Tetrahedron Vol 47, No 36, pp 7689-7698, 1991
Printed in Great Britain

0040-4020/91 $3 00+ 00

Cyclisation Chemistry of Some Functionalised Allylsilanes

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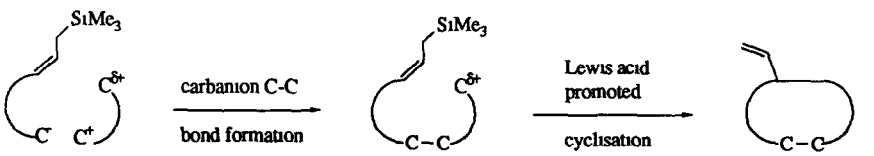
(*Received in UK 7 May* 1991)

Abstract Two allylic silanes bearing additional functionality in the form of either a bromide or a phenylsulphonyl group were synthesised and condensed with a variety of electrophilic partners Subsequent cyclisation of some of the products was then possible by utilising the acid-promoted reactions of the allylsilane grouping, to give one spiropentannulated product (**8**) and two medium ring ether sulphones (**12**) and (**13**)

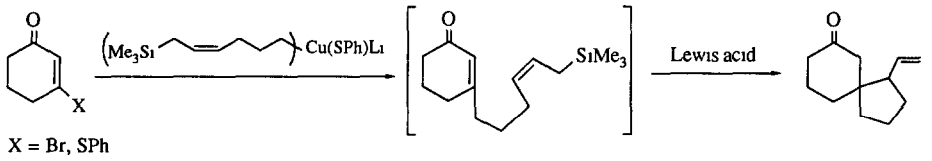
Introduction

Some time ago we became interested in the possibility of using functionalised allylsilanes for the construction of carbocyclic and heterocyclic rings We planned to synthesise some simple allylsilanes incorporating an additional functional group which would enable the formation of a nucleophilic carbon centre The idea was to use such compounds as *bis*-nucleophiles in reactions in which an anion would initially react with a suitable electrophilic partner, and then a subsequent cyclisation would be brought about by bringing into play the allylsilane in a second nucleophilic C-C bond forming process This type of idea is illustrated in a generalised form in Scheme 1



Scheme 1

We envisaged a number of possible situations in which such a tandem coupling process could be brought about with a predictable regiochemical outcome, and with a degree of stereocontrol An important general feature of this scheme was that only the more reactive sites on the two reaction partners should be involved in the initial C-C bond-forming reaction Only then would the latent nucleophilic character of the allylsilane be used to couple with the second electrophilic site [1] A specific example of the type of reaction planned, in which we anticipated a double addition to a suitable cycloalkenone bearing a leaving group at the β-position, is shown in Scheme 2



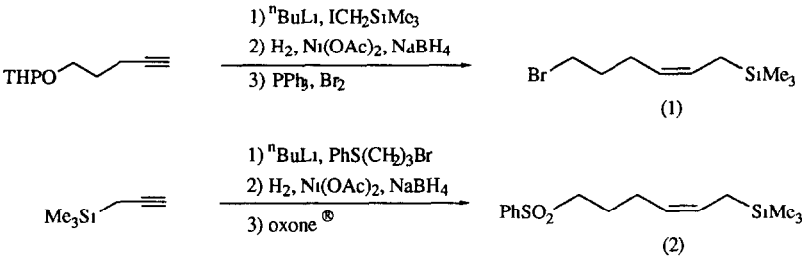
Scheme 2

This type of reaction was modelled on a number of literature reports in which cuprates were used as nucleophiles for both additions [2] The second step also had some precedent in the work of Majetich and Schinzer, the ring closure having been shown to be stereoselective [3] The use of a mixed cuprate species in the first step, followed by addition of a suitable Lewis acid to promote allylsilane reaction, appeared a good way to effect two sequential Michael additions, leading to a spiro-fused product

Here we describe our efforts to bring about such reaction sequences, resulting in two successful types of cyclisations, leading to a spiro-fused carbocycle, and two medium ring ethers respectively

Results and Discussion

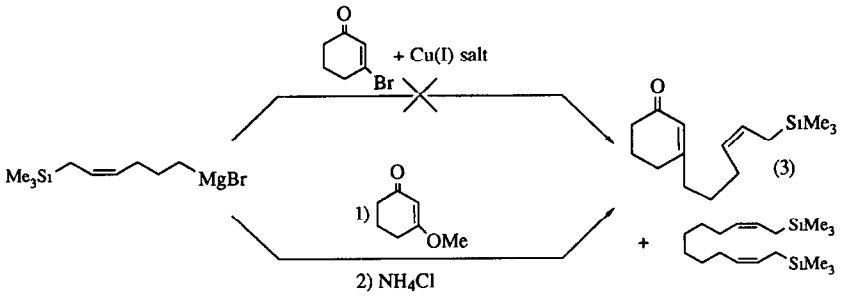
Two simple allylsilanes, suitably functionalised for the generation of a remote carbanion were prepared by the routes shown in Scheme 3



