Conformational Studies on Oligosubstituted Adamantane Derivatives – Structural Features of Tetravinyl-, Tetracyclopropyl-, and Tetraisopropyladamantane

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Professor Wolfgang Lüttke on the occasion of his 85th birthday

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1,3-Diisopropyl- (**4**), 1-*tert*-butyl-3-isopropyl- (**5**), 1,3,5-triisopropyl- (**6**) and 1-*tert*-butyl-3,5-diisopropyladamantane (**7**) were prepared from the same synthetic precursor – methyl 3-isopropyladamantane-1-carboxylate (**10**) – applying a standard set of repetitive procedures in 65, 77, 24, and 34 % overall yield, respectively. 1,3,5,7-Tetraethenyladamantane (**17**) was obtained in two steps – Swern oxidation and Wittig olefination – from 1,3,5,7-tetrakis(hydroxymethyl)adamantane (**15**) in 45 % overall yield and converted into 1,3,5,7-tetracyclopropyladamantane (**8**) by fourfold cyclopropanation with diazomethane catalyzed by palladium(II) acetate (91 % yield). Hydrogenolysis of **8** over a platinum catalyst furnished 1,3,5,7-tetraisopropyladamantane (**9**) in quantitative yield. 1-Isopropyladamantane (**3**) as well as the hydrocarbons **4**–**7** did not give any crystals suitable for X-ray crystal structure analysis, even when using the Optical Heating and Crystallization Device (OHCD). This method was rather successful when applied to the tetravinyl derivative **17**, X-ray crystal structure analysis of which revealed an approximately C_2-symmetric conformation in the solid state at 150 K. However, no well-defined orientation was detected for the cyclopropyl groups in **8**, and the molecules were severely disordered even at 30(1) K. In contrast to this, X-ray crystal structure analysis of the tetraisopropyl derivative **9** revealed an S_4-symmetric conformation for this hydrocarbon at 203 K.

Introduction

The static and dynamic stereochemistry of compounds, which contain quaternary carbon centers with the maximum number of geminal cyclopropyl or isopropyl groups, R_nC (R = cyclopropyl or isopropyl), has attracted considerable attention.[1,2] A recent report shows that the parent tetracyclopropylmethane (**1**) exists as an S_4-symmetric conformer in the solid state as well as in solution, while tetraisopropylmethane (**2**) adopts a D_{2d}-symmetric conformation in the crystal, but in solution exists as a 93:7 mixture of D_{2d} and S_4 conformers.[1,2] Far less complete and systematic studies exist for the conformational behavior of small molecules in which four identical sterically demanding groups are symmetrically attached to a tetrahedral organic skeleton such as an adamantane core. In a sense such molecules can be regarded as steric analogues of **1** and **2**, with the central carbon atom being replaced by the wider hydrocarbon skeleton. Information about the conformation of such molecules is very scarce. It was reported that the molecules of tetra-*tert*-butyl-[3] and tetra(trimethylsilyl)tetrahedrane[4] adopt approximately T_d symmetry in the solid state. Among the cubane (O_h symmetry) derivatives, the structures of only tetramethyl cubane-1,3,5,7-tetracarboxylate[5] and 1,3,5,7-tetranitrocubane[6] are known. Adamantane (tricyclo[3.3.1.1^{3,7}]decane) derivatives with identical substituents on all four bridgeheads may show more complex conformational behaviour, because the skeleton is wider. Structural studies of adamantane itself have attracted a great deal of attention,[7] because in the solid state it forms a so-called plastic phase, in which the molecules are orientationally disordered. Symmetrical 1,3,5,7-tetrasubstituted adamantanes with all-carbon substituents are also very reluctant to crys-

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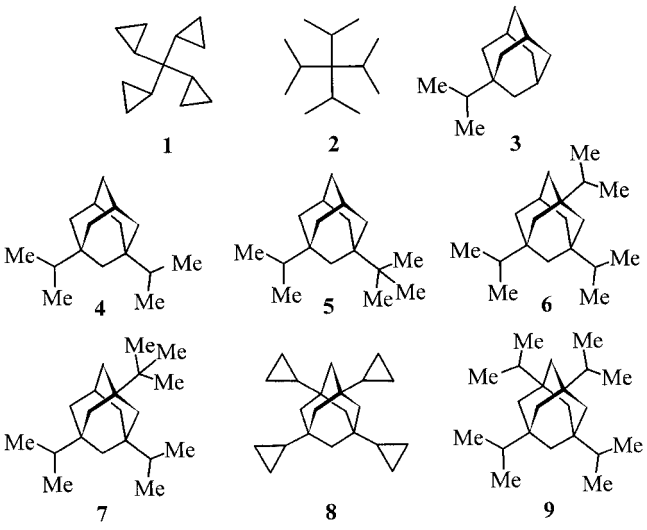
tallize. Nevertheless, several publications concerning conformations of such compounds in the solid state have appeared up to now. X-ray crystal structure analyses of 1,3,5,7-tetramethyl-,[8a] 1,3,5,7-tetrakis(pentafluoropropenyl)-[8b] (which "did not give satisfactory data for atomic resolution"), 1,3,5,7-tetrakis(1,1,2,3,3,3-hexafluoropropyl)-[8b] (which was severely disordered), and 1,3,5,7-tetrakis(4-ethynylphenyl)adamantane[8c] as well as 1,3,5,7-adamantanetetracarboxylic acid[8d] and its salts[8e] have been reported.



