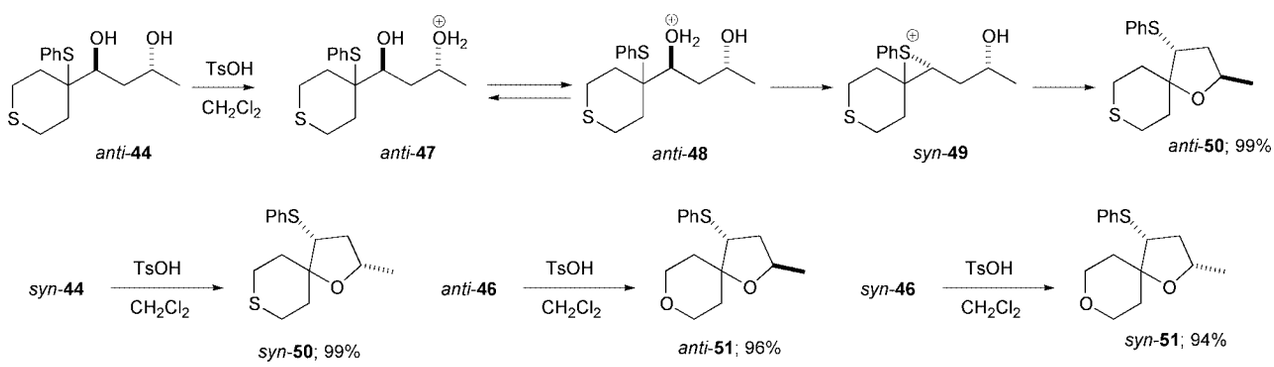
Scheme 6

Rearrangement of all four diols *syn*- and *anti*-**44** and **45** gave stereospecifically the corresponding spirocyclic ethers (*e.g. anti*-**50**) in excellent yield (Scheme 8). The stereochemistry was inverted at the migratory terminus and retention was observed at the nucleophilic centre (by NOE experiments). In no case was any [1,4]-SPh migration observed. Surprisingly, the secondary alcohol in *anti*-**48** was sufficiently protonated to give the episulfonium ion *syn*-**49** *via* [1,2]-SPh participation and hence the rearrangement to *anti*-**50**. It is difficult to believe that either secondary alcohol is more basic, so the low concentration of cation *anti*-**48** must rearrange at least two orders of magnitude faster than that of *anti*-**47**. In all cases so far studied, [1,2]-SPh participation was much more efficient than [1,4]-SPh participation, which is clearly different from previous reports that both [1,2]-SPh and [1,4]-SPh participation occur at the same rate for simple acyclic systems.[29] However, our case is different since the presence of the nucleophilic tertiary phenylsulfide (R_2CSPh) evidently makes the [1,2]-SPh participation much more efficient than [1,4]-SPh participation. This is presumably due to the Thorpe–Ingold effect (both angle and conformational effects)[33,34] which is well known to enhance in particular three-membered ring formation.

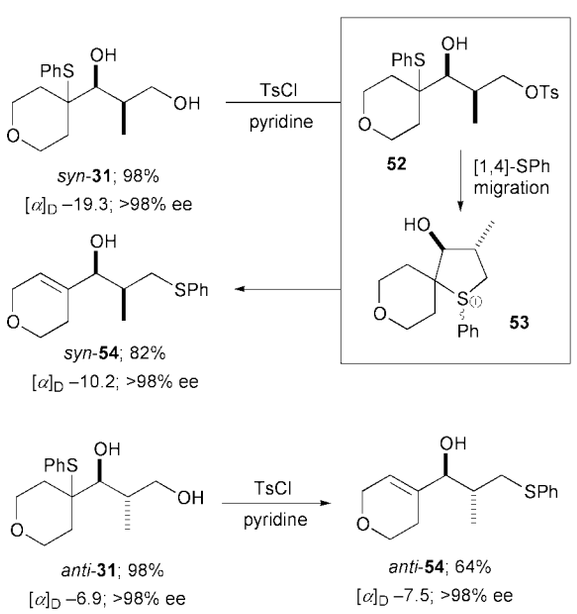
This was in sharp contrast to the treatment of diols *anti*- and *syn*-**31** with toluene-*p*-sulfonyl chloride (TsCl) in pyridine



Scheme 7



Scheme 8

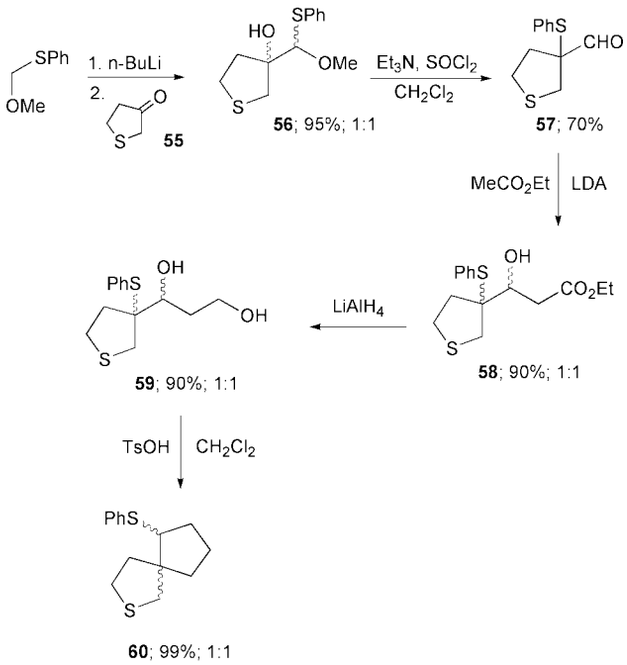


Scheme 9

giving allylic alcohols *anti*- and *syn*-**54** respectively in excellent yield, presumably formed *via* a [1,4]-SPh participation (Scheme 9). In these cases no [1,2]-SPh participation was observed which must be due to the chemoselective activation of the less sterically hindered alcohol, to give the primary tosylate **52**, subsequent [1,4]-SPh participation leads to the sulfonium intermediate **53** and decomposition gives the allylic alcohol *syn*-**54** in good yield. Migration of the toluene-*p*-sulfonate group from the primary alcohol to the secondary alcohol (for THF formation to occur) is evidently much slower than that of proton transfer.

Preliminary approaches to the 1-oxa-7-thiaspiro[4.4]nonane system were equally successful except in the important area of stereochemistry (Scheme 10). The starting point for this synthesis was the commercially available ketone **55**. Conversion to the aldehyde **57** was simply achieved using the method outlined by de Groot and Jansen.[16–18] Addition of the enolate of ethyl acetate to the aldehyde **57** gave an inseparable diastereoisomeric mixture (1:1) of aldol adducts **58** in excellent yield. Reduction ($LiAlH_4$ in ether) and cyclisation (TsOH in CH_2Cl_2) gave the spirocyclic THF **60**, with a stereogenic centre introduced at the spiro-carbon atom. We were unable to separate the diastereoisomers **58** to **60** using the approach outlined in Scheme 10. This is not that important if the PhS group is removed,[10] but it does detract from the route as a synthetic method.

In conclusion, we have shown the assembly of spirodecanes with two oxygen atoms not having an acetal relationship, *i.e.* being 1,5-related rather than joined to the same carbon atom, or their thia-analogues, can be efficiently achieved in high yield by a [1,2]-SPh migration with full control over relative or absolute stereochemistry. Neither oxygen or sulfur interferes with any of the rearrangements. We have also shown that secondary and tertiary alcohols can act as nucleophiles in the cyclisation of 1,3-diols to form THFs with stereospecific PhS migration. The heterocyclic secondary alcohols react stereospecifically (with retention of configuration) and the reactions are as efficient as in the carbocyclic and open-chain systems.



Scheme 10

Experimental

All solvents were distilled before use. Tetrahydrofuran (THF) and ether were freshly distilled from $LiAlH_4$, whilst dichloromethane (CH_2Cl_2) and toluene were freshly distilled from CaH_2. Petroleum ether refers to light petroleum (bp 40–60 °C). Triphenylmethane was used as the indicator for THF. *n*-BuLi was titrated against diphenylacetic acid before use. All reactions were carried out under nitrogen using oven-dried glassware. Flash column chromatography was carried out using Merck Kieselgel 60 (230–400 mesh). Thin layer chromatography (TLC) was carried out on commercially available pre-coated plates (Merck Kieselgel $60F_{254}$ silica). Proton and carbon NMR spectra were recorded on a Bruker WM 200, WM 250 or WM400 Fourier transform spectrometers using an internal deuterium lock. Chemical shifts are quoted in parts per million downfield from tetramethylsilane. Carbon NMR spectra were recorded with broad proton decoupling and Attached Proton Test (ATP). The symbol * after the carbon shift indicates an even number of attached protons; *i.e.* CH_2 or quaternary carbons. The symbols *i*-, *o*-, *m*- and *p*- denote the *ipso*-, *ortho*-, *meta*- and *para*- positions respectively for the phenyl ring (PhS group). Mass spectra were recorded on a AEI Kratos MS30 or MS890 machine using a DS503 data system for high resolution analysis. Optical rotation measurements were performed on a Perkin-Elmer 241 Na^{589} polarimeter and are given the units 10^{-1} deg cm^2 g^{-1}. All compounds were isolated using flash chromatography and were assumed to have a purity of greater than 98% (determined by NMR).

4-[Methoxy(phenylsulfanyl)methyl]-3,4,5,6-tetrahydro-(2*H*)-pyran-4-ol 15; X = O

n-BuLi (9.4 ml, 14.26 mmol, 1.52 M in hexane) was added dropwise to a solution of methoxymethyl phenyl sulfide (2 g, 1.91 ml, 12.9 mmol) in THF (50 ml) at –78 °C and stirred for 30 min. Tetrahydropyran-4(4*H*)-one **5** (1.2 ml, 12.9 mmol) in THF (5 ml) was added dropwise and the solution was stirred for a further 20 min. A solution of brine (50 ml) was added and the mixture was allowed to warm to room temperature. The solution was extracted with ether (3 × 50 ml) and the combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with petroleum ether–ethyl acetate (3:1) to give the *alcohol* **15**; X = O (2.56 g, 78%) as a colourless oil; R_f [petroleum ether–EtOAc (3:1)] 0.12; ν_{max}(NaCl)/cm^{-1} 3400 (OH) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.49–7.21 (5 H, m, SPh), 4.44 (1 H, s, CHSPh), 3.85–3.69 (4 H, m, 2 × CH_2O^{eq+ax}), 3.43 (3 H, s, OMe), 2.57 (1 H, s, OH), 2.05–1.87 (2 H, m, 2 × $CH_AH_B^{ax}$), 1.59 (1 H, dd, *J* 13.8 and 2.2, $CH_AH_B^{eq}$) and 1.49 (1H, dd, *J* 13.7 and 2.2, $CH_AH_B^{eq}$); δ_C(100 MHz; $CDCl_3$) 135.5, 132.9, 129.3, 127.6, 103.0, 72.0, 63.6, 63.4, 57.7, 33.7 and 33.5 (Found M^+, 254.0978. $C_{13}H_{18}O_3S$ requires *M*, 254.0976); *m*/*z* (EI) 254 (80%, M), 145 (80, M − Ph), 109 (60, SPh) and 83 (100, C_5H_8S).

4-Hydroxy-4-[methoxy(phenylsulfanyl)methyl]thiane 16; X = S

In the same way as alcohol **15**; X = O, methoxymethyl phenyl sulfide (6.0 g, 6.0 ml, 38.9 mmol), *n*-BuLi (31.4 ml, 1.3 M in hexanes, 40.8 mmol) and tetrahydrothiopyran-4(2*H*)-one **6** (4.3 g, 37.1 mmol) in THF (120 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9:1), the *alcohol* **16**; X = S (9.7 g, 97%) as a colourless oil; R_f [petroleum ether–ether (9:1)] 0.1; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH) and 1550 (SPh); δ_H(200 MHz; $CDCl_3$) 7.61–7.35 (5 H, m, SPh), 4.41 (1 H, s, CHSPh), 3.45 (3 H, s, OMe), 3.20–2.88 (2 H, m, 2 × $SCH_AH_B^{eq}$), 2.50–2.30 (3 H, m, 2 × $SCH_AH_B^{ax}$ and OH) and 2.19–1.69 (4 H, m, 2 × CH_2^{eq+ax}); δ_C(100 MHz; $CDCl_3$) 135.3* (*i*-SPh), 132.7 (*m*-SPh), 129.1 (*o*-SPh), 127.4 (*p*-SPh), 104.0 (*C*HOMe), 72.6* (COH), 57.5 (MeO), 34.1* (CH_2S), 33.7* (CH_2S), 23.8* (CH_2) and 23.4* (CH_2) (Found M^+, 270.0743. $C_{13}H_{18}O_2S_2$ requires *M*, 270.0748); *m*/*z* 270.1 (20%, M), 161.1 (100, M − SPh), 153.0 (20, PhSCHOMe), 129.0 (M − SPh − MeOH), 110.0 (30, PhSH) and 77.0 (5, Ph).