Scheme 3

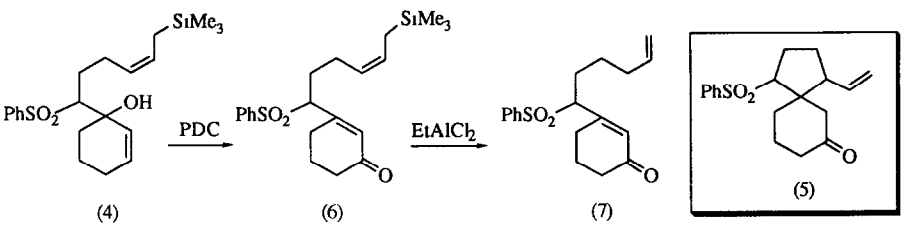
Both sequences proceeded unremarkably, allowing multigram preparation of either the bromide (**1**) or the sulphone (**2**) Although the sulphone was initially prepared via (**1**), by reaction with $PhSO_2Na$, we preferred the second route, which avoids the use of the expensive alkylating agent Me_3SiCH_2I

However, our efforts to react the Grignard reagent derived from (**1**) with 3-bromocyclohex-2-enone proved fruitless An alternative approach to the desired intermediate (**3**), described by Schinzer, involving Grignard addition to a vinylogous ester was also explored, but in our hands gave poor results [4] A recurring problem with this approach is the tendency of the Grignard reagent to undergo Wurtz coupling to give a *bis*-allylsilane, Scheme 4



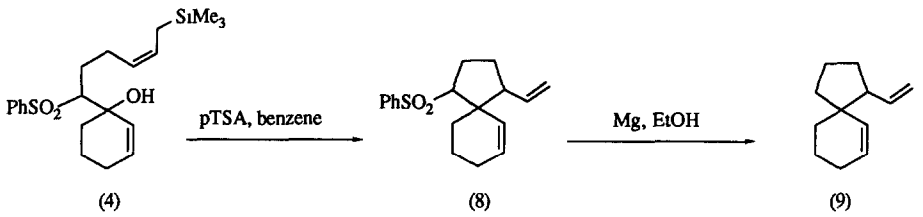
Scheme 4

By contrast, the generation and electrophilic quenching of the sulphone (**2**) was found to be highly efficient For example, exclusive 1,2-addition to cyclohex-2-enone took place to give adduct (**4**) as an equal mixture of diastereoisomers, in 79% yield We briefly explored the possibility of converting this alcohol into a spirocyclic product (**5**) by firstly treating it with PDC to give the enone (**6**) in 75% yield [5] All attempts to cyclise this material, using either Lewis-acids, such as $TiCl_4$ and $EtAlCl_2$, or by treatment with TBAF, failed, the only product formed in such reactions was (**7**), resulting from simple desilylation, Scheme 5



Scheme 5

The ready availability of allylic alcohol (**4**) turned our attention to the possibility of using this type of compound in alternative modes of cyclisation Initial attempts to effect a palladium-mediated cyclisation of the acetate derived from (**4**) were unrewarding However, we observed that by simply heating the allylic alcohol (**4**) in benzene containing a stoichiometric amount of pTSA efficient cyclisation took place to give spirocyclic product (**8**) as a mixture of two diastereoisomers, Scheme 6 Unfortunately nOe experiments on the separated isomers were inconclusive However, the mixture of spirocyclic sulphones was succesfully desulphonylated to give the hydrocarbon (**9**), which was also obtained as a mixture of diastereoisomers Thus it appears that the sulphone (**8**) is a mixture of epimers at C-4

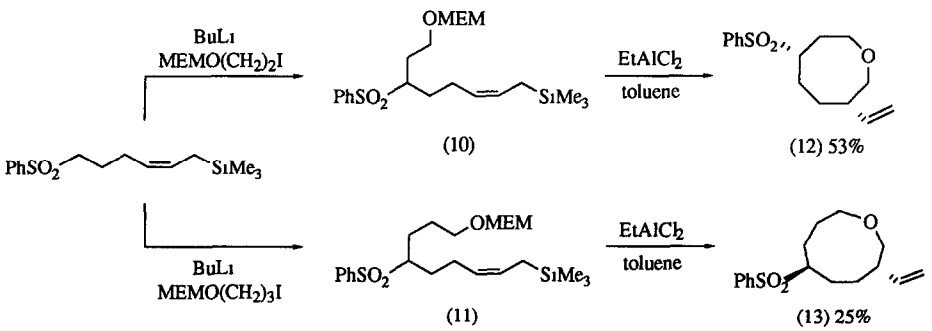


(4) (8) (9)

