Diels-Alder approach for the synthesis of spiro compounds related to Fredericamycin A

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The synthesis of a variety of spirodiones 7,12 related to fredericamycin A has been reported. The preparation of Diels-Alder adducts employing the non-functionalised and functionalised isobenzofurans 13, 14 as dienes and spirodiones 7, 12 as dienophiles has been described. The subsequent acid induced rearrangement of Diels-Alder adducts 15, 17, 19, 21 leads to the formation of spiro compounds 16, 18, 20, 22 related to fredericamycin A.

Fredericamycin A 1 is an antitumor antibiotic produced by a strain of *Streptomycyes griseus*. The molecule contains a cyclopentanoisoquinolone moiety fused to a cyclopentanonaphthoquinone nucleus in a spiro fashion. The presence of a novel spiro 1,3-dione system, undoubtedly makes this molecule unique for this class of natural products. The spiro system imparts certain interesting spatial characteristics to the molecule and may be significant in determining its biological activities. Numerous synthetic approaches have been reported in the literature for its partial and/or total synthesis. Most interestingly, the unusual 1,4-diketo spiro[4.4]nonane skeleton has triggered worldwide interest in the recent literature describing strategies directed towards the synthesis of model spiro compound. It has shown activity against ascites, mammary tumors, leukemia cells and marginal activity against melanoma tumors.

We have reported an efficient methodology for spiro creation by the reaction of cyclic ketals with 1,2-disilyloxyoctylbute. Furthermore, we have extended this methodology for the synthesis of a variety of spirodiones which were subsequently utilised as dienophile precursor in the Diels-Alder reaction leading to the spiro compounds related to fredericamycin A. Our synthetic strategy for the preparation of spiro compounds involves Diels-Alder approach using spirodione as dienophile and

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Results and Discussion

Synthesis of spirodiones 7, 12: The ketals of cyclopentanone and cyclohexanone were prepared following standard synthetic procedure. Thus, cyclopentanone 2a and cyclohexanone 2b on treatment with ethylene glycol in the presence of p-TSA gave excellent yields of the respective ketals 4a and 4b. These ketals were reacted with 1,2-disilyloxyoctylbute 5 in the presence of excess BF₃·Et₂O to give the corresponding spirodione 6 which was subsequently converted into spiroenedione 7 by following the bromination-dehydrobromination sequence (Scheme 1). The spiroenediones 7 were characterised by their spectroscopic data which were in full agreement with those described in the literature.

The reaction of 1-indanone 8a or α-tetralone 8b
with ethylene glycol in the presence of catalytic amount of p-TSA was not very satisfactory and gave only low yield of the product. In an alternative route, the protecting group such as 2, 2-dimethyl-1, 3-propanediol 9a gave moderate yield of the product while the ketone protection of indane and α-tetralone was successfully carried out by the use of 2,2-diethyl-1,3-propanediol 9b and pyridinium p-toluenesulphonate (PPTS) in refluxing benzene in about 95% yield. (Scheme I). The cyclic ketal 10 then was allowed to react with 1, 2-disilyloxy cyclobutene 5, in the presence of excess of BF_3·Et_2O at -78°C followed by overnight stirring at room temperature to give the spirodione 11 in good yield. The spirodione 11 was then converted into spiroenedione 12 by bromination and dehydrobromination reaction. It should be mentioned here that the synthetic approach described for 12, a dienophile precursor for Diels-Alder reaction, is short, efficient and high yielding as compared to the literature report.  

Diels-Alder reaction. The Diels-Alder reaction was carried out at room temperature using spirodione as dienophile and isobenzofuran as diene. The addition of spirodione 7a, 12 to isobenzofuran 13 led to the formation of the endo/exo mixture of Diels-Alder adducts 15, 19 respectively. The endo and exo isomers were not separated as both of them on acid induced rearrangement were expected to end up in the same aromatized product. Indeed, the endo-exo mixture of adducts 15 and 19 on heating with p-TSA in toluene gave compounds 16 and 20 respectively as single product in excellent yields. (Scheme II).