4-(Phenylsulfanyl)-3,4,5,6-tetrahydropyran-4(2*H*)-carboxaldehyde 17; X = O

Thionyl chloride (0.93 g, 0.6 ml, 7.86 mmol) was added dropwise to a solution of the alcohol **15**; X = O (1 g, 2.93 mmol) and Et_3N (5.5 ml, 3.93 mmol) in CH_2Cl_2 (40 ml) at 0 °C and stirred for 45 min. This solution was then poured into ice-cold hydrochloric acid (28 ml, 3 M) and extracted with CH_2Cl_2 (3 × 50 ml). The combined extracts were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether–ethyl acetate (4:1) to give the aldehyde **17**; X = O (0.63 g, 74%) as an orange oil; R_f [petroleum ether–ethyl acetate (3:1)] 0.27; ν_{max}(NaCl)/cm^{-1} 1714 (CO) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 9.30 (1 H, s, CHO), 7.51–7.26 (5 H, m, SPh), 3.94 (2 H, dt, *J* 11.8 and 4.6, 2 × OCH^{eq}), 3.47 (2 H, ddd, *J* 11.8, 8.6 and 3.4, 2 × OCH^{ax}), 1.90 (2 H, dt, *J* 13.7 and 4.0, 2 × CH^{eq}) and 1.83 (2 H, ddd, *J* 13.3, 8.6 and 4.0, 2 × CH^{ax}); δ_C(100 MHz; $CDCl_3$) 193.6, 137.2, 129.9, 129.1, 127.8, 64.5, 57.2 and 30.3 (Found M^+, 222.0708. $C_{13}H_{14}O_2S$ requires *M*, 222.0714); *m*/*z* (EI) 222 (20%, M), 193 (100, M − CHO), 83 (50, M − CHO − SPh) and 83 (100, C_5H_8S).

4-(Phenylsulfanyl)thiane-4-carboxaldehyde 18; X = S

In the same way as the aldehyde **17**; X = O, the alcohol **16**; X = S (8 g, 29.6 mmol), Et_3N (31.9 g, 43.0 ml, 0.316 mol) and thionyl chloride (5.29 g, 3.30 ml, 44.4 mmol) in CH_2Cl_2 (300 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9:1) the *aldehyde* **18**; X = S (5.92 g, 84%) as an orange oil; R_f [petroleum ether–ether (9:1)] 0.45; ν_{max}(film, $CDCl_3$)/cm^{-1} 1750 (CO); δ_H(200 MHz; $CDCl_3$) 9.71 (1 H, s, CHO), 7.43–7.25 (5 H, m, SPh), 2.96–2.80 (2 H, m, 2 × SCH^{eq}), 2.61–2.47 (2 H, m, 2 × SCH^{ax}) and 2.19–1.90 (4 H, m, 2 × CH_2^{eq+ax}); δ_C(50 MHz; $CDCl_3$) 193.68 (CHO), 137.09 (*m*-SPh), 129.78 (*p*-SPh), 128.97 (*o*-SPh), 127.47 (*i*-SPh), 58.92 (*C*SPh), 31.04 (CH_2S) and 24.54 (CH_2) (Found M^+, 238.0486. $C_{12}H_{14}OS_2$ requires *M*, 238.0486); *m*/*z* 238.0 (100%, M), 209.0 (90, M − CHO), 129.0 (30, M − SPh) and 110.0 (60, PhSH).

2,6-Dimethylphenyl (2*SR*,3*RS*)-3-hydroxy-2-methyl-3-[4′-(phenylsulfanyl)-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl]propionate *anti*-20

n-BuLi (1.8 ml, 1.5 M in hexanes, 2.66 mmol) was added to a stirred solution of diisopropylamine (0.35 g, 0.47 ml, 3.45 mmol) in THF (50 ml) at −78 °C and the solution was stirred for 30 minutes. A solution of Heathcock's ester **19** (0.43 g, 2.42 mmol) in THF (10 ml) was slowly added and the solution was stirred for a further 30 minutes. The aldehyde **17** (0.5 g, 2.25 mmol) in THF (10 ml) was slowly added to this solution and stirred for 30 minutes. Saturated NH_4Cl (50 ml) was added and the solution allowed to warm to room temperature and extracted with ether (3 × 100 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether–ether (9:1) to give the *ester anti*-**20** (0.76 g, 86%) as white cubes, mp 128–129 °C (from hexane–ether); R_f [ether] 0.4; ν_{max}(NaCl)/cm^{-1} 1730 (CO) and 1587 (SPh); δ_H(400 MHz; $CDCl_3$) 7.55–7.48 (2 H, m, SPh), 7.41–7.29 (3 H, m, SPh), 7.06 (3 H, m, OAr), 4.33 (1 H, d, *J* 8.5, OH), 4.13 (1 H, td, *J* 11.7 and 1.8, OCH^{ax}), 4.00 (1 H, td, *J* 11.7 and 1.8, OCH^{ax}), 3.88–3.78 (3 H, m, 2 × OCH^{eq} and C*H*Me), 3.46 (1 H, dd, *J* 8.5 and 2.4, C*H*OH), 2.30 (1 H, ddd, *J* 15.0, 12.0 and 4.9, C$H_AH_B^{ax}$), 2.18 (6 H, s, 2 × Me, Ar), 2.11–1.98 (1 H, m, C$H_AH_B^{ax}$), 1.62 (3 H, d, *J* 7.4, CHMe) and 1.42–1.36 (2 H, m, 2 × CH$_A$*H*$_B^{eq}$); δ_C(100 MHz; $CDCl_3$) 175.1, 147.6, 137.3, 130.1, 129.7, 129.3, 129.1, 128.8, 126.2, 79.5, 63.6, 63.5, 56.8, 37.8, 30.5, 30.4, 18.8 and 16.7 (Found M^+, 400.1712. $C_{23}H_{28}O_4S$ requires *M*, 400.1708); *m*/*z* (EI) 400 (20%, M), 193 (50, $C_{11}H_{13}OS$) and 122 (100, $Me_2C_6H_3OH$).

2,6-Dimethylphenyl (2*SR*,3*RS*)-3-hydroxy-2-methyl-3-[4′-(phenylsulfanyl)thianyl]propionate *anti*-21

In the same way as ester *anti*-**20**, diisopropylamine (0.53 g, 0.72 ml, 5.29 mmol), *n*-BuLi (3.19 ml, 1.3 M in hexanes, 4.15 mmol), Heathcock's ester **168** (0.71g, 3.97 mmol) and aldehyde **18**; X = S (0.9 g, 3.78 mmol) in THF (100 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9:1), the *ester anti*-**21** (1.3 g, 87%) as a colourless oil; R_f [petroleum ether–ether (9:1)] 0.1; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH) and 1680 (CO); δ_H(200 MHz; $CDCl_3$) 7.59–7.28 (5 H, m, SPh), 7.03 (3 H, s, OAr), 4.42 (1 H, d, *J* 8.0, CHO*H*), 3.78 (1 H, qd, *J* 7.3 and 2.3, C*H*Me), 3.56–3.28 (3 H, m, 2 × CHS^{eq} and C*H*OH), 2.49–2.31 (3 H, m, 2 × CHS^{ax} and C$H_AH_B^{eq}$), 2.21 (6 H, s, 2 × Me, Ar), 2.18–2.04 (1 H, m, C$H_AH_B^{eq}$), 1.95–1.68 (2 H, m, 2 × CH$_A$*H*$_B^{ax}$) and 1.61 (3 H, d, *J* 7.3, *Me*CH); δ_C(50 MHz; $CDCl_3$) 174.8 (CO), 147.5 (*i*-OAr), 137.2 (*i*-SPh), 137.0 (*m*-OAr), 130.0, 129.3, 129.2, 129.0, 126.0 (*o*-, *m*-, *p*-SPh, *p*-OAr and *i*-*C*Me), 79.2 (CHOH), 58.6 (*C*SPh), 37.4 (*C*HMe), 31.6 (CH_2S), 31.5 (CH_2S), 23.7 (CH_2), 23.5 (CH_2), 18.7 (2 × Me, Ar) and 16.6 (*Me*CH) (Found M^+, 416.1483. $C_{22}H_{28}O_3S_2$ requires *M*, 416.1479); *m*/*z* 416.1 (20%, M), 307.1 (2, M − SPh), 295.1 (30, M − OAr), 209.0 (40, C_5H_8SSPh), 122.1 (100, ArOH) and 110.0 (PhSH).

(1*RS*,2*SR*)-2-Methyl-1-(4-phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)pyran-4-yl)propane-1,3-diol *syn*-22; X = O

Lithium aluminium hydride (0.161 g, 4.2 mmol) was added to a stirred solution of ester *syn*-**27**; X = O (0.55 g, 1.4 mmol) in ether (80 ml) at 0 °C. The solution was stirred for 3 hours and poured onto an ice–brine mixture. NaOH (20 ml) was added and the solution extracted with ether (3 × 100 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with petroleum ether–ether (1:1) to give the *diol syn*-**22**; X = O (0.24 g, 82%) as white plates, mp 97–98 °C (from ether–hexane); R_f [petroleum ether–ether (1:1)] 0.37; ν_{max}(NaCl)/cm^{-1} 3451 (OH) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.53–7.30 (5 H, m, SPh), 4.05 (1 H, td, *J* 11.5 and 2.3, OCH^{ax}), 4.00 (1 H, td, *J* 11.6 and 2.2, OCH^{ax}), 3.84–3.77 (2 H, m, 2 × OCH^{eq}), 3.63–3.57 (3 H, m, C*H*OH and CH_2OH), 3.02 (1 H, br s, CHO*H*), 2.21–2.13 (2 H, m, C$H_AH_B^{ax}$ and C*H*Me), 1.91 (1 H, ddd, *J* 14.3, 11.4 and 4.8, CH$_A$*H*$_B^{ax}$), 1.51 (1H, dd, *J* 14.6 and 2.2, C$H_CH_D^{eq}$), 1.30 (1 H, dd, *J* 14.3 and 2.2, CH$_C$*H*$_D^{eq}$) and 1.08 (3 H, d, *J* 7.0, CH*Me*); δ_C(100 MHz; $CDCl_3$) 137.4, 137.3, 129.7, 129.6, 129.4, 129.2, 75.5, 69.2, 64.1, 63.6, 58.8, 35.2, 30.8, 30.4 and 11.7 (Found MH^+, 282.1268. $C_{15}H_{22}O_3S$ requires *M*, 282.1289); *m*/*z* (EI) 283 (40%, MH), 282 (30, M) and 265 (100, MH − H_2O).

(1*RS*,2*SR*)-2-Methyl-1-(4-phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)propane-1,3-diol *anti*-22; X = O

In the same way as the diol *anti*-**22**; X = O, the ester *anti*-**20**; X = O (0.3 g, 0.74 mmol) and $LiAlH_4$ (85 mg, 2.2 mmol) in ether (10 ml) gave, after flash column chromatography on silica gel eluting with petroleum ether–ether (1:1) the *diol anti*-**22**; X = O (0.19 g, 95%) as a colourless oil; R_f [petroleum ether–ether (1:1)] 0.37; ν_{max}(NaCl)/cm^{-1} 3451 (OH) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.51–7.32 (5 H, m, SPh), 4.08 (1 H, td, *J* 11.5 and 2.0, OCH^{ax}), 3.97 (1 H, td, *J* 11.7 and 2.3, OCH^{ax}), 3.87 (1 H, dd, *J* 11.6 and 4.2, OCH^{eq}), 3.81–3.67 (3 H, m, 2 × CH$_A$*H*$_B$OH and OCH^{eq}), 3.32 (1 H, d, *J* 4.9, CHO*H*) and 2.96 (1 H, br s, CH_2O*H*), 2.15–2.03 (2 H, m, C*H*Me and C$H_AH_B^{ax}$), 1.78 (1 H, ddd, *J* 14.3, 11.6 and 4.8, C$H_AH_B^{ax}$), 1.51 (1 H, dd, *J* 15.7 and 2.0, CH$_A$*H*$_B^{eq}$), 1.22 (1 H, dd, *J* 14.4 and 2.1, CH$_A$*H*$_B^{eq}$) and 0.88 (3 H, d, *J* 7.0, CH*Me*); δ_C(100 MHz; $CDCl_3$) 137.4, 129.6, 129.2, 129.0, 79.3, 66.5, 64.0, 63.4, 56.7, 34.6, 29.9, 29.3 and 15.3 (Found M^+, 282.1288. $C_{15}H_{22}O_3S$ requires *M*, 282.1289); *m*/*z* (EI) 282 (60%, M), 193 (100, $C_{11}H_{13}OS$) and 83 (43, C_5H_8O).