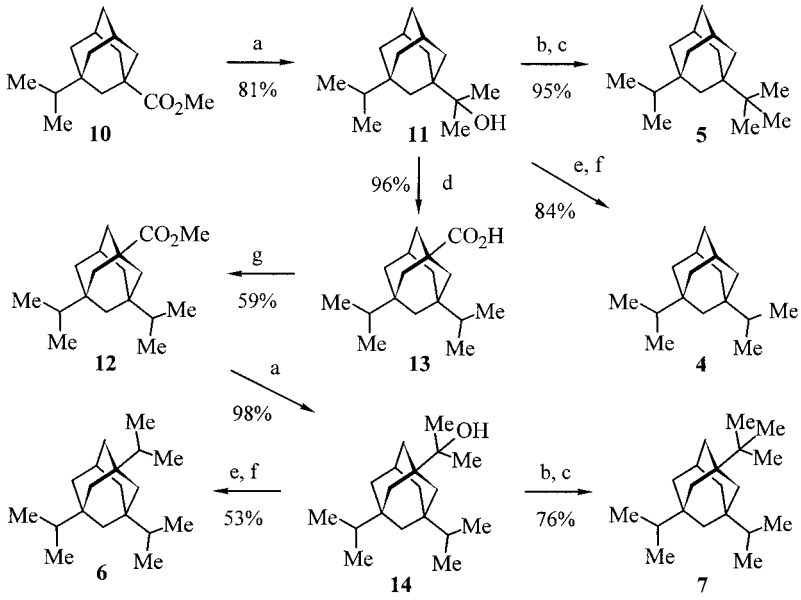
We have prepared a series of mono-, di-, tri-, and tetrasubstituted adamantanes containing isopropyl, cyclopropyl and *tert*-butyl groups as substituents in order to determine their conformations in the solid state by X-ray crystal structure analysis.

Results and Discussion

1-Isopropyladamantane (**3**)[9] was prepared according to the published procedure. 1,3-Diisopropyl- (**4**), 1-*tert*-butyl-3-isopropyl- (**5**), 1,3,5-triisopropyl- (**6**), and 1-*tert*-butyl-3,5-diisopropyladamantane (**7**) were obtained from the same synthetic precursor – methyl 3-isopropyladamantane-1-carboxylate (**10**)[10] – applying a standard set of repetitive procedures in 65, 77, 24 and 34% overall yield, respectively (Scheme 1).[11] The typical synthetic sequence starts with the transformation of the methoxycarbonyl group into a hydroxyisopropyl group with an excess of methyllithium to yield the tertiary alcohols **11** or **14**. These were then converted into hydrocarbons **4**, **6** or **5**, **7** applying the ionic hydrogenation procedure[12] or Adcock's protocol,[13] respectively. The acid **13** was prepared from the alcohol **11** using a Koch-Haaf carboxylation,[10,14] and then transformed into its methyl ester **12** by treatment with diazomethane.

1,3,5,7-Tetracyclopropyladamantane (**8**) was obtained by fourfold cyclopropanation of the known 1,3,5,7-tetraethenyladamantane (**17**)[15] which was prepared in two steps – Swern oxidation[16] and subsequent Wittig olefination[17] – from 1,3,5,7-tetrakis(hydroxymethyl)adamantane (**15**)[18] in 45% overall yield (Scheme 2). The cyclopropanation of **17** with diazomethane catalyzed by palladium(II) acetate gave good yields only when the catalyst was added in one portion to a solution of **17** and diazomethane.[19] 1,3,5,7-Tetraisopropyladamantane (**9**) was obtained by hydrogenolysis of the tetracyclopropyl derivative **8** over a platinum catalyst in acetic acid in quantitative yield.[20]

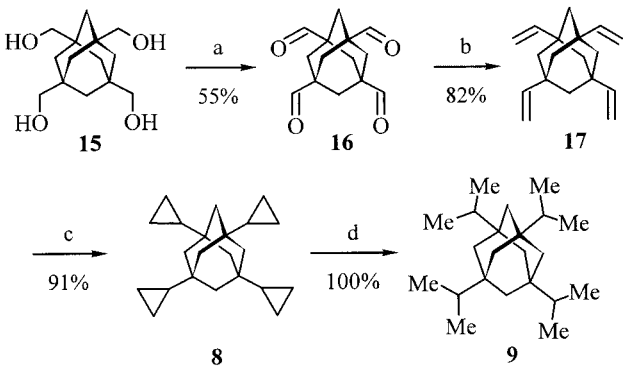
Unfortunately, compounds **4**–**7** are liquid under ambient conditions and all our attempts to in situ grow crystals of these hydrocarbons suitable for X-ray structure analysis, ap-



Scheme 1. Reagents and conditions: (a) MeMgI (3 equiv.), Et_2O, 34 °C, 1.5 h; (b) gaseous HCl, CH_2Cl_2, –50 °C, 15 min; (c) Me_3Al, CH_2Cl_2, –90 °C, 1 h, then –90 to 0 °C, 2 h; (d) HCO_2H, H_2SO_4/cyclohexane, 20 °C, 5 h; (e) Et_3SiH (2 equiv.), TFA (1.95 equiv.), CH_2Cl_2, 0 to 20 °C, 1 h; (f) H_2, Pd/C, EtOH/HOAc 50:1, 20 °C, 24 h; (g) CH_2N_2 (10 equiv.), MeOH/H_2O, 10:1, 20 °C, 1.5 h.