Scheme 6

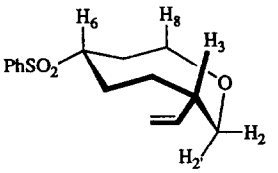
Following this initial success we were prompted to prepare further addition products by reaction of the sulphone carbanion derived from (**2**) with a variety of carbonyl partners, including acetone, chalcone, benzaldehyde, and methyl vinyl ketone Surprisingly none of these products could be induced to undergo cyclisation under the reaction conditions effective previously, or a variety of modified conditions We were therefore eventually forced to abandon our attempts to generalise the spirocyclisation leading to products related to (**8**)

During the course of this work we were attracted to reports from several laboratories that efficient cyclisation of enol silanes,[6] vinyl silanes[7] and allyl silanes[8] could be carried out onto appropriately positioned acetal groups We decided to incorporate a suitable acetal into our sulphonyl allylsilane (**2**) in order to test such reactions on our system Two suitable substrates, (**10**) and (**11**) were prepared very simply, by alkylation of the sulphone with the methoxyethoxymethyl (MEM) ether of either 2-iodoethanol or 3-iodopropanol respectively We were then delighted to find that, on treatment with $EtAlCl_2$ in toluene, both these compounds underwent the desired cyclisation, to give the cyclic ether products (**12**) and (**13**), Scheme 7



Scheme 7

Although the chemical yields are not high it should be remembered that this type of ring closure is usually difficult unless special high dilution techniques are used The structures shown are supported by ^{13}C nmr and 400 MHz ^{1}H nmr (including COSY) as well as combustion analysis Significantly, one diastereosomer predominated in both the 8- and 9-membered ring products (*ca* 4 1 ratio) [9] Based on the coupling constants of the low field ring hydrogens, and on NOE difference experiments carried out on (**12**) we have assigned the stereochemistry of the major stereoisomer for this compound as shown in Fig 1



nOe enhancements	couplings
H_6 - H_8 4%	$J_{2,2'}$ 12Hz
H_6 - H_3 5%	$J_{2,3}$ 5Hz
	$J_{2',3}$ 12Hz

Figure 1

The results are best accommodated by a chair-boat type conformation of the oxocane ring, with both the vinyl and phenylsulphonyl substituents occupying equatorial positions Analogous nmr studies on (**13**) were less informative, although the great similarity of the low field region of the ^{1}H nmr spectrum suggests a similar local conformation around the ether oxygen and sulphone groups, presumably with the ring substituents in pseudo-equatorial positions as before We tentatively assign the *trans*-stereochemistry shown in Scheme 7 for this compound

In conclusion, we have probed the cyclisation chemistry of bifunctional silanes, and discovered both a novel spiroannulation leading to (**8**), and a new stereoselective route to medium ring ether compounds Both of these types of products are of significant interest due to their presence in natural products [10] The presence of both a vinyl and a sulphone group in (**12**) and (**13**) make them interesting candidates for further regioselective transformations

Acknowledgements

We are grateful to the SERC and to ICI Pharmaceuticals for a CASE award to R C

Experimental

Melting points for solid products were determined using a Reichert Microscope apparatus, and are uncorrected Products without melting points are colourless oils Infra-red spectra were recorded on a Perkin-Elmer 298, Philips PU9706 or Pye Unicam SP3-100 grating spectrophotometer, or a Perkin-Elmer 1720 FTIR instrument NMR spectra were recorded on a Bruker WP80, Bruker AM250 or Bruker AM400 machine, with Me_4Si as internal standard Mass spectra were recorded on Hewlett Packard 5980A, AEI MS-902 or VG micromass 70E spectrometers Microanalyses were performed at the microanalytical laboratory at Nottingham University using a Perkin-Elmer 240B analyser

Analytical tlc was performed on Merck precoated silica gel F_{254} plates Preparative chromatography was carried out on columns of Merck Keiselgel 60 (230-400 mesh) Solvents were purified by standard techniques

(Z)-1-Bromo-6-trimethylsilylhex-4-ene (1)

(i) 6-(Tetrahydropyran-2-yloxy)-1-trimethylsilylhex-2-yne

To a solution of THP-protected 4-pentyn-1-ol (15 43g, 32mmol) in THF (50ml) under nitrogen at -30°C was added n-BuLi (26 3ml of a 1 6M solution in hexane, 42mmol) after which the flask and contents were warmed to room temperature Iodomethyltrimethylsilane (8 22g, 38 4mmol) in THF (20ml) was then added and the mixture stirred overnight at 42°C

The mixture was poured into a saturated aqueous solution of NH_4Cl (50ml) and extracted with ether (2x50ml)

The combined organic extracts were washed with brine (50ml), dried ($MgSO_4$) and the solvent removed under reduced pressure

