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EASY ACCESS TO MEDIUM RINGS BY ENTROPY/STRAIN REDUCTION, PART 4.[1] A SIMPLE AND MILD ROUTE TO SOME SUBSTITUTED 2,7-DIHYDRO-1*H*-OXEPINS, THIEPINS AND A PHOSPHEPIN

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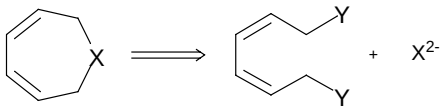
Abstract – Reaction of substituted 1,6-dibromohexa-2,4-dienes (**3**) with sulfide ion leads to the corresponding dihydro-1*H*-thiepins (**5**) which were characterised as their sulfones (**6**). Reaction of **3** with dichlorophenylphosphine in the presence of sodium gives a low yield of dihydro-1*H*-phosphepin oxide (**7**). Reaction of the 1,6-diols (**2**) with butyllithium and *p*-toluenesulfonyl chloride gives the dihydro-1*H*-oxepins (**8**).

INTRODUCTION

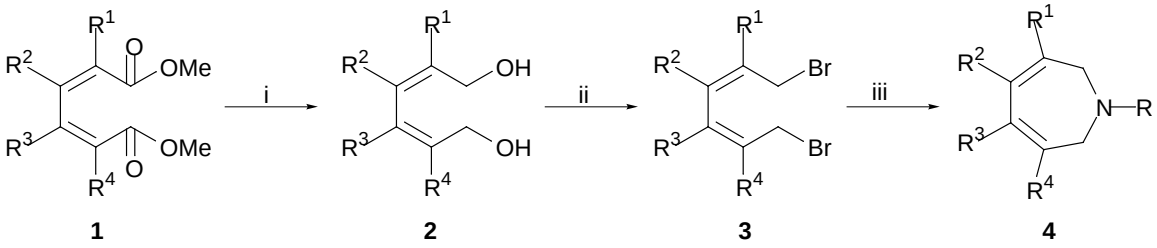
The synthesis of medium and large rings has always been a challenging problem.[3] We have previously communicated[1,4,5] a entropy/strain reduction strategy to overcome the low yields inherent in cycloaddition routes to medium rings. This is based on the use of a *cis,cis*-2,4-hexadiene[6] unit as one of the components in the cycloaddition which has the effect of (i) reducing the degrees of freedom in the chain; (ii) bringing the ends of the chain within reacting distance in certain conformations and (iii) reducing or eliminating eclipsing and transannular steric interactions in the product. Thus, for example, a seven-membered ring is readily constructed based on a [6+1] disconnection, Scheme 1.



Scheme 1

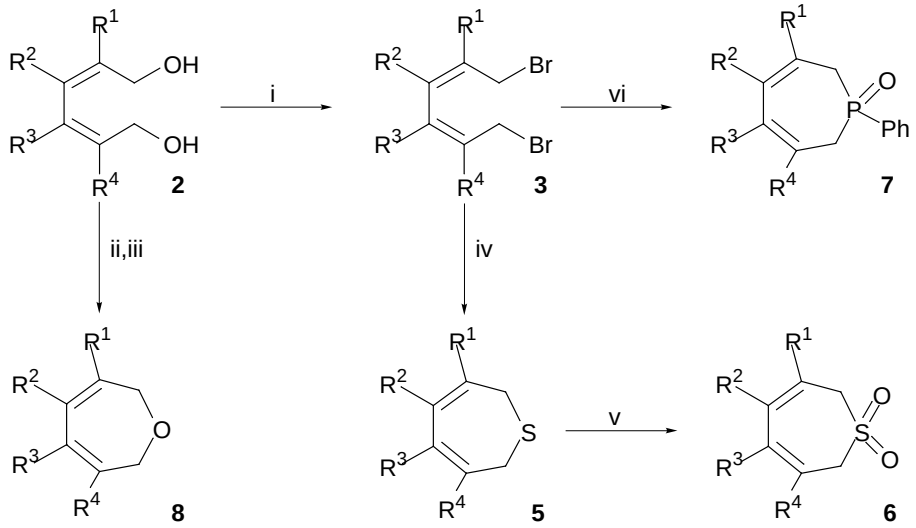
This strategy is crucially dependent on the ready availability of a precursor 1,6-biselectrophile with the correct *cis,cis* stereochemistry of the double bonds. We recently reported[7] the details of lead tetraacetate oxidative ring-opening of catechols which is an effective source of just such stereochemistry furnishing substituted *Z,Z*-2,4-diene-1,6-dioates (**1**) in high yields and free of any of the other alkene isomers. We also reported[5] the conversion of these esters, *via* the derived diols (**2**), to the required dibromides (**3**) and the use[1,5] of the latter for the construction of substituted 2,7-dihydroazepines (**4**) using primary amines as nucleophiles, Scheme 2. This sequence provided the first ready access to the

