Cross-Coupling of Highly Pyramidalized Alkenes: A Straitghtforward Access to Functionalized Tetrasecododecahedradienes

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Supporting Information Available: Experimental procedures and characterization data for compounds **18-20** and **22-30**. Torsional and bending parameters not parameterized for the 1,2-dicarbonyl groups of compounds **28** and **29** (13 pages including the title one).

General Remarks: Melting points were determined on a MFB 595010 Gallenkamp melting point apparatus. 500 MHz ^{1}H NMR spectra were performed on a Varian VXR 500 spectrometer, while 300 MHz ^{1}H NMR and 75.4 MHz ^{13}C NMR spectra on a Varian Gemini 300. Except where otherwise stated, ^{1}H NMR spectra were recorded at 500 MHz and ^{13}C NMR spectra at 75.4 MHz, in $CDCl_3$. Chemical shifts (δ) are reported in ppm related to internal tetramethylsilane. Assignments given for the NMR spectra are based on DEPT, ^{1}H / ^{1}H, ^{1}H / ^{13}C COSY (HMQC sequence) and NOE experiments. IR spectra were recorded on a FT/IR Perkin-Elmer spectrometer, model 1600. Neutral Aluminum oxide MN and Silica gel SDS 60 (60-200 μm) were usually used for the column chromatography. GC/MS spectra were performed on a Hewlett-Packard gas chromatograph, model 5890 Series II [30 metre HP-5 (5% diphenyl-95% dimethyl-polysiloxane) gas chromatographic column], connected to a Hewlett-Packard mass spectrometer HP-5989 operating at 70 eV. Elemental analyses were carried out at the Microanalysis Service of the *Centro de Investigación y Desarrollo* (C.I.D), Barcelona, Spain. Systematic names for **22** and **26 – 30** were obtained by using the POLCYC program.[1]

Pentacyclo[6.4.0.0^{2,10}.0^{3,7}.0^{4,9}]dodeca-5,11-diene-8,9-dicarboxylic anhydride, 18: A solution of diacid **17** (15 g, 61.5 mmol) in acetic anhydride (350 mL) was heated under reflux for 1 h. After evaporation of the solvent, crude anhydride was obtained (14.1 g). Sublimation at 130-140ºC / 2 Torr afforded pure **18** as a white solid (11.95 g, 86% yield), m.p. 175-176ºC. IR (KBr), ν: 3072, 2997, 1837, 1772, 1343, 1242, 1200, 1062, 902, 785, 748, 705, 680 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$), δ: 2.93 [m, 2 H, 2(3)-H], 3.61 [pseudo q, *J* = 2.1 Hz, 4 H, 1(4,7,10)-H], 6.16 [pseudo t, *J* = 2.0 Hz, 4 H, 5(6,11,12)-H]. ^{13}C NMR ($CDCl_3$), δ: 63.9 [CH, C1(4,7,10)], 65.2 [CH, C2(3)], 68.9 [C, C8(9)], 132.5 [CH, C5(6,11,12)], 169.9 (C, CO). MS, m/z (%), significant ions: 226 ($M^{\cdot+}$, 4), 181 (6), 161 [$(M - C_5H_5)^+$, 100], 154 (26), 153 (61), 152 (32), 91 (11), 89 (25), 76 (27), 63 (24), 51 (21). Anal. Calcd. for $C_{14}H_{10}O_3$, C 74.33, H 4.46. Found C 74.28, H 4.44.

