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THE USE OF ORGANOTIN CHEMISTRY TO ACHIEVE CHEMOSPECIFICITY IN A ONE-POT [3+2] ANNULATION SEQUENCE

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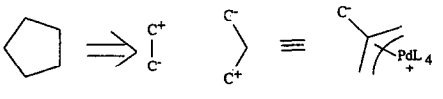
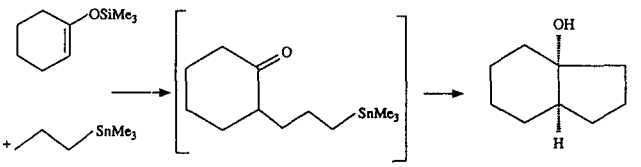
Summary: A highly controlled intermolecular reaction of the acetal-stannane (7) with silyl enol ethers, followed by intramolecular reaction on the thus formed ketone by the C-Sn bond, is the basis for a highly useful one-pot [3+2] annulation sequence.

Bifunctional reagents are inherently valuable in organic synthesis, offering amongst other advantages the opportunity for performing multi-bond forming reactions. Such possibilities have been realised in practice by various research groups, notably for the preparation of carbocyclic rings, with a range of [3+2] annulation reactions having been developed for the novel synthesis of cyclopentanes[1].



(1)

SCHEME 1



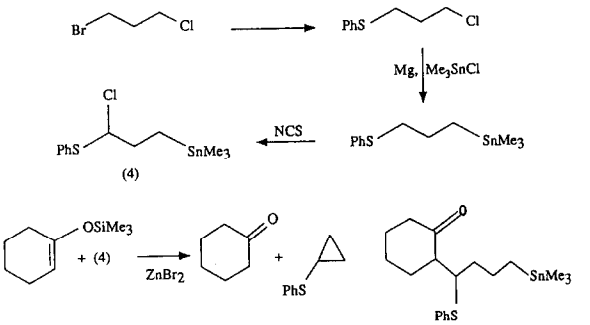
(2) (3)

This conceptually simple approach which is represented in SCHEME 1 has so far been most successfully developed by Trost in the use of the palladium complex of trimethylene methane (1)[2]. The unique feature of this zwitterionic reagent is that initially it reacts exclusively at the negative end of the zwitterion with an external electrophile. In contrast most other donor-acceptor bifunctional annulating reagents avoid the problem of the electrophilic and nucleophilic centres 'destroying' each other by utilising centres which are activated under two sets of different and incompatible conditions[3]. The result of this is that these reagents require a two-stage reaction sequence often with the associated reduction in efficiency. It was therefore of interest and value to attempt to develop a bifunctional annulating reagent in which the two reactive centres are activated by one set of conditions, but sequentially.

We therefore set out to study the process shown in SCHEME 1. In this the known intramolecular Lewis acid induced ring closure of an alkyl tin substituted ketone (3)[4] to give a fused cyclopentane would be the second stage of a one pot process in which the first stage would be the formation of (3) from an O-silylated enolate and some hypothetical electrophile (2). Since both reactions require

a Lewis acid such a scheme would provide us with the opportunity to try to develop a one-pot bifunctional annulating reagent in which both reactive centres are activated under one set of conditions. We now describe in full our efforts to achieve these aims for the synthesis of cyclopentanes.

The proposition that one could use an electrophilic species such as (2) in this way relies heavily upon the expectation that it is possible to select an electrophilic centre which upon activation will not react intramolecularly with the latently nucleophilic carbon-tin bond but will be sufficiently long lived to permit preferential intermolecular attack by the more nucleophilic enol silane. The potential difficulties in doing this are reflected in reports upon cyclization studies of γ-hydroxy stannanes[5] and were graphically illustrated by our own initial studies.