cis,cis-stereochemistry of 2,4-diene-1,6-diols and dibromides and the first general route to 2,6-dihydro-1-*H*-azepines.



Scheme 2. R^1-R^4 = H, Me, *t*-Bu, Hal: i, DIBAL-H, hexane/toluene, rt, 12 h; ii, PBr_3, Et_2O, 0 ˚C, 12 h; iii, RNH_2, K_2CO_3, THF, rt, 1-2 days.

We now report full details[4] of the demonstration of this route for the easy synthesis from **3** of some dihydrothiepins (**5**), characterised as their sulfones (**6**), as well as a dihydrophosphepin oxide (**7**), and also, from **2,** of some dihydrooxepins (**8**), Scheme 3, Table. Thiepins and oxepins are important classes of heterocycles[8] and there is a limited literature on dihydrothiepins[9] which have been used as precursors to the thiepins.[9a] However the literature on dihydrooxepins is very limited[10] while that of either phosphepins[11] or dihydrophosphepins[12] is almost non-existent. One of the thiepins included in this work (**5**, R^1-R^4 = Cl) has been previously reported.[9d]



Scheme 3. i, PBr_3, Et_2O, 0 ˚C, 12 h; ii *t*-BuLi, HMPA, Et_2O, 0 ˚C; iii TsCl, 12-24 h, R^1-R^4 = H, *t*-Bu; iv, Li_2S, Al_2O_3, THF, rt, 2-3 d, R^1-R^4 = H, *t*-Bu, Hal; v, MCPBA, Et_2O, rt, 1-2 d; vi, Na/$PhPCl_2$, PhMe, reflux, 16 h, $R^1 = R^3$= *t*-Bu, $R^1 = R^4$ = H.

RESULTS AND DISCUSSION

Dihydrothiepins. Our source of dianionic sulfur was lithium sulfide in the presence of neutral alumina in dry THF. α,ω-Dibromoalkanes are well known in reaction with sodium sulfide, either on its own[13] or as an intimate mixture with alumina.[14] In this work it was not found necessary to make an intimate mixture of sulfide and alumina. Simply adding them to a THF solution of dibromide and stirring for 2-3 days at room temperature gave reasonable yields in the three cases studied (Table, Entries 1-3). It was found that the reaction would also proceed in the absence of the alumina but at a very slow rate and it

was also found that basic alumina did not work in the reaction. As the dihydrothiepins formed were somewhat unstable liquids, for characterisation they were converted to their respective sulfones by treatment with *meta*-chloroperbenzoic acid.

Table. Yields of dihydroheterepins obtained from diols (**2**) and dibromides (**3**) according to Scheme 3.

Entry	Precursor	R^1	R^2	R^3	R^4	Product[a]	Yield
1	**3a**	^{t}Bu	H	^{t}Bu	H	**5a**	82[b]
2	**3b**	H	^{t}Bu	H	H	**5b**	81[b]
3	**3c**	Cl	Cl	Cl	Cl	**5c**	66[b]
4	**3a**	^{t}Bu	H	^{t}Bu	H	**7a**	22[c]
5	**2a**	^{t}Bu	H	^{t}Bu	H	**8a**	83[b]
6	**2b**	H	^{t}Bu	H	H	**8b**	87[b]

[a] for procedures: see experimental section; [b] liquid, yield after chromatography; [c] solid, yield after chromatography.