plying the Optical Heating and Crystallization Device (OHCD) (which uses a miniature zone melting procedure with focused IR-laser light[21]) failed. Therefore, the conformational equilibrium in solutions at very low temperatures was studied by NMR spectroscopy for the simplest compounds **3**–**5**.[22] However, this was not possible for more complicated cases such as hydrocarbons **6**–**9**, because the NMR spectra were not interpretable or the substance was insoluble in the freon mixture at low temperature.[23]

In contrast to this, appropriate crystals of 1,3,5,7-tetraethenyladamantane (**17**) were grown applying the above mentioned device and X-ray data were collected at 150 K.[24] Tetraethenylmethane exhibits a C_1-symmetric conformation in the crystal[25] as well as in the gas phase[26] with three of the vinyl groups forming a propeller of approximate local C_3 symmetry. The same symmetry has very recently been reported for the tetraethenylphosphonium cation and several oligoethenyl organoelement compounds.[27] In contrast to this, tetraethenyladamantane (**17**) in the crystal adopts an approximately C_2-symmetric conformation (Figure 1). All four vinyl groups are in an eclipsed conformation, i.e. one of the C=C–C–C torsional angles is close to 0°. Apparently as a consequence of this, the corresponding C–C bond of the adamantane core is slightly shortened [1.531(av.) vs. 1.541(av.) Å], while the corresponding C–C–C angle is widened to an average value of 113.2°. It is noteworthy that the C–C and C=C bonds adjacent to and in the vinyl moieties are essentially shortened in comparison to those in tetraethenylmethane (Figure 1), and the C–C=C angles are widened [127.9(2)° in **17** vs. 126.3(1)° average]. Thus, in spite of the regular arrangement of all four substituents, the adamantane core in **17** has lost its ideal T_d symmetry. In the crystal packing of **17**, no abnormally short intermolecular distances between ethenyl groups were found.



Scheme 2. Reagents and conditions: (a) $(COCl)_2$ (8.6 equiv.), DMSO, CH_2Cl_2, –78 °C, 1 h, then NEt_3 (39.8 equiv.), –78 to 0 °C; (b) $Ph_3P{=}CH_2$ (6 equiv.), THF, –78 °C, 4 h; (c) CH_2N_2 (10 equiv.), Et_2O, one-portion inverse addition of $Pd(OAc)_2$ (5.1 mol-%), –25 to 30 °C, repeated three times; (d) H_2, PtO_2, AcOH/hexane, 20 °C, 2 h.

Tetraisopropyladamantane **9** in the crystal occupies a special position on the fourfold rotoinversion axis, and therefore exhibits S_4 symmetry with almost equivalent C–C bonds in the adamantane core. All four isopropyl groups are in staggered orientations with respect to the adjacent C–C bond of the skeleton. The bond lengths and angles in the adamantane skeleton are essentially the same as in the unsubstituted hydrocarbon,[7c,7d] but the C–C bonds in the isopropyl moieties are significantly shortened in comparison with those in tetraisopropylmethane (**2**) (1.530 vs. 1.556 Å, Figure 2).

Tetracyclopropyladamantane **8** forms beautiful cubic crystals, however, the X-ray structure analysis thereof was not as successful as those for **9** and **17**. The broad diffraction peaks indicated a disordered phase, similar to that of

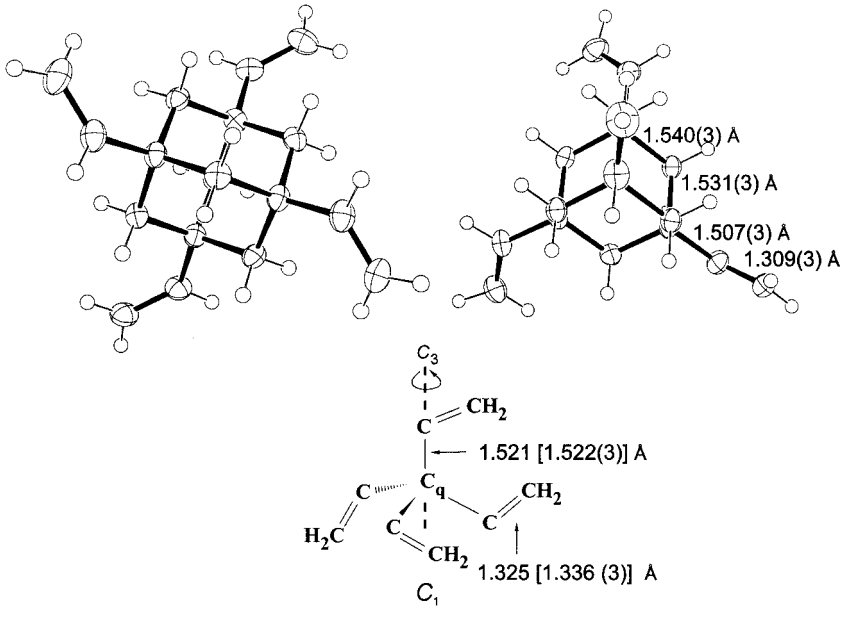


Figure 1. Molecular structure of 1,3,5,7-tetraethenyladamantane (**17**) in the crystal[24] in comparison to that of tetraethenylmethane[25] [bond lengths in square brackets are those determined by gas phase electron diffraction (GED)[26]].

