(s, 2 H), 7.1–7.2 (m, 4 H); MS *m/e* 192 (M^+), 177, 150, 117, 107, 91, 43.

2-(*p*-Isopropylbenzyl)-*p*-benzoquinone. The procedure described for toluene in ref 10 has been used with *p*-cymene. The yield of isolated 2-(*p*-isopropylbenzyl)-*p*-benzoquinone was 40%: mp 51–52 °C; NMR δ 1.2 (d, 6 H), 2.85 (m, 1 H), 3.8 (d, 2 H), 6.35 (m, 1 H), 6.7 (s, 2 H), 7.1–7.2 (m, 4 H); MS *m/e* 238 (M^+), 237, 223, 197, 165, 139, 128, 115, 102, 91, 77.

p-Isopropylbenzyl alcohol and *p*-isopropylbenzaldehyde, obtained in the same reaction, were isolated by preparative GLC and identified by comparison with authentic samples.

Registry No.—**1**, 13098-88-9; **2**, 59230-57-8; naphthalene, 91-20-3; α-acetoxynaphthalene, 830-81-9; β-acetoxynaphthalene, 1523-11-1; 2-(*p*-isopropylbenzyl)-*p*-benzoquinone, 69897-58-1; *p*-isopropylbenzyl alcohol, 536-60-7; *p*-cymene, 99-87-6; *p*-isopropylbenzaldehyde, 122-03-2.

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Preparation and Reactivity of 3,7-*endo*-Diphenylbicyclo[3.3.0]octane Derivatives

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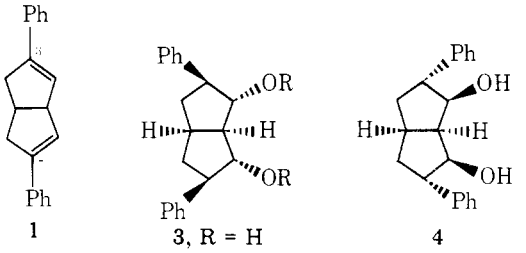
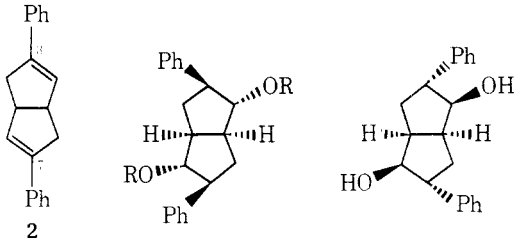
We wish to report a study of 3,7-*endo*-diphenylbicyclo[3.3.0]octane derivatives, i.e., systems of the Ar_1–C_n–Ar_2 type, in which two aromatic rings are fixed on the endo side of the "U-shaped"[2] *cis*-bicyclo[3.3.0]octane skeleton. This work was undertaken as part of a project aimed at the study of ring–ring interactions between aromatic molecules. In recent work,[3] we described the stacking interactions between aromatic moieties (nucleotide bases and antimalarial quinolines) by preparing Ar_1–$(CH_2)_3$–Ar_2 models, in which the aromatic residues are linked by a trimethylene bridge, which allows, but does not impose, the intramolecular ring–ring stacking. In a search for more rigid linking systems which could favor to a larger extent this type of interaction, we have examined a series of polycyclic skeletons and have finally turned to the *cis*-bicyclo[3.3.0]octane system, since in one of the possible conformations (as indicated by molecular models) the endo C_3-H and C_7-H bonds are nearly parallel at a distance of 3.5 to 4 Å, i.e., close to the width of an aromatic ring. There are few data in the literature on the conformation of 3,7-disubstituted bicyclooctane derivatives;[4] consequently, we have prepared as models the simplest compounds in the series, the diphenyl derivatives **11–23**, in order to ascertain whether these systems can achieve conformations in which the aromatic moieties interact. We describe here the preparation and some spectroscopic and reactivity data of these compounds.