These yields may be compared to those obtained by Mock[9a] for similarly substituted dihydrothiepins from the photochemical ring opening of cyclohexadienes followed by the reaction of the product, *cis*-hexatrienes, with sulfur dioxide (yields 4-14% overall). The overall yields of our system, from quinone/catechol through to the sulfone, are in the region 30-40%. Another comparison is with the method of Singh *et al.* for saturated thiacycloheptane[13] from sodium sulfide and 1,6-dibromohexane without the presence of alumina which produced a surprisingly high yield of 59%. Our superior values for the thiepins (**5**) can be attributed to both the presence of alumina and the rigid stereocontrol.

The ^{1}H NMR spectra of thiepins (**5**) showed little change from those of the precursor dibromide (**3**) save for the expected upfield shift (of *ca.* 1 ppm) of the methylene hydrogens which was then reversed on conversion to the sulfones (**6**). There is a corresponding downfield shift in the ^{13}C NMR spectra for the methylene carbons on conversion of **5** to **6** (of *ca.* 20 ppm). The IR spectra of the sulfones showed the typical sulfur dioxide bands between 1100 and 1350 cm^{-1}. MS gave the predicted parent molecular ion peak for all of the structures with the expected fragmentation patterns. In the sulfones the first fragment lost was the SO_2 moiety revealing the readiness with which this group is lost.

Synthesis of a Dihydrophosphepin. A similar mild source of dianionic phosphorus is not available. A possibility would be the treatment of RPH_2 with alkyllithiums[15] but for the purpose of testing our method we used the simple if harsh system of Braye and co-workers[16] who reported that P^{2-} could be generated *in situ* by refluxing molten sodium in mesitylene with dichlorophenylphosphine. We used toluene as solvent and then added dibromide (**3a**), and continued refluxing for 24 hours. The reaction was worked up with hydrogen peroxide to destroy any remaining dichlorophenylphosphine and to convert the product into the more air-stable phosphine oxide. Despite these harsh conditions, a small but appreciable yield (Table, Entry 4) was obtained of material having characteristics consistent with the target compound. The ^{1}H NMR spectrum showed two *tert*-butyl signals and the typical multiplet for a

phenyl group attached to P=O. As well as the alkene signals, the allylic hydrogens were shifted upfield to 2.5-3.0 ppm, appearing as a complex phosphorus-coupled multiplet. The ^{13}C NMR spectrum showed a similar phosphorus coupling and the signal numbers and shift positions were consistent with those expected. The MS gave the expected molecular ion for the structure proposed and the fragmentation was also consistent. Two side-products were also present by TLC analysis. The low yield is undoubtedly due to the harsh conditions employed. If a less harsh source of P^{2-} were used such as a disilylphosphine masked version[17] and/or if less strenuous conditions were developed[15] a higher yield should be possible.

Dihydrooxepins. For the case of oxygen heterocycles, a source of an O^{2-} synthon for Scheme 1 is not so obvious as in the cases above. However, a ready made solution presents itself in the form of the diol precursors (**2**) because the most common synthesis of cyclic ethers is by cyclodehydration of diols.[18] In fact just such reaction was discovered fortuitously in one of our attempts to convert the diols (**2**) to the associated halides (**3**) *via* treatment with *p*-toluenesulfonyl chloride, n-butyllithium and hexamethylphosphoric triamide.[19] Thus when we subjected diols (**2a**) and (**2b**) to this process they afforded oxepins (**8a**) and (**8b**) as liquids in high yield (Table, Entries 4,5).