Similarly, under the above reaction conditions, the spirodiones 7a and 12a were allowed to react with
active diene 14 (which was generated in situ) to give the corresponding Diels-Alder adducts 17a and 21 respectively in good yields. The endo: exo ratio for 17a as determined by $^1$H-NMR was 90:10 whereas in the case of 21, the ratio was found to be 80:20. Similarly, the reaction of the substituted diene 7b with 14 at room temperature led to the formation of Diels-Alder adducts 17b in 66% yield. The ratio of endo: exo was 92:8 as determined by $^1$H-NMR spectrum. Here again the mixtures of endo and exo isomers were not separated as both of them were expected to end up in the same aromatized product by acid induced rearrangement. Subsequently, the Diels-Alder adducts 17, 21 on treatment with trifluoroacetic acid in CHCl$_3$, gave the desired products 18 and 22 respectively in good yields.

Experimental Section

General information. Melting points were determined with a Mel-Temp apparatus and are uncorrected. Infrared spectra were recorded on a Perkin-Elmer model 683 grating infrared spectrometer. Proton and $^{13}$C NMR spectra were recorded on Varian FT-80A, Bruker WH-90 FT NMR and Bruker AC-200 NMR spectrometers (chemical shifts in δ ppm) using tetramethylsilane as an internal standard and mass spectra on a Finnigan MAT-1020B-70-eV mass spectrometer. Elemental analyses were carried out on a Carlo Erba CHNS-O analyzer.

General procedure for the preparation of ketals 4a, b. A mixture of ketone (0.01 mole), p-toluene-sulphonic acid (20mg) and 1,2-ethanediol (0.015 mole) in 50 mL of dry benzene was heated under reflux for 3-5 hr using a Dean-Stark water separator. The progress of the reaction was monitored by TLC. The mixture was cooled to room temperature and benzene layer was washed with aqueous sodium bicarbonate solution (2x20 mL), followed by washing with brine (2x10 mL) and water (2x10 mL). The organic layer was separated and dried over anhydrous
sodium sulphate. Removal of solvent gave crude ketals, which were purified by distillation under reduced pressure.

**1,4-Dioxaspiro[4.4]nonane 4a**: Colorless liquid; yield 86%; b.p. 59°C/18 mm (lit.19 57°C/18 mm); 1H-NMR (CDCl3): δ 1.65 (s, 8 H), 3.9 (s, 4 H).

**1,4-Dioxaspiro[4.5]decane 4b**: Colorless liquid; 90%, b.p. 73°C/16 mm (Lit. 73°C/16 mm); 1H-NMR (CDCl3): δ 1.60 (s, 10H), 3.9 (s, 4 H).

**General procedure for the preparation of 1-indanone and α-tetralone ketals 10a,b,c**. A mixture of 1-indanone 8a or α-tetralone 8b (0.01 mole), pyridinium p-toluenesulphonate (25 mg) and one of these diols (2,2-dimethyl-1,3-propanediol 9a or 2,2-diethyl-1,3-propanediol 9b) (0.015 mole) in 50 mL of dry benzene was heated under reflux for 5 hr using a Dean-Stark water separator. The mixture was cooled and washed with saturated sodium bicarbonate solution (2×15 mL) and water (2×15 mL). The organic layer was separated and dried over anhydrous sodium sulphate. Removal of solvent under reduced pressure led to a residue, which was purified by neutral alumina column using pet. ether as eluent and recrystallisation from 1-n-hexane.

**Spiroindane-2, 1'-5, 5-dimethyl-1, 3-dioxane 10a**: Colorless crystalline solid; yield 46%; m.p. 78°C; 1H-NMR (CDCl3): δ 0.9 (s, 3 H), 1.3 (s, 3 H), 2.4 (t, 2H), 2.9 (t, 2H), 3.6–3.8 (q, 4H), 7.2 (m, 3H), 7.5 (m, 1H); MS (m/z, rel. int. %): M+ 218 (8%), 133 (100), 115 (7), 104 (21), 91 (5), 77 (8), 69 (5), 55 (5). Anal. Found: C, 76.75; H, 8.52. Calcd for C17H20O2 (218.38): C, 76.75; H, 8.31%.