5α,6α:11α,12α–Bis(isopropylidenedioxy)pentacyclo[6.4.0.0^{2,10}.0^{3,7}.0^{4,9}]dodecane-8,9-dicarboxylic acid, **19:** To a cold (0ºC) solution of *N*-methylmorpholine-*N*-oxide (3.85 g, 32.9 mmol) and $K_2OsO_4{\cdot}2H_2O$ (180 mg, 0.49 mmol) in a mixture of *t*-BuOH / H_2O in the ratio of 1:1 (30 mL), a solution of anhydride **18** (3.0 g, 13.3 mmol) in acetone (15 mL) was added dropwise. The mixture was stirred at room temperature for 23 h (TLC monitoring). The mixture was concentrated to dryness *in vacuo* and the residue was poured into acetone (125 mL), conc. H_2SO_4 (2.5 mL) was added and the mixture was heated under reflux for 18 h. The cold (room temperature) mixture was poured into water (350 mL) and extracted with ethyl acetate (3×100 mL). The combined organic phases were evaporated under reduced pressure to give a solid which was taken in H_2O (500 mL), washed with CH_2Cl_2 (3×75 mL) and extracted with ethyl acetate (5×100 mL). The combined ethyl acetate extracts were dried with anhydrous Na_2SO_4, filtered and evaporated under reduced pressure to give **19** (4.35 g, 84 % yield), m.p. > 300ºC. IR (KBr), ν: 3600-2400 (max. at 3185, 2991, 2712 and 2594), 1737, 1704, 1431, 1380, 1327, 1254, 1207, 1164, 1147, 1047, 929, 860 cm^{-1}. ^1H NMR (DMSO-d_6), δ: 1.17 (s, 6 H) and 1.29 (s, 6 H) [$(CH_3)_2C$], 2.49 [m, 2 H, 2(3)-H], 2.58 [d, *J* = 2.0 Hz, 4 H, 1(4,7,10)-H], 4.51 [s, 4 H, 5(6,11,12)-H], 12.70 (broad s, 2 H, CO_2H). ^{13}C NMR (DMSO-d_6), δ: 24.1 (CH_3) and 25.9 (CH_3) [$(\underline{C}H_3)_2C$], 42.5 [CH, C2(3)], 55.3 [C, C8(9)], 60.2 [CH, C1(4,7,10)], 76.3 [CH, C5(6,11,12)], 107.2 [C, $(CH_3)_2\underline{C}$], 171.6 (C, CO_2H). MS, m/z (%), significant ions: 378 (21), 377 [$(M - CH_3)^+$, 100), 359 [$(M - H_2O$

– $CH_3)^+$, 7], 259 (20), 169 (13), 141 (18), 137 (18), 128 (22), 115 (21), 81 (23), 59 (33). Anal. Calcd. for $C_{20}H_{24}O_8\cdot1/4\ H_2O$, C 60.52, H 6.23. Found C 60.26, H 6.12.

8,9-Diiodo-5α,6α:11α,12α–bis(isopropylidenedioxy)pentacyclo[6.4.0.0^{2,10}.0^{3,7}.0^{4,9}] dodecane, **20:** A suspension of diacid **19** (3.0 g, 7.65 mmol), iodosobenzene diacetate (5.42 g, 16.8 mmol) and iodine (4.27 g, 16.8 mmol) in anhydrous benzene (120 mL) was irradiated under reflux with two 100-W tungsten-lamps for 4 h. The mixture was allowed to cool to room temperature, more iodosobenzene diacetate (5.42 g, 16.8 mmol) and iodine (4.27 g, 16.8 mmol) were added and irradiation under reflux was continued for 18 h more. The cold (room temperature) solution was washed with 10% aqueous solution of sodium thiosulfate (3×75 mL), saturated $NaHCO_3$ aqueous solution (3×75 mL) and brine (2×50 mL), dried with anhydrous Na_2SO_4 and concentrated *in vacuo* to give a residue (1.97 g) which was submitted to column chromatography (silica gel, hexane / ethyl acetate mixture in the ratio of 85:15) affording pure **20** (1.4 g, 33% yield), m.p. 291.7-292.3ºC (acetone). IR (KBr), ν: 2983, 2924, 1456, 1380, 1269, 1247, 1219, 1204, 1181, 1159, 1047, 1013, 933, 880, 835 cm^{-1}. ^{1}H NMR, δ: 1.27 (s, 6 H) and 1.37 (s, 6 H) [$(CH_3)_2C$], 2.37 [m, 2 H, 2(3)-H], 2.46 [broad d, *J* = 2.5 Hz, 4 H, 1(4,7,10)-H], 4.45 [s, 4 H, 5(6,11,12)-H]. ^{13}C NMR, δ: 23.9 (CH_3) and 25.8 (CH_3) [$(\underline{C}H_3)_2C$], 42.4 [CH, C2(3)], 50.3 [C, C8(9)], 64.5 [CH, C1(4,7,10)], 78.9 [CH, C5(6,11,12)], 108.7 [C, $(CH_3)_2\underline{C}$]. MS, m/z (%), significant ions: 542 (18), 541 [$(M – CH_3)^+$, 100], 486 [$(M – C_3H_6O – CH_3)^+$, 6], 441 [$(M + H – 2\ C_3H_6O)^+$, 5], 296 (14), 263 (18), 169 (46), 141 (34), 129 (44), 128 (53), 127 (26), 115 (56), 100 (58), 77 (27). Anal. Calcd. for $C_{18}H_{22}I_2O_4$, C 38.87, H 3.99, I 45.63. Found C 38.72, H 4.01, I 45.53.