ACKNOWLEDGEMENT

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EXPERIMENTAL

Elemental analyses were carried out commercially by the Microanalysis Department at University College Cork. IR spectra were obtained as potassium bromide discs or as a thin film between sodium chloride plates on a Perkin-Elmer 783 spectrophotometer. MS were obtained in the EI mode on an A.E.I. 30 instrument and on a Kratos Profile machine. Mps were determined using a Reichart hot-stage apparatus and are uncorrected. Unless otherwise stated ^{1}H and ^{13}C NMRs were obtained in deuteriochloroform and were recorded using the Fourier transform mode at 80 Mz and 20 Mz respectively on a Brucker AC80 spectrometer using tetramethylsilane (TMS) as internal standard (*J* values are given in Hz). Analytical TLC was performed on commercial silica-coated aluminum sheets with a fluorescent indicator (Merck-Art. 5554) or on neutral aluminum oxide-coated aluminum sheets with fluorescent indicator (Merck-Art. 5550). Realisation was by UV irradiation. Preparative chromatography was performed on Flash grade silica gel supplied by Aldrich Fine Chemicals (cat. no. 22,719-6,230-400 mesh) and neutral aluminum oxide (Aldrich cat. no. 19,997-4). The columns were pressurised using a fish pump which was found to be adequate for all diameters up to and including 4 cm. Solvents were dried using recognised procedures.[20] Oxygen-free nitrogen (Irish Industrial Gases) was dried by passage through concentrated sulfuric acid and then sodium hydroxide pellets. The starting substituted 2,4-hexadiene-1,6-diols and dibromides (**2**) and (**3**) were prepared by oxidation with lead tetraacetate of the appropriate catechol or *o*-benzoquinone to the diester and reduction of the latter with DIBAL according to our published procedures.[1,5,7] All other chemicals were purchased from Aldrich Chemical Company.

Substituted dihydrothiepins - general procedure. This is a modified version of the method of Nicolaou and co-workers.[14a] A mixture of lithium sulfide (x g, 1 eqv.) and neutral alumina (2x g) was stirred in anhydrous THF (*ca*. 100

mL/g alumina). To this stirred mixture, under dry nitrogen, a solution of the relevant dibromide, (1 eqv.) in anhydrous THF (*ca*. 20 mL/g) was added quickly. The resultant mixture was stirred at rt and the reaction monitored by TLC. When completed the mixture was evaporated and treated with, usually, dichloromethane. The solution was filtered, dried over $MgSO_4$ and evaporated to give the crude product. This was then purified by chromatography, if necessary, and characterised.

3,5-Bis-*tert*-butyl-2,7-dihydro-1*H*-thiepin (5a). From (2*E*,4*Z*)-1-bromo-5-bromomethyl-3-*tert*-butyl-6,6-dimethylhepta-2,4-diene (**3a**)[5] (0.68 g, 1.9 mmol), lithium sulfide (0.13 g, 2.8 mmol) and alumina (0.28 g) over 72 h. Work-up of the resulting cloudy, yellow-tinged solution gave a crude yellow semi-viscous liquid which was already rather pure. Further purification was performed by column chromatography on a short column of silica with elution by ether/pentane (1:1): (0.36 g, 82%); ν_{max}/cm^{-1}: 2980, 2880, 1620, 1480, 1470, 1430, 1390, 950, 850, 840, 750, 670, 63; δ_H: 1.05 (s, 9H, -*t*-butyl), 1.19 (s, 9H, -*t*-butyl), 2.85 (d, 2H, -CH_2-, ^3J = 7.6 Hz), 2.95 (s, 2H, -CH_2-), 5.81 (t, 1H, -CH=CH-, ^3J = 7.6 Hz), 5.94 (s, 1H, -CH=CH-); δ_C: 26.3, 26.4,(-CH_2-), 29.8, 30.6 (-CH_3), 36.1, 36.9 (-C-), 117.6, 122.8, 149.5, 153.3 (-CH=CH-); m/z: 225 (0.2%, M^++1), 224 (2, M^+), 167 (4, M^+-t-butyl), 110 (9, M^+-2x-t-butyl), 78 (5), 69 (4), 58 (15), 57 (100, -*t*-butyl).