(1*RS*,2*SR*)-2-Methyl-1-[4′-(phenylsulfanyl)thianyl]propane-1,3-diol *anti*-23; X = S

In the same way as diol *anti*-**22**; X = O, the ester *anti*-**21** (0.92 g, 2.21 mmol) and $LiAlH_4$ (0.25 g, 6.63 mmol) in ether (200 ml) gave, after column chromatography on silica gel eluting with ether, the *diol anti*-**23**; X = S (0.57 g, 87%) as a colourless oil; R_f [ether] 0.5; ν_{max}(film, $CDCl_3$)/cm^{-1} 3500–3300 (OH); δ_H(200 MHz; $CDCl_3$) 7.50–7.26 (5 H, m, SPh), 3.80–3.15 (5 H, m, 2 × CHS^{eq}, C*H*OH and CH_2O), 3.15–2.85 (1 H, br s, OH), 2.50–2.31 (2 H, m, 2 × CHS^{ax}), 2.21–1.95 (3 H, m, 2 × C$H_AH_B^{eq}$ and C*H*Me), 1.90–1.75 (1 H, m, CH$_A$*H*$_B^{ax}$), 1.61–1.48 (1 H, m, CH$_A$*H*$_B^{ax}$) and 0.92 (3 H, d, *J* 7.0, *Me*CH); δ_C(50 MHz; $CDCl_3$) 137.0 (*m*-SPh), 129.5 (*p*-SPh), 129.1 (*o*-SPh), 128.4 (*i*-SPh), 79.2 (CHOH), 66.3 (CH_2O), 61.6 (*C*SPh), 34.4 (CH_2S), 31.2 (CH_2S), 30.2 (*C*HMe), 23.9 (CH_2), 23.6 (CH_2) and 18.4 (MeCH) (Found M^+, 298.1060. $C_{15}H_{22}O_2S_2$ requires *M*, 298.1061); *m*/*z* 298.1 (30%, M), 209.0 (100, C_5H_8SSPh), 189.1 (20, M − SPh) and 110.0 (60, PhSH).

(1*RS*,2*RS*)-2-Methyl-1-[4′-(phenylsulfanyl)thianyl]propane-1,3-diol *syn*-23; X = S

In the same way as diol *anti*-**22**; X = O, the ester *syn*-**28** (0.15 g, 3.7 mmol) and $LiAlH_4$ (41.7 mg, 1.11 mmol) in ether (50 ml) gave, after column chromatography on silica gel eluting with ether, the *diol syn*-**23**; X = S (0.1 g, 93%) as a colourless oil; R_f [ether] 0.6; ν_{max}(film, $CDCl_3$)/cm^{-1} 3500–3300 (OH); δ_H(200 MHz; $CDCl_3$) 7.56–7.23 (5 H, m, SPh), 3.58–3.12 (5 H, m, 2 × CHS^{eq}, C*H*OH and CH_2O), 2.49–1.52 (9 H, m, 2 × CHS^{ax}, 2 × CH_2, 2 × OH and C*H*Me) and 1.08 (3 H, d, *J* 6.8, *Me*CH); δ_C(50 MHz; $CDCl_3$) 137.0 (*m*-SPh), 129.4 (*i*-SPh), 129.3 (*p*-SPh), 129.0 (*o*-SPh), 75.0 (CHOH), 68.9 (CH_2O), 60.9 (*C*SPh), 35.0 (*C*HMe), 31.9 (CH_2S), 31.7 (CH_2S), 24.0 (CH_2), 23.7 (CH_2) and 11.7 (*Me*CH); *m*/*z* 298.1 (20%, M), 209.0 (100, C_5H_8SSPh), 189.1 (20, M − SPh) and 110.0 (30, PhSH).

(3*RS*,4*SR*)-3-Methyl-4-phenylsulfanyl-1,8-dioxaspiro[4.5]-decane *anti*-24; X = O

Toluene-*p*-sulfonic acid (5.3 mg, 28 μmol) was added to a stirred solution of *anti*-**22**; X = O (40 mg, 0.14 mmol) in CH_2Cl_2 (2 ml). The solution was refluxed for 10 min. The solution was allowed to cool to room temperature and filtered through a silica plug. The solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether–ether (9 : 1) to give the *tetrahydrofuran anti*-**24**; X = O (35 mg, 94%) as a yellow oil; R_f [petroleum ether–ether (1 : 1)] 0.4; ν_{max}(NaCl)/cm^{-1} 1583 (SPh); δ_H (400 MHz; $CDCl_3$) 7.51–7.21 (5 H, m, SPh), 3.99 (1 H, t, *J* 8.3, CH_AH$_B$O), 3.85–3.81 (1 H, m, OCH_CH$_D^{eq}$), 3.75–3.64 (3 H, m, OCH_CH$_D^{eq}$ and 2 × OCH$_C H_D^{ax}$), 3.38 (1 H, t, *J* 8.7, OCH$_A H_B$), 2.81 (1 H, d, *J* 10.6, CHSPh), 2.30–2.25 (1 H, m, C*H*Me), 2.05 (1 H, ddd, *J* 13.1, 12.8 and 5.1, CH_EH$_F^{ax}$), 1.75 (1 H, ddd, *J* 13.3, 12.8 and 5.7, CH_EH$_F^{ax}$), 1.44 (1 H, dd, *J* 13.6 and 2.2, CH$_E H_F^{eq}$), 1.29 (1 H, dd, *J* 11.4 and 1.9, CH$_E H_F^{eq}$) and 1.15 (3 H, d, *J* 6.6, Me); δ_C(100 MHz; $CDCl_3$) 135.6, 132.0, 129.1, 127.2, 81.5, 71.3, 64.7, 64.6, 64.1, 40.1, 36.4, 32.3 and 16.4 (Found M$^+$, 264.1186. $C_{15}H_{20}O_2S$ requires *M*, 264.1183); *m*/*z* (EI) 264 (32%, M) and 164 (100, $C_{11}H_{13}OS$).

(3*RS*,4*RS*)-3-Methyl-4-phenysulfanyl-1,8-dioxaspiro[4.5]-decane *syn*-24; X = O

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol *syn*-**22**; X = O (50 mg, 0.17 mmol) and toluene-*p*-sulfonic acid (6.8 mg, 36 μmol) in CH_2Cl_2 (1.5 ml) gave, the *tetrahydrofuran syn*-**24**; X = O (45 mg, 99%) as white needles, mp 72–73 °C (from hexane–ether); R_f [petroleum ether–ether (1 : 1)] 0.37; ν_{max}(NaCl)/cm^{-1} 1581 (SPh); δ_H(400 MHz; $CDCl_3$) 7.45–7.37 (2 H, m, SPh), 7.31–7.25 (2 H, m, SPh), 7.21–7.17 (1 H, m, SPh), 4.00 (1 H, dd, *J* 8.8 and 6.9, CH_AH$_B$O), 3.79–3.70 (4 H, m, 2 × CH$_2$O^{eq+ax}), 3.55 (1 H, dd, *J* 8.8 and 6.0, CH$_A H_B$O), 3.45 (1 H, d, *J* 7.8, CHSPh), 2.70 (1 H, sept, *J* 7.0, C*H*Me), 1.94 (1 H, ddd, *J* 13.6, 11.8 and 5.1, CH_AH$_B^{ax}$), 1.85 (1 H, ddd, *J* 13.4, 10.7 and 6.4, CH_AH$_B^{ax}$), 1.66 (1 H, dd, *J* 13.6 and 2.4, CH$_A H_B^{eq}$), 1.47 (1 H, dd, *J* 13.4 and 2.4, CH_AH$_B^{eq}$) and 1.13 (3 H, d, *J* 7.1, Me); δ_C(100 MHz; $CDCl_3$) 136.6, 130.2, 129.1, 126.4, 81.3, 72.0, 64.8, 64.3, 60.8, 37.2, 36.4, 33.7 and 15.5 (Found M$^+$, 264.1184. $C_{15}H_{22}O_3S$ requires *M*, 264.1183); *m*/*z* (EI) 264 (30%, M), 164 (100, $C_{11}H_{13}OS$) and 110 (45, PhSH).

(3*SR*,4*RS*)-3-Methyl-4-(phenylsulfanyl)-1-oxa-8-thiaspiro[4.5]-decane *anti*-25; X = S

In the same way as THF *anti*-**24**; X = O, the diol *anti*-**23**; X = S (88 mg, 0.29 mmol) and toluene-*p*-sulfonic acid (11.2 mg, 59 μmol) in CH_2Cl_2 (1 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9 : 1) the *tetrahydrofuran anti*-**25**; X = S (81.5 mg, 99%) as a colourless oil; R_f [petroleum ether–ether (9 : 1)] 0.4; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH), 1550 and 1500 (SPh); δ_H(400 MHz; $CDCl_3$) 7.47–7.20 (5 H, m, SPh), 3.96 (1 H, t, *J* 8.7, CH_AH$_B$O), 3.36 (1 H, t, *J* 8.7, CH$_A H_B$O), 3.04–2.94 (2 H, m, 2 × CHS^{eq}), 2.74 (1 H, d, *J* 10.6, C*H*SPh), 2.41–2.22 (2 H, m, CHS^{ax}), 2.03 (1 H, dt, *J* 13.4 and 3.4, CH_AH$_B^{eq}$), 1.92–1.83 (1 H, m, CH_AH$_B^{eq}$), 1.78–1.63 (2 H, m, 2 × CH$_A H_B^{ax}$) and 1.13 (3 H, d, *J* 6.5, *Me*CH); δ_C(100 MHz; $CDCl_3$) 135.6* (*i*-SPh), 132.1 (*m*-SPh), 129.1 (*o*-SPh), 127.2 (*p*-SPh), 82.3* (CO), 71.3* (CH_2O), 65.9 (*C*HSPh), 40.1 (*C*HMe), 37.7* (CH_2S), 33.5* (CH_2S), 25.1* (CH_2), 24.2* (CH_2) and 16.3 (*Me*CH) (Found M$^+$, 280.0950. $C_{15}H_{20}OS_2$ requires *M*, 280.0956); *m*/*z* 280.1 (50%, M), 171.1 (5, M − SPh), 164.1 (100, M − C_5H_8SO), 116.1 (10, C_5H_8SO) and 109.0 (20, SPh).

(3*RS*,4*RS*)-3-Methyl-4-phenylsulfanyl)-1-oxa-8-thiaspiro[4.5]-decane *syn*-25; X =S

In the same way as THF *anti*-**24**; X = O, the diol *syn*-**23**; X = S (20 mg, 67.1 mmol) and toluene-*p*-sulfonic acid (2.3 mg, 13.4 μmol) in CH_2Cl_2 (1 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9 : 1) the *tetrahydrofuran syn*-**25** (18.6 mg, 99%) as a colourless oil; R_f [petroleum ether–ether (9 : 1)] 0.2; ν_{max}(film, $CDCl_3$)/cm^{-1} 1600 and 1550 (SPh); δ_H(400 MHz; $CDCl_3$) 7.41–7.18 (5 H, m, SPh), 3.98 (1 H, dd, *J* 8.9 and 6.8, CH_AH$_B$O), 3.52 (1 H, dd, *J* 8.9 and 5.9, CH$_A H_B$O), 3.39 (1 H, d, *J* 8.3, C*H*SPh), 3.10–2.94 (2 H, m, 2 × CHS^{eq}), 2.74–2.63 (1 H, m, CHS^{ax}), 2.46–2.34 (2 H, m, CHS^{ax} and CH_AH$_B^{eq}$), 2.10–2.08 (1 H, m, CH_AH$_B^{eq}$), 1.95–1.78 (3 H, m, 2 × CH$_A H_B^{eq}$ and C*H*Me) and 1.12 (3 H, d, *J* 7.1, *Me*CH); δ_C(100 MHz; $CDCl_3$) 136.6* (*i*-SPh), 130.5 (*m*-SPh), 129.0 (*o*-SPh), 126.4 (*p*-SPh), 82.1* (CO), 71.9* (CH_2O), 61.5 (*C*HSPh), 38.0* (CH_2S), 37.1 (*C*HMe), 24.2* (CH_2S), 25.2* (CH_2), 24.4* (CH_2) and 15.7 (*Me*CH) (Found M$^+$, 280.0956. $C_{15}H_{20}OS_2$ requires *M*, 280.0955); *m*/*z* 280.1 (50%, M), 164.1 (100, M − C_5H_8SO) and 110.0 (59, PhSH).