The above sodium thiosulfate aqueous layer was extracted with ethyl acetate (3×75 mL). The organic extracts were dried with anhydrous Na_2SO_4, filtered and concentrated in vacuo to give 1.14 g (38%) of diacid **19**.

The $NaHCO_3$ aqueous layer was acidified with conc. HCl and extracted with ethyl acetate (3×75 mL). The organic extracts were dried with anhydrous Na_2SO_4, filtered and concentrated in vacuo to give 0.33 g (11%) of diacid **19** (49% global yield of recovered **19**).

4α,5α:10α,11α–Bis(isopropylidenedioxy)-1,14-diphenyl-21-oxaoctacyclo[12.6.1.$0^{2,9}$.$0^{2,13}$.$0^{3,7}$.$0^{6,13}$.$0^{8,12}$.$0^{15,20}$]henicosa-15,17,19-triene, **22**: A mixture of **20** (200 mg, 0.36 mmol) and 1,3-diphenylisobenzofuran (117 mg, 0.43 mmol) in anhydrous THF (6 mL) was cooled to –78ºC and a solution of *t*-butyllithium (1.7 M in pentane, 360 μL, 0.61 mmol) was added dropwise. After stirring for 30 min. at this temperature, methanol (3 mL) and water (10 mL) were added and the mixture was extracted with diethyl ether (3×10 mL). The combined organic phases were dried with anhydrous Na_2SO_4 and concentrated *in vacuo* to give a residue (235 mg), which was submitted to column chromatography (silica gel, mixture of hexane / ethyl acetate in the ratio of 85:15) to give pure **22** (129 mg, 63% yield), m.p. 267.1-268.3ºC (hexane). IR (KBr), ν: 3064, 3027, 2990, 2955, 1458, 1382, 1369, 1263, 1205, 1161, 1041, 926, 881, 753, 704 cm^{-1}. ^1H NMR, δ: 0.87 (s, 3 H) and 1.29 (s, 3 H) [*anti*-$(CH_3)_2C$], 1.07 (s, 3 H) and 1.25 (s, 3 H) [*syn*-$(CH_3)_2C$], 2.57 [d, *J* = 2.5 Hz, 2 H, 3(6)-H], 2.63 (m, 1 H, 7-H), 2.64 [d, *J* = 3.0 Hz, 2 H, 9(12)-H], 2.81 (tt, *J* = 5.0 Hz, *J'* = 2.5 Hz, 1 H, 8-H), 3.50 [s, 2 H, 10(11)-H], 4.28 [s, 2 H, 4(5)-H], 6.80 [dd, *J* = 5.5 Hz, *J'* = 3.0 Hz, 2 H, 17(18)-H], 7.07 [dd, *J* = 5.5 Hz, *J'* = 3.0 Hz, 2 H, 16(19)-H], 7.38 (broad t, *J* = 7.0 Hz, 2 H, H*para* phenyl), 7.45 (broad t, *J* = 7.0 Hz, 4 H, H*meta* phenyl), 7.54 (broad s, 4 H, H*ortho* phenyl). At +50ºC, the ^{1}H NMR spectrum of **22** shows neat signals for the phenyl protons: 7.38 (t, *J* = 7.2 Hz, 2 H, H*para* phenyl), 7.47 (t, *J* = 7.5 Hz, 4 H, H*meta* phenyl), 7.56 (d, *J* = 7.8 Hz, 4 H, H*ortho* phenyl). ^{13}C NMR, δ: 23.2 (CH_3) and 25.3 (CH_3) [*anti*-$(\underline{C}H_3)_2C$], 24.0 (CH_3) and 25.7 (CH_3) [*syn*-$(\underline{C}H_3)_2C$], 42.8 (CH, C7), 48.9 (CH, C8), 58.9 [CH, C9(12)], 60.1 [CH, C3(6)], 62.2 [C, C2(13)], 77.2 [CH, C10(11)], 77.6 [CH, C4(5)], 88.2 [C, C1(14)], 106.9 (C) and 107.1 (C) [2 $(CH_3)_2\underline{C}$], 121.4 [CH, C17(18)], 125.0-126.0 (CH, C*ortho* phenyl), 126.9 [CH, C16(19)], 128.0 (CH, C*para* phenyl), 128.4-129.2 (CH, C*meta* phenyl), 137.4 (C, C*ipso* phenyl), 148.8 [C, C15(20)]. At +50ºC, the broad signals at δ 125.0-126.0 and 128.4-129.2 became sharper (δ 125.7 and 128.8 respectively). MS, m/z (%), significant ions: 572 ($M^{\cdot+}$, 5), 557 [$(M - CH_3)^+$, 23], 499 [$(M - C_3H_6O - CH_3)^+$, 3], 439 (3), 411 (3), 271 (18), 270 (18), 241 (15), 239 (12), 165 (12), 105 (100), 77 (52). Anal. Calcd. for $C_{38}H_{36}O_5$, C 79.69, H 6.34. Found C 79.30, H 6.45.