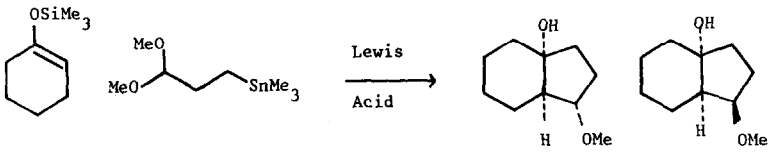


(5)

As shown above we attempted to use the unstable phenylthio-chloride (4) as a potential annulating reagent. The preparation of (4) was straightforward except that the reagent itself rapidly decomposes, via elimination of hydrogen chloride, so that it had to be prepared and used immediately without prior purification. Upon reaction of (4) with an O-silylated enolate in the presence of a catalytic amount of zinc bromide we observed formation of 1-phenylthiocyclopropane and hydrolysis of the enol silane. Thus clearly upon activation of the electrophilic centre intramolecular cyclization occurs[6]. By similarly preparing the next higher homologue of (4) we were able to isolate a modest 40% yield of the alkylated ketone (5). Thus in this case the electrophilic centre is sufficiently long lived to permit intermolecular attack, in an observation which presumably reflects the well known slower rate of cyclization to cyclobutanes compared to cyclopropanes. This rate difference is obviously large enough to allow intermolecular attack to compete effectively. However this reaction would essentially be restricted to this size of chain which when combined with the inherent instability of these phenylthio chlorides makes it most unattractive.

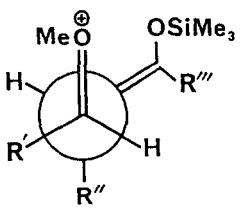
An alternative potential annulating reagent was therefore prepared, namely the acetal stannane (7) (SCHEME 2), the electrophilic centre of which would hopefully form a longer lived intermediate, through solvation effects[7]. The synthesis of (7) involves a Grignard reaction on the known[8] bromo-acetal (6) to give a 75% overall yield of the required product. The acetalstannane is easy to purify and handle being stable at 0°C for many months so offering an immediate advantage over its phenylthiochloro counterpart. Initially we reacted (7) with the O-silylated enolate of cyclohexanone in the presence of trimethylsilyl trifluoromethane sulphonate (TMSOTf) to form the ketone (8) in 71% yield. Treatment of (8) directly with titanium tetrachloride gave 70% yield of the cyclic alcohol (9) in a process initially involving activation of the electrophilic centre of (7) and preferential intermolecular attack by an enol. This is followed by intramolecular nucleophilic attack on the previously masked carbonyl group by the carbon-tin bond to result in a one-pot [3+2] annulation reaction. As shown in TABLE 1 other Lewis acids or combinations of Lewis acids can be used with different degrees of success and with different stereochemical outcomes. In all cases the ring closure proceeded to form exclusively the cis-fused cyclopentane but the

TABLE



(l) (u)

Entry	Lewis Acid	Yield (%)	Ratio of (l): (u)
1.	(i) TMSOTf (ii) $TiCl_4$	64	90:10
2.	$AlCl_3$	55	>95:<5
3.	(i) BF_3 (ii) $TiCl_4$	27	66:34
4.	$TiCl_4$	60	60:40
5.	$TiCl_4$:$Ti(OPr^i)_4$ (3:1)	41	85:15



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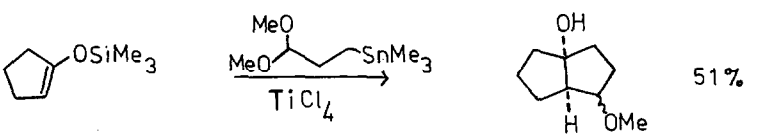

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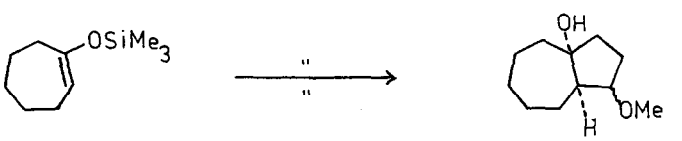