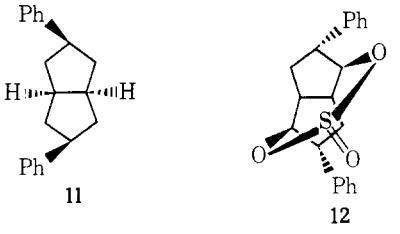
Results and Discussion

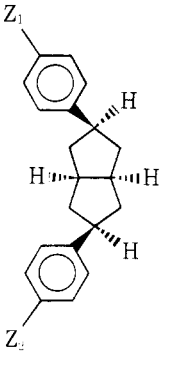
cis-Bicyclo[3.3.0]octane-3,7-dione was reacted with phenylmagnesium bromide to give a dihydroxy compound which was dehydrated in methanolic hydrochloric acid to a 50:50 mixture of the isomeric dienes **1** and **2**[5] which could be separated on silica impregnated with silver nitrate. The "endo-endo" positioning of the benzene rings was accomplished by taking advantage of the more accessible (exo) face of the double bonds:[2] treatment of diene **1** with diborane, followed by H_2O_2 oxidation led to an ca. 15:1 mixture of two isolable diols, **3** and **4**. Treated similarly, diene **2** gave **5** and **6** in the same 15:1 ratio. The NMR spectra of the four diols and the corresponding derivatives, namely the acetates **7** and **8** and the tosylates **9** and **10**, were recorded in different solvents or in the presence of $Eu(dpm)_3$ (for the diols themselves). Con-

exo: ┈┈ endo: ◄









11, $Z_1 = Z_2 = H$
13, $Z_1 = H$; $Z_2 = COCH_3$
14, $Z_1 = Z_2 = COCH_3$
15, $Z_1 = H$; $Z_2 = COPh$
16, $Z_1 = Z_2 = COPh$
17, $Z_1 = H$; $Z_2 = CO(CH_2)_2CH_3$
18, $Z_1 = Z_2 = CO(CH_2)_2CH_3$
19, $Z_1 = H$; $Z_2 = CO_2H$
20, $Z_1 = Z_2 = CO_2H$
21, $Z_1 = H$; $Z_2 = CO_2CH_3$
22, $Z_1 = Z_2 = CO_2CH_2CH_3$
23, $Z_1 = H$; $Z_2 = NO_2$

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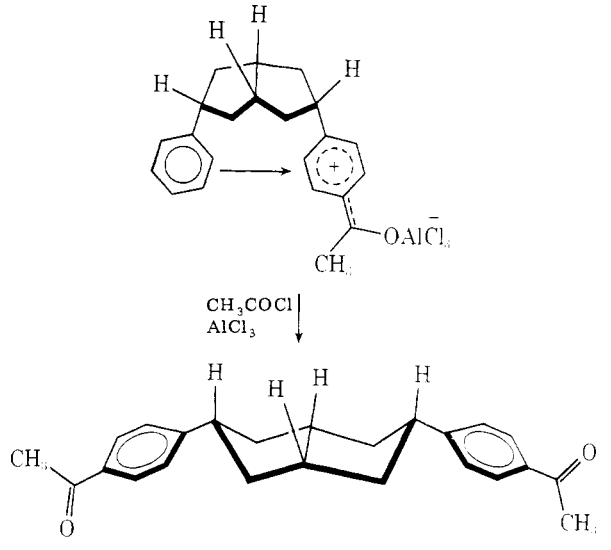
sequent analysis clearly shows, for all compounds, the identical nature of the two RO–C–**H** nuclei present in each molecule (the two protons appear as a single triplet or doublet of doublets according to the compound considered), indicating the symmetrical structure of the systems which possess two OR groups either endo-endo or exo-exo. The major diols **3** and **5** were shown to belong to the same "stereochemical series", as they could be converted to the unique hydrocarbon **11** by the $LiAlH_4$ reduction of their tosylates **9** and **10**. One consequence of this result, together with the symmetry considerations, is that the minor diols **4** and **6** also belong to the same "stereochemical series". Minor diol **6** when reacted with $SOCl_2$ in pyridine gave the cyclic sulfite **12**. This reaction unambiguously proves the endo-endo nature of the two hydroxylic groups in **6** and consequently the stereochemistry of the four diols and of their derivatives, notably the diaryl hydrocarbon **11** (as expected the ^{13}C NMR spectrum of **11** shows three peaks corresponding to the eight carbon atoms of the bicyclic backbone). The structure of **11** and of the subsequent derivatives **12–13** was indeed unambiguously confirmed later by the X-ray analysis of the diacetyl compound **14**.[6] It is to be noted that no unsymmetrical exo-endo diol could be detected after treatment of the dienes by diborane and oxidation. This can be interpreted by the fact that the addition of diborane proceeds to a major extent from the less hindered exo face of the molecules, giving after oxidation the major diols **3** and **5**. The unfavored approach of B_2H_6 from the endo side most probably leads to simultaneous addition on the two double bonds, leading to a cyclic dialkylborane, the oxidation of which gives the minor endo-endo compounds **4** and **6**. This is confirmed by the observation that no endo-endo diol could be detected when the dienes were treated by the more bulky hydroboration agent 9-borabicyclononane.