**Spiro (tetralane-2, 1'-4, 5-dimethyl-1,3-dioxane 10b**: Colorless crystalline solid; yield 47%; m.p. 62°C; 1H-NMR (CDCl3): δ 0.92 (s, 3 H), 1.31 (s, 3H), 2.52-2.92 (m, 6H), 3.71-3.91 (q, 4H), 7.22 (m, 3H), 7.51 (m, 1H). Anal. Found: C, 77.32; H, 8.92. Calcd for C17H20O2 (218.38): C, 77.55; H, 8.68%.

**Spiro (tetracane-2, 1'-5, 5-dimethyl-1,3-dioxane 10c**: Colorless crystalline solid; yield 95%; m.p. 34°C; 1H-NMR (CDCl3): δ 0.65-1.34 (m, 8H), 1.66-2.11 (m, 4H), 2.17-2.51 (m, 2H), 2.68-2.92 (t, 2H), 3.55-4.00 (q, 4H), 7.0-7.42 (m, 3H), 7.86-8.0 (m, 1H); MS (m/z, rel. int. %): M+ 260 (25%), 232 (65), 147 (74), 118 (100), 90 (46), 69 (30), 55 (75). Anal. Found: C, 78.13; H, 9.49. Calcd for C17H20O2 (260.36): C, 78.42; H, 9.29%.

**Typical one pot procedure for the conversion of ketals into spiro (4a) dione system.** In an oven-dried 50 mL two-necked round-bottomed flusk containing a magnetic stirring bar was placed the ketal (0.001 mole). The flask was flushed with nitrogen and sealed with a rubber septum. Dry dichloromethane (25 mL) and 1,2-bis-(trimethylsilyloxy)cyclobutene 5 (0.003 mole) were added successively with the help of a syringe. The flask was cooled to −78°C and BF₃-Et₂O (10 eq.) was added slowly with the help of a syringe. The reaction mixture was stirred at the same temperature for 6–8 hr and allowed to attain room temperature by overnight stirring. After monitoring the progress of the reaction by TLC, in which normally all the ketal disappears, the reaction mixture was worked up by washing with saturated NaHCO₃ solution and finally with brine. The organic layer was dried over anhydrous sodium sulphate and solvent was removed to yield essentially pure spiro(4a) diones which were further purified by passing through a small silica gel column and eluting with pet. ether: acetone mixture.

**Spiro (4.4) nonane-1,4-dione 6a**: Elution using 3% acetone in pet. ether during column chromatography and recrystallisation from pet. ether afforded the product as a colorless solid, yield 92%; m.p. 68°C; IR (Nujol): 1720, 1440, 1270 cm⁻¹; 1H-NMR (CDCl₃): δ 1.8 (br s, 8H), 2.75 (s, 4H); MS (m/z, rel. int. %): M+ 152 (100%), 153 (72), 124 (32), 68 (32), 56 (22).

**Spiro (4.5) decane-1,4-dione 6b**: Elution using 3% acetone in pet. ether during column chromatography and recrystallisation from pet. ether afforded the product in 93% yield. m.p. 62°C (lit. 62-64°C). IR (Nujol): 1720, 1450, 1220, 1180 cm⁻¹; 1H-NMR (CDCl₃): δ 1.6 (brs, 10H), 2.7 (s, 4H); MS (m/z, rel. int. %): M+ 166 (100%), 137 (24), 124 (36), 112 (87), 111 (83), 109 (27), 85 (38), 81 (48), 67 (95), 59 (48), 54 (45), 53 (42), 41 (58), 30 (64).

**Spiro (cyclopentane-1'-indan)-2,5-dione 11a**: Elution using 6% acetone in pet. ether during column chromatography and recrystallisation from hexane and ethyl acetate (90:10) afforded the product as yellow solid, yield 64%; m.p. 109°C (lit. 107-108°C); IR (Nujol): 1720, 1478, 1456 cm⁻¹; 1H-NMR (CDCl₃): δ 2.37-2.42 (t, 2H), 2.80-2.95 (m, 2H), 2.9-3.1 (m, 2H), 3.15-3.20 (t, 2H), 6.85-6.9 (d, 1H), 7.12-7.15 (t, 1H), 7.20-7.25 (m, 1H), 7.3-7.35 (d, 1H).