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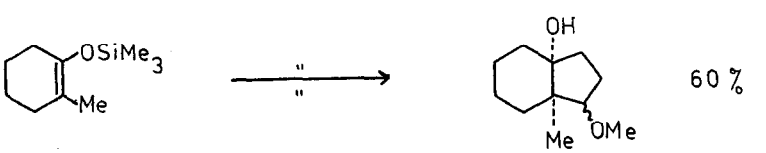
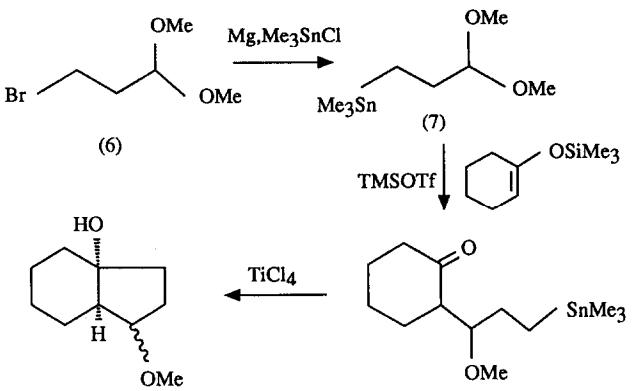


(13)

SCHEME 2

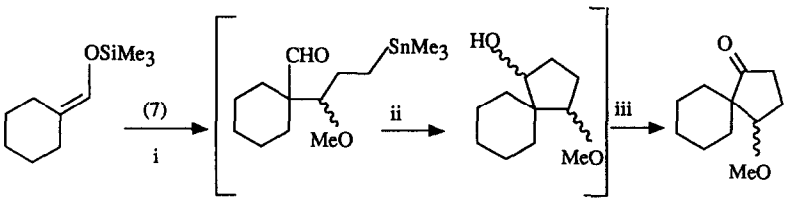


stereoselectivity in the first stage for form either the u or 1 isomer showed a dependence upon the Lewis acid used.[9,10] Reaction with $TiCl_4$ or aluminium trichloride gave excellent selectivity for the 1 isomer. The two diastereoisomers are separable by column chromatography to give 9a) and 9b) in a ratio essentially identical to the ratio of the two compounds determined by comparison of the methoxy signals in the nmr of the crude reaction product (9a OCH_3 = δ 3.30 and 9b OCH_3 = δ 3.31). The structures of the two products was confirmed by a series of difference n.O.e. experiments involving irradation of the C-5 proton and noting its effect on the C-4 proton, followed by the reverse sequence of irradation to confirm the assignment. This showed an enhancement for 9b) so determining the C-4/C-5 relative stereochemistry for this isomer. Similarly. preparation of the methyl ether of the C-1 tertiary alcohol (NaH/CH_3I) and irradiation of this methoxy signal (δ = 3.25) showed for both isomers enhancement of the C-5 proton so confirming the exclusive formation of the cis ring junction in the second stage of the new reaction, as precedented[4].

The stereochemical outcome of the first stage of the reaction can best be explained by a transition state (10) in which the topology of the two approaching reagents is such that the donor atom and acceptor atom are in a gauche arrangement as suggested by Seebach[11]. Such an approach results in the formation of the 1 isomer as observed. The variations in stereochemistry observed with different Lewis acids may reflect an enhancement, with stronger Lewis acids (e.g. $AlCl_3$), of chelation of an acetal oxygen and the enol oxygen immediately prior to formation of (10) so enhancing this 'gauche' topology.

The use of other O-silylated enolates gives directly the bicyclo [3.3.0] system (11) and the perhydroazulane (12) whilst using the thermodynamic enol of the 2-methylcyclohexanone forms the bicyclic alcohol (13). This result confirms the expected regiochemistry of the reaction and shows that the reaction does accommodate additional bridgehead functionality.

The reaction is not limited to the one-pot preparation of fused ring systems but allows a remarkably efficient synthesis of spirocyclic compounds[12]. Thus the reaction of the O-silylated enolate of cyclohexane carboxaldehyde with the acetal (7) forms an intermediate aldehyde which rapidly cyclizes to the alcohol (14). The yield of this spiroannulation is improved by the addition of pyridinium dichromate to the alcohol (14), prior to work up, so giving an 83% isolated yield of the ketone (15). This makes this sequence a highly efficient way to prepare, in one pot, spirocyclic systems, including besides the example shown the [4.4] (48%), the [6.4] (62%) and the [5.5] (68%) system[12].