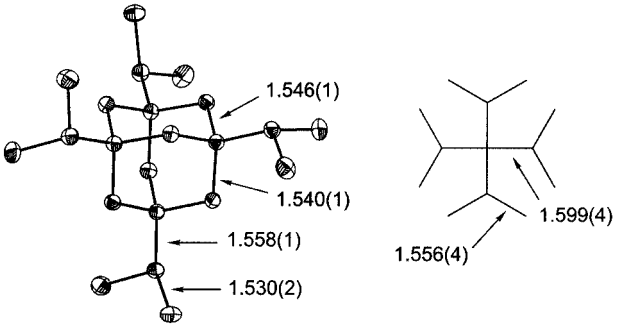


Figure 2. Molecular structure of 1,3,5,7-tetraisopropyladamantane (**9**) in the crystal[24] in comparison to that of tetraisopropylmethane (**2**)[1] (bond lengths in Å).

adamantane itself and, indeed, all attempts to solve the structure revealed just a severely disordered adamantane core, and no well-defined orientation of the cyclopropyl substituents could be found. Even slow cooling of the crystal down to 30(1) K, using a "Helix" open-flow helium cryo-cooling device,[28] did not improve the results. Obviously, if a phase transition to an ordered phase of compound **8** does happen at all, it must happen below 30 K. This is in line with the unusual behavior of the hydrocarbon **8** upon attempted anodic oxidation: while substitution of adamantane in positions 1, 3, 5, and 7 with methyl, isopropyl and *tert*-butyl groups does not affect or slightly increases its oxidation potential of 2.37 eV in acetonitrile,[20b] oxidation of tetracyclopropyladamantane **8** proceeds irreversibly with an extremely low oxidation potential.[29]

^{13}C–^{13}C coupling constants ($^1J_{C,C}$) have been established to be a sensitive indicator of hybridization changes due to changes in bonding and even conformational angles.[30] The small but significant increase of $^1J_{C,C}$ for the bond between the central core and the triisopropyl group on going from tetraisopropyladamantane (**9**) to tetraisopropylmethane (**2**) (Figure 3) is consistent with the observed lengthening of the corresponding bond on going from **9** to **2** due to the increased mutual steric interaction between the isopropyl groups in **2** (Figure 2).

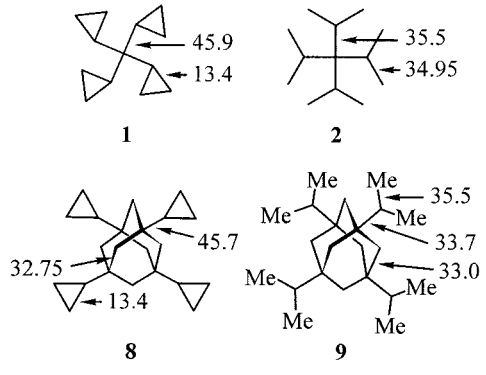


Figure 3. ^{13}C-^{13}C coupling constants ($^1J_{C,C}$) in tetrasubstituted methane and adamantane derivatives.

The fact that the corresponding $^1J_{C,C}$ values in tetracyclopropyladamantane (**8**) and tetracyclopropylmethane (**1**) are virtually identical (Figure 3), then indicates that the effects of steric repulsion between the smaller cyclopropyl groups and the cores in **8** and **1** are not very different.

Experimental Section

General: NMR: spectra were recorded on Bruker AM 250 (250 MHz for ^1H and 62.9 MHz for ^{13}C NMR) and Varian Unity 300 (75.5 and 300 MHz for ^{13}C NMR) instruments. Multiplicities were determined by DEPT (Distortionless Enhancement by Polarization Transfer) measurements. Chemical shifts refer to δ_{TMS} = 0.00 according to the chemical shifts of residual $CHCl_3$ or $C_6D_{11}H$ signals. GC analyses: Siemens Sichromat 1–4 instrument. M.p.: Büchi 510 capillary melting point apparatus, uncorrected values. TLC: Macherey–Nagel precoated sheets, 0.25 mm Sil G/UV_{254}. Column chromatography: Merck silica gel, grade 60, 230–400 mesh. Starting materials: 1-Isopropyladamantane (**3**),[9] methyl 3-isopropyladamantane-1-carboxylate (**10**)[10] and 1,3,5,7-tetrakis(hydroxymethyl)adamantane (**15**)[18] were prepared according to known procedures. Diethyl ether and THF were dried by distillation from sodium benzophenone ketyl, DMSO from calcium hydride, CH_2Cl_2 from P_2O_5. All other chemicals were used as commercially available. All operations in anhydrous solvents were performed under an argon atmosphere in flame-dried glassware. Organic extracts were dried over $MgSO_4$.

General Procedure (GP) 1 for the Preparation of 2-(Isopropyladamantan-1-yl)propan-2-ols (11 and 14): To the Grignard reagent prepared from MeI (21.43 g, 9.4 mL, 151 mmol) and magnesium turnings (3.8 g, 158 mmol) in anhydrous diethyl ether (150 mL) was added dropwise under an argon atmosphere a solution of the corresponding ester **10** or **12** (50 mmol) in Et_2O (50 mL) over a period of 45 min. The reaction mixture was stirred under reflux for an additional 1 h, cooled to 0 °C, and the reaction was quenched by careful addition of sat. aqueous NH_4Cl solution (50 mL), The aqueous layer was extracted with Et_2O (3 × 50 mL), the combined extracts were washed with brine (100 mL), dried and concentrated under reduced pressure. The product was purified by column chromatography on silica gel.