4-*tert*-Butyl-2,7-dihydro-1*H*-thiepin (5b). From (2*E*,4*Z*)-3-*tert*-butyl-1,6-dibromohexa-2,4-diene (**3b**)[5] (0.35 g, 1.2 mmol), lithium sulfide (0.06 g, 1.3 mmol) and alumina (0.24 g) over 48 h. Work-up gave a clear brown liquid which was purified by column chromatography (silica, ether/hexane (1:3)): (0.16 g, 81%); ν_{max}/cm^{-1}: 2960, 2920, 2860, 1730, 1470, 1460, 1410, 870, 770, 67; δ_H: 1.06 (s, 9H, -*t*-butyl), 2.80-2.90 (m, 4H, -CH_2-), 5.78-6.22 (m, 3H, -CH=CH-); δ_C: 25.7, 26.4 (-CH_2-), 29.6 (-CH_3), 35.8 (-C-), 119.2, 128.2, 132.2, 152.9 (-CH=CH); m/z: 168(9%, M^+), 167 (21, M^+-1), 153 (32, M^+-CH_3), 148 (58), 111 (30, M^+-*t*-butyl), 85 (25), 79 (16), 57 (100, -*t*-butyl).

3,4,5,6-Tetrachloro-2,7-dihydro-1*H*-thiepin (5c). From (2*Z*,4*Z*)-1,6-dibromo-2,3,4,5-tetrachlorohexa-2,4-diene (**3c**)[1] (0.5 g; 1.32 mmol), lithium sulfide (0.07 g; 1.41 mmol) and alumina (0.26 g) over 72 h. Work-up gave a clear brown liquid which was one predominant product by TLC and NMR. This was purified by column chromatography (silica, ether/cyclohexane (1:1)) to give a clear light brown liquid which partially solidified: (0.22 g, 66%); ν_{max}/cm^{-1}:2920, 2860, 1580, 1420, 940, 810, 670; δ_H: 3.52 (s, -CH_2-, lit.,[9d] 3.76); δ_C: 36.0 (-CH_2-), 126.8, 134.3 (-CH=CH-); m/z: 255 (3%), 253 (6), 251 (12), 249 (19), 247 (13, M^+-1), 220 (2), 218 (6), 216 (15), 214 (12, M^++1-Cl), 185 (32), 183 (40), 181 (29, M^++1-2xCl).

Thiepin-1,1-dioxides - general procedure. The 2,7-dihydro-1*H*-thiepin (1 eqv.) was dissolved in ether (30 mL) and to this was added excess MCPBA (3 eqv.) and the resultant solution stirred at rt for the times indicated. A slight temperature rise was noted directly after the addition of the oxidising agent. After stirring, the solvent was evaporated and the solid residue subjected to column chromatography on alumina with initial elution by cyclohexane and subsequently chloroform.

3,5-Bis-*tert*-butyl-2,7-dihydro-1*H*-thiepin-1,1-dione (6a). From 3,5-bis-*tert*-butyl-2,7-dihydro-1*H*-thiepin (**5a**) (0.15 g, 0.67 mmol) and *m*-CPBA (85%, 0.35 g, 2.0 mmol) over 48 h. Work-up and chromatography gave a viscous yellow tinged liquid from which white crystals slowly precipitated. These were washed in cyclohexane and vacuum dried (0.13 g, 76%) mp 95-97 ˚C Anal. Calcd for $C_{14}H_{24}O_2S$: C, 65.58; H, 9.43; S, 12.50. Found: C, 65.27; H, 9.39; S, 12.40; ν_{max}/cm^{-1}: 2960, 2880, 1620, 1600, 1470, 1410, 1320 (S=O), 1130 (S=O), 910, 840, 800, 690, 650, 600, 530, 430; δ_H: 1.10 (s, 9H, -*t*-butyl), 1.21 (s, 9H, -*t*-butyl), 3.52 (d, 2H, -CH_2-, ^3J = 7.4 Hz), 3.62 (s, 2H, -CH_2-), 5.76 (t, 1H, -CH=CH-, ^3J = 7.4 Hz), 6.44 (s, 1H, -CH=CH-); δ_C: 29.6, 30.0 (-CH_3), 37.0, 38.1 (-C-), 54.4, 55.4 (-CH_2-), 112.9, 126.2, 145.9, 156.7 (-CH=CH-); m/z: 257 (1%, M^++1), 256 (13, M^+), 192 (67, M^+-SO_2), 177 (83, M^+-SO_2-CH_3), 137 (75, M^+-SO_2-*t*-butyl), 121 (86, M^+-CH_2SO_2-*t*-butyl), 57 (100, -*t*-butyl).