***S*-Phenyl (2*RS*,3*RS*)-3-hydroxy-2-methyl-3-(4-phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)propanethioate *syn*-27; X = O**

S-Phenyl thiopropionate (0.38 g, 0.35 ml, 2.31 mmol) and diisopropylethylamine (0.31 g, 0.42 ml, 2.42 mmol) in ether (6 ml) was added dropwise to a solution of 9-BBN-triflate (8 ml, 2.31 mmol, 0.5 M in ether) at 0 °C and stirred for 10 min. The aldehyde **17** (0.5 g, 2.20 mmol) was added and the solution was stirred for a further 3 hours. Phosphate buffer (pH = 7, 10 ml), MeOH (20 ml) and H_2O_2 (30%, 10 ml) was added and stirred for 5 min. Saturated NH_4Cl (10 ml) was added and the solution was extracted with ether (3 × 80 ml). The combined organic extracts were washed ($NaHCO_3$), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with petroleum ether–ether (9 : 1) to give the ester *syn*-**27**; X = O (0.73 g, 86%) as a yellow oil; R_f [petroleum ether–ether (1 : 1)] 0.24; ν_{max}(NaCl)/cm^{-1} 1693 (C=O) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.54–7.31 (10 H, m, SPh and Ph), 4.04 (1H, td, *J* 11.5 and 1.8, OCH^{ax}), 4.01 (1H, td, *J* 11.5 and 2.0, OCH^{ax}), 3.90 (1 H, t, *J* 4.4, C*H*OH), 3.82 (1H, ddd, *J* 11.3, 4.6 and 1.8, OCH^{eq}), 3.79 (1H, ddd, *J* 11.5, 4.6 and 2.2, OCH^{eq}), 3.49 (1H, qd, *J* 7.0 and 5.0, C*H*Me), 2.77 (1 H, d, *J* 4.2, OH), 2.10 (1 H, ddd, *J* 14.6, 11.5 and 4.8, CH_AH$_B^{ax}$), 1.99 (1H, ddd, *J* 14.4, 11.4 and 4.7, CH_AH$_B^{ax}$), 1.47 (1 H, dd, *J* 14.6 and 2.1, CH$_A H_B^{eq}$), 1.47–1.42 (1 H, m, CH$_A H_B^{eq}$) and 1.41 (3 H, d, *J* 7.0, CH*Me*); δ_C(100 MHz; $CDCl_3$) 210.7, 137.4, 137.2, 134.5, 134.3, 129.5, 129.3, 129.2, 129.1, 127.3, 74.6, 63.8, 63.5, 57.8, 48.8, 31.3, 30.6 and 15.0 (Found M − SPh$^+$, 279.1057. $C_{21}H_{24}O_3S_2$ requires *M*, 388.1166); *m*/*z* (EI) 279 (40, M − SPh) and 150 (100).

***S*-Phenyl (2*SR*,3*SR*)-3-[(4′-phenylsulfanyl)thianyl]-3-hydroxy-2-methylpropanethioate *syn*-28; X = S**

In the same way as ester *syn*-**27**; X = O, 9-BBNOTf (6.6 ml, 0.5 M in toluene, 3.3 mmol), *i*-Pr_2NEt base (0.45 g, 0.61 ml, 3.46 mmol), *S*-phenyl thiopropionate **26** (0.55 g, 0.50 ml, 3.3 mmol) and aldehyde **18**; X = S (0.75 g, 3.15 mmol) in ether (20 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (1 : 1), the *ester syn*-**28**; X = S (0.72 g, 58%) as a colourless oil; R_f [petroleum ether–ether (1 : 1)] 0.5; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH) and 1700 (CO); δ_H(200 MHz; $CDCl_3$) 7.60–7.30 (10 H, m, 2 × SPh), 3.90–3.80 (1 H, t, *J* 5.0, C*H*OH), 3.45–3.20 (4 H, m, 2 × CH$_2$S^{eq+ax}), 3.00 (1 H, d, *J* 5.0, OH), 2.50–1.90 (5 H, m, 2 × CH$_2^{eq+ax}$ and C*H*Me) and 1.45 (3 H, d, *J* 7.5, *Me*CH); δ_C(50 MHz; $CDCl_3$) 201.1 (CO), 137.0 (*o*-SPh^a), 137.0 (*i*-SPh^a), 134.3 (*p*-SPh^a), 134.2 (*m*-SPh^a), 129.7 (*p*-SPh^b), 129.4 (*m*-SPh^b), 129.2 (*o*-SPh^b), 128.7 (*i*-SPh^b), 74.0 (CHOH), 60.0 (*C*SPh), 48.5 (*C*HMe), 32.3, 31.5, 23.8, 23.7 (4 CH_2) and 15.1 (*Me*CH) (Found M$^+$, 404.0916. $C_{22}H_{24}O_2S_3$ requires *M*, 404.0938); *m*/*z* 404.1 (40%, M), 295.1 (40, M − SPh), 209.0 (20, C_5H_8SSPh), 110.0 (100, PhSH) and 77.0 (20, Ph).

(2*S*,3*S*)-4-Benzyl-3-[3-hydroxy-2-methyl-1-oxo-3-(4-sulfanyl-3,4,5,6-phenyltetrahydro-(2*H*)-pyran-4-yl)propionyl]oxazolidin-2-one *syn*, *anti*-30

Diisopropylethylamine (0.36 g, 0.48 ml, 2.77 mmol) was added to a solution of 4-benzyl-3-propionyloxazolidin-2-one **29** (0.52 g, 2.25 mmol) in CH_2Cl_2 (10 ml) at 0 °C, followed by dropwise addition of Bu_2BOTf (2.47 ml, 1 M in CH_2Cl_2, 2.47 mmol). The reaction was stirred for 45 min. A solution of the aldehyde **17** (0.5 g, 2.25 mmol) in CH_2Cl_2 (10 ml) at –78 °C was added dropwise and the resultant solution stirred for 5 h, after which MeOH (9 ml) and H_2O_2 (30%, 1.8 ml) were added. The reaction mixture was then allowed to warm to 0 °C for 1 h. Saturated NH_4Cl (50 ml) was added and the solution allowed to warm to room temperature and extracted with ether (3 × 100 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether–ether (1:1) to give the *aldol syn, anti*-**30** (0.76 g, 74%) as white cubes, mp 54–58 °C (from ether–hexane); $[\alpha]_D$ +129.8 (*c* 0.77 in $CHCl_3$); R_f [ether] 0.4; ν_{max}(NaCl)/cm^{-1} 3455 (OH), 1778 (CO) and 1693 (CO); δ_H(400 MHz; $CDCl_3$) 7.59–7.16 (10 H, m, SPh and Ph), 4.64–4.56 (1 H, m, CHN), 4.38 (1 H, qd, *J* 7.0 and 5.3, CHCO), 4.20–4.11 (2 H, m, CH_2O), 4.04–3.94 (3 H, m, 2 × CHO^{ax} and C*H*OH), 3.81–3.74 (2 H, m, OCH^{eq}), 3.25 (1 H, dd, *J* 13.2 and 3.0, CH_AH_BPh), 2.81 (1 H, d, *J* 4.3, CHO*H*), 2.58 (1 H, dd, *J* 13.1 and 10.3, CH_AH_BPh), 2.18 (1 H, ddd, *J* 16.4, 11.8 and 4.8, $CH_AH_B^{ax}$), 1.94 (1 H, ddd, *J* 16.3, 11.6 and 4.7, $CH_AH_B^{ax}$), 1.54–1.40 (2 H, m, 2 × $CH_AH_B^{eq}$) and 1.33 (3 H, d, *J* 7.0, CH*Me*); δ_C(100 MHz; $CDCl_3$) 177.0, 152.8, 137.0, 136.9, 135.1, 130.1, 129.4, 129.2, 129.1, 129.0, 128.9, 127.4, 74.8, 66.1, 63.7, 63.5, 57.4, 55.3, 38.3, 37.7, 32.3, 30.9 and 14.5 (Found M^+, 455.1759. $C_{25}H_{29}NO_5S$ requires *M*, 455.1766); *m*/*z* (EI) 455 (20%, M) and 346 (95, M − SPh).

(2*S*,3*R*)-4-Benzyl-3-[3-hydroxy-2-methyl-3-[(4-phenylsulfanyl)-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl]propionyl]oxazolidin-2-one *anti*,*syn*-30

Diisopropylethylamine (0.21 g, 0.28 ml, 1.6 mmol) was added to a solution of 4-benzyl-3-propionyloxazolidin-2-one **29** (0.32 g, 1.35 mmol) in CH_2Cl_2 (10 ml) at 0 °C, followed by dropwise addition of Bu_2BOTf (0.45 ml, 1 M in CH_2Cl_2, 1.62 mmol). The reaction was stirred for 45 min. A solution of the aldehyde **17** (0.6 g, 2.7 mmol) with Et_2AlCl (5.4 ml of a solution 1 M in hexane, 5.4 mmol) in CH_2Cl_2 (10 ml) at −88 °C was added dropwise and the resultant solution stirred for 5 h, after which MeOH (9 ml) and H_2O_2 (30%, 1.8 ml) was added. The reaction mixture was then allowed to warm to 0 °C for 1 h. Saturated NH_4Cl (50 ml) was added and the solution allowed to warm to room temperature and extracted with ether (3 × 100 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether–ether (1:1) to give the *aldol anti, syn*-**30** (0.58 g, 94%) as white cubes, mp 158–159 °C (from ether); R_f [ether] 0.6; ν_{max}(NaCl)/cm^{-1} 3452 (OH), 1777 (CO), 1660 (CO) and 1580 (SPh); δ_H(400 MHz; $CDCl_3$) 7.56–7.17 (10 H, m, SPh and Ph), 4.93 (1 H, d, *J* 8.3, OH), 4.73–4.59 (2 H, m, CHCO and CHN), 4.25–4.15 (2 H, m, OCH_2), 4.08–3.66 (4 H, m, 4 × CHO), 3.54 (1 H, d, *J* 8.3, C*H*OH), 3.42 (1 H, dd, *J* 13.2 and 2.5, CH_AH_BPh), 2.56 (1 H, dd, *J* 13.2 and 11.1, CH_AH_BPh), 2.03 (1 H, ddd, *J* 15.0, 11.5 and 4.6, $CH_AH_B^{ax}$), 1.89 (1 H, ddd, *J* 15.0, 11.5 and 4.9, $CH_AH_B^{ax}$), 1.65–1.35 (2 H, m, 2 × $CH_AH_B^{eq}$) and 1.43 (3 H, d, *J* 7.1, Me); δ_C(100 MHz; $CDCl_3$) 179.0, 152.8, 136.9, 135.5, 130.3, 129.9, 129.4, 129.3, 129.0, 129.8, 127.3, 84.0, 66.0, 63.6, 56.0, 55.6, 37.3, 34.3, 32.3, 31.7 and 14.6 (Found M^+, 455.1766. $C_{25}H_{29}O_5S$ requires *M*, 455.1766); *m*/*z* (EI) 55 (30%, M) and 346 (M − SPh).