Flash-chromatography (2-10% ether light petroleum) gave the title compound (6 32g, 77%) (Found C, 65 70, H, 10 10 $C_{14}H_{26}O_2Si$ requires C, 66 07, H, 10 32%), ν_{max}(film) 2952, 2873, 2360 1441, 1354, 1249, 1201, 1161, 1121, 1077, 1035, 991, 852 and 817 cm^{-1}, δ_H (250MHz, $CDCl_3$) 4 57 (1H, t, J 3Hz), 3 75-3 84 (2H, m), 3 42-3 49 (2H, m), 2 19-2 26 (2H, m), 1 48-1 78 (8H, m), 1 39 (2H, t, J 3Hz) and 0 06 (9H, s, $SiMe_3$), *m/z* 254 (M^+, 1 4%), 85 (100) and 73 ($SiMe_3^+$, 59) (Found M^+ 254 1701 $C_{14}H_{26}O_2Si$ requires M, 254 1702)

(ii) (*Z*)-6-(Tetrahydropyran-2-yloxy)-1-trimethylsilylhex-2-ene

To a stirred solution of nickel acetate (1 74g, 7mmol) in ethanol (20ml) under nitrogen was added a solution of sodium borohydride (0 27g, 7mmol) in ethanol (5ml) and the mixture stirred for 5-10 min The reaction vessel was evacuated and then flushed with hydrogen for 5 min The alkyne prepared in (i) above (3 54g, 14mmol) was then added and the slurry was stirred under a hydrogen atmosphere for a further 1 5h The reaction mixture was then filtered through a carbon/kieselguhr pad and the solvent removed under reduced pressure

Flash-chromatography (20-40% ether light petroleum) gave the desired *cis*-alkene (2 3g, 65%) ν_{max}(film) 3038, 2930, 1630, 1430, 1345, 1238, 1190, 1130, 1070, 1050, 981, 830 and 690 cm^{-1}, δ_H (80 MHz, $CDCl_3$) 5 00-5 70 (2H, m), 4 56 (1H, t, J 3Hz), 3 20-4 00 (4H, m), 1 00-2 20 (12H, m) and 0 05 (9H, s), *m/z* 256 (M^+, 1 3%), 85 (100) and 73 ($SiMe_3^+$, 97) (Found M^+ 256 1856 $C_{14}H_{28}O_2Si$ requires M, 256 1858)

(iii) (*Z*)-1-Bromo-6-trimethylsilylhex-4-ene (**1**)

To a stirred solution of triphenylphosphine (3 07g, 11 7mmol) in dichloromethane (10ml) at 0°C was added dropwise bromine (0 94g, 11 7mmol) The solution was then warmed to room temperature over 45 min and then cooled to -50°C and the allylsilane from (ii) (3g, 11 7mmol) in dichloromethane (15ml) added and the reaction mixture warmed to room temperature over 2h The reaction mixture was diluted with petrol (50ml), filtered through a pad of celite, and the solvent removed under reduced pressure

Flash-chromatography (2-8% ether light petroleum) gave the bromide (**1**) (1 74g, 63%), ν_{max} 3008, 2955, 1646, 1433, 1394, 1248, 1152, 857, 774, 726, 566 and 500 cm^{-1}, δ_H (250MHz, $CDCl_3$) 5 52 (1H, m), 5 25 (1H, m), 3 43 (2H, t, J 6Hz), 2 15-2 30 (2H, m), 1 83-2 07 (2H, m), 1 51 (2H, d, J 8Hz, CH_2-$SiMe_3$) and 0 09 (9H, s), δ_C (63MHz, $CDCl_3$) 127 52, 125 52, 33 64, 33 15, 25 88, 18 90 and 1 40 ($SiMe_3$), *m/z* 234 (M^+, 6 4%) and 73 ($SiMe_3^+$, 100) (Found M^+ 234 0442 $C_9H_{19}BrSi$ requires M, 234 0440)

(*Z*)-1-Phenylsulphonyl-6-trimethylsilylhex-4-ene (2)

(i) 1-Phenylthio-6-trimethylsilylhex-4-yne

Propargyltrimethylsilane* (15g, 134mmol) in THF (130ml) was treated with n-BuLi (92 13ml of a 1 6M solution, 0 15mol) at -30°C The mixture was then warmed to room temperature and then 3-bromopropyl phenyl sulphide (30 96g, 134mmol) in THF (130ml) was added and the mixture refluxed for 6-7h

After addition of sat NH_4Cl (200ml), the resulting mixture was extracted with ether (200ml), washed with brine (3x200ml) and the organic extracts dried ($MgSO_4$), filtered and evaporated

Removal of the unreacted starting bromo-sulphide by distillation followed by flash-chromatography of the residue on silica eluting with petrol gave the required alkyne (5 0g, 31%) [90% based on recovered bromo-sulphide], (Found C, 68 17, H, 8 63 $C_{15}H_{22}SSi$ requires C, 68 64, H, 8 45%), ν_{max} (film) 2900, 2120, 1590, 1480, 1440, 1250, 1170, 1095, 1030, 850, 740 and 690 cm^{-1}, δ_H (400MHz, $CDCl_3$) 7 14-7 50 (5H, m, phenyl), 3 03 (2H, t, J 7Hz, CH_2-SPh), 2 28-2 33 (2H, m), 1 81-1 76 (2H, m), 1 42 (2H, t, J 3Hz) and