4-*tert*-Butyl-2,7-dihydro-1*H*-thiepin-1,1-dione (6b). From 4-*tert*-butyl-2,7-dihydro-1*H*-thiepin (**5b**) (0.24 g, 1.4 mmol) and *m*-CPBA (85%, 0.64 g, 3.7x10^{-3} mole) overnight. Work-up and chromatography generated the desired product, initially as a faint yellow liquid which during vacuum drying formed a cream white solid, recrystallised from chloroform/hexane (1:2) (0.22 g, 77%) mp 70-72 ˚C Anal. Calcd for $C_{10}H_{16}O_2S$: C, 59.97; H, 8.05; S, 16.01. Found: C, 59.79; H, 7.96; S, 15.96; ν_{max}/cm^{-1}: 2960, 2920, 2880, 1480, 1470, 1400, 1300 (S=O), 1210, 1120 (S=O), 910, 860, 830, 820, 780, 750, 670, 620, 580, 570, 490, 470, 430; δ_H: 1.12 (s, 9H, -*t*-butyl), 3.54-3.64 (m, 4H, -CH_2-), 5.75-6.76 (m, 3H, -CH=CH-); δ_C: 29.4 (-CH_3), 36.1 (-C-), 53.9, 54.1 (-CH_2-), 114.4, 123.1, 135.6, 156.1 (-CH=CH-); m/z: 201 (15%, M$^+$+1), 137 (5), 136 (46, M$^+$-SO_2), 121 (100, M$^+$-SO_2-CH_3), 107 (10, M$^+$-CH_2SO_2-CH_3), 93 (73, M$^+$-$(CH_2)_2SO_2$-CH_3), 79 (69, M$^+$-SO_2-*t*-butyl), 57 (62, -*t*-butyl).

3,4,5,6-Tetrachloro-2,7-dihydro-1*H*-thiepin-1,1-dione (6c). From 3,4,5,6-tetrachloro-2,7-dihydro-1*H*-thiepin (**5c**) (0.35 g, 1.4 mmol) and *m*-CPBA (85%, 0.75 g, 4.3 mmol) over 48 h. Work-up and chromatography gave a pale yellow liquid which slowly formed a yellow tinged solid, recrystallised from ether/cyclohexane (1:1) to give a white solid (0.13 g, 41%) mp 138-141 ˚C Anal. Calcd for $C_6H_4O_2Cl_4S$: C, 25.26; H, 1.43; S, 11.37; Cl, 50.29. Found: C, 25.53; H, 1.27; S, 11.03; Cl, 49.02; ν_{max}/cm^{-1}: 2920, 1570, 1410, 1330 (S=O), 1280, 1140 (S=O), 960, 800, 690; δ_H: 4.15 (s, -CH_2-); m/z: 285 (3%), 284 (5), 283 (6), 282 (9), 281 (5), 280 (7, M$^+$), 220 (10), 218 (20), 216 (16, M$^+$-SO_2), 185 (42), 183 (99), 181 (100, M$^+$-SO_2-Cl), 148 (66), 147 (49), 146 (85), 145 (64, M$^+$-SO_2-2xCl), 111 (44), 109 (33, M$^+SO_2$-3xCl); insufficient sample for a ^{13}C NMR spectrum.