(14) (15)

In conclusion a highly efficient [3+2] annulation sequence, allowing the preparation of both fused and spirocyclic rings has been developed. This relies upon a novel type of bifunctional annulating reagent containing an isolated electrophilic and nucleophilic centre within the same molecule, for which the two centres are activated by the same set of conditions. This highly controlled mode of reaction, which prevents the self destruction of the annulating reagent, reflects the value of the C-Sn bond in this molecule. The latently nucleophilic character of the function is sufficiently weak that a much stronger nucleophile (the enol ether) can compete totally, even intermolecularly, for reaction with the electrophilic acetal. However when needed the C-Sn bond will react very efficiently with a stronger electrophilic centre, generated by the same Lewis acid. Such selectivity clearly demonstrates a major advantages of using organtin compound in synthesis.

Acknowledgements: We would like to thank SERC for their support of this work GR/D/14747) and for a studentship to KLE.

EXPERIMENTAL

Tetrahydrofuran was distilled from sodium/benzophenone. Dichloromethane was distilled from calcium hydride. TMEDA was distilled under reduced pressure from potassium hydroxide. Triethylamine was distilled from calcium hydride. Ether refers to diethyl ether which was distilled before use. Methanol was distilled from magnesium,trimethylorthoformate was distilled from potassium hydroxide. Carbon tetrachloride was distilled from potassium hydroxide. Infra-red spectra were recorded on a Perkin-Elmer 1420 spectrophotometer, nmr on JEOL PMX60 and GX270 spectrometers using TMS or CH_2Cl_2 as an internal standard, and mass spectra were obtained on a VG9090 mass spectrometer. Magnesium sulphate was used to dry solutions of organic compounds.

1-Chloro-1-phenylthio-4-trimethylstannylbutane

A solution of 4-bromo-1-phenythiobutane (5.00g; 20.3 mmol) in dry THF (20ml) was slowly added to a suspension of magnesium (0.49g, 20.3mmol) in dry THF (30ml). The mixture was refluxed for 60 mins until all of the magnesium had been consumed when a solution of trimethyltin chloride 4.03g, 20.3mmol) in dry THF (30ml) was added in one portion. After 60h the reaction mixture was

poured into water (100ml) and extracted with ether (2 x 100ml). Flash chromatography using petrol as eluent gave the alkyl tin as a colourless oil. (3.96g, 59% b.p. 110-115°C/0.1mmHg) ν_{max} (neat) 3070, 2820, 1570cm^{-1}; $\delta(CCl_4)$, 7.15 (5H, m, PhS), 2.85 (2H, t, J = 7H_2, CH_2S), 2.0-1.2 (4H, m, CH_2), 1.2-0.6 (2H, m, CH_2 Sn), 0.05 (9H, s, $SnMe_3$); m/z, 314 (M^+).

Sulphuryl chloride (0.85g; 6.36mmol) was added to the above alkyltin compound (2.0g; 6.36mmoles) in dry CH_2Cl_2 (20ml) under N_2 at ambient temperature. After effervescence had ceased (10 mins) the solvent was evaporated to provide g; (98%) of a yellow liquid which was used immediately without purification. $\delta(CCl_4)$ 7.2 (5H, m, PhS, 5.3 (1H, t, J = 6Hz, PhSC<u>H</u>Cl), 2.1-1.5 (4H, m, CH_2), 1.2-0.8 (2H, m, CH_2Sn) 0.05 (9H, s, $SnMe_3$).

2(1-Phenylthio-4-(trimethylstannylbutycyclohexanone (5)

To crude 1-chloro-1-phenylthio-4-trimethylstannylbutane (1.06g; 2.92mmoles) and 1-trimethylsilyloxycyclohexene (0.52g; 3.06mmoles) in dry CH_2Cl_2 (15mls) was added with stirring pre-dried $ZnBr_2$ (20mg) under nitrogen at ambient temperature. After 2 hrs, water (25ml) was added and the mixture was washed with CH_2Cl_2 (2 x 50ml) to afford a brown oil which gave, after flash chromatography 0.45g; (37%) of the ketone (5) as a colourless oil. ν_{max} (neat), 3060, 1715, 1590cm^{-1}; $\delta(CCn_4)$, 7.45 (5H, s, aryl), 3.7 (1H, m, C<u>H</u> S Ph), 2.6-1.6 (13H, m, CH_2), 1.2-0.8 (2H, m, CH_2 Sn), 0.07 (9H, s, $SnMe_3$); m/z 317, 315, 313 (M^+-SPh), 178 (100%). Found: 315.2400. $C_{13}H_{25}OS_n^{118}$ requires 315.2417.