0 10 (9H, s), δ_C (100MHz, $CDCl_3$) 136.53 (*phenyl, quat*), 129 10 (*phenyl*), 128.85 (*phenyl*), 125 81 (*phenyl*), 78 49 (*C*≡C), 78 29 (*C*≡C), 32 58, 28 73, 18 09, 6.96 and 0 05 ($SiMe_3$), *m/z* 262 (M^+, 4%) and 73 ($SiMe_3^+$, 100) (Found M^+ 262 1212 $C_{15}H_{22}SSi$ requires M, 262 1212)

* Obtained as a mixture with toluene (*ca* 20%) from propargylbromide (supplied stabilised with toluene) by the method of Slutsky and H Kwart[11]

(ii) (*Z*)-1-Phenylthio-6-trimethylsilylhex-4-ene

To a stirred solution of nickel acetate (15 8g, 63 4mmol) in ethanol (90ml) under nitrogen was added a solution of sodium borohydride (2 4g, 63 4mmol) in ethanol (70ml) and the mixture stirred for 15 min The reaction vessel was then flushed with hydrogen for 15-20 min The alkyne from (i) (16 6g, 63 4mmol) in ethanol (70ml) was then added and the slurry was stirred under a hydrogen atmosphere for a further 5-6h The reaction mixture was then filtered through a kieselguhr pad and the solvent removed under reduced pressure Flash-chromatography (petrol) gave the title alkene (10 52g, 63%), ν_{max} (film) 3020, 2960, 1640, 1590, 1485, 1440,1250, 1150, 860, 745 and 700 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 27-7 35 (5H, m), 5 15-5 39 (1H, m), 5 40-5 52 (1H, m), 2 93 (2H, t, J 7Hz, CH_2-SPh), 2 14 (2H, m), 1 73 (2H, m), 1 45 (2H, d, J 8Hz, CH_2-$SiMe_3$) and 0 10 (9H, s), δ_C (23MHz, $CDCl_3$) 129 42, 129 09, 126 92, 126 38, 126 00, 33 69, 29 57, 26 48, 18 85 and 0 05, *m/z* 264 (M^+, 36%) and 73 ($SiMe_3^+$, 100) (Found M^+, 264 1347 $C_{15}H_{24}SSi$ requires M, 264 1368)

(iii) (*Z*)-1-Phenylsulphonyl-6-trimethylsilylhex-4-ene (**2**)

To a stirred suspension of sulphide from (ii) (5 26g, 19 92mmol) in methanol (150ml) was added oxone® (7 35g, 119mmol) and the mixture was stirred for 8h The mixture was diluted with water (500ml), extracted into chloroform (3x300ml) then the combined organic extracts were dried ($MgSO_4$), filtered and evaporated Flash-chromatography (30% ether petrol) gave the sulphone (**2**) (4 53g, 77%) (Found C, 61 04, H, 8 48 $C_{15}H_{24}O_2SSi$ requires C, 60 76, H, 8 16%), ν_{max} (film) 3003, 2950, 1640, 1580, 1440, 1310, 1245, 1145, 1085, 850, 725 and 685 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 81-8 10 (2H, m), 7 42-7 65 (3H, m), 5 43 (1H, m), 5 17 (1H, m), 2 95-3 19 (2H, m, CH_2-SO_2Ph), 2 09-2 20 (2H, m), 1 50-1 80 (2H, m), 1 42 (2H, d, J 8Hz, CH_2-$SiMe_3$) and 0 06 (9H, s), *m/z* 296 (M^+, 3%) and 73 ($SiMe_3^+$, 100) (Found M^+ 296 1250 $C_{15}H_{24}O_2SSi$ requires M, 296 1266)

(*Z*)-1-(1-Phenylsulphonyl-6-trimethylsilylhex-4-enyl)cyclohex-2-en-1-ol (4)

To a solution of the sulphone (**2**) (856mg, 2 9mmol) in THF (5ml) under nitrogen at -78°C was added n-BuLi (2ml of a 1 6M solution in hexane, 3 19mmol) after which the flask and contents were stirred at -78°C for 1 h Cyclohex-2-enone (330mg, 3 48mmol) in THF (3ml) was then added and the mixture was stirred between -78°C and -50°C for 3 h