(2*R*,3*R*)-2-Methyl-1-(4-(phenylsulfanyl)-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)propane-1,3-diol *syn*-31

$LiBH_4$ (0.40 ml, 2 M in THF, 0.79 mmol) was added dropwise to a solution of the aldol *syn*, *anti*-**30** (0.33 g, 0.72 mmol) and H_2O (14 μl, 0.79 mmol) in ether (15 ml) at 0 °C and stirred for 4 hours. NaOH (0.30 ml, 2.5 M) was added and the mixture was stirred until both layers become clear. Saturated NH_4Cl (1 ml) was added and the solution was extracted with ether (3 × 30 ml). The combined organic extracts were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with petroleum ether–ether (5:1) to give the *diol syn*-**31** (0.2 g, 98%) as white cubes, mp 115–116 °C (from ether–hexane); $[\alpha]_D$ −19.25 (*c* 0.92 in $CHCl_3$); ν_{max}(NaCl)/cm^{-1} 3411 (OH) and 1583 (SPh); δ_H(400 MHz; $CDCl_3$) 7.53–7.30 (5 H, m, SPh), 4.05 (1 H, td, *J* 11.5 and 2.3, OCH^{ax}), 4.00 (1 H, td, *J* 11.6 and 2.2, OCH^{ax}), 3.84–3.77 (2 H, m, 2 × OCH^{eq}), 3.63–3.57 (3 H, m, C*H*OH and CH_2OH), 3.02 (1 H, br s, CHO*H*), 2.21–2.13 (2 H, m, $CH_AH_B^{ax}$ and C*H*Me), 1.91 (1 H, ddd, *J* 14.3, 11.4 and 4.8, $CH_AH_B^{ax}$), 1.51 (1H, dd, *J* 14.6 and 2.2, $CH_CH_D^{eq}$), 1.30 (1 H, dd, *J* 14.3 and 2.2, $CH_CH_D^{eq}$), 1.08 (3 H, d, *J* 7.0, CH*Me*); δ_C(100 MHz; $CDCl_3$) 137.4, 137.3, 129.7, 129.6, 129.4, 129.2, 75.5, 69.2, 64.1, 63.6, 58.8, 35.2, 30.8, 30.4 and 11.7 (Found M^+, 282.1287. $C_{15}H_{22}O_3S$ requires *M*, 282.1289); *m*/*z* (EI) 283 (40%, MH), 282 (30, M) and 265 (100, MH – H_2O).

(1*R*,2*R*)-2-Methyl-1-(4-phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)propane-1,3-diol *anti*-31

In the same way as the diol *syn*-**31**, the aldol *anti*, *syn*-**30** (0.19 g, 0.42 mmol), $LiBH_4$ (0.33 ml, 2 M in THF, 0.46 mmol) and H_2O (8 μl, 0.46 mmol) in THF (15 ml) gave, after flash column chromatography on silica gel eluting with petroleum ether–ether (1:1), the *diol anti*-**31** (58 mg, 82%) as a colourless oil; R_f [petroleum ether–ether (1:3)] 0.37; $[\alpha]_D$ −6.9 (*c* 0.69 in $CHCl_3$); ν_{max}(NaCl)/cm^{-1} 3451 (OH) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.51–7.32 (5 H, m, SPh), 4.08 (1 H, td, *J* 11.5 and 2.0, $OCH_AH_B^{ax}$), 3.97 (1 H, td, *J* 11.7 and 2.3, $OCH_AH_B^{ax}$), 3.87 (1 H, dd, *J* 11.6 and 4.2, $OCH_AH_B^{eq}$), 3.81–3.67 (3 H, m, 2 × CH_2OH and $OCH_AH_B^{eq}$), 3.32 (1 H, d, *J* 4.9, CHO*H*), 2.96 (1 H, br s, CH_2OH), 2.15–2.03 (2 H, m, C*H*Me and $CH_AH_B^{ax}$), 1.78 (1 H, ddd, *J* 14.3, 11.6 and 4.8, $CH_AH_B^{ax}$), 1.51 (1 H, dd, *J* 15.7 and 2.0, $CH_AH_B^{eq}$), 1.22 (1 H, dd, *J* 14.4 and 2.1, $CH_AH_B^{eq}$) and 0.88 (3 H, d, *J* 7.0, CH*Me*); δ_C(100 MHz; $CDCl_3$) 137.4, 129.6, 129.2, 129.0, 79.3, 66.5, 64.0, 63.4, 56.7, 34.6, 29.9, 29.3 and 15.3 (Found M^+, 282.1288. $C_{15}H_{22}O_3S$ requires *M*, 282.1289); *m*/*z* (EI) 282 (60%, M), 193 (100, $C_{11}H_{13}OS$) and 83 (43, C_5H_8O).

(3*R*,4*R*)-3-Methyl-4-phenysulfanyl-1,8-dioxaspiro[4.5]decane *syn*-32

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol *syn*-**31** (50 mg, 0.17 mmol) and toluene-*p*-sulfonic acid (6.8 mg, 36 μmol) in CH_2Cl_2 (1.5 ml) gave, the *tetrahydrofuran syn*-**32** (43 mg, 96%) as white needles, mp 72–73 °C (from hexane–ether); R_f [petroleum ether–ether (1:1)] 0.37; $[\alpha]_D$ −36.4 (*c* 1.0 in $CHCl_3$); ν_{max}(NaCl)/cm^{-1} 1581 (SPh); δ_H (400 MHz; $CDCl_3$) 7.45–7.17 (5 H, m, SPh), 4.00 (1 H, dd, *J* 8.8 and 6.9, CH_AH_BO), 3.79–3.70 (4 H, m, 2 × CH_2O^{eq+ax}), 3.55 (1 H, dd, *J* 8.8 and 6.0, CH_AH_BO), 3.45 (1 H, d, *J* 7.84, CHSPh), 2.70 (1 H, heptet, *J* 7.0, C*H*Me), 1.94 (1 H, ddd, *J* 13.6, 11.8 and 5.1, $CH_AH_B^{ax}$), 1.85 (1 H, ddd, *J* 13.4, 10.7 and 6.4, $CH_AH_B^{ax}$), 1.66 (1 H, dd, *J* 13.6 and 2.4, $CH_AH_B^{eq}$), 1.47 (1 H, dd, *J* 13.4 and 2.4, $CH_AH_B^{eq}$) and 1.13 (3 H, d, *J* 7.1, Me); δ_C(100 MHz; $CDCl_3$) 136.6, 130.2, 129.1, 126.4, 81.3, 72.0, 64.8, 64.3, 60.8, 37.2, 36.4, 33.7 and 15.5 (Found M^+, 264.1184. $C_{15}H_{22}O_3S$ requires *M*, 264.1183); *m*/*z* (EI) 264 (30%, M), 164 (100, $C_{11}H_{13}OS$) and 110 (45, PhSH).

(3*R*,4*S*)-3-Methyl-4-phenylsulfanyl-1,8-dioxaspiro[4.5]decane *anti*-32

In the same way as for the tetrahydrofuran *anti*-**24**; X = O, the diol *anti*-**31** (10 mg, 34 μmol) and toluene-*p*-sulfonic acid (1.5 mg, 8 μmol) in CH_2Cl_2 (1.5 ml) gave the *tetrahydrofuran* *anti*-**32** (8 mg, 90%) as yellow oil, R_f [petroleum ether–ether (1:1)] 0.40; $[a]_D$ +82.2 (*c* 0.79 in $CHCl_3$); ν_{max}(NaCl)/cm^{-1} 1583 (SPh); δ_H(400 MHz; $CDCl_3$) 7.51–7.21 (5 H, m, SPh), 3.99 (1 H, t, *J* 8.3, CH_AH$_B$O), 3.85–3.81 (1 H, m, OCH_CH$_D^{eq}$), 3.75–3.64 (3 H, m, OCH_CH$_D^{eq}$ and 2 × OCH$_C$$H_D^{ax}$), 3.38 (1 H, t, *J* 8.7, OCH$_A$$H_B$), 2.81 (1 H, d, *J* 10.6, CHSPh), 2.30–2.25 (1 H, m, C*H*Me), 2.05 (1 H, ddd, *J* 13.1, 12.8 and 5.1, CH_EH$_F^{ax}$), 1.75 (1 H, ddd, *J* 13.3, 12.8 and 5.7, CH_EH$_F^{ax}$), 1.44 (1 H, dd, *J* 13.6 and 2.2, CH$_E$$H_F^{eq}$), 1.29 (1 H, dd, *J* 11.4 and 1.9, CH$_E$$H_F^{eq}$) and 1.15 (3 H, d, *J* 6.6, Me); δ_C(100 MHz; $CDCl_3$) 135.6, 132.0, 129.1, 127.2, 81.5, 71.3, 64.7, 64.6, 64.1, 40.1, 36.4, 32.3 and 16.4 (Found M$^+$, 264.1186. $C_{15}H_{20}O_2S$ requires *M*, 264.1183); *m*/*z* (EI) 264 (32%, M) and 164 (100, $C_{11}H_{13}OS$).

4-Hydroxy-4-(4-phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)butan-2-one 34

n-BuLi (2.21 ml, 1.2M in hexanes, 2.66 mmol) was added to a solution of diisopropylamine (0.35 g, 0.47 ml, 3.45 mmol) in THF (25 ml) at −78 °C and stirred for 40 min. Acetone **33** (0.14 g, 0.18 ml, 2.42 mmol) was added dropwise and the solution was stirred for a further 40 min. The aldehyde **17** (0.49 g, 2.2 mmol) in THF (2 ml) was slowly added and the solution was stirred for a further 20 min. Saturated NH_4Cl (1 ml) was added and the solution was extracted with ether (3 × 30 ml). The combined organic extracts were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with petroleum ether–ether (1:3) to give the aldol **34** (0.55 g, 90%) as white cubes, mp 98–99 °C (from ether); R_f [ether] 0.32; ν_{max}(NaCl)/cm^{-1} 3417 (OH), 1712 (CO); δ_H(400 MHz; $CDCl_3$) 7.48–7.29 (5 H, m, SPh), 4.07–3.92 (3 H, m, C*H*OH and 2 × CHO^{ax}), 3.81–3.77 (2 H, m, 2 × CHO^{eq}), 3.12 (1 H, d, *J* 3.3, CHO*H*), 3.05 (1 H, dd, *J* 17.0 and 1.6, CH_AH$_B$CO), 2.74 (1 H, dd, *J* 17.0 and 10.0, CH$_A$$H_B$CO), 2.24, (3 H, s, Me), 2.03 (1 H, ddd, *J* 14.8, 11.9 and 4.9, OCH^{ax}), 1.90 (1 H, ddd, *J* 14.5, 11.8 and 4.9, OCH^{ax}) and 1.36–1.32 (2 H, m, 2 × OCH^{eq}); δ_C(100 MHz; $CDCl_3$) 209.2, 137.4, 129.7, 129.3, 129.1, 128.6, 71.9, 63.6, 63.5, 55.4, 44.5, 31.1, 30.0 and 29.9 (Found M$^+$, 280.1135. $C_{15}H_{20}O_3S$ requires *M*, 280.1133); *m*/*z* (EI) 280 (40, M), 193 (80) and 69 (100).

3-Methyl-1-(4-phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)butane-1,3-diol 35

MeMgCl (70 μl, 3 M in ether, 0.22 mmol) was added to a solution of the ketone **34** (28 mg, 0.1 mmol) in THF (2 ml) at 0 °C and stirred for 30 min. Saturated NH_4Cl (10 ml) was added and the solution was extracted with ether (3 × 30 ml). The combined organic extracts were washed ($NaHCO_3$), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with CH_2Cl_2–methanol (1:3) to give the diol **35** (28 mg, 96%) as a colourless oil; R_f [ether] 0.32; ν_{max}(NaCl)/cm^{-1} 3387 (OH); δ_H(400 MHz; $CDCl_3$) 7.51–7.48 (2 H, m, SPh), 7.40–7.29 (3 H, m, SPh), 4.08–3.94 (2 H, m, 2 × CHO^{ax}), 3.84–3.75 (3 H, m, 2 × CHO^{eq} and C*H*OH), 2.02 (1 H, ddd, *J* 14.6, 11.9 and 5.0, CH_AH$_B^{ax}$), 1.85–1.70 (2 H, m, CH_AH$_B^{ax}$ and CH_CH$_D$), 1.46 (1 H, dd, *J* 14.6 and 2.1, CH$_A$$H_B^{eq}$), 1.27 (3 H, s, Me), 1.27–1.24 (2 H, m, CH$_A$$H_B^{eq}$ and CH$_C$$H_D$) and 1.24 (3 H, s, Me); δ_C(100 MHz; $CDCl_3$) 137.4, 129.5, 129.4, 129.1, 128.6, 72.8, 71.0, 63.8, 63.6, 57.6, 41.1, 31.9, 29.9, 29.7 and 27.8 (Found M$^+$, 296.1445. $C_{16}H_{24}O_3S$ requires *M*, 296.1446); *m*/*z* (EI) 296 (M, 60), 280 (30, M − OH) and 193 (100, M − $C_5H_{12}O_2$).