**Spiro (cyclopentane-1'-tetralane)-2, 5-dione 11b**: Elution using 5% acetone in pet. ether during column chromatography and recrystallisation from n-
hexane:ethyl acetate (90:10) afforded the product as a colorless solid, yield 70%; m.p.110-12°C; IR (Nujol): 1735, 1705, 1510, 1465, 1230 cm\(^{-1}\); \(^1\)H-NMR (CDCl\(_3\)): \(\delta\) 1.87-2.08 (t, 4H), 2.72-3.14 (m, 6H), 6.52-6.72 (d, 1H), 7.08-7.4 (m, 3H); \(^13\)C-NMR (CDCl\(_3\)): \(\delta\) 214.46 (s), 138.39 (s), 131.82 (s), 129.53 (d), 128.19 (d), 127.34 (d), 126.10 (d), 62.08 (s), 35.12 (t), 31.32 (t), 28.59 (t), 17.82 (t); Ms (m/z, rel.int %) M\(^+\) 214 (100%), 186 (13), 157 (24), 129 (43), 115 (17). Anal. Found: C, 78.31; H, 6.61. Calc'd for

**Spiro (3-cyclopentene-1,1'-indan)-2,5-dione 12b:** Elution using 3% acetone in pet. ether during column chromatography and recrystallisation from \(n\)-hexane afforded the product as a yellow crystalline solid, yield 55%; m.p. 82°C (lit. 80-81°C); IR (Nujol): 3062, 2980, 1700, 1672, 1470, 1455 cm\(^{-1}\); \(^1\)H-NMR (CDCl\(_3\)): \(\delta\) 2.4-2.45 (t, 2H), 3.2-3.3 (t, 2H), 6.75-6.80 (d, 1H), 7.1-7.5 (t, 1H), 7.2-7.3 (m, 1H), 7.32-7.35 (d, 1H), 7.5 (s, 2H).

**Spiro (3-cyclopentene-1,1'-tetralan)-2,5-dione 12b:** Elution using 3% acetone in pet. ether during column chromatography and recrystallisation from \(n\)-hexane afforded the product as a yellow crystalline solid, yield 65%; m.p. 94.5°C; IR (Nujol) \(\lambda\) 1718, 1640, 1230 cm\(^{-1}\); \(^1\)H-NMR (CDCl\(_3\)): \(\delta\) 1.92-2.2 (m, 4H), 2.78-3.04 (t, 2H), 6.63-6.78 (d, 1H), 7.12-7.36 (m, 3H), 7.54 (s, 2H); \(^13\)C-NMR (CDCl\(_3\)): \(\delta\) 205.50 (s), 149.37 (d), 138.75 (s), 131.12 (s), 129.86 (d), 127.39 (d), 126.68 (d), 126.14 (d), 54.18 (s), 29.75 (t), 28.82 (t), 18.54 (t). MS (m/z, rel. int. %): M\(^+\) 212 (100%), 194 (17), 184 (24), 166 (18), 129 (41), 115 (26). Anal. Found: C, 78.92; H, 5.96. Calc'd for C\(_{14}\)H\(_{12}\)O\(_2\) (212.24): C, 79.22; H, 5.70%.

**General procedure for the preparation of isobenzofuran 13 in situ** and successive reaction with spiro (4,n) enedione to prepare the endo and exo Diels-Alder adducts 15, 19. To an ice-cooled solution of disopropylamine 0.49g (0.7 mL, 5mmole) in 4 mL of dry benzene was added 2.64 mL of 1.6M hexane solution of n-butyllithium (4.2 mmole). The stirred lithium disopropylamide (LDA) solution was allowed to warm to room temperature and then 1-methoxy-1, 4-dihydroisobenzofuran \(11^a\) (0.25g, 1.66 mmole) in 5 mL of dry benzene was added within a few minutes. After 10 min of stirring, the reaction mixture was quenched by adding 6 mL of aqueous NH\(_4\)Cl solution. The benzene layer was separated and dried over anhydrous sodium sulphate. After 30 min, the benzene solution was filtered and one of the spiro (4,n)-enediones \(7a, 12 (0.85-0.95\text{ mmole})\) was added to it; reaction mixture was kept stirring and progress of the reaction was monitored by TLC. After 5 to 6 hr, some solid was separated out from the reaction mixture. The solvent was then removed under reduced pressure. Dichloromethane (20 mL) was added. The organic layer was washed with water (2\times 10 mL) and brine (2\times 10 mL) and dried over anhydrous sodium sulphate. Removal of solvent gave a mixture of endo and exo Diels-Alder adducts in 66-74% yields.