1,1-Dimethoxy-3-trimethylstannyl propane (7)

A solution of 3-bromo-1,1-dimethoxypropane[8] (7.39g; 41.0mol) in dry THF (100ml) was added slowly over 1.5h, to a suspension of magnesium (0.96g; 41.0mol in dry THF (5ml) under nitrogen. The reaction temperature was maintained between 35° and 40°C until all of the magnesium had been consumed. Then a solution of trimethylstannylchloride (8.0g; 41.0mol) in dry THF (100ml) was added in one portion. After 12h the reaction mixture was poured into water (200ml) and extracted with diethyl ether (2 x 200ml). Dry flash chromatography using petrol as eluent gave the acetal(7) as a colourless oil. (8.19g, 76%), b.p. 65-75°C/1.0mmHg ν_{max} 2920, 2810, 1200, 1120cm^{-1}; $\delta(CDCl_3)$, 4.15 (1H, t, J = 6Hz, C<u>H</u> $(OCH_3)_2$), 3.25 (6H, S, OCH_3), 2.05-1.05 (2H, m, CH_2), 1.05-0.6 (2H, m, CH_2 Sn), 0.1 (9H, s, $SnMe_3$), m/z, 266 (M^+); Found C, 36.2%; H, 7.5%; $C_8H_{20}O_2Sn$ requires C, 36.0%; H, 7.55%.

General procedure for [3 + 2] annulation - Method A

A solution of trimethylsilyltrifluoromethane sulphonate (0.1 molar equiv., freshly distilled) in dry CH_2Cl_2 (5ml) was added dropwise to a mixture of a 1-trimethylsilyloxycycloalkene and the acetal <u>7</u> in dry CH_2Cl_2 (20ml) at -78°C under nitrogen. The reaction was kept at -78°C until t.l.c. analysis indicated that the starting materials had been consumed (ca. 1-2h). A solution of freshly distilled titanium tetrachloride (molar equiv.) in dry CH_2Cl_2 (20ml) was slowly added to the reaction mixture at -78°C. The mixture was kept at -78°C until t.l.c. analysis had indicated the complete consumption of the intermediate when water was added to the reaction mixture, followed by extraction with CH_2Cl_2. Flash chromatography using petrol:ether (1:2) as eluent afforded the desired product as a colourless oil.

Method B

A solution of titanium tetrachloride (0.85g, 0.50mmol) in dry CH_2Cl_2 (20ml) was slowly added to a mixture of acetal <u>7</u> (1.0g, 3.76mmol) and a 1-trimethylsilyloxycycloalkene (3.76mmol) in dry CH_2Cl_2 (50ml) under nitgrogen at -78°C. When t.l.c. analysis had indicated that the starting materials had been consumed (ca. 1h), the reaction mixture was poured into water (50ml) and given a normal CH_2Cl_2 workwup followed by flash chromatography using petrol: ether (1:2) to afford the cyclized products.

Method C

Aluminium trichloride (1.18g, 8.87mmol) was added to a mixture of acetal 7 (0.6g, 2.26mmol) and a 1-trimethylsilyloxycycloalkene (0.38g, 2.23mmol) in dry CH_2Cl_2 at -78°C under nitrogen. When t.l.c. analysis had indicated that the starting materials had been consumed (ca. 4h), the reaction was poured into water (50ml) and given a normal CH_2Cl_2 work up followed by flash chromatography to afford the cyclized product as one diastereoisomer.

The following compounds were prepared by one or more of these methods:-

1-Hydroxy-4-methoxybicyclo[4.3.0.]nonane (9)

General procedure A was followed using trimethylsilylfluoromethane sulphonate (0.084g, 0.07ml, 0.38mmol), the acetal (7) (1.10g, 4.14mmol), 1-trimethylsilyloxycyclohexene (0.64g, 3.76mmol) and titanium tetrachloride (0.71g, 0.42ml, 3.76mmol). Flash chromatography gave first the alcohol 9a (0.36g; 56%) and then the alcohol 9b (0.051g; 8%) as colourless oils.