4-Hydroxy-4-[(4′-phenylsulfanyl)thianyl]butan-2-one 36

In the same way as the ketone **34**, diisopropylamine (1.66 g, 2.24 ml, 16.5 mmol), *n*-BuLi (9.92 ml, 1.3 M in hexanes, 12.9 mmol), acetone (0.72 g, 12.3 mmol) and aldehyde **18**; X = S (2.8 g, 11.7 mmol) in THF (300 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (1:1), the *ketone* **36** (3.1 g, 89%) as a colourless oil; R_f [petroleum ether–ether (1:1)] 0.5; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH) and 1700 (CO); δ_H(200 MHz, $CDCl_3$) 7.54–7.38 (5 H, m, SPh), 3.92 (1 H, dt, *J* 10.0 and 2.7, C*H*OH), 3.41–3.29 (2 H, m, 2 × CHS^{eq}), 3.28–2.48 (5 H, m, 2 × CHS^{ax}, CH_2CO and OH), 2.23 (3 H, s, Me) and 2.20–1.68 (4 H, m, 2 × CH$_2^{eq+ax}$); δ_C(50 MHz; $CDCl_3$) 208.5 (CO), 136.9 (*m*-SPh), 130.1 (*i*-SPh), 129.2 (*p*-SPh), 128.9 (*o*-SPh), 71.4 (CHOH), 57.2 (*C*SPh), 44.1 (*C*H$_2$CO), 31.2 (CH$_2$S), 30.9 (CH$_2$S), 23.6 (CH$_2$) and 23.5 (CH$_2$) (Found M$^+$, 296.0944. $C_{15}H_{20}O_2S_2$ requires *M*, 296.0946); *m*/*z* 296.1 (10%, M), 209.0 (40, C_5H_8SSPh), 110.0 (100, PhSH), 99.0 (40, C_5H_7S) and 77.0 (45, Ph).

2,4-Dihydroxy-2-methyl-4-[(4′-phenylsulfanyl)thianyl]butane 37

In the same way as the diol **35**, the ketone **36** (0.15 g, 0.56 mmol) and MeMgCl (0.33 ml, 3 M in ether, 1.01 mmol) in ether (5 ml) gave, after column chromatography on silica gel eluting with ether, the *diol* **37** (0.136 g, 90%) as a colourless oil; R_f [ether] 0.5; ν_{max}(film, $CDCl_3$)/cm^{-1} 3400–3300 (OH); δ_H(200 MHz; $CDCl_3$) 7.54–7.27 (5 H, m, SPh), 3.87 (1 H, s, OH), 3.65 (1 H, dd, *J* 11.2 and 2.2, C*H*OH), 3.48 (1 H, s, OH), 3.38–3.18 (2 H, m, 2 × CHS^{eq}), 2.52–2.34 (2 H, m, 2 × CHS^{ax}), 2.12–1.51 (6 H, m, 2 × CH$_2^{eq+ax}$ and CH$_2$), 1.27 (3 H, s, Me) and 1.21 (3 H, s, Me); δ_C(50 MHz; $CDCl_3$) 137.1 (*m*-SPh), 129.4 (*p*-SPh), 129.0 (*o*-SPh), 128.5 (*i*-SPh), 72.3 (CHOH), 70.8 (COH), 59.5 (*C*SPh), 40.1 (*C*H$_2$CO), 31.7 (CH$_2$S), 31.2 (CH$_2$S), 30.7 (CH$_2$), 27.6 (CH$_2$), 23.8 (Me) and 23.7 (Me); *m*/*z* 312.1 (20%, M) and 294.1 (100, M − H_2O).

2,2-Dimethyl-4-(phenylsulfanyl)-1-oxa-8-thiaspiro[4.5]decane 41

In the same way as the tetrahydrofuran **24**; X = O, the diol **37** (20 mg, 64.1 μmol) and toluene-*p*-sulfonic acid (2.2 mg, 12.8 μmol) in CH_2Cl_2 (1 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9:1), the *tetrahydrofuran* **41** (18 mg, 98%) as a colourless oil; R_f [petroleum ether–ether (9:1)] 0.5; ν_{max}(film, $CDCl_3$)/cm^{-1} 1550 (SPh); δ_H(400 MHz; $CDCl_3$) 7.43–7.21 (5 H, m, SPh), 3.36 (3 H, dd, *J* 11.6 and 7.1, C*H*SPh), 3.13–3.01 (2 H, m, 2 × CHS^{eq}), 2.43–2.29 (2 H, m, 2 × CHS^{ax}), 2.24 (1 H, dd, *J* 12.6 and 7.1, CH_AH$_B^{eq}$), 2.10 (1 H, t, *J* 12.0, CH_AH$_B^{eq}$), 1.94–1.85 (3 H, m, 2 × CH$_A$$H_B^{ax}$ and CH_CH$_D$), 1.68–1.63 (1 H, m, CH$_C$$H_D$), 1.32 (3 H, s, Me) and 1.18 (3 H, s, Me); δ_C(100 MHz; $CDCl_3$) 135.5* (*i*-SPh), 131.6 (*m*-SPh), 129.0 (*o*-SPh), 127.0 (*p*-SPh), 82.0* (CO), 78.8* (CO), 57.0 (*C*HSPh), 45.7* (*C*H$_2$CO), 39.1* (CH$_2$S), 34.6* (CH$_2$S), 30.7 (Me), 30.5 (Me), 25.2* (CH$_2$) and 24.1* (CH$_2$) (Found M$^+$, 294.1115. $C_{16}H_{22}OS_2$ requires *M*, 294.1112); *m*/*z* 294.1 (75%, M), 178.1 (100, M − C_5H_8SO), 163.1 (50, C_5H_9SPh) and 110.0 (60, PhSH).

2,2-Dimethyl-4-phenylsulfanyl-1,8-dioxaspiro[4.5]decane 42

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol **35** (18 mg, 60 μmol) and toluene-*p*-sulfonic acid (2.3 mg, 12 μmol) in CH_2Cl_2 (1.5 ml) gave the *tetrahydrofuran* **42** (12 mg, 76%) as white needles, mp 58–59 °C (from hexane); R_f [ether] 0.7; ν_{max}(NaCl)/cm^{-1} 1560 (SPh); δ_H(400 MHz; $CDCl_3$) 7.43–7.21 (5 H, m, SPh), 3.84–3.70 (4 H, m, 2 × CH$_2$O^{eq+ax}), 3.46 (1 H, dd, *J* 11.1 and 7.1, CHSPh), 2.27 (1 H, dd, *J* 12.6 and 7.1, CH(S)CH_AH$_B$), 2.01 (1 H, t, *J* 12.6, CH(S)CH$_A$$H_B$), 1.97–1.85 (2 H, m, 2 × OCH^{ax}), 1.49 (1 H, dd, *J* 13.3 and 2.2, OCH^{eq}), 1.33 (3 H, s, Me), 1.30 (1 H, dd, *J* 13.4 and 2.3, OCH^{eq}) and 1.21 (3 H, s, Me); δ_C(100 MHz; $CDCl_3$) 131.5, 129.1, 127.0, 81.2, 78.8, 64.8, 64.1, 55.8, 45.7, 37.8, 33.6, 30.7 and 30.5.

(2*SR*,4*RS*)-2,4-Dihydroxy-4-[(4′-phenylsulfanyl)thian-4′-yl]-butane *anti*-44

In the same way as the diol *anti*-**48**, ketone **36** (0.1 g, 0.34 mmol) and tetramethylammonium triacetoxyborohydride (0.71 g, 2.69 mmol) in AcOH–MeCN (4 ml, 1:1) gave, after flash column chromatography on silica gel eluting with petroleum ether–ether (1:1) a separable diastereoisomeric mixture (94:6, *anti*:*syn*) of the *diol anti*-**44** (91 mg, 90%) as a colourless oil; R_f [petroleum ether–ether (1:1)] 0.15; ν_{max}(film, $CDCl_3$)/cm^{-1} 3450–3300 (OH); δ_H(200 MHz; $CDCl_3$) 7.58–7.28 (5 H, m, SPh), 4.10 (1 H, sext, *J* 5.4, C*H*Me), 3.66 (1 H, t, *J* 6.2, C*H*OH), 3.48–3.15 (4 H, m, 2 × CH_2S^{eq+ax}), 2.71–2.48 (1 H, br s, OH), 2.48–2.32 (2 H, m, 2 × $CH_AH_B^{eq}$), 2.08–1.82 (2 H, m, CH_2), 1.75–1.52 (2 H, m, 2 × $CH_AH_B^{ax}$) and 1.18 (3 H, d, *J* 6.2, *Me*CH); δ_C(50 MHz; $CDCl_3$) 137.0 (*m*-SPh), 129.4 (*p*-SPh), 128.9 (*o*-SPh), 128.8 (*i*-SPh), 71.2 (CHOH), 65.2 (CHOH), 59.3 (*C*SPh), 38.1 (CH_2CHO), 31.2 (CH_2S), 30.9 (CH_2S), 23.7 (CH_2) and 23.6 (CH_2) (Found M^+, 298.1056. $C_{15}H_{22}O_2S_2$ requires *M*, 298.1061); *m*/*z* 298.1 (100%, M), 209.0 (90, M − C_4H_9S), 123.0 (20, $PhSCH_2$), 110.0 (70, PhSH) and 101.1 (90, C_5H_9S).

(2*SR*,4*SR*)-2,4-Dihydroxy-4-[(4′-phenylsulfanyl)thian-4′-yl]-butane *syn*-44

In the same way as the diol *syn*-**48**, the ketone **36** (0.1 g, 0.34 mmol), diethylmethoxyborane (0.34 ml, 1 M in THF, 0.34 mmol) and $NaBH_4$ (25.3 mg, 0.67 mmol) in ether (50 ml) gave, after flash column chromatography on silica gel eluting with petroleum ether–ether (1:1) a separable diastereomeric mixture (3:97, *anti*:*syn*) of the *diol syn*-**44** (96 mg, 96%) as a colourless oil; R_f [petroleum ether–ether (1:1)] 0.25; ν_{max}(film, $CDCl_3$)/cm^{-1} 3500–3300 (OH); δ_H(200 MHz; $CDCl_3$) 7.53–7.30 (5 H, m, SPh), 3.99–3.75 (3 H, m, CHOH and C*H*OH), 3.53–3.14 (3 H, m, 2 × CHS^{eq} and OH), 2.46–2.31 (2 H, m, 2 × CHS^{ax}), 2.12–1.48 (6 H, m, 3 × CH_2) and 1.18 (3 H, d, *J* 6.3, *Me*CH); δ_C(50 MHz; $CDCl_3$) 137.1 (*m*-SPh), 129.3 (*p*-SPh), 129.0 (*o*-SPh), 128.6 (*i*-SPh), 75.6 (CHOH), 66.4 (CHOH), 59.2 (*C*SPh), 37.6 (CH_2CHO), 31.0 (CH_2S), 30.5 (CH_2S), 23.7 (CH_2) and 23.6 (CH_2) (Found M^+, 298.1065. $C_{15}H_{22}O_2S_2$ requires *M*, 298.1061); *m*/*z* 298.1 (50%, M), 209.0 (85, M − C_4H_9S), 122.0 (20, PhSCH), 109.0 (65, SPh) and 101.1 (100, C_5H_9S).

(1*SR*,3*SR*)-1-(4-Phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)butane-1,3-diol *syn*-46

Et_2BOMe (0.29 ml, 1 M in THF, 0.29 mmol) was added to a solution of the aldol **34** (80 mg, 0.29 mmol) in THF–MeOH (4 ml, 3:1) at −78 °C and stirred for 5 min. $NaBH_4$ (22 mg, 0.58 mmol) was added and the solution was stirred for a further 2 h. Acetic acid (1 ml) was then added and the mixture was allowed to warm to room temperature. Saturated NH_4Cl (10 ml) was added and the solution was extracted with ether (3 × 30 ml). The combined organic extracts were washed ($NaHCO_3$), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with CH_2Cl_2–methanol (1:3) to give the diol *syn*-**46** (78 mg, 96%) as white plates, mp 102–103 °C (from ether–hexane); R_f [CH_2Cl_2–MeOH (50:1)] 0.34; ν_{max}(NaCl)/cm^{-1} 3381 (OH) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.49–7.31 (5 H, m, SPh), 4.10–3.96 (3 H, m, C*H*OH and 2 × OCH^{ax}), 3.85–3.78 (2 H, m, 2 × OCH^{eq}), 3.74 (1 H, br s, CHO*H*), 3.59 (1 H, dd, *J* 10.5 and 1.8, C*H*OH), 3.52 (1 H, br s, CHO*H*), 2.00 (1 H, ddd, *J* 14.6, 11.9 and 5.0, $CH_AH_B^{ax}$), 1.82–1.74 (2 H, m, CH_CH_D and $CH_AH_B^{eq}$), 1.64–1.55 (1 H, m, CH_CH_D), 1.47 (1 H, dd, *J* 14.6 and 2.0, $CH_AH_B^{ax}$), 1.27–1.20 (1 H, m, $CH_AH_B^{eq}$) and 1.19 (3 H, d, *J* 6.3, Me); δ_C(100 MHz; $CDCl_3$) 137.5, 129.5, 129.3, 129.2, 75.9, 68.7, 63.8, 63.5, 57.8, 38.1, 29.8, 29.4 and 23.9 (Found M − $C_4H_9O_2^+$, 193.0696. $C_{11}H_{13}OS$ requires *M*, 193.0687); *m*/*z* (EI) 193 (90, M − $C_4H_9O_2$) and 110 (100, SPh).