The quantity of reactant spiro (4, n)-enedione used...
in the above reaction and various adducts obtained are given below. Formation of adducts (endo-exo) were confirmed by the absence of enone protons corresponding to the ene dione in their $^1$H-NMR spectra.

Spiro (4,4) non-2, 3-ene-1, 4-dione 7a (128 mg, 0.85mmol) gave 168 mg of adduct 15.

Adduct 15: Yield 74%; IR (CHCl$_3$): 1720, 1450, 1330 cm$^{-1}$; $^1$H-NMR (CDCl$_3$): $\delta$ 1.6-1.88 (m, 8H), 3.55 (s, 2H), 5.54 (s, 2H), 7.41-7.65 (m, 4H).

Spiro (3-cyclopentene-1-tetralan)-2,5-dione 12a (178 mg, 0.95 mmole) gave 187 mg of adduct 19a.

Adduct 19a: Yield 68%; IR (Nujol): 1720, 1470, 1460 cm$^{-1}$; $^1$H-NMR (CDCl$_3$): $\delta$ 2.4-2.6 (t, 2H), 3.2-3.4 (t, 2H), 4.0-4.1 (m, 2H), 5.8-6.0 (dd, 2H), 6.8-7.5 (m, 8H).

Spiro(cyclopentene-1-tetralan)-2,5-dione 12b (200mg, 0.95 mmol) gave 212mg of adduct 19b.

Adduct 19b: Yield 68%; IR (Nujol): 1720, 1470, 1460 cm$^{-1}$; $^1$H-NMR (CDCl$_3$): $\delta$ 1.82-2.22 (m, 4H), 2.72-3.05 (m, 2H), 3.31 (s, 2H), 5.8 (s, 2H), 6.53-6.68 (d, 1H), 7.0-7.55 (m, 7H); MS (m/z, rel. int. %): M$^+$ 330 (4%), 312 (5), 231 (7), 212 (100), 174 (12), 159 (10), 127 (18), 118 (38), 89 (10).

2,2-Tetramethylene-benz(f)indane-1,3-dione 16. The mixture of Diels-Alder adduct 15 (120mg, 0.45 mmole) in dry toluene (10 mL) containing 5 mg of PTSA was refluxed for 3 hr under nitrogen atmosphere. The progress of the reaction was monitored by TLC. The reaction mixture was cooled to room temperature; toluene layer was washed with water (2x5 mL), brine (2x5 mL) and dried over anhydrous sodium sulphate. Removal of solvent led to a residue, which on purification by silica gel column chromatography using 2% aceton in pet. ether and subsequent recrystallisation form n-hexane yielded 172 mg (89%) of pure 20b as a yellow crystalline solid, m.p. 231$^\circ$C; IR (Nujol): 1740, 1710, 1630, 1610 1480, 1470, 1390, 1255 cm$^{-1}$; $^1$H-NMR (CDCl$_3$): $\delta$ 2.1-2.31 (t, 4H), 2.89-3.16 (m, 2H), 6.56-6.72 (d, 1H), 6.94-7.16 (m, 1H), 7.18-7.38 (m, 2H), 7.4-7.96 (m, 2H), 8.12-8.36 (m, 2H), 8.69 (s, 2H); $^{13}$C-NMR (CDCl$_3$): $\delta$ 203.02 (s), 138.73 (s), 136.65 (s), 133.11 (s), 130.54 (d), 129.93 (d), 129.65 (d), 127.79 (d), 127.36 (d), 126.23 (d), 125.05 (d), 59.41 (s), 30.84 (t), 29.06 (t), 18.84 (t); MS (m/z, rel. int. %): M$^+$ 312 (100%), 297 (20), 284 (24), 265 (15), 183 (12), 155 (20), 126 (35), 77 (8). Anal. Found: C, 84.36; H, 5.04. Calcd for C$_{22}$H$_{16}$O$_3$: C, 84.59; H 5.16%.