9a) ν_{max}, 3400 (OH), 1200cm^{-1}; $\delta(CDCl_3)$ 3.65 (1H, brs, OH), 3.52 (1H, m, C<u>H</u> OCH_3), 3.30 (3H, s, $OC\underline{H}_3$), 2.10-0.70 (13H, m, CH_2); ^{13}C $\delta(CDCl_3)$ 88.54 (d, C-OCH_3), 80.57 (S, C-OH), 56.23 (q), 50.69(d), 33.97, 33.51, 28.23, 27.19, 24.32, 22.83 (all t); m/z 170(M^+-32).

Found C, 70.60; H, 10.7%, $C_{10}H_{18}O_2$ requires C, 70.60; H, 10.7%.

9b) ν_{max}, 3400 (OH), 1100cm^{-1}; $\delta(CDCl_3)$, 4.26 (1H, m, C<u>H</u>-OCH_3), 3.31 (3H, s, $OC\underline{H}_3$), 2.32-1.92 (2H, m, CH, OH), 1.9-0.8 (12H, m, CH_2); $^{13}C\delta(CDCl_3)$, 83.72 (d, C-OCH_3), 80.88 (s, C-OH), 57.41 (q, OCH_3), 48.86 (d, CH), 36.99, 31.92, 27.28, 24.45, 23.93, 23.29 (all t); m/z 170 (M^+), 138 (M^+-32).

Found C, 70.80; H, 10.9%; $C_{10}H_{18}O_2$ requires C, 70.60; H, 10.7%. From the preparation of (9) using *Method B* was obtained 9a) (32%) and 9b (21%) whilst using *Method C* gave 9a (62%) with no trace of 9b).

1-Hydroxy-4-methoxybicyclo[3.3.0]octane (11)

General procedure A was followed using trimethylsilyltrifluoromethanesulphonate (0.08g, 0.07ml 0.38mmol), the acetal (7) (1.1g, 4.14mmol), 1-trimethylsilyloxycyclopentene (0.59, 3.76 mmol) and titanium tetrachloride (0.71g, 0.42ml, 3.76mmol). Flash chromatography using petrol: ether (2:3) as eluent gave the α-OCH_3 isomer 11a) 0.184g; 31%) and the β-OCH_3 isomer 11b) (0.116g; 20%).

11a) ν_{max}, 3400, 1070cm^{-1}; $\delta(CDCl_3)$, 3.70 (1H, m, C<u>H</u>-OCH_3), 3.31 (3H, s, $OC\underline{H}_3$), 2.80 (1H, brs, OH), 2.20-1.10 (11H, m, CH & CH_2); ^{13}C $\delta(CDCl_3)$, 89.98 (s, C-OH), 88.18 (d, C-OCH_3), 57.83 (d, CH), 56.29 (q, CH_3), 41.36, 38.23, 31.41, 30.00, 25.96 (all t); m/z, 156(M^+), 124 (M^+-CH_3OH), Found, 156.2240. $C_9H_{16}O_2$ requires 156.2242.

11b) ν_{max}, 3400, 1100cm^{-1}; $\delta(CDCl_3)$, 3.87 (1H, m, C<u>H</u>-OCH_3), 3.30 (3H, s, OCH_3), 2.40-2.21 (1H, m, CH), 2.1 (1H, brs, OH), 2.0-1.4 (10H, m, CH_2); ^{13}C $\delta(CDCl_3)$, 89.81 (s, C-OH), 82.04 (d, C-OCH_3), 57.11 (q, CH_3), 53.74 (d, CH), 43.10, 37.20, 30.61, 26.27, 25.92 (all t); m/z, 156(M^+); Found 156.2232; $C_9H_{16}O_2$ requires 156.2242.

1-Hydroxy-4-methoxybicyclo[5,3,0]decane(12)

General procedure A was followed using trimethylsilyltrifluoromethane sulphonate (0.08g, 0.07ml 0.38mmol), acetal 7, (1.1g, 4.14mmol), 1-trimethylsilyloxycycloheptene (0.70g, 3.76mmol) and titanium tetrachloride (0.71g, 0.42ml, 3.76mmol). Flash chromatography using petrol:ether (2:3) as eluent gave two diastereoisomers, 12a) 0.34g; 49% and 12b) 0.25g; 36%, as colourless oils.