Cross reaction of pentacyclic diiodide 20 and tricyclic diiodide 9b with melted sodium: Isolation of 3,3’,7,7’-tetramethyl-1,1’-bi(tricyclo[3.3.0.0^{3,7}]octyl), 23, 4,5,10,11-tetramethylpentacyclo[8.2.1.1^{2,5}.1^{4,7}.1^{8,11}]hexadeca-1,7-diene, 14b, 2-(3,7-dimethyltricyclo[3.3.0.0^{3,7}]oct-1-yl)-1,4-dioxane, 24, 4α,5α:10α,11α –bis(isopropylidenedioxy)-16,17-dimethylnonacyclo[14.2.1.1^{14,17}.0^{1,14}.0^{2,9}.0^{2,13}.0^{3,7}.0^{6,13}.0^{8,12}]icosane, 27, 4α,5α:10α,11α–bis(isopropylidenedioxy)-16,17-dimethylheptacyclo [14.2.1.1^{14,17}.0^{2,9}.0^{3,7}.0^{6,13}.0^{8,12}]icosa-1,13-diene, 26, and 5α,6α:11α,12α–bis (isopropylidenedioxy)pentacyclo[6.4.0.0^{2,10}.0^{3,7}.0^{4,9}]dodecane, 25.

A mixture of freshly cut sodium (1.47 g, 63.9 mmol) in anhydrous 1,4-dioxane (27 mL) was heated under reflux until sodium melted. Then, a mixture of diiodides **20** (1.11 g, 2.0 mmol) and **9b** (2.33 g, 6.0 mmol) was added at once and the mixture was heated under reflux for 4 h. The resulting suspension was allowed to warm to room temperature and filtered through Celite®. The solid material was washed with diethyl ether (3×20 mL) and the combined organic phases were concentrated *in vacuo* to give an oily residue (1.7 g). Column chromatography (alumina, hexane / ethyl acetate mixtures) of the above residue furnished, in order of elution: **23**[2] (hexane, 35 mg, 4.3% yield), **14b**[4] (hexane, 300 mg, 37% yield), **24** (hexane / ethyl acetate in the ratio of 98.5:1.5, 15 mg, 1.2% yield), a mixture of **27** and **26** (hexane / ethyl acetate in the ratio of 97:3, 480 mg, 55% yield) and **25** (hexane / ethyl acetate in the ratio of 96:4, 115 mg, 19% yield).

Compound 27 by irradiation of 26: The above mixture of **26** and **27** (480 mg, 1.10 mmol) was irradiated in freshly distilled ciclohexane (100 mL) using a quartz photoreactor and a low pressure 125 W mercury lamp for 6 h. The solvent was removed *in vacuo* at 30ºC and the residue was submitted to column chromatography (alumina, mixture of hexane / ethyl acetate in the ratio of 98:2) obtaining **27** quantitatively.

Diene 26 from 27: A solution of **27** (31.5 mg, 0.072 mmol) in anhydrous 1,4-dioxane (3 mL) was heated under reflux for 24 h. The solvent was removed under reduced pressure to furnish **26** quantitatively.