The endo-endo diaryl hydrocarbon **11** was submitted to the electrophilic substitution reaction as a test for eventual proximity effects between the two phenyl rings. Treatment with acetyl chloride in the presence of aluminium trichloride as catalyst (1 mol of hydrocarbon, 2 mol of AcCl, 4 mol of $AlCl_3$) led to the rapid acylation of one aromatic ring to give **13**. The functionalization of the second ring required a longer reaction time to obtain the diacyl compound **14**. From a study of the composition of the reaction mixture as a function of time, the rate ratio for monoacylation of hydrocarbon **11** (**11** → **13**) vs. the rate of formation of the diacyl compound from the monoacyl derivative (**13** → **14**) was evaluated to be of the order of 5. The same observation was made during the acylation of the hydrocarbon **11** with benzoyl chloride or butyric anhydride in the presence of aluminium trichloride. Respectively **15** and **16** and **17** and **18** were successively obtained. (The electrophilic nitration of **11** (HNO_3–Ac_2O–AcOH–, 25°C) afforded the mononitro derivative **23** after 3 h of reaction (45% yield; 90% based on **11** consumed).)

Comparable intramoelcular deactivating influences by proximate aromatic rings are well known, notably in the acylation of [*m.n*]paracyclophanes.[7] The presence of a positive charge on the monoacylbenzene ring, as a result of the complexation of the catalyst with the carbonyl group, deactivates the proximate unsubstituted ring toward electrophilic attack. The deactivation is related to the proximity of the aromatic rings. For example, in the [4.4]paracyclophane an acetyl group in one aromatic ring strongly deactivates the other while no transannular deactivating influence is observed in the [6.6]-paracyclophane. The substitutions of the two aromatic rings proceed independently of one another.[7] The results we observe for hydrocarbon **11** can therefore be interpreted as an indication of the presence of a weak intramolecular interaction between the phenyl groups, i.e., an indication of a certain proximity of the benzene rings when one ring becomes electron deficient.

Scheme I



14 x-ray structure

In the absence of any such charge on one ring, it seems on the other hand that the system exists preferentially in conformations where the rings do not exhibit interactions, as indicated by the absence of any perturbation in the NMR and UV spectra of all the compounds **11–23** prepared in the series (working in the UV with or without an external acceptor such as tetracyanoethylene). Similarly, the hydrocarbon **11** possesses normal fluorescence characteristics in cyclohexane, showing no excimer formation comparable to that described for example by F. Hirayama in a series of diphenyl- and triphenylalkanes.[8] In the solid, as revealed by the X-ray structure of diacetate **14**, the system exists in an "extended" conformation[6] (Scheme I) in which the centers of the two phenyl rings are approximately 10 Å apart. The conformations in solution may very well resemble those in the solid as suggested by the spectroscopic results.

As a consequence, the *cis*-bicyclo[3.3.0]octane skeleton constitutes a bridging system which allows the interactions between aromatic moieties attached at positions 3 and 7 when a positive charge is present in one ring but in no case does it impose or favor the intramolecular ring–ring stacking.