11a) ν_{max}, 3400, 1100cm^{-1}; $\delta(CDCl_3)$ 3.4 (1H, m, C<u>H</u>-OCH$_3$) 3.33 (3H, s, OCH$_3$), 2.47 (1H, brs, OH), 2.0-1.10 (15H, m, CH$_2$); ^{13}C $\delta(CDCl_3)$, 90.37 (d, C-OCH$_3$), 83.52 (S, C-OH), 58.32 (q, OCH$_3$), 56.59 (d, CH), 40.18, 39.52, 31.34, 31.23, 30.11, 28.86, 23.50 (all t, CH$_2$); m/z, 184(M^+), 183, 152 (M^+-CH$_3$OH); Found: C, 71.99; H, 11.04%. $C_{11}H_{20}O_2$ requires C, 71.70; H, 10.94%.

11b) ν_{max} 3500, 1100cm^{-1}; $\delta(CDCl_3)$, 3.66 (1H, m, C<u>H</u>-OCH$_3$), 3.27 (3H, s, OCH$_3$), 3.2 (1H, brs, OH), 2.10-1.20 (15H, m, CH$_2$); ^{13}C $\delta(CDCl_3)$, 87.67 (d, C-OCH$_3$), 81.67 (s, C-OH), 56.65 (q, CH$_3$), 51.99 (d, CH), 43.61, 40.50, 27.61, 27.01, 25.86, 23.39, 21.32 (all t, CH$_2$); m/z 184(M^+), 152 (M^+-CH$_3$OH).

General procedure for the preparation of spiroannulated rings

A solution of trimethylsilyltrifluoromethane sulphonate (0.1 molar equiv., freshly distilled) in dry CH_2Cl_2 was added dropwise to a mixture of a 1-(trimethylsilyloxymethylene) cycloalkane and the acetal <u>7</u> in dry CH_2Cl_2 at -78°C under nitrogen. The reaction was kept at -78°C until t.l.c. analysis indicated that the starting materials had been consumed (<u>ca</u>. 1-2h). A solution of titanium tetrachloride (redistilled, 1 molar equiv.) in dry CH_2Cl_2 was slowly added to the reaction mixture at -78°C. The mixture was kept at -78°C until t.l.c. analysis had indicated the complete consumption of the tin intermediates. PDC (1.5 equivalents) was then added and the reaction mixture as allowed to warm to room temperature and left to stir overnight (<u>ca</u>. 16h). Ether was added and the chromate salts were filtered off using an alumina column. Removal of the solvent by distillation under reduced pressure followed by flash chromatography using petrol:ether (4:1) as eluent afforded the required product as colourless oils.

2-Oxo-5-methoxyspiro[5.4]decane (17)

Using a solution of trimethylsilyltrifluoromethanesulphonate (1.0mmol) in dry CH_2Cl_2 (5 mls), the reaction of (1-trimethylsilyloxymethylene) cyclohexane (2.0g; 10.86mmoles), the acetal (7) (2.89g; 10.86mmoles) in CH_2Cl_2 (50mls) gave an intermediate aldehyde to which was added $TiCl_4$ (2.39g; 13.0mmoles) followed, after 2 hrs, by PDC work-up (6.27g, 18.0mmols). Purification afforded the ketone (17), 1.66g; 83% as a colourless oil.

ν_{max}, 1720 (C=O), 1100cm^{-1}; $\delta(CDCl_3)$, 3.78 (1H, m, C<u>H</u>-OCH$_3$) 3.70 (3H, s, OCH$_3$), 2.40-1.80 (4H, m, CH$_2$), 1.8-1.2 (10H, m, CH$_2$); ^{13}C$\delta(CDCl_3)$, 221.30 (s, CO), 83.87 (d, C-OCH$_3$), 56.92 (q, OCH$_3$), 54.11 (s, quat C), 34.12, 31.25, 25.94, 25.64, 22.77, 22.40 and 22.13 (all t, CH$_2$); m/z, 182 (M^+);

Found: C,72.60; H 9.94%. $C_{11}H_{18}O_2$ requires C, 72.49; H, 9.95%. Aqueous work-up prior to the addition of PDC, afforded two diastereoisomers of *2-Hydroxy-5-methoxyspiro[5.4]decone (16)* as colourless oils.