Compound 23[2]: m.p. 96.7-98.0ºC (sublimed at 60-65ºC / 0.5 Torr). IR (KBr), ν: 2974, 2945, 2925, 2874, 1474, 1451, 1376, 1298, 1084 cm^{-1}. ^{1}H NMR, δ: 1.10 [s, 12 H, 3(3',7,7')-CH$_3$], 1.24 [complex signal, 8 H, 2(2',8,8')-H$_\beta$ and 4(4',6,6')-H$_\beta$], 1.31 (d, *J* = 7.5 Hz, 4 H, 2(2',8,8')-H$_\alpha$], 1.46 [dd, *J* = 7.5, *J'* = 3.0 Hz, 4 H, 4(4',6,6')-H$_\alpha$], 2.03 [t, *J* = 2.8 Hz, 2 H, 5(5')-H]. ^{13}C NMR, δ : 17.1 [CH$_3$, 3(3',7,7')-CH$_3$], 41.5 [CH, C5(5')], 47.0

[C, C3(3’,7,7’)], 53.2 [C, C1(1’)], 54.1 [$CH_{2,}$ C4(4’,6,6’)], 55.8 [$CH_{2,}$ C2(2’,8,8’)]. Anal. Calcd. for $C_{20}H_{30}$, C 88.81, H 11.19. Found C 89.03, H 11.28.

Compound 24: m.p. 42.5-43.4ºC (sublimed at 60ºC / 0.5 Torr). IR (KBr), ν: 2952, 2881, 2851, 1480, 1460, 1447, 1380, 1351, 1305, 1289, 1268, 1229, 1120, 1101, 1083, 935, 899, 879 cm^{-1}. ^{1}H-NMR, δ: 1.11 (s, 6 H, 3-CH_3 and 7-CH_3), 1.21-1.29 (complex signal, 4 H, 2-H_α, 4-H_β, 6-H_β, 8-H_α), 1.38-1.43 (complex signal, 2 H, 2-H_β and 8-H_β), 1.45 (dd, *J* = 8.3 Hz, *J’* = 2.7 Hz, 2 H, 4-H_α and 6-H_α), 2.22 (t, *J* = 2.7 Hz, 1H, 5-H), 3.39 (dd, *J* = 11.0 Hz, *J’* = 10.0 Hz, 1 H, dioxane, 3-H_{ax}), 3.56 (dt, *J* = 3.2 Hz, *J’* = 11.4 Hz, dioxane 6-H_{ax}), 3.66 (dd, *J* = 11.5 Hz, *J’* = 3.0 Hz, 1 H, dioxane, 6-H_{eq}), 3.68-3.80 (complex signal, 4 H, rest of dioxane H). ^{13}C-NMR, δ: 16.69 (CH_3) and 16.74 (CH_3) (3-CH_3 and 7-CH_3), 40.8 (CH, C5), 46.8 (C) and 46.9 (C) (C3 and C7), 51.6 (C, C1), 53.5 (CH_2) and 53.6 (CH_2) (C4 and C6), 54.2 (CH_2) and 54.8 (CH_2) (C2 and C8), 66.6 (CH_2) and 67.2 (CH_2) (dioxane C5 and C6), 69.1 (CH_2, dioxane C3), 77.4 (CH, dioxane C2). MS, m/z (%), significant ions: 222 ($M^{\cdot+}$, 8), 180 (12), 147 (12), 145 (13), 136 (20), 135 (62), 107 (58), 105 (55), 94 (59), 93 (83), 91 (90), 79 (100), 77 (76), 67 (54), 55 (76), 53 (57). Anal. Calcd. for $C_{14}H_{22}O_2$, C 75.63, H 9.98. Found C 75.56, H 10.01.

Compound 27: m.p. 191.2–192.3ºC (acetone). IR (KBr), ν: 2997, 2970, 2931, 2884, 1478, 1456, 1380, 1367, 1278, 1256, 1224, 1202, 1166, 1035, 988, 884, 832 cm^{-1}. ^{1}H-NMR, δ: 1.08 [s, 6 H, 16(17)-CH_3], 1.31 (s, 6 H) and 1.43 (s, 6 H) [$(CH_3)_2C$], 1.45 [d, *J* = 7.0 Hz, 4 H, 15(18,19,20)-H_α], 1.89 [d, *J* = 7.5 Hz, 4 H, 15(18,19,20)-H_β], 2.45 [d, *J* = 1.5 Hz, 4 H, 3(6,9,12)-H], 2.51 [broad s, 2 H, 7(8)-H], 5.00 [s, 4 H, 4(5,10,11)-H]. ^{13}C-NMR, δ: 15.8 [CH_3, 16(17)-CH_3], 24.1 (CH_3) and 25.6 (CH_3) [$(\underline{C}H_3)_2C$], 44.5 [CH, C7(8)], 47.4 (C) and 48.0 (C) [C2(13) and C1(14)], 50.6 [C, C16(17)], 55.8 [CH_2, C15(18,19,20)], 61.3 [CH, C3(6,9,12)], 77.6 [CH, C4(5,10,11)], 107.0 [C, $(CH_3)_2\underline{C}$]. MS, m/z (%), significant ions: 437 (9), 436 ($M^{\cdot+}$, 28), 421 [$(M - CH_3)^+$, 2], 303 (11), 275 (11), 129 (46), 128 (45), 115 (58), 101 (80), 95 (47), 93 (58), 91 (100), 79 (56), 77 (62), 60 (47), 55 (98). Anal. Calcd. for $C_{28}H_{36}O_4$, C 77.03, H 8.32. Found C 76.83, H 8.41.