Experimental Section[9]

Hydroboration of 3,7-Diphenylbicyclo[3.3.0]octa-2,7-diene (1). 2,8-Dihydroxy-3,7-diphenylbicyclo[3.3.0]octanes (3 and 4). A solution of 2.0 g (7.75 mmol) of diene **1** in 2 mL of tetrahydrofuran was treated with 7 mL of a 1.2 M solution of diborane in tetrahydrofuran (8.4 mmol) for 14 h at 0 °C. To this solution brought to room temperature were successively added a few drops of water, 6 mL of a 3 N sodium hydroxide solution, and 6 mL of 30% aqueous H_2O_2. After the mixture was stirred for 1 h, it was extracted with chloroform to give 2.10 g of a crude product which was chromatographed on 150 g of silica. The first fraction, eluted with 45:45 hexane–ether, amounted to 1.6 g of 2,8-*exo*-dihydroxy-3,7-*endo*-diphenylbicyclo[3.3.0]octane (**3**); elution with methanol gave 0.10 g of 2,8-*endo*-dihydroxy-3,7-*exo*-diphenylbicyclo[3.3.0]octaine (**4**). Diol **3** was recrystallized from ethyl acetate–hexane: mp 153–154 °C; IR ($CHCl_3$) 3600, 3450, 1600, 1500, and 1475 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 3.95 (dd, 2 H, J = 6 and 10 Hz), 3.36 (s, 2 H), 3.16–2.66 (m, 3 H), 2.65–1.20 (m, 5 H); ^{13}C NMR ($CDCl_3$) 128.5, 127.3, 126.7 (aromatic C), 84.2 (C–OH), 58.3, 56.4, 39.1, 38.2 (other aliphatic ring C).

Anal. Calcd for $C_{20}H_{22}O_2$: C, 81.60; H, 7.53. Found: C, 81.53; H, 7.49.

The minor diol **4** was purified by crystallization from ethyl acetate–hexane: mp 143.5–144.5 °C; IR ($CHCl_3$) 3610, 3450, 1600, 1500, and 1480 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 4.67 (br unresolved t, 2 H), 3.50–1.30 (m, 10 H).

Anal. Calcd for $C_{20}H_{22}O_2$: C, 81,60; H, 7.53. Found: C, 81,58; H, 7.49.

2,8-*exo*-Diacetoxy-3,7-*endo*-diphenylbicyclo[3.3.0]octane (7). This diacetate derivative was obtained from **3** (acetic anhydride, pyridine) as white crystals, mp 88–89.5 °C, after purification on preparative TLC and recrystallization from ethyl acetate–hexane: IR ($CHCl_3$) 1730, 1600, 1500, and 1455 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 5.47 (dd, J = 7 and 10 Hz, 2 H), 3.34 (br m, 3 H), 1.95 (s, 6 H), 3.33–1.60 (m, 11 H).

Anal. Calcd for $C_{24}H_{26}O_4$: C, 76.16; H, 6.95. Found: C, 75.91; H, 7.10.

2,8-*exo*-Ditosyloxy-3,7-*endo*-diphenylbicyclo[3.3.0]octane (9). The ditosylate **9** (from **3**, anhydrous pyridine, *p*-toluenesulfonyl chloride) was purified by crystallization from ethyl acetate–hexane: mp 154–155 °C; IR ($CHCl_3$) 1605, 1500, 1460, 1370, and 1180 cm^{-1}; NMR ($CDCl_3$) δ 7.55–6.90 (m, 18 H), 5.05 (dd, J = 5 and 8 Hz, 2 H), 3.66–3.00 (m, 3 H), 2.90–1.50 (m, 11 H with a sharp peak at 2.34 assigned to CH_3).

Anal. Calcd for $C_{34}H_{34}O_6S_2$: C, 67.80; H, 5.69. Found: C, 67.52; H, 5.69.

Hydroboration of 3,7-Diphenylbicyclo[3.3.0]octa-2,6-diene (2). 2,6-Dihydroxy-3,7-diphenylbicyclo[3.3.0]octanes (5 and 6). Hydroboration–oxidation of diene **2** (2.2 g) conducted as described for **1** led to the mixture (2.4 g) of diols **5** and **6** which were separated on silica. Elution with 45:55 hexane–ether gave the major compound 2,6-*exo*-dihydroxy-3,7-*endo*-diphenylbicyclo[3.3.0]octaine (**5**) (1.8 g), which was crystallized from ethyl acetate–hexane: mp 133–134.5 °C; IR ($CHCl_3$) 3620, 3460, 1600, 1500, and 1460 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 3.84 (dd, 2 H, J = 6 and 10 Hz), 3.30–2.70 (m, 2 H), 2.70–2.10 (m, 4 H), 2.00 (s, 2 H), 1.90–1.50 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 128.6, 127.4, 126.8 (aromatic C), 86.4 (C–OH), 56.6, 47.3, 36.2 (other aliphatic ring C).