2-(3-Isopropyladamantan-1-yl)propan-2-ol (11):[31] From the ester **10** (12.268 g, 51.9 mmol) and corresponding quantities of reagents and solvents, alcohol **11** (9.86 g, 81%) was obtained according to GP1 after column chromatography (R_f = 0.41, 250 g of silica gel, 25 × 6 cm column, hexane/Et_2O, 2:1) as a colorless oil. ^1H NMR (250 MHz, $CDCl_3$): δ = 0.80 (d, J = 7.0 Hz, 6 H), 1.12 (s, 6 H), 1.16–1.61 (m, 14 H), 2.05 (m, 2 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.4 (2 CH_3), 24.3 (2 CH_3), 28.9 (2 CH), 34.9 (C), 36.0 (2 CH_2), 36.8 (CH_2), 37.8 (CH), 38.0 (CH_2), 38.5 (2 CH_2), 39.4 (C), 74.8 (C).

2-(3,5-Diisopropyladamantan-1-yl)propan-2-ol (14):[31] From the ester **12** (4.26 g, 15.3 mmol) and corresponding quantities of reagents and solvents, alcohol **14** (4.17 g, 98%) was obtained according to GP1 after column chromatography (R_f = 0.31, 80 g of silica gel, 20 × 3 cm column, hexane/Et_2O, 3:1) as a colorless oil. ^1H NMR (250 MHz, $CDCl_3$): δ = 0.82 (d, J = 7.0 Hz, 12 H), 1.15 (s, 6 H), 1.23 (s, 2 H), 1.26 (sept, J = 7.0 Hz, 2 H), 1.27 (d, J = 6.3 Hz, 4 H), 1.31 (br. d, J = 3.0 Hz, 4 H), 1.45 (br. d, J = 3.0 Hz, 2 H), 1.56 (br. s, 1 H), 2.13 (sept, J = 3.1 Hz, 1 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.6 (4 CH_3), 24.5 (2 CH_3), 29.2 (CH), 35.5 (CH_2), 35.8 (2 C), 37.7 (2 CH), 37.8 (2 CH_2), 38.2 (2 CH_2), 40.1 (C), 40.5 (CH_2), 74.9 (C).

3,5-Diisopropyladamantane-1-carboxylic Acid (13):[11] To a vigorously stirred mixture of sulfuric acid (200 mL) and cyclohexane

(30 mL) was added dropwise a solution of the alcohol **11** (6.33 g, 27 mmol) in anhydrous formic acid (20 mL) with a syringe pump over a period of 4 h. After stirring for an additional 1 h, the reaction mixture was poured onto cracked ice (1 kg) and extracted with diethyl ether (4×80 mL). The combined extracts were washed several times with water (50 mL portions) until neutral, dried and concentrated under reduced pressure to give the crude acid **13** (6.86 g, 96%) as a colorless solid which had m.p. 80–81 °C (ref.[11] 81–82 °C) and was used without further purification. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.82 (d, J = 7.0 Hz, 10 H), 1.18 (s, 2 H), 1.26 (sept, J = 7.0 Hz, 2 H), 1.35 (br. d, J = 11.6 Hz, 4 H), 1.41 (br. d, J = 11.6 Hz, 2 H), 1.51 (d, J = 13 Hz, 2 H), 1.59 (d, J = 13 Hz, 2 H), 1.74 (br. d, J = 3.0 Hz, 2 H), 2.15 (sept, J = 2.3 Hz, 1 H), 11.10 (s, 1 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.4 (4 CH_3), 28.7 (CH), 35.3 (2 C), 37.8 (2 CH), 38.1 (2 CH_2), 38.9 (CH_2), 40.1 (2 CH_2), 40.3 (CH_2), 42.1 (C), 184.9 (C).

Methyl 3,5-Diisopropyladamantane-1-carboxylate (12): To a stirred solution of the adamantanecarboxylic acid **13** (6.855 g, 25.93 mmol) in a mixture of methanol and water (200 mL, 10:1 per volume) was added dropwise a solution of diazomethane [prepared from 26.73 g (259.3 mmol) of *N*-methyl-*N*-nitrosourea] in diethyl ether (150 mL) maintaining the temperature in the range of 20–25 °C with a water bath. After stirring for an additional 1 h, the solvents were evaporated under reduced pressure. The residue was taken up with Et_2O (200 mL), washed with 5% aqueous NaOH solution (80 mL) and brine (100 mL), dried and concentrated under reduced pressure. The product was purified by column chromatography (R_f = 0.37, 200 g of silica gel, 20×6 cm column, hexane/Et_2O, 10:1) to give the ester **12** (4.255 g, 59%) as a colorless oil. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.80 (d, J = 7.0 Hz, 12 H), 1.16 (s, 2 H), 1.37–1.45 (br. d, J = 7.3 Hz, 4 H), 1.47 (br. d, J = 13 Hz, 2 H), 1.55 (br. d, J = 13.0 Hz, 2 H), 1.76 (br. d, J = 3.1 Hz, 2 H), 2.13 (sept, J = 2.3 Hz, 1 H), 2.61 (sept, J = 7.0 Hz, 2 H), 3.63 (s, 3 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.4 (4 CH_3), 28.7 (CH), 35.3 (2 C), 37.4 (2 CH), 37.8 (2 CH_2), 38.4 (CH_2), 40.3 (2 CH_2), 40.4 (CH_2), 42.2 (C), 51.5 (CH_3), 178.5 (C). $C_{18}H_{30}O_2$ (278.42): calcd. C 77.65, H 10.86; found C 77.31, H 10.75.