Compound 26: m.p. 194.8–195.3ºC (hexane). IR (KBr), ν: 3054, 2990, 2968, 2935, 2899, 2847, 1465, 1443, 1376, 1282, 1265, 1254, 1204, 1166, 1024, 995, 942, 879, 825 cm^{-1}. ^{1}H-NMR, δ: 1.07 [s, 6 H, 16(17)-CH_3], 1.37 (s, 6 H) and 1.47 (s, 6 H) [$(CH_3)_2C$], 1.96 [d, *J* = 12.5 Hz, 4 H, 15(18,19,20)-H_α], 2.90 [d, *J* = 12.5 Hz, 4 H, 15(18,19,20)-H_β], 3.01 [m, 2 H, 7(8)-H], 3.03 [broad d, *J* = 1.0 Hz, 4 H, 3(6,9,12)-H], 5.90 [s, 4 H, 4(5,10,11)-H]. ^{13}C-NMR, δ: 23.85 (CH_3) and 26.1 (CH_3) [2 $(\underline{C}H_3)_2C$], 23.92 [CH_3, 16(17)-CH_3], 38.3 [C, C16(17)], 43.3 [CH, C7(8)], 48.0 [CH_2, C15(18,19,20)], 60.8 [CH, C3(6,9,12)], 82.2 [CH, C4(5,10,11)], 107.5 [C, $(CH_3)_2\underline{C}$], 132.5 (C) and 133.1 (C) [C2(13) and C1(14)]. MS, m/z (%), significant ions: 437 (30), 436 ($M^{\cdot+}$, 100), 421 [$(M - CH_3)^+$, 11), 361 (11), 303 (19), 291 (21), 165 (30), 129 (37), 128 (37), 115 (40), 101 (37), 91 (61), 77 (47), 59 (68), 55 (47). Anal. Calcd. for $C_{28}H_{36}O_4$, C 77.03, H 8.32. Found C 77.21, H 8.54.

Compound 25: m.p. 218.9–220.2ºC (ethyl acetate). IR (KBr), ν: 2981, 2924, 2884, 1458, 1375, 1274, 1248, 1202, 1163, 1041, 980, 932, 876, 826 cm^{-1}. ^{1}H-NMR, δ: 1.24 (s, 6 H) and 1.39 (s, 6 H) [$(CH_3)_2C$], 1.42 [t, *J* = 2.3 Hz, 2 H, 8(9)-H], 2.35 [d, *J* = 2.0 Hz, 4 H, 1(4,7,10)-H], 2.50 [broad signal, 2 H, 2(3)-H], 4.27 [s, 4 H, 5(6,11,12)-H]. ^{13}C-NMR, δ: 23.8 (CH_3) and 25.8 (CH_3) [$(\underline{C}H_3)_2C$], 36.6 [CH, C8(9)], 43.6 [CH, C2(3)], 56.8 [CH, C1(4,7,10)], 78.3 [CH, C5(6,11,12)], 107.6 [C, $(CH_3)_2\underline{C}$]. MS, m/z (%), significant ions: 290 (19), 289 [$(M - CH_3)^+$, 100], 247 (9), 189 (20), 171 (19), 143 (19), 128 (12), 103 (11), 91 (10), 79 (10). Anal. Calcd. for $C_{18}H_{24}O_4$, C 71.02, H 7.95. Found C 71.07, H 8.02.

Cross reaction of pentacyclic diiodide 20 and tricyclic diiodide 9b with Na(Hg): Formation of 23, 12b, 14b, 27 and 25.