General Procedure for the preparation of 1-trimethylsilyl-3-trimethylsilyloxy isobenzofuran 14 in situ and its successive reaction with spiro(4,4)-enediones to prepare the Diels-Alder adducts 18 and 22. In an oven-dried 50 mL two necked round bottomed flask, equipped in an inert atmosphere was charged a solution of phthaldialde (208 mg, 1.6 mmole) in dry THF (3 mL). To this, LDA (1.8 mmole) which is prepared at 0$^\circ$C by mixing disopropyl amine (181 mg) in dry THF
(2 mL), butyllithium 1.5 mL (1.2 M) was added at -78°C where by the solution turned yellow. After 30 min, a freshly distilled and dried chlorotrimethylsilane 0.6 g (5.5 mmole) was added and the solution was warmed to 0°C for 1.5 hr. The solution was reduced to one third of its original volume in vacuo while warming gently. The solution was cooled to -78°C and LDA (1.8 mmole) (preparation as above) was added where by the solution became dark red. After 1.5 hr, chlorotrimethylsilane 0.6 g (5.5 mmole) was added and the solution was warmed to 0°C for 1.5 to 2 hr (till the solution became lightened). To this, one of the spiro (4.n)-enediones 7a, 7b, 12a (0.74-0.91 mmole) was added and the reaction mixture was stirred for 6 hr. The solvent was then removed under diminished pressure. Dichloromethane (20 mL) was added. The organic layer was washed with brine (2x10 mL), water (2x10 mL), and dried over anhydrous sodium sulphate. Removal of solvent gave the endo and exo mixture of Diels-Alder adducts in 55-66% yields.

The quantity of reactant spiro(4.n)-enedione used in the above reaction and the various adducts obtained are given below. Formation of adducts (endo+exo) was confirmed by the absence of enone protons corresponding to the ene diene in their 1H-NMR spectra.

Spiro (4.4) non-2, 3-ene-1, 4-dione 7a (136 mg, 0.91 mmole) gave 225 mg of adduct 17a.

Adduct 17a: Yield 58%; 1H-NMR (CDCl3): δ 0.05-0.30 (m, 18H), 2.00 (s, 8H), 3.65-3.81 (m, 2H), 7.22-7.38 (t, 1H), 7.44-7.51 (t, 1H), 7.62-7.71 (d, 1H), 7.87-8.00 (d, 1H).

Spiro (4.5) dec-2, 3-ene-1, 4-dione 7b (140 mg, 0.85 mmole) gave 250 mg of adduct 17b.

Adduct 17b: Yield 66%; 1H-NMR (CDCl3): δ 0.05-0.25 (m, 18H), 1.38-1.92 (m, 10H), 3.70-3.85 (m, 2H), 7.25-7.40 (t, 1H), 7.47-7.52 (t, 1H), 7.65-7.73 (d, 1H), 7.9-8.0 (d, 1H).

Spiro (3-cyclopentene-1-1-indan)-2, 5-dione 12a (146 mg, 0.74 mmole) gave 193 mg of adduct 21.

Adduct 21: Yield 55%; 1H-NMR (CDCl3): δ 0.1-0.35 (m, 18H), 2.35-2.50 (t, 2H), 2.60-2.72 (t, 2H), 3.16-3.28 (t, 2H), 3.30-3.45 (t, 2H), 4.10-4.42 (dd, 2H), 6.70-6.83 (d, 1H), 7.05-7.85 (m, 5H), 8.05-8.25 (m, 2H).