General Procedure (GP) 2 for the Preparation of 1,3-Diisopropyl- (4) and 1,3,5-Triisopropyladamantane (6): Under an argon atmosphere, to a stirred solution of the respective alcohol **11** or **14** (6.42 mmol) in anhydrous dichloromethane (20 mL) were added at 0 °C in one portion each triethylsilane (1.49 g, 2.05 mL, 12.83 mmol) and then TFA (1.43 g, 0.96 mL, 12.51 mmol). The reaction mixture was stirred at ambient temp. for 30 min, poured into ice-cold 5% aqueous $NaHCO_3$ solution (200 mL) and the mixture extracted with CH_2Cl_2 (3×20 mL). The combined organic extracts were dried, concentrated under reduced pressure, and the residue purified by column chromatography on silica gel (100 g of silica gel, 30×3 cm column, hexane) collecting a fraction with R_f = 0.73–0.65 which, according to its ^{1}H NMR spectrum, was a mixture of isopropyl and isopropenyl derivatives. This fraction was taken up with a mixture of EtOH and AcOH (30 mL, 50:1 per volume), Pd/C (Merck, 10% Pd, 683 mg, 0.64 mmol, 10 mol-%) was added, and the mixture was vigorously stirred under H_2 (1 bar) at 20 °C for 24 h. The catalyst was filtered off, the filtrate was concentrated under reduced pressure, and the product was isolated by column chromatography (60 g of silica gel impregnated with 3% $AgNO_3$, 15×3 cm column, hexane) followed by distillation under reduced pressure.

1,3-Diisopropyladamantane (4):[32] From the alcohol **11** (1.50 g, 6.35 mmol) and corresponding quantities of reagents and solvents, hydrocarbon **4** (1.18 g, 84%) was obtained according to GP2 as a colorless oil, b.p. 68 °C (0.2 Torr) (ref.[32] 294–296 °C). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.82 (d, J = 7.0 Hz, 12 H), 1.19 (s, 2 H), 1.22 (sept, J = 7.0 Hz, 2 H), 1.35 (br. d, J = 14.0 Hz, 4 H), 1.46 (br. d, J = 14.0 Hz, 4 H), 1.57 (narrow m, 2 H), 2.03 (sept, J = 2.9 Hz, 2 H). ^{13}C NMR (62.9 $CDCl_3$): δ = 16.4 (4 CH_3), 29.1 (2 CH), 35.0 (2 C), 37.2 (CH_2), 37.8 (2 CH), 38.9 (4 CH_2), 41.4 (CH_2).

1,3,5-Triisopropyladamantane (6):[11] From the alcohol **14** (2.21 g, 7.93 mmol) and corresponding quantities of reagents and solvents, hydrocarbon **6** (1.11 g, 53%) was obtained according to GP2 as a colorless oil, b.p. 93–95 °C (0.2 Torr), m.p. ca. –20 °C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.83 (d, J = 7.0 Hz, 18 H), 1.06 (br. d, J = 12.0 Hz, 3 H), 1.19 (br. d, J = 12.0 Hz, 3 H), 1.24 (sept, J = 7.0 Hz, 3 H), 1.31 (br. d, J = 3.0 Hz, 6 H), 2.09 (sept, J = 3.1 Hz, 1 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.6 (6 CH_3), 29.5 (CH), 35.5 (3 C), 37.8 (3 CH), 38.6 (3 CH_2), 40.9 (3 CH_2).

General Procedure (GP) 3 for the Preparation of 1-*tert*-Butyl-3-isopropyl- (5) and 1-*tert*-Butyl-3,5-diisopropyladamantane (7): Dry HCl gas was bubbled into a vigorously stirred solution of the respective alcohol **11** or **14** (8.44 mmol) in anhydrous CH_2Cl_2 (40 mL) at –50 °C for 0.5 h. The solvent was evaporated under reduced pressure, the residue was dried in vacuo (0.1 Torr) for 10 min, taken up with anhydrous CH_2Cl_2 (40 mL) and cooled to –95 °C. To this solution Me_3Al (11.73 mmol, 5.87 mL of a 2 M solution in hexane) was added dropwise at such a rate that the temperature was maintained at –90 °C. The reaction mixture was allowed to warm up to room temperature within 2 h, then cooled back to 0 °C, before a mixture of MeOH (5 mL) and CH_2Cl_2 (10 mL) was added very cautiously, followed by a 5% H_2SO_4 solution (10 mL). The inorganic phase was extracted with CH_2Cl_2 (3×20 mL), the combined organic extracts were washed with 5% aqueous $NaHCO_3$ solution (50 mL) and brine (50 mL), dried and concentrated under reduced pressure. The product was purified by column chromatography (70 g of silica gel and 30 g of silica gel impregnated with 3% $AgNO_3$, 30×3 cm column, hexane) followed by distillation in vacuo.

1-*tert*-Butyl-3-isopropyladamantane (5): From the alcohol **11** (1.98 g, 8.38 mmol) and corresponding quantities of reagents and solvents, hydrocarbon **5** (1.88 g, 95%) was obtained according to GP3 as a colorless oil, R_f = 0.66, b.p. 72–73 °C (0.2 Torr). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.81 (d, J = 6.8 Hz, 6 H), 0.82 (s, 9 H), 1.22 (sept, J = 6.8 Hz, 1 H), 1.27 (s, 2 H), 1.30–1.59 (m, 10 H), 2.04 (t, J = 2.8 Hz, 2 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.6 (2 CH_3), 24.8 (3 CH_3), 29.2 (2 CH), 34.9 (2 C), 36.0 (2 CH_2), 37.0 (C), 37.1 (CH), 38.0 (CH), 38.2 (CH_2), 38.7 (2 CH_2). $C_{17}H_{30}$ (234.41): calcd. C 87.10, H 12.90; found C 87.03, H 12.66.