16a) 1.05g; 50%. ν_{max}, 3500, 2920, 1100cm^{-1}, $\delta(CDCl_3)$ 3.78, (1H, m, C<u>H</u>-OCH$_3$), 3.45 (1H, m, C<u>H</u>-OH), 3.28 (3H, s, OCH$_3$), 2.86 (1H, brs, OH), 2.1-1.14 (14H, m, CH$_2$); ^{13}C $\delta(CDCl_3)$ 88.48 (d, <u>C</u>H-OCH$_3$), 79.0 (d, <u>C</u>H-OH), 57.01 (q, OCH$_3$), 50.94 (s, quat C), 33.02, 31.92, 26.77, 26.37, 25.94, 23.13 and 22.71 (all t, CH$_2$); m/z, 184(M^+); Found: C, 72.14; H, 11.14%. $C_{11}H_{20}O_2$ requires C,71.70; H, 10.94%.

16b) 0.25g; 12% ν_{max} 3500, 1100cm^{-1}; $\delta(CDCl_3)$, 4.04 (1H, m, C<u>H</u>-OCH$_3$) 3.53 (1H, m, C<u>H</u>-OH), 3.30 (3H, s, OCH$_3$) 2.12-2.02 (2H, m, CH$_2$), 1.67-1.45 (13H, m, CH$_2$ OH); ^{13}C $\delta(CDCl_3)$, 85.55 (d, CHOCH$_3$), 76.66 (d, <u>C</u>H-OH), 57.41 (q, OCH$_3$), 48.56 (s, quat C=, 29.45, 28.02, 27.74, 26.10, 25.60, 22.95 and 22.89 (all t, CH$_2$); m/z, 184 (M^+);

Found: C,71.55; H, 11.00%. $C_{11}H_{20}O_2$ requires C, 71.70; H, 10.94%.

REFERENCES AND NOTES

1. Lee, T.V., Boucher, R.J., Porter, J.R., Taylor, D.A. *Tetrahedron* 1988, 44, 4233. Lee, T.V., Richardson, K.A. *Tetrahedron Lett.* 1985, 26, 3629 and references therein.

2. Trost, B.M. *Angew. Chem., Int. Ed. Engl.* 1986, 25, 1.

3. Knapp, S., O'Connor, V., Mobilio, D. *Tetrahedron Lett.*, 1980, 21, 4557. Danishefsky, S., Etheridge, S.J. *J. Org. Chem.* 1982, 47, 4791. Piers, E., Karunaratre, V. *J. Chem. Soc. Chem. Commun.*, 1984, 959. DeLombaert, S., Nemery, I., Roekens, B., Carretero, J.C., Kimmel, T., Ghosez, L. *Tetrahedron Lett.*, 1986, 27, 5099.

4. Macdonald, T.L., Mahalingham, S. *J. Amer.Chem.Soc.*, 1980, 102, 2113.

5. Fleming, I., Urch, C.J. *Tetrahedron Lett.*, 1983, 24, 4591.

6. Murayama, E., Vematsu, M., Nishio, H., Sato, T. *Tetrahedron Lett.*, 1984, 25, 313.

7. Bernadi, F. et al. *J. Amer. Chem. Soc.* 1975, 97, 2209 and references therein.

8. Battersby, A.R., Buckley, D.G., Staunton, J., Williams, P.J. *J. Chem. Soc. Perkin Trans. I*, 1979, 2550.

9. Seebach, D., Prelog, V., *Angew. Chem. Int. Ed. Engl.*, 1982, 21, 654.

10. All chiral compounds shown are racemic mixtures but for clarity only one enantiomer is shown.

11. Seebach, D., Golinski, J. *Helv. Chim. Acta*, 1981, 64, 1413.

12. Lee, T.V., Richardson, K.A., Taylor, D.A. *Tetrahedron Lett.*, 1986, 27, 5027.