The reaction was quenched with sat NH_4Cl (10ml), extracted into ether (2x10ml) and the combined organic extracts washed with brine (3x10ml), dried ($MgSO_4$), filtered and the solvent removed under reduced pressure Flash-chromatography (20% ether petrol) gave (**4**) as a mixture of diastereomers in a 1 1 ratio (900mg, 79%) (Found C, 63 98, H, 8 15 $C_{21}H_{32}O_3SSi$ requires C, 64 24, H, 8 22%), ν_{max} (film) 3500, 3000, 2960, 1640, 1580, 1445, 1300, 1245, 1140, 1080 and 850 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 93-7 98 (2H, m), 7 56-7 70 (3H, m), 6 00 (1H, m), 5 48 (1H, d, J 1Hz), 5 25 (1H, m), 4 80 (1H, m), 4 53 (1H, s, O*H*), 3 25 (1H, m, C*H*-SO_2Ph), 1 51-2 34 (10H, m), 1 29 (2H, d, J 9Hz, CH_2-$SiMe_3$) and 0 10 (9H, s), *m/z* 296 (M^+-C_6H_8O, 2%), 96 ($C_6H_8O^+$, 12) and 73 ($SiMe_3^+$, 100) [Found (M^+-C_6H_8O) 296 1240 ($C_{21}H_{32}O_3SSi$ - C_6H_8O) requires M, 296 1267]

(Z)-3-(1-Phenylsulphonyl-6-trimethylsilylhex-4-enyl)cyclohex-2-en-1-one (6)

To a solution of sulphone (4) (740mg, 1 88mmol) in CH_2Cl_2 (15ml) at room temperature was added pyridinium dichromate (1 08g, 2 88mmol) and the mixture was stirred at room temperature for 94h The mixture was filtered through kiesulghr and the solvent removed under reduced pressure

Flash-chromatography (20-40% ether petrol) gave enone (6) (550mg, 75%) as white crystalline solid m p 60-63°C, ν_{max} (KBr disc) 3100, 2953, 1675, 1448, 1308, 1248, 1149, 1086 and 856 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 77-7 85 (2H, m), 7 50-7 75 (3H, m), 5 65 (1H, s), 5 41-5 56 (1H, m), 5 00-5 20 (1H, m), 3 65-3 75 (1H, m, C*H*-SO_2Ph), 1 80-2 62 (10H, m), 1 40 (2H, d, J 7Hz, CH_2-$SiMe_3$) and 0 10 (9H, s), δ_C (23MHz, $CDCl_3$) 198 22 (*C*=O), 155 37 (OC=*C*H), 134 35, 132 40, 129 36, 129 20, 128 49, 124 43, 72 42 (*C*H-SO_2Ph), 66 03, 37 65, 26 54, 24 32, 22 80, 19 01 and 0.57 ($SiMe_3$), *m/z* 249 (M^+-SO_2Ph, 15%), 195 (25), 77 (3) and 73 ($SiMe_3^+$, 100) [Found (M^+-SO_2Ph) 249 1673 ($C_{21}H_{30}O_3SSi$ - SO_2Ph) requires M, 249 1675]

Attempted cyclisation of (6)

To a solution of enone (6) (54mg, 0 14mmol) in CH_2Cl_2 (8ml) at -78°C was added $EtAlCl_2$ (0 15ml of a 1M solution in hexane, 0 15mmol) and the mixture was stirred at this temperature for 4h The reaction mixture was poured into a saturated solution of $NaHCO_3$ (25ml), extracted into ether (25ml), the organic layer was washed with brine (3x25ml), dried ($MgSO_4$) filtered and the solvent removed under reduced pressure

Flash-chromatography (30-60% ether petrol) gave the desilylated enone (7) (24mg, 55%), ν_{max} (film) 3000, 2927, 2360, 1674, 1448, 1307, 1256, 1192, 1148, 1085, 998, 965, 914, 740 and 690 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 76-7 89 (2H, m), 7 45-7 75 (3H, m), 5 60-5 81 (2H, m), 4 87-5 05 (2H, m), 3 60-3 72 (1H, dd, J 3, 8Hz, C*H*-SO_2Ph), 1 98-2 65 (8H, m), 1 90-1 97 (2H, t, J 8Hz) and 1 30-1 39 (2H, t, J 8Hz)

Cyclisation of (4) to give (8)

A solution of (4) (200mg, 0 5mmol) and *p*TSA (95mg, 0 5mmol) in benzene (5ml) were refluxed together in a pre-warmed oil bath for 40 minutes The cooled mixture was diluted with a saturated solution of $NaHCO_3$ (15ml) and the organic layer was diluted with ether (15ml), washed with brine (15ml), dried ($MgSO_4$), filtered and evaporated

Flash-chromatography (20-60% ether petrol) gave (8) (114mg, 74%) as a white crystalline solid m p 94-96°C (major diastereomer), ν_{max} (KBr disc) 3040, 2800, 1630, 1540, 1448, 1300, 1150, 1090 and 1000 cm^{-1},