To a 0.45% sodium amalgam [prepared in a glovebox under argon by adding freshly cut sodium (860 mg, 37.4 mmol) to mercury (189 g, 942 mmol)] a solution of **20** (200 mg, 0.36 mmol) and **9b** (418 mg, 1.08 mmol) in anhydrous 1,4-dioxane (5 mL) was added. The heterogeneous mixture was stirred at room temperature overnight. The mixture was filtered through a pad of Celite®, washing the solid material with diethyl ether (3×20 mL). The combined filtrate and washings were concentrated *in vacuo* to give a residue (300 mg) which on column chromatography (alumina, hexane / ethyl acetate mixtures) furnished, in order of elution: **23**[2] (hexane, 8 mg, 5.3% yield), a mixture of **12b**[3] and **14b**[4] (hexane, 60 mg, 41.5% yield), **27** (mixture of hexane / ethyl acetate in the ratio of 97:3, 81 mg, 52% yield) and **25** (mixture of hexane / ethyl acetate in the ratio of 96:4, 53 mg, 48.5% yield).

16,17-Dimethylnonacyclo[14.2.1.1^{14,17}.0^{1,14}.0^{2,9}.0^{2,13}.0^{3,7}.0^{6,13}.0^{8,12}]icosane-4α,5α,10α,11α–tetrol, 30: To a suspension of **27** (127 mg, 0.29 mmol) in methanol (4 mL), 2 N HCl (4 mL) was added, and the mixture was heated at 75ºC for 16 h. The mixture was allowed to warm to room temperature and 10% aqueous Na_2CO_3 was added until basic pH. The aqueous layer was extracted with ethyl acetate (3×10 mL), the combined organic phases were dried with anhydrous Na_2SO_4, filtered and evaporated to dryness, affording pure **30** (103 mg, 99% yield). m.p. > 330ºC (dec, chloroform / methanol). IR (KBr), ν: 3394, 2932, 2886, 2863, 1443, 1401, 1281, 1213, 1158, 1110, 1068, 1038, 1016, 986, 966 cm^{-1}. ^{1}H-NMR ($CDCl_3$ / CD_3OD), δ: 0.91 [s, 6 H, 16(17)-CH_3], 1.26 [d, *J* = 7.5 Hz, 4 H, 15(18,19,20)-H_α], 1.80 [d, *J* = 7.5 Hz, 4 H, 15(18,19,20)-H_β], 2.12 [d, *J* = 2.0 Hz, 4 H, 3(6,9,12)-H], 2.50 [broad s, 2 H, 7(8)-H], 4.57 [s, 4 H, 4(5,10,11)-H]. ^{13}C-NMR ($CDCl_3$ / CD_3OD), δ: 15.4 [CH_3, 16(17)-$\underline{C}H_3$], 44.4 [CH, C7(8)], 46.8 (C) and 49.2 (C) [C2(13) and C1(14)], 50.5 [C, C16(17)], 54.8 [CH_2, C15(18,19,20)], 64.0 [CH, C3(6,9,12)], 69.0 [CH, C4(5,10,11)]. MS, m/z (%), significant ions: 356 ($M^{\cdot+}$, 10), 320 (16), 304 (14), 288 (18), 252 (23), 157 (44), 143 (50), 141 (46), 128 (58), 115 (64), 105 (45), 95 (57), 91 (83), 79 (57), 77 (68), 69 (54), 57 (49), 55 (100), 53 (50). Anal. Calcd. for $C_{22}H_{28}O_4 \cdot 3/4\ H_2O$, C 71.42, H 8.04. Found C 71.59, H 7.76.