3,5-Bis-*tert*-butyl-2,7-dihydro-1-phenyl-1*H*-phosphepin-1-one (7a). Molten sodium (0.13 g, 5.65 mmol) was generated in refluxing dry toluene (15 mL) under dry nitrogen for 1 h. To this refluxing solution was added slowly dichlorophenylphosphine (0.25 g, l.42 mmol) in dry toluene (10 mL) giving initially a grey colored solution.[16] After 6 h the mixture had become light green in color and to it was added portionwise over a period of a half an hour (2*E*,4*Z*)-1-bromo-5-bromomethyl-3-*tert*-butyl-6,6-dimethylhepta-2,4-diene (**3a**)[5] (0.5 g, 1.42 mmol) in dry toluene (15 mL) giving a beige colored solution. This mixture was refluxed gently for a further 16 h yielding a green colored solution. After cooling, the residual sodium present was destroyed by the addition of aqueous alcohol giving a beige colored solution. After stirring, at rt for 2 h, hydrogen peroxide (6 vol, 1.8 wt % solution in water, 10 mL) was added to destroy the residual dichlorophenylphosphine present and to oxidise the phosphepin. The reaction mixture was left stirring for a further 24 h and then the two layers were separated and the organic layer washed with water (3x10 mL) and dried over $MgSO_4$. Evaporation yielded a yellow-tinged viscous liquid for which TLC analysis showed the presence of three products. These were subsequently separated by column chromatography on silica with successive elution of three fractions by pentane, ether and finally ethyl acetate. These fractions, collected as liquids, were analysed by NMR and the ethyl acetate fraction was found to be consistent with the title compound (**7a**). This liquid slowly solidified into a fibrous white solid. It was recrystallised from ethyl acetate (0.15 g, 28%) mp 59-60 ˚C Anal. Calcd for $C_{20}H_{29}OP$: C, 75.92; H, 9.24. Found: C, 75.69; H, 9.11; ν_{max}/cm^{-1}: 3040, 2960, 2920, 2900, 2860, 1620, 1480, 1470, 1440, 1250 (P=O), 1230 (P=O), 1190 (P=O), 920, 900, 880, 820, 790, 770, 750, 730, 640, 630; δ_H: 1.10 (s, 9H, -*t*-butyl), 1.19 (s, 9H, -*t*-butyl), 2.58-2.86 (m, 4H, -CH_2-), 5.60 (apparent quartet, 1H, J = 6.3 Hz, -CH=CH-), 6.22 (s, 1H, -CH=CH-), 7.41-7.86 (m, 5H, -Ar); δ_C: 29.8 (d, ^{4}J = 1.7 Hz), 30.0 (s, -*t*-butyl), 30.3, 30.54, 30.78, 31.0 (-C-, ^{3}J/^{4}J not assignable with confidence), 33.4, 34.0, 36.6, 37.4 (-CH_2-, ^{1}J not assignable with confidence), 114.2 (d, ^{2}J = 9.6 Hz), 122.1 (d, ^{3}J = 3.8 Hz), 147.0 (d, ^{2}J = 13.7 Hz), 151.7 (d, ^{3}J = 5.6 Hz, -CH=CH-), 129.1 (d, ^{1}J = 10.3 Hz), 131.0 (d, ^{2}J = 7.7 Hz), 132.5 (d, ^{3}J = 2.7 Hz), 135.5 (s, -Ar); m/z: 318 (3%, M$^+$+2), 317 (29%, M$^+$+1), 316 (100, M$^+$), 301 (60, M$^+$-CH_3), 274 (8), 273 (15, M$^+$-C_3H_7), 260 (64, M$^+$+ 1-*t*-butyl), 245 (60, M$^+$+1-*t*-butyl-CH_3).