Major isomer δ_H (400MHz, $CDCl_3$) 7 86-7 89 (2H, m, *phenyl*), 7 50-7 63 (3H, m, *phenyl*), 5 62-5 70 (2H, m), 5 30 (1H, m), 5 01-5 14 (2H, m), 3 42 (1H, dd, J 6, 9Hz, C*H*-SO_2Ph), 2 82 (1H, m), 2 42-2 46 (1H, m), 1 90-2 19 (5H, m) and 1 57-1 78 (4H, m), δ_C (23MHz, $CDCl_3$) 145 21 (*C-11*), 143 21 (*phenyl, quat*), 139 38, 133 42, 130 66, 129 25, 128 55, 116 03 (*C-12*), 71.94 (*C-1*), 53 63 (*C-4*), 51 19 (*C-5*), 29 25 (CH_2), 27 89 (CH_2), 25 51 (CH_2), 25 35 (CH_2), and 19 88 (CH_2)

Minor isomer δ_H (400MHz, $CDCl_3$) 7 85-7 87 (2H, m, phenyl), 7 48-7 63 (3H, m, *phenyl*), 5 65-5 83 (3H, m), 4 92-5 08 (2H, m), 3 42 (1H, dd, J 7, 9Hz, C*H*-SO_2Ph), 2 79-2 85 (1H, m), 2 00-2 37 (2H, m), 1 90-1 99 (2H, m), 1 80-1 86 (2H, m), 1 56-1 78 (2H, m) and 1 32-1 46 (2H, m), *m/z* 161 (M^+-SO_2Ph, 52%), 160 (M^+-HSO_2Ph, 59) and 91 (100) [Found (M^+ - HSO_2Ph) 160 1249 ($C_{18}H_{22}O_2S$ - HSO_2Ph) requires M, 160 1253]

Desulphonylation of (8) to give (9)

Magnesium turnings (10g) were activated by washing repeatedly with portions of 0 5% aqueous HCl by swirling and decanting the liquid After washing (x10) the magnesium was rinsed with water (x10), dry ethanol

and finally ether The metal was then heated in an oven (150°C) overnight

A mixture of dry methanol (10ml) and activated magnesium (96mg) was heated to 50°C until hydrogen gas was continuously evolved, then the heating source was removed and the sulphone (8) (150mg, 0 5mmol) was added The mixture was then stirred for 2-5 h with intermittent addition of magnesium (5x96mg over this period) and solvent, and heating was continued to maintain the reaction

After the reduction was complete (t l c) the reaction was poured into ice-cold dilute HCl (15ml), and then extracted into ether (15ml) The organic layer was washed with KOH (3x15ml), brine (2x15ml), dried ($MgSO_4$), filtered and the solvent removed under reduced pressure

Flash-chromatography (petrol) gave the hydrocarbon (**9**) (57mg, 71%), ν_{max} (film) 3025, 2856, 2839, 1641, 1437, 1338, 1248, 994, 910 and 858 cm-1, δ_H (250MHz, $CDCl_3$) 5 61-5 90 (2H, m), 5 35 (1H, m), 4 90-5 15 (2H, m), 2 72 (1H, m), 1 81-2 43 (8H, m) and 1 33-1 81 (4H, m)

Sulphones (10) and (11)

To a solution containing the sulphone (**2**) (0 5g, 1 69mmol) in THF (4ml) and hexamethylphosphoric triamide (0 302g, 1 69mmol) at -78°C was added n-BuLi (1 16ml of a 1 6M solution in hexane, 1 86mmol) and the mixture was stirred for 1h Then, MEM-protected 2-iodoethanol (2 20g, 8 45mmol) in THF (3ml) was added at -78°C and the mixture warmed to -50°C over 0 5h The reaction mixture was quenched with a saturated solution of NH_4Cl (20ml) and extracted with ether (20ml) The combined organic extracts were washed with brine (3x20ml) and the organic layer was dried ($MgSO_4$), filtered and evaporated

Flash-chromatography (40-60% ether petrol) gave sulphone (**10**) (392mg, 55%), ν_{max} 3150, 2952, 1645, 1586, 1448, 1305, 1248, 1147, 855, 731 and 693 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 90-7 99 (2H, m), 7 55-7 77 (3H, m), 5 35-5 51 (1H, m), 5 05-5 19 (1H, m), 4 65 (2H, s, -OC*H*$_2$O), 3 54-3 70 (6H, m), 3 40 (3H, s, O*Me*), 3 12-3 29 (1H, m), 1 50- 2 39 (6H, m), 1 41 (2H, d, J 9Hz, C*H*$_2$-SiMe$_3$) and 0 05 (9H, s, Si*Me*$_3$), *m/z* 429 (M^++ H, 3%), 425 (3), 401 (4) and 43 (100) [Found (M^++ H) 429 0201 $C_{21}H_{36}O_5SSi$ + H) requires M, 429 0213