16,17-Dimethylnonacyclo[14.2.1.1^{14,17}.0^{1,14}.0^{2,9}.0^{2,13}.0^{3,7}.0^{6,13}.0^{8,12}]icosane-4,5,10,11-tetrone, 29: To a solution of DMSO (200 μL, 2.81 mmol) in anhydrous CH_2Cl_2 (6 mL) at –60ºC, trifluoroacetic anhydride (398 μL, 2.81 mmol) was added dropwise and the resulting suspension was stirred for 15 min at –60ºC. A solution of **30** (100 mg, 0.28 mmol) in a mixture of CH_2Cl_2 (1 mL) and DMSO (1.4 mL) was added dropwise and the mixture was stirred at –60ºC for 2 h. Triethylamine (0.9 mL, 6.46 mmol) was added to the cold solution and the yellow mixture was stirred at –60ºC for 90 min and then allowed to warm to room temperature. The solution was diluted with CH_2Cl_2 (10 mL), washed with 1 N HCl (3×10 mL) and brine (3×10 mL). The organic layer was dried over anhydrous Na_2SO_4, the solvent was removed at 30ºC *in vacuo* and the residue (137 mg) was submitted to column chromatography (alumina, mixture of hexane / ethyl acetate in the ratio of 20:80) affording pure **29** (59 mg, 60% yield). m.p. > 320ºC (dec., acetone / hexane). IR (KBr), ν: 2966, 2945, 2920, 2891, 2863, 1769, 1736, 1716, 1484, 1446, 1282, 1192, 1161, 894, 761 cm^{-1}. ^{1}H-NMR, δ: 0.93 [s, 6 H, 16(17)-CH_3], 1.36 [d, *J* = 7.5 Hz, 4 H, 15(18,19,20)-H_α], 1.50 [d, *J* = 7.5 Hz, 4 H, 15(18,19,20)-H_β], 3.17 [t, *J* = 1.5 Hz, 2 H, 7(8)-H], 3.52 [d, *J* = 2.0 Hz, 4 H, 3(6,9,12)-H]. ^{13}C-NMR ($CDCl_3$ / CD_3OD), δ: 15.0 [CH_3, 16(17)-CH_3], 47.6 [CH, C7(8)], 49.2 [C, C1(14)], 51.6 [C, C16(17)], 53.5 [CH_2, C15(18,19,20)], 57.8 [C, C2(13)], 66.9 [CH, C3(6,9,12)], 201.7 [C, C4(5,10,11)]. MS, m/z (%), significant ions: 349 (5), 348 ($M^{\cdot+}$, 26), 292 (28), 249 (13), 236 (18), 221 (16), 158 (37), 115 (23), 91 (21), 77 (21). Anal. Calcd. for $C_{22}H_{20}O_4$, C 75.84, H 5.79. Found C 75.45, H 5.82.

16,17-Dimethylheptacyclo[14.2.1.1^{14,17}.0^{2,9}.0^{3,7}.0^{6,13}.0^{8,12}]icosa-1,13-diene-4,5,10,11-tetrone, 28: A solution of **29** (37 mg, 0.106 mmol) in anhydrous 1,4-dioxane (5 mL) was heated under reflux for 3 h. The solvent was removed under reduced pressure to furnish quantitatively **28**, m.p. >350ºC (1,4-dioxane). IR (KBr), ν: 3019, 2974, 2922, 2864, 1757, 1726, 1470, 1449, 1191, 1166, 1112, 760 cm^{-1}. ^1H-NMR, δ: 0.97 [s, 6 H, 16(17)-CH_3], 2.03 [d, *J* = 13.5 Hz, 8 H, 15(18,19,20)-H_α], 2.39 [d, *J* = 14.0 Hz, 8 H, 15(18,19,20)-H_β], 3.18 [m, 2 H, 7(8)-H], 3.91 [dd, *J* = 5.3 Hz, *J'* = 1.8 Hz, 4 H, 3(6,9,12)-H]. ^{13}C-NMR, δ: 23.5 [CH_3, 16(17)-CH_3], 40.0 [C, C16(17)], 43.6 [CH, C7(8)], 48.5 [CH_2, C15(18,19,20)], 59.5 [CH, C3(6,9,12)], 133.6 [C, C1(14)], 141.3 [C, C2(13)], 202.7 (C, CO). MS, m/z (%), significant ions: 349 (25), 348 ($M^{\cdot+}$, 100), 293 (19), 292 [$(M - 2\ CO)^{\cdot+}$, 84)], 264 (22), 249 (31), 236 (39), 221 (34), 165 (31), 158 (66), 157 (25), 128 (31), 115 (42), 91 (40), 77 (38). Anal. Calcd. for $C_{22}H_{20}O_4$, C 75.84, H 5.79. Found C 75.56, H 5.86.

MM2 CALCULATIONS

In the molecular mechanics calculations carried out on compounds **28** and **29** some torsional and bending parameters not parameterized for the 1,2-dicarbonyl group were introduced.[5]

Torsional parameters

For angle 1133 parameters for 1132 were used

For angle 3315 parameters for 2315 were used

For angle 1337 parameters for 1237 were used

For angle 1331 parameters for 1231 were used

For angle 7337 parameters for 2222 were used

For angle 2133 parameters for 2122 were used

Bending parameters:

For angle 133 parameters for 132 were used

For angle 337 parameters for 237 were used

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[5] Parameters used were taken from the *Operating Instructions for MM2(91) Program*, N. L. Allinger, 1991.