(1*SR*,3*RS*)-1-(4-Phenylsulfanyl-3,4,5,6-tetrahydro-(2*H*)-pyran-4-yl)butane-1,3-diol *anti*-46

$Me_4N(AcO)_3BH$ (0.73 g, 2.8 mmol) was added to a solution of the ketone **34** (0.1 g, 0.35 mmol) in AcOH–MeCN (4 ml, 1:1) at −30 °C and stirred for 5 days. Saturated $NaHCO_3$ (50 ml) was added and the solution was extracted with ether (3 × 30 ml). The combined organic extracts were washed ($NaHCO_3$), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with CH_2Cl_2–methanol (1:3) to give the diol *anti*-**46** (91 mg, 90%) as a colourless oil; R_f [CH_2Cl_2–MeOH (50:1)] 0.26; ν_{max}(NaCl)/cm^{-1} 3381 (OH) and 1582 (SPh); δ_H(400 MHz; $CDCl_3$) 7.54–7.31 (5 H, m, SPh), 4.20–4.10 (1 H, m, C*H*OH), 4.08–3.95 (2 H, m, 2 × OCH^{ax}), 3.86–3.77 (2 H, m, 2 × OCH^{eq}), 3.74 (1 H, dd, *J* 9.8 and 2.8, C*H*OH), 3.17 (1 H, br s, OH), 2.10–1.96 (1 H, br s, OH), 1.96 (1 H, ddd, *J* 14.6, 11.8 and 4.9, CH^{ax}), 1.79 (1 H, ddd, *J* 14.6, 11.6 and 4.8, CH^{ax}), 1.72–1.63 (2 H, m, CH_2), 1.49 (1 H, dd, *J* 14.6 and 2.1, CH^{eq}), 1.28 (1 H, dd, *J* 14.4 and 2.1, CH^{eq}) and 1.23 (3 H, d, *J* 6.3, CH_3); δ_C(100 MHz; $CDCl_3$) 137.6, 129.6, 129.3, 129.2, 76.0, 68.8, 63.5, 63.4, 57.7, 38.9, 29.3, 29.2 and 23.4.

(2*RS*,4*RS*)-2-Methyl-4-(phenylsulfanyl)-1-oxa-8-thiaspiro[4.5]-decane *anti*-50

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol *anti*-**44** (40 mg, 0.13 mmol) and toluene-*p*-sulfonic acid (4.6 mg, 26.8 μmol) in CH_2Cl_2 (1 ml) gave, after column chromatography on silica gel eluting with light petroleum (40–60 °C)–ether (9:1) the *tetrahydrofuran anti*-**50** (37 mg, 99%) as a colourless oil; R_f [petroleum ether–ether (9:1)] 0.5; ν_{max}(film, $CDCl_3$)/cm^{-1} 3500–3300 (OH); δ_H(400 MHz; $CDCl_3$) 7.43–7.19 (5 H, m, SPh), 4.19 (1 H, sext, *J* 6.1, C*H*CH_3), 3.32 (1 H, t, *J* 8.1, CHO), 3.06–2.95 (2 H, m, 2 × SCH^{eq}), 2.44–2.34 (2 H, m, 2 × OCH^{ax}), 2.20–1.70 (6 H, m, 3 × CH_2) and 1.20 (3 H, d, *J* 6.1, C*H*$_3$CH); δ_C(100MHz, $CDCl_3$) 135.6* (*i*-SPh), 131.2 (*m*-SPh), 129.0 (*o*-SPh), 126.9 (*p*-SPh), 82.3* (CO), 71.5 (CHO), 55.9 (*C*HSPh), 40.6* (*C*H_2CO), 38.8* (CH_2S), 32.3* (CH_2S), 25.3* (CH_2), 24.5* (CH_2) and 22.5 (*C*H_3CH) (Found M^+, 280.0951. $C_{15}H_{20}OS_2$ requires *M*, 280.0955); *m*/*z* 280.1 (55%, M), 164.1 (100, M − C_5H_8SO) and 110.0 (45, PhSH).

(2*RS*,4*SR*)-2-Methyl-4-(phenylsulfanyl)-1-oxa-8-thiaspiro[4.5]-decane *syn*-50

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol *syn*-**44** (40 mg, 0.13 mmol) and toluene-*p*-sulfonic acid (4.6 mg, 26.8 μmol) in CH_2Cl_2 (1 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9:1), the *tetrahydrofuran syn*-**50** (37 mg, 99%) as a colourless oil; R_f [petroleum ether–ether (9:1)] 0.4; ν_{max}(film, $CDCl_3$)/cm^{-1} 1550 (SPh); δ_H(400 MHz; $CDCl_3$) 7.42–7.20 (5 H, m, SPh), 4.08 (1 H, double quintet, *J* 9.6 and 5.9, C*H*Me), 3.32 (1 H, dd, *J* 10.7 and 6.7, C*H*SPh), 3.10–2.98 (2 H, m, 2 × SCH^{eq}), 2.49–2.39 (3 H, m, 2 × SCH^{ax} and $CH_AH_B^{eq}$), 1.93 (2 H, dd, *J* 7.9 and 3.7, 2 × CH_2), 1.87–1.65 (3 H, m, $CH_AH_B^{eq}$ and 2 × $CH_AH_B^{ax}$) and 1.25 (3 H, d, *J* 6.0, *Me*CH); δ_C(100 MHz; $CDCl_3$) 135.5* (*i*-SPh), 131.4 (*m*-SPh), 129.0 (*o*-SPh), 127.0 (*p*-SPh), 81.4* (CO), 72.5 (CHO), 57.4 (*C*HSPh), 41.5* (*C*H_2CO), 37.5* (CH_2S), 35.7* (CH_2S), 25.1* (CH_2), 24.4* (CH_2) and 22.2 (*Me*CH) (Found M^+, 280.0955. $C_{15}H_{20}OS_2$ requires *M*, 280.0955); *m*/*z* 280.1 (40%, M), 164.1 (100, M − C_5H_8SO) and 110.0 (40, PhSH).

(2*RS*,4*SR*)-2-Methyl-4-phenylsulfanyl-1,8-dioxaspiro[4.5]-decane *syn*-51

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol *syn*-**46** (50 mg, 0.18 mmol) and toluene-*p*-sulfonic acid (6.8 mg, 36 μmol) in CH_2Cl_2 (2.5 ml) gave, the *tetrahydrofuran syn*-**51** (43 mg, 94%) as a colourless oil; R_f [ether] 0.68; ν_{max}(NaCl)/cm^{-1}

1583 (SPh); δ_H(400 MHz; $CDCl_3$) 7.42–7.37 (2 H, m, SPh), 7.31–7.20 (3 H, m, SPh), 4.10–4.03 (1 H, double quintet, *J* 9.4 and 6.4, OC*H*Me), 3.82–3.72 (4 H, m, 2 × OCH_2^{eq+ax}), 3.41 (1 H, dd, *J* 10.1 and 7.1, CHSPh), 2.49 (1 H, ddd, *J* 12.8, 7.0 and 6.0, CH_AH_B), 1.96 (1 H, ddd, *J* 13.3, 11.6 and 5.2, $CH_CH_D^{ax}$), 1.8 (1 H, ddd, *J* 14.7, 11.6 and 4.5, $CH_CH_D^{ax}$), 1.71 (1 H, dt, *J* 12.8 and 10.1, CH_AH_B), 1.56 (1 H, qd, *J* 13.3 and 2.4, $CH_CH_D^{eq}$), 1.43 (1 H, qd, *J* 13.4 and 2.3, $CH_CH_D^{eq}$) and 1.28 (3 H, d, *J* 6.1, Me); δ_C(100 MHz; $CDCl_3$) 135.6, 131.3, 129.1, 126.9, 80.7, 72.4, 64.7, 64.4, 56.1, 41.4, 36.4, 34.6 and 22.2.

(2*RS*,4*RS*)-2-Methyl-4-phenylsulfanyl-1,8-dioxaspiro[4.5]-decane *anti*-51

In the same way as the tetrahydrofuran *anti*-**24**; X = O, the diol *anti*-**46** (50 mg, 0.18 mmol) and toluene-*p*-sulfonic acid (6.8 mg, 36 μmol) in CH_2Cl_2 (2.5 ml) gave, the *tetrahydrofuran anti*-**51** (45 mg, 96%) as a colourless oil; R_f [ether] 0.7; ν_{max}(NaCl)/cm^{-1} 1583 (SPh); δ_H(400 MHz; $CDCl_3$) 7.42–7.38 (2 H, m, SPh), 7.31–7.20 (3 H, m, SPh), 4.24 (1 H, sext, *J* 6.3, OC*H*Me), 3.82–3.70 (4 H, m, 2 CH_2O^{eq+ax}), 3.42 (1 H, t, *J* 7.5, CHSPh), 2.16 (1 H, dt, *J* 13.0 and 7.2, CH_AH_B), 2.06 (1 H, ddd, *J* 13.1, 7.9 and 6.4, CH_AH_B), 1.94–1.81 (2 H, m, 2 × $CH_CH_D^{ax}$), 1.60 (1 H, dq, *J* 12.5 and 2.5, $CH_CH_D^{eq}$), 1.40 (1 H, dq, *J* 13.3 and 2.5, $CH_CH_D^{eq}$) and 1.23 (3 H, d, *J* 6.2, Me); δ_C(100 MHz; $CDCl_3$) 135.6, 131.3, 131.2, 129.1, 126.8, 81.4, 71.8, 64.8, 64.4, 55.5, 40.5, 37.8, 31.6 and 22.5 (Found M^+, 264.1184. $C_{15}H_{20}O_2S$ requires *M*, 264.1183); *m*/*z* (EI) 264 (20%, M), 164 (100) and 110 (60, SPh).

(1*SR*,2*SR*)-1-(3,6-Dihydro-(2*H*)-pyran-4-yl)-2-methyl-3-phenylsulfanylpropan-1-ol *anti*-54

Toluene-*p*-sulfonyl chloride (80 mg, 0.39 mmol) was added to a stirred solution of the diol *anti*-**31** (0.1 g, 0.35 mmol) in pyridine (1 ml). The solution was stirred for 12 hours. Ether (20 ml) was added and the solution was extracted with HCl (10 ml, 3 M) and evaporated under reduced pressure. The residue was purified by flash chromatography on silica gel eluting with petroleum ether–ether (1 : 1) to give the *allylic alcohol anti*-**54** (33 mg, 64%) as a colourless oil; R_f [ether] 0.6; $[\alpha]_D$ −7.5 (*c* 0.2 in $CHCl_3$); ν_{max}(NaCl)/cm^{-1} 3426 (OH) and 1580 (SPh); δ_H(400 MHz; $CDCl_3$) 7.37–7.31 (2 H, m, Ph), 7.27–7.24 (2 H, m, Ph), 7.16–7.13 (1 H, m, Ph), 5.68 (1 H, s, CH=C), 4.16–4.14 (2 H, m, OCH_2CH=), 3.88 (1 H, d, *J* 7.6, C*H*OH), 3.80 (1 H, dt, *J* 10.9 and 5.4, CH_AH_BO), 3.71 (1 H, ddd, *J* 11.3, 6.9 and 4.5, CH_AH_BO), 3.32 (1 H, dd, *J* 12.9 and 3.6, CH_AH_BS), 2.75 (1 H, dd, *J* 12.9 and 8.4, CH_AH_BS), 2.14–2.09 (1 H, m, CH_CH_D), 1.99–1.91 (2H, m, CH_CH_D and C*H*Me) and 0.98 (3 H, d, *J* 6.8, Me); δ_C(100 MHz; $CDCl_3$) 137.0, 136.7, 129.5, 128.9, 128.8, 125.7, 123.2, 79.3, 65.2, 64.2, 36.7, 36.0, 24.0 and 16.4 (Found M^+, 264.1183. $C_{15}H_{22}O_3S$ requires *M*, 264.1183); *m*/*z* (EI) 264 (20%, M), 143 (100) and 109 (30, SPh).