3,5-Bis-*tert*-butyl-2,7-dihydro-1*H*-oxepin (8a). (2*Z*,4*E*)-2,4-Bis-*tert*-butylhexa-2,4-diene-1,6-diol (**2a**)[5] (0.25 g, 1.1 mmol) and hexamethylphosphoramide (0.38 mL, 2.2 mmol) were stirred together in ether solution (25 mL). This mixture was cooled to 0 ˚C and n-butyllithium (0.87 mL of a 2.5M solution in hexanes, 2.18 mmol) was syringed in slowly. *p*-Toluenesulfonyl chloride (0.44 g, 2.57 mmol) in ether (15 mL) was added slowly to the reaction mixture leading to a cloudy white solution. After stirring at rt for 24 h, the cloudy reaction mixture was filtered to remove some white solid. The opaque filtrate was washed repeatedly with water (5x10 mL), the clear yellow tinted ether layer dried with Na_2SO_4 and the solvent removed to yield a viscous clear slightly yellow tinted liquid which was purified by column chromatography (silica, ether/hexane (1:9)) to give a clear viscous liquid (0.38 g, 83%); Anal. Calcd for $C_{14}H_{24}O$: C, 80.71; H, 11.61. Found: C, 80.41; H, 11.47; ν_{max}/cm^{-1}: 3400, 2960, 2900, 2860, 1470, 1460, 930, 900, 820, 810, 670, 650; δ_H: 1.09 (s, 9H, -*t*-butyl), 1.16 (s, 9H, -*t*-butyl), 3.76 (d, 2H, -CH_2-, ^3J = 6.5 Hz), 3.87 (s, 2H, -CH_2-), 5.86 (t, 1H, -CH=CH-, ^3J = 6.5 Hz), 6.28 (s, 1H, -CH=CH-); δ_C: 30.0 (2xCH_3-), 36.0, 36.8 (-C-), 63.2 (2x-CH_2-), 120.9, 125.5, 153.4, 156.5 (-CH=CH-); m/z: 209 (1.5%, M^++1), 208 (4, M^+), 193 (5, M^+-CH_3), 165 (5, M^+-C_3H_7), 151 (14, M^+-*t*-butyl), 94 (12, M^+-2x-*t*-butyl), 57 (100, -*t*-butyl), 43 (35,-C_3H_7).

4-*tert*-Butyl-2,7-dihydro-1*H*-oxepin (8b). From (2*E*,4*Z*)-3-*tert*-butylhexa-2,4-diene-1,6-diol (**2b**)[5] (0.23 g, 1.35 mmol), hexamethylphosphoramide (0.47 mL, 2.7x10^{-3} mole), n-butyllithium (1.08 mL of a 2.5M solution in hexanes, 2.7 mmol) and *p*-toluenesulfonyl chloride (0.25 g, 1.35 mmol) in dry ether (10 mL) over 12 h by the method in the previous section. Work-up gave a yellow/green liquid which was purified by column chromatography (silica, ether/hexane (1:5)) to give a clear yellow tinged liquid (0.18 g, 87%); Anal. Calcd for $C_{10}H_{16}O$: C, 78.90; H, 10.59. Found: C, 78.45; H, 10.38; ν_{max}/cm^{-1}: 2960, 2940, 2910, 1480, 1460, 1440, 1400, 880, 820, 780, 750, 68; δ_H: 1.07 (s, 9H, -*t*-butyl), 3.93-4.01 (m, 4H, -CH_2-), 5.52-6.01 (m, 3H, -CH=CH-); δ_C: 29.6 (CH_3-), 36.9 (-C-), 61.4, 63.1 (-CH_2-), 120.9, 129.4, 130.0, 149.3 (-CH=CH-); m/z: 152 (1%, M^+), 137 (2, M^+-CH_3), 109 (4, M^+-C_3H_7), 95 (4, M^+-*t*-butyl), 91 (11), 79 (2, M^+-*t*-butyl-O), 57 (23, -*t*-butyl), 43 (6,-C_3H_7).

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