1-*tert*-Butyl-3,5-diisopropyladamantane (7): From the alcohol **14** (2.16 g, 7.75 mmol) and corresponding quantities of reagents and solvents, hydrocarbon **7** (1.63 g, 76%) was obtained according to GP3 as a colorless oil, R_f = 0.68, b.p. 100–103 °C (0.2 Torr). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.83 (d, J = 6.7 Hz, 12 H), 0.84 (s, 9 H), 1.13–1.31 (m, 12 H), 1.42 (br. d, J = 3.0 Hz, 2 H), 2.11 (sept, J = 3.1 Hz, 1 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 16.6 (4 CH_3), 24.9 (3 CH_3), 29.5 (CH), 35.0 (C), 35.5 (2 C), 35.8 (CH_2), 37.5 (C), 37.9 (2 CH_2), 38.0 (2 CH), 38.4 (2 CH_2), 40.6 (CH_2). $C_{20}H_{36}$ (276.49): calcd. C 86.87, H 13.13; found C 86.51, H 13.02.

1,3,5,7-Tetraformyladamantane(16): A solution of oxalyl chloride (12.77 g, 100 mmol, 8.8 mL) in anhydrous CH_2Cl_2 (230 mL) was cooled to –78 °C under an atmosphere of argon. Under vigorous stirring a solution of DMSO (14.6 mL) in anhydrous CH_2Cl_2 (90 mL) was added over a period of 20 min, and the reaction mixture was stirred at this temp. for an additional 15 min. A solution of 1,3,5,7-tetrakis(hydroxymethyl)adamantane (**15**) (3.00 g,

11.7 mmol) in a mixture of anhydrous DMSO (45 mL) and anhydrous CH_2Cl_2 (90 mL) was added dropwise over a period of 25 min, and the reaction mixture was stirred at this temp. for an additional 1 h. After this, triethylamine (65 mL) was added dropwise, the mixture was allowed to warm up to ambient temp., and water (150 mL) was added. The two phases were separated, the organic one was washed with 5% aqueous HCl solution (2 × 50 mL), water (50 mL), 5% aqueous $NaHCO_3$ solution (100 mL) and brine (50 mL), dried and concentrated under reduced pressure to give crude **16** (1.60 g, 55%) as a colorless solid which could be used without further purification. An analytical sample was purified by column chromatography on silica gel (R_f = 0.32, benzene/EtOAc, 2:1), m.p. 143–145 °C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.78 (s, 12 H), 9.50 (s, 4 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 33.7 (6 CH_2), 44.8 (4 C), 201. 8 (4 CH). $C_{14}H_{16}O_4$ (248.3): calcd. C 67.72, H 6.50; found C 67.60, H 6.45.

1,3,5,7-Tetraethenyladamantane (17):[15] Anhydrous THF (185 mL) was added to a solid mixture of powdered potassium *tert*-butoxide (4.35 g, 38.76 mmol) and methyltriphenylphosphonium bromide (15.23 g, 42.64 mmol) under an atmosphere of argon at ambient temp. The resulting mixture was stirred for 2 h, cooled to –78 °C, and a solution of the tetraaldehyde **16** (1.60 g, 6.44 mmol) in THF (20 mL) was added dropwise over a period of 15 min. After stirring at this temp. for an additional 4 h, the mixture was allowed to warm up to ambient temp. and stirred overnight. The solvent was evaporated under reduced pressure, the residue was vigorously stirred with pentane (100 mL) for 1 h, the mixture then filtered, and the filtrate was concentrated under reduced pressure. Chromatographic purification of the residue (R_f = 0.52, 300 g of silica gel, 30 × 3 cm column, pentane) afforded the desired product **17** (1.28 g, 82%) as a colorless oil, m.p. ca. –10 °C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.36 (s, 12 H), 4.90 (dd, J = 1.5, 10.8 Hz, 4 H), 4.94 (ddd, J = 0.5, 1.5, 18.0 Hz, 4 H), 5.79 (dd, J = 10.8, 18.0 Hz, 4 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 37.2 (4 C), 44.8 (6 CH_2), 110.1 (4 CH_2), 148.1 (4 CH). The structure of this compound was verified by X-ray crystal structure analysis.

1,3,5,7-Tetracyclopropyladamantane (8) (applying the cyclopropanation protocol ofSuda[19])**:** To a precooled (–25 °C) solution of diazomethane [prepared from 4.90 g (47.5 mmol) of *N*-methyl-*N*-nitrosourea] and 1,3,5,7-tetraethenyladamantane (**17**) (1.08 g, 4.49 mmol) in diethyl ether (50 mL) in a 500 mL Erlenmeyer flask was added a solution of $Pd(OAc)_2$ (51 mg, 0.228 mmol, 5.1 mol-%) in CH_2Cl_2 (1 mL) in one portion. (***Caution:* this reaction proceeds very violently**) The temperature immediately raised to 30 °C. The reaction mixture was stirred for an additional 10 min, filtered through a 3 cm pad of Celite and carefully concentrated under reduced pressure. The residue was taken up with a new 50 mL portion of diazomethane solution, and the procedure was repeated three times with GC monitoring. The product was then purified by column chromatography (60 g of silica gel impregnated with 3% $AgNO_3$, 15 × 3 cm column, hexane) to give **8** (1.21 g, 91%) as a colorless solid of 99% purity. An analytical sample was purified by sublimation at 100 °C (0.1 Torr), m.p. 193–195 °C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.15–0.20 (m, 16 H), 0.46–0.57 (m, 4 H), 0.90 (s, 12 H). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = –1.2 (8 CH_2), 22.7 (4 CH), 32.5 (4 C), 44.5 (6 CH_2). ^{13}C NMR (75.5/300 MHz, C_6D_{12}): δ = –0.7 (8 CH_2, $^1J_{C,C}$ = 13.4 Hz), 23,4 (4 CH, $^1J_{C,C}$ = 13.4, 45.7 Hz), 33.4 (4 C, $^1J_{C,C}$ = 32.75, 45.7 Hz), 45.5 (6 CH_2, $^1J_{C,C}$ = 32.75 Hz). $C_{22}H_{32}$ (296.48): calcd. C 89.12, H 10.88; found C 89.01, H 10.75.