(1*SR*,2*SR*)-1-(3,6-Dihydro-(2*H*)-pyran-4-yl)-2-methyl-3-phenylsulfanylpropan-1-ol *syn*-54

In the same way as the allylic alcohol *anti*-**54**, the diol *syn*-**31** (100 mg, 0.35 mmol) and toluene-*p*-sulfonyl chloride (80 mg, 0.39 mmol) in pyridine (1 ml) gave, after flash column chromatography on silica gel eluting with petroleum ether–ether (3 : 1) the *allylic alcohol syn*-**54** (76 mg, 82%), as a colourless oil; R_f [ether] 0.6; $[\alpha]_D$ −10.2 (*c* 0.82 in $CHCl_3$); ν_{max}(NaCl)/cm^{-1} 3426 (OH) and 1580 (SPh); δ_H(400 MHz; $CDCl_3$) 7.36–7.15 (5 H, m, Ph), 5.69 (1 H, br s, CH=C), 4.16–4.15 (3 H, m, OCH_2CH=C and C*H*OH), 3.80–3.70 (2 H, m, CH_2O), 3.05 (1 H, dd, *J* 13.0 and 6.7, CH_AH_BS), 2.79 (1 H, dd, *J* 13.0 and 6.9, CH_AH_BS), 2.06–1.99 (1 H, m, CH_CH_D), 1.94–1.80 (2 H, m, CH_CH_D and C*H*Me) and 0.99 (3 H, d, *J* 6.7, Me); δ_C(100 MHz; $CDCl_3$) 136.6, 136.5, 129.0, 129.7, 126.1, 121.3, 76.1, 65.4, 64.1, 38.0, 35.6, 25.1 and 13.5 (Found M^+, 264.1184. $C_{15}H_{20}O_2S$ requires *M*, 264.1189); *m*/*z* (EI) 264 (65%, M), 155 (100, M − SPh), 110 (90, SPh) and 83 (40, C_5H_7O).

3-Hydroxy-3-[methoxy(phenylsulfanyl)methyl]thiolane 56

In the same way as alcohol **15**; X = O, methoxymethyl phenyl sulfide (4.75 g, 4.55 ml, 30.9 mmol), *n*-BuLi (24.9 ml, 1.3 M in hexanes, 32.4 mmol) and tetrahydrothiophen-3-one **55** (3.0 g, 2.51 ml, 29.4 mmol) in THF (150 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9 : 1), an inseparable diastereomeric mixture (54 : 46) of the *alcohol* **56** (7.1 g, 95%) as a colourless oil; R_f [petroleum ether–ether (9 : 1)] 0.1; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH) and 1550 (SPh); δ_H(200 MHz; $CDCl_3$) 7.55–7.23 (10 H, m, SPh^{maj} and SPh^{min}), 7.75 (1 H, s, C*H*SPh^{maj}), 4.74 (1 H, s, C*H*SPh^{min}), 3.49 (6 H, s, OMe^{maj} and OMe^{min}), 3.23–2.65 (8 H, m, 2 × CH_2^{maj} and 2 × CH_2^{min}) and 2.20–2.08 (4 H, m, CH_2^{maj} and CH_2^{min}); δ_C(50 MHz; $CDCl_3$) 134.9 (*i*-SPh^{min}), 134.8 (*i*-SPh^{maj}), 132.9 (*m*-SPh^{maj} and *i*-SPh^{min}), 129.4 (*o*-SPh^{maj} and *o*-SPh^{min}), 127.7 (*p*-SPh^{maj} and *p*-SPh^{min}), 99.0 (C*H*SPh^{maj} and C*H*SPh^{min}), 86.2 (COH^{min}), 86.0 (COH^{maj}), 57.5 (MeO^{maj} and MeO^{min}), 39.8, 39.6, 39.5 and 39.2 (2 × CH_2S^{maj} and 2 × CH_2S^{min}), 29.2 (CH_2^{min}) and 29.0 (CH_2^{maj}) (Found M^+, 256.0588. $C_{12}H_{16}O_2S_2$ requires *M*, 256.0591); *m*/*z* 256.1 (40%, M), 147.1 (35, M − SPh) and 115.0 (100, M − SPh − MeOH).

3-(Phenylsulfanyl)thiolane-3-carboxaldehyde 57

In the same way as aldehyde **17**; X=O, the alcohol **56** (6.0 g, 23.4 mmol), Et_3N (25.2 g, 34.0 ml, 0.25 mol) and thionyl chloride (8.36 g, 5.23 ml, 70.3 mmol) in CH_2Cl_2 (350 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9 : 1), the *aldehyde* **57** (3.66 g, 70%) as a colourless oil; R_f [petroleum ether–ether (9 : 1)] 0.35; ν_{max}(film, $CDCl_3$)/cm^{-1} 1750 (CO) and 1550 (SPh); δ_H(200 MHz; $CDCl_3$) 9.31 (1 H, s, CHO), 7.49–7.25 (5 H, m, SPh), 3.12 (1 H, AB quartet, CH_AH_BS), 3.05–2.97 (1 H, m, CH_CH_DS), 2.94 (1 H, AB quartet, CH_AH_BS), 2.83–2.70 (1 H, m, CH_CH_DS), 2.55–2.42 (1 H, m, CH_EH_F) and 2.15–1.99 (CH_EH_F); δ_C(50 MHz; $CDCl_3$) 191.9 (CHO), 136.3 (*m*-SPh), 129.8 (*p*-SPh), 129.2 (*i*-SPh), 129.1 (*o*-SPh), 66.3 (*C*SPh), 35.5 (CH_2S), 35.3 (CH_2S) and 29.0 (CH_2) (Found M^+, 224.0327. $C_{11}H_{12}OS_2$ requires *M*, 224.0329); *m*/*z* 224.0 (50%, M), 195.0 (20, M − CHO), 115.1 (40, M − SPh), 109.0 (45, SPh) and 87.0 (100, C_4H_6S + H).

Ethyl 3-[(3′-phenylsulfanyl)thiolanyl]propionate 58

In the same way as ester *anti*-**20**; X = O, diisopropylamine (0.94 g, 1.26 ml, 9.29 mmol), *n*-BuLi (5.61 ml, 1.3 M in hexanes, 7.3 mmol), ethyl acetate (0.61 g, 0.68 ml, 6.97 mmol) and aldehyde **57** (1.5 g, 6.63 mmol) in THF (150 ml) gave, after HPLC eluting with petroleum ether–ether (1 : 1), an inseparable diastereomeric mixture (50 : 50) of the *ester* **58** (1.88 g, 90%) as a colourless oil; R_f [petroleum ether–ether (1 : 1)] 0.35; ν_{max}(film, $CDCl_3$)/cm^{-1} 3300 (OH) and 1700 (CO); δ_H(200 MHz; $CDCl_3$) 7.68–7.31 (10 H, m, 2 × SPh), 4.35–4.11 (6 H, m, 2 × CH_2 and 2 × OH), 3.31–3.05 (8 H, m, 4 × CH_2S), 2.99–2.85 (4 H, m, 2 × CH_2CO_2), 2.42–1.89 (4 H, m, 2 × CH_2) and 1.29 (6 H, t, *J* 7.2, 2 × Me); δ_C(50 MHz; $CDCl_3$) 172.5 and 172.4 (2 × CO), 138.9 (2 × *o*-SPh), 138.4 (2 × *o*-SPh), 131.3 and 131.3 (2 × *i*-SPh), 129.7 (2 × *p*-SPh), 71.0 and 71.0 (2 × CHOH), 67.8 and 67.8 (2 × CH_2O), 61.0 (2 × *C*SPh), 38.9 and 38.9 (2 × CH_2CO_2), 37.3, 37.2 and 37.1 (4 × CH_2S), 29.6 and 29.5 (2 × CH_2) and 14.2 (2 × Me) (Found M^+, 312.0846. $C_{15}H_{20}O_3S_2$ requires *M*, 312.0853); *m*/*z* 312.1 (30, M), 267.0 (20, M − OEt), 202.1 (65, M − PhSH), 185.1 (100, M − SPh − H_2O), 110.0 (55, PhSH), 87.0 (70, C_4H_7S) and 77.0 (20, Ph).

3-[(3′-Phenylsulfanyl)thiolanyl]propan-1,3-diol 59

In the same way as diol *anti*-**22**, the ester **58** (1.8 g, 5.76 mmol) and $LiAlH_4$ (0.65 g, 17.3 mmol) in ether (20 ml) gave, after

column chromatography on silica gel eluting with ether, an inseparable diastereoisomeric mixture (50:50) of *diol* **59** (1.4 g, 90%) as a colourless oil; R_f [ether] 0.55; ν_{max}(film, $CDCl_3$)/cm^{-1} 3500–3300 (OH); δ_H(200 MHz; $CDCl_3$) 7.65–7.28 (10 H, m, 2 × SPh), 3.95–3.73 (6 H, m, 2 × CH_2O and 2 × C*H*OH), 3.21–2.61 (12 H, m, 4 × CH_2S and 4 × OH) and 2.29–1.70 (8 H, m, 4 × CH_2); δ_C(50 MHz; $CDCl_3$) 137.2 (2 × *m*-SPh), 130.2 (2 × *i*-SPh), 129.4 (2 × *p*-SPh), 128.9 (2 × *o*-SPh), 74.2 and 73.8 (2 × CHOH), 69.0 and 69.0 (2 × CH_2O), 61.7 and 61.6 (2 × *C*SPh), 37.4, 36.7 and 36.6 (4 × CH_2S), 33.8, 33.7 and 29.8 (4 × CH_2) (Found M^+, 270.0741. $C_{13}H_{18}O_2S_2$ requires *M*, 270.0748); *m*/*z* 270.1 (60%, M), 252.1 (5, M − H_2O), 109.0 (30, SPh) and 87.0 (100, C_4H_6S + H).

4-(Phenylsulfanyl)-1-oxa-6-thiaspiro[4.4]nonane 60

In the same way as tetrahydrofuran *anti*-**24**; X = O, the diol **59** (0.1 g, 0.33 mmol) and toluene-*p*-sulfonic acid (12.6 mg, 66 μmol) in CH_2Cl_2 (1 ml) gave, after column chromatography on silica gel eluting with petroleum ether–ether (9:1), an inseparable diastereomeric mixture (50:50) of the *syn*- and *anti-tetrahydrofuran* **60** (93 mg, 99%) as a colourless oil; R_f [petroleum ether–ether (9:1)] 0.3; ν_{max}(film, $CDCl_3$)/cm^{-1} 1550 (SPh); δ_H(400 MHz; $CDCl_3$) 7.57–7.21 (10 H, m, SPh^a and SPh^b), 4.04–3.93 (2 H, m, $CH_AH_BO^a$ and $CH_AH_BO^b$), 3.89–3.83 (1 H, m, $CH_AH_BO^a$ and $CH_AH_BO^b$), 3.74–3.67 (2 H, m, $CH_AH_BS^a$ and $CH_AH_BS^b$), 3.22 (1 H, d, *J* 11.4, C*H*SPh), 3.04–2.78 (7 H, m, $CH_AH_BS^a$, $CH_AH_BS^b$, CH_2S^a, CH_2S^b and C*H*SPh), 2.52–2.43 (2 H, m, $CH_AH_B{}^a$ and $CH_AH_B{}^b$) and 2.19–1.86 (6 H, m, $CH_2{}^a$, $CH_2{}^b$, $CH_AH_B{}^a$ and $CH_AH_B{}^b$); δ_C(100 MHz, $CDCl_3$) 135.1* (*i*-SPh), 131.3 (*m*-SPh), 129.2 (*o*-SPh), 127.2 (*p*-SPh), 93.9* (CO), 65.0* (CH_2O), 51.7 (*C*HSPh), 40.3* (CH_2S), 36.5* (CH_2S), 34.5* (CH_2) and 29.1* (CH_2) (Found M − $C_2H_4{}^+$, 252.0641. $C_{13}H_{16}OS_2$ requires *M* − C_2H_4, 252.0642); *m*/*z* 252.1 (100%, M − C_2H_4).

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