Cyclopentane-1-spiro-2'-[4', 9'-dihydroxy-2(1H)-benzof]inden-1',3',5-dione 18a. Trifluoro-acetic acid (1 mL) was added to a solution of Diels-Alder adduct 17a (210 mg, 0.5 mmole) in chloroform (15 mL) and the reaction mixture was refluxed for 6-8 hr under nitrogen atmosphere. The progress of the reaction was monitored by TLC. After completion of the reaction, the solution was cooled to room temperature; organic layer was washed with sodium bicarbonate solution (2x10 mL), brine (2x10 mL) and water (2x10 mL). The organic layer was dried over anhydrous sodium sulphate. Removal of solvent led to a residue, which on purification by silicone gel column chromatography using 4% acetone in petrol ether yielded 90 mg (65%) of pure 18a as a yellow crystalline solid, m.p. 160-161°C (lit.12 163-164°C); IR (CHCl3): 3350, 1730, 1680, 1625, 1600 cm⁻¹; 1H-NMR (CDCl3): δ 2.00 (s, 8H), 7.65-7.82 (m, 2H), 7.90-8.10 (m, 1H), 8.40-8.55 (m, 1H), 9.90 (bs, 2H). MS (m/z, rel. int. %): M⁺ 282 (2%), 266 (74), 248 (12), 225 (100), 194 (12), 181 (13), 171 (15), 142 (13), 114 (10).

Cyclohexane-1-spiro-2'-[4', 9'-dihydroxy-2H-benzof]inden-1',3'-dione 18b. Trifluoro-acetic acid (1 mL) was added to a solution of Diels-Alder adduct 17b (230 mg, 0.52 mmole) in chloroform (15 mL) and the reaction mixture was refluxed for 6-7 hr under nitrogen atmosphere. The progress of the reaction was monitored by TLC. After completion of the reaction, the solution was cooled to room temperature; organic layer was washed with sodium bicarbonate solution (2x10 mL) and water (2x10 mL). The organic layer was separated and dried over anhydrous sodium sulphate. Removal of solvent led to a residue, which on purification by silicone gel column chromatography using 8% acetone in petrol ether yielded 112 mg (73%) of pure 18b as a yellow crystalline solid. It was further recrystallised from acetone: n-hexane (0.5:9.5) mixture, m.p. 159-160°C; IR (Nujol): 3380-3310, 1700, 1685, 1630, 1600, 1460 cm⁻¹; 1H-NMR (CDCl3): δ 1.45-2.02 (m, 10H), 7.58-7.85 (2H, m), 7.90-8.03 (m, 1H), 8.35-8.57 (m, 1H), 10.00 (bs, 2H); 13C-NMR (CDCl3): δ 208.45 (s), 203.95 (s), 156.13 (s), 138.73 (s), 134.33 (s), 130.84 (d), 130.71 (d), 128.63 (d), 124.46 (d), 116.51 (s), 115.93 (s), 54.64 (s), 30.06 (t), 25.36 (t), 21.38 (t); MS (m/z, rel. int. %): M' 296 (5%), 280 (100), 262 (12), 252 (12), 238 (14), 225 (61), 212 (48), 199 (12), 171 (25), 165 (13), 152 (14), 114 (29), 55 (14). Anal. Found: C, 72.63; H, 5.21. Calcd. for C18H16O4 (296.31): C, 72.96; H, 5.44%.

4, 9-Dihydroxy spiro [2H-benzof] inden-2',1'-
indan]-1,3-dione 22. Trifluoroacetic acid (1 mL) was added to a solution of Diels-Alder adduct 21 (170 mg, 0.35 mmole) in dry chloroform (15 mL) and the reaction mixture was refluxed with stirring for 5-6 hr under nitrogen atmosphere. The progress of the reaction was monitored by TLC. After completion of the reaction, the solution was cooled to room temperature, organic layer was washed with sodium bicarbonate solution (2×10 mL) and with water (2×10 mL). The organic layer was separated and dried over anhydrous sodium sulphate. Removal of solvent led to a residue, which on purification by silica gel column chromatography using 20% acetone in pet. ether yielded 67 mg (57%) of pure 22 as crystalline solid, m.p. 250°C (dec.) (lit. 248°C); IR (CHCl₃): 3400-3300, 1703, 1680 cm⁻¹; ¹H-NMR (CDCl₃): δ 2.57-2.62 (2H), 3.25-3.30 (2H), 6.87-6.90 (1H), 7.08-7.13 (1H), 7.24-7.28 (1H), 7.37-7.40 (1H), 7.88-7.91 (2H), 8.47-8.50 (m, 2H), 9.52 (brs, 2H); MS (m/z, rel. int. %): M⁺ 330 (5%), 314 (10), 205 (12), 175 (13), 149 (20), 133 (30), 104 (34), 97 (55), 83 (52), 69 (100), 67 (22).

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References