A similar procedure gave (**11**) (76%) (Found C, 59 74, H, 9.09 $C_{22}H_{38}O_5SSi$ requires C, 59 69, H, 8 65%), ν_{max} (film) 3018, 2900, 1640, 1450, 1310, 1250, 1150, 1080, 1050 and 870 cm^{-1}, δ_H (250MHz, $CDCl_3$) 7 82-7 86 (2H, m, *phenyl*), 7 46-7 65 (3H, m, *phenyl*), 5 38 (1H, m), 5 03 (1H, m), 4 60 (2H, s, OC*H*$_2$O), 3 59-3 63 (2H, m, C*H*$_2$-OMe), 3 46-3 52 (4H, m, C*H*$_2$O), 3.34 (3H, s, O*Me*), 2 90-3 00 (1H, m, C*H*-SO_2Ph), 1 55-2 18 (8H, m), 1 37 (2H, d, J 9Hz, C*H*$_2$-SiMe$_3$) and 0 06 (9H, s, Si*Me*$_3$), *m/z* 265 (3%), 124 (5) and 105 (100)

Cyclisation of (10) and (11) to give cyclic ethers (12) and (13) respectively

To a solution of (**10**) (400mg, 0 93mmol) in toluene (40ml) at -78°C was added ethylaluminium dichloride (3 73ml of a 1M solution in hexane, 3 73mmol) The reaction was kept between -78°C and -50°C for 5h and then warmed to -4°C overnight

The reaction mixture was quenched with a saturated solution of NH_4Cl (15ml) and extracted with ether (2x20ml) The combined organic extracts were washed with brine (20ml), dried ($MgSO_4$), filtered and evaporated

Flash-chromatography (30-60% ether petrol) gave *6-phenylsulphonyl-3-vinyloxocane* (**12**) (141mg, 53%) (Found C, 64 07, H, 7 17 $C_{15}H_{20}O_3S$ requires C, 64 26, H, 7 19%), ν_{max} (film) 3010, 2927, 2359, 1640, 1586, 1447, 1304, 1289, 1146, 1105, 1086, 736, 692 and 604 cm^{-1}, δ_H (400MHz, $CDCl_3$) 7 88-7 90 (2H, m, *phenyl*), 7 26-7 68 (3H, m, *phenyl*), 5 59 (1H, m), 4 96-5 04 (2H, m), 3 88 (1H, dt, J 4, 13Hz, H_8), 3 66 (1H, dd, J 5, 12Hz, H_2), 3 58-3 65 (1H, m, $H_{8'}$), 3 32 (1H, t, J 12Hz, $H_{2'}$), 3 17-3 23 (1H, m, C*H*-

SO_2Ph), 2 03-2 40 (5H, m) and 1 66-1 71 (2H, m), δ_C (100MHz, $CDCl_3$) 138 58 (*C-9*), 137 57 (*phenyl, quat*), 133 73 (*phenyl*), 129 25 (*phenyl*), 129 07 (*phenyl*) 115 54 (*C-10*), 73 51 (CH_2O), 68 13 (CH_2O), 63 19 (*C-6*), 41 60 (*C-3*), 28 78 (CH_2), 26 71 (CH_2) and 24 60 (CH_2), *m/z* 256 (M^+-CH_2O, 11%), 195 (13) and 109 (18) [Found· (M^+ - CH_2O) 250 1023 ($C_{15}H_{20}O_3S$ - CH_2O) requires M, 250 1027]

A similar procedure gave *6-phenylsulphonyl-3-oxonane* (**13**) (25%) (Found C, 65 29, H, 7 83 $C_{12}H_{22}O_3S$ requires C, 65 28, H, 7 53%), ν_{max} (film) 3068, 2921, 2865, 1639, 1585, 1480, 1447, 1289, 1197, 1145, 1086, 999, 917, 810, 760, 729 and 693 cm^{-1}, δ_H (400MHz, $CDCl_3$) 7 56-7 93 (2H, m, *phenyl*), 7 17-7 27 (3H, m, *phenyl*), 5 58 (1H, m), 4 94-5 01 (2H, m), 3 82 (1H, dt, J 4, 7Hz, H_9), 3 73 (1H, dd, J 4, 11Hz, H_2), 3 64-3 68 (1H, m, *CH*-SO_2Ph), 3 42-3 50 (1H, m, $H_{9'}$), 3 13 (1H, t, J 11Hz, $H_{2'}$) and 1 39-2 35 (9H, m), δ_C (100MHz, $CDCl_3$) 138 94 (*C-10*), 137 92 (*phenyl, quart*), 133 32 (*phenyl*), 128 97 (*phenyl*), 128 77 (*phenyl*), 114 75 (*C-11*), 75 20 (CH_2O), 72 43 (CH_2O), 62 78 (*C-6*), 42 75 (*C-3*), 28 88 (CH_2), 27 12 (CH_2), 26 47 (CH_2) and 24 95 (CH_2), *m/z* 153 (M^+-SO_2Ph, 100%), 123 (6), 98 (5) and 71 (99) [Found (M^+ - SO_2Ph) 153 1251 ($C_{16}H_{22}O_3S$ - SO_2Ph) requires M, 153 1279]

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