1,3,5,7-Tetraisopropyladamantane (9): A vigorously stirred suspension of PtO_2 (200 mg, 0.88 mmol, 88 mol-%) in acetic acid (10 mL) was exposed to an atmosphere of hydrogen at a pressure of 1.2 bar for 30 min. After this, a solution of the hydrocarbon **8** (297 mg, 1.0 mmol) in hexane (2 mL) was added in one portion, and stirring under hydrogen atmosphere was continued for 2 h. The reaction mixture was taken up with hexane (50 mL), and the mixture washed successively with water (2 × 50 mL), 5% aqueous $NaHCO_3$ solution (3 × 50 mL) and brine (50 mL), dried and concentrated under reduced pressure to give pure **9** (305 mg, 100%) as a colorless solid, m.p. 77.5–78.5 °C. ^{1}H NMR ($CDCl_3$): δ = 0.82 (d, J = 7.0 Hz, 24 H), 1.03 (s, 12 H), 1.26 (sept, J = 7.0 Hz, 4 H). ^{13}C NMR ($CDCl_3$): δ = 16.7 (8 CH_3), 35.9 (4 C), 37.8 (4 CH), 40.5 (6 CH_2). ^{13}C NMR (75.5/300 MHz, C_6D_{12}): δ = 17.1 (8 CH_3, $^1J_{C,C}$ = 35.5 Hz), 36.8 (4 C, $^1J_{C,C}$ = 33.0, 33.7 Hz), 38.7 (4 CH, $^1J_{C,C}$ = 33.7, 35.5 Hz), 41.5 (6 CH_2, $^1J_{C,C}$ = 33.0 Hz). The structure of this hydrocarbon was verified by X-ray crystal structure analysis.

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[24] **Crystal Structure Determinations:** Crystals of 1,3,5,7-tetracyclopropyladamantane (**8**) and 1,3,5,7-tetraisopropyladamantane (**9**) were grown by slow evaporation of their solutions in Et_2O/MeOH mixtures and measured on a Siemens SMART CCD diffractometer using graphite monochromated Mo-K_α radiation. The crystal of 1,3,5,7-tetraethenyladamantane (**17**) was grown in situ with the Optical Heating and Crystallization Device (OHCD) using a miniature zone melting procedure with focused IR-laser light.[21] The device was mounted on a Nicolet R3m/V four circle diffractometer, and the crystal formation detected using graphite monochromated Mo-K_α radiation. Correction for the cylindrical shape of the crystals (0.3 mm diameter) was applied for **17**. The structure solutions and refinements on F^2 were performed with the Bruker AXS SHELXTL program suite (Version 5.10). The hydrogen atoms were located in difference Fourier maps and refined as riding groups with the 1.2 fold isotropic displacement parameter of the corresponding C atom. **17**: $C_{18}H_{24}$ (240.37), crystal shape: cylindrical, T = 150(2) K, triclinic, a = 9.614(2), b = 9.778(2), c = 10.048(3) Å, α = 115.04(2), β = 100.39(2), γ = 111.75(2)°, V = 728.3(3) Å^3, Z = 2, space group $P\bar{1}$, ρ = 1.096 g cm^{-3}, μ = 0.061 mm^{-1}, intensities measured: 3510 ($2\theta_{max}$ = 55.10°), independent: 3319 (R_{int} = 0.0297), 163 parameters refined, R_1 = 0.0644 for 2165 reflections with $I > 2\sigma(I)$, wR_2 (all data) = 0.1840, Gof = 1.026, maximum and minimum residual electron density 0.320 and –0.277 e·Å^{-3}. **9**: $C_{22}H_{40}$ (304.54), crystal size 0.38 × 0.32 × 0.23 mm, T = 203(2) K, tetragonal, a = b = 11.065(3), c = 7.835(2) Å, α = β = γ = 90°, V = 959.3(4) Å^3, Z = 2, space group $P\bar{4}2_1c$, ρ = 1.054 g cm^{-3}, μ = 0.058 mm^{-1}, intensities measured: 3702 ($2\theta_{max}$ = 56.88°), independent: 1148 (R_{int} = 0.0268), 51 parameters refined, R_1 = 0.0670 for 1098 reflections with $I > 2\sigma(I)$, wR_2 (all data) = 0.1612, Gof = 1.141, maximum and minimum residual electron density 0.537 and –0.318 e·Å^{-3}. CCDC-251236 (for **9**) and CCDC-251237 (for **17**) contain the crystallographic data (excluding structure factors) for the structures reported in this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.
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