Anal. Calcd for $C_{20}H_{22}O_2$: C, 81.60; H, 7.53. Found: C, 81.68; H, 7.50.

Elution with methanol gave the minor diol 2,6-*endo*-dihydroxy-3,7-*exo*-diphenylbicyclo[3.3.0]octane (**6**) (0.10 g), which was purified by preparative thin-layer chromatography on silica and crystallization from methanol: mp 145–146.5 °C; IR ($CHCl_3$) 3630, 3450, 1605, 1500, and 1480 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 3.85 (br dd, 2 H, J = 6 and 8 Hz), 3.80–10 (m, 10 H).

Anal. Calcd for $C_{20}H_{22}O_2$: C, 81.60; H, 7.53. Found: C, 81.51; H, 7.68.

2,6-*exo*-Diacetoxy-3,7-*endo*-diphenylbicyclo[3.3.0]octane (8). Acetylation of **5** (acetic anhydride, pyridine) afforded diacetate **8** which was purified by preparative thin-layer chromatography on silica and crystallization from ethyl acetate–cyclohexane: mp 117–118.5 °C; IR ($CHCl_3$) 1730, 1600, 1580, and 1425 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 4.97 (dd, 2 H, J = 4 and 10 Hz), 3.34 (br m, 2 H), 3.33–1.68 (m, 12 H), 1.97 (s, 6 H).

Anal. Calcd for $C_{24}H_{26}O_4$: C, 76.16; H, 6,95. Found: C, 76.71; H, 6.96.

2,6-*exo*-Ditosyloxy-3,7-*endo*-diphenylbicyclo[3.3.0]octane (10). **10** was obtained from **5** (*p*-toluenesulfonyl chloride, pyridine, 0 °C) and crystallized from ethyl acetate–hexane: mp 188–189 °C; IR ($CHCl_3$) 1600, 1500, 1460, 1365, and 1180 cm^{-1}; NMR ($CDCl_3$) δ 7.55–6.95 (m, 18 H), 4.60 (dd, 2 H, J = 4 and 10 Hz), 3.60–2.83 (m, 4 H), 2.34 (s, 6 H), 2.33–1.50 (m, 10 H).

Anal. Calcd for $C_{34}H_{34}O_6S_2$: C, 67.80; H, 5.69. Found: C, 67.57; H, 5.71.

3,7-*endo*-Diphenylbicyclo[3.3.0]octane (11). From Ditosylate 9. A mixture of 0.680 g (1.13 mmol) of the ditosylate in anhydrous tetrahydrofuran (50 mL) was treated under nitrogen with 0.10 g (2.6 mmol) of lithium aluminium hydride. The mixture was stirred at 60 °C during 1 week for complete reaction. The mixture was cooled to 0 °C, and the excess hydride was decomposed with ethyl acetate. After acidification with diluted sulfuric acid and extraction with ether, the crude oily product (0.350 g) was chromatographed on 15 g of silica. Elution with hexane afforded the hydrocarbon **11** (0.250 g, 84%). Unreacted ditosylate (0.070 g) was recovered when washing the column with ethyl ether. Hydrocarbon **11** was obtained as white crystals by crystallization from ethanol: mp 65–66 °C; IR ($CHCl_3$) 1605, 1500, and 1470 cm^{-1}; NMR ($CDCl_3$) δ 7.25 (s, 10 H), 3.50–0.84 (complex m, 12 H); ^{13}C NMR ($CDCl_3$) δ 128.2, 126.9, 125.9 (aromatic C), 50.0, 44.3, 42.1 (aliphatic ring C).

Anal. Calcd for $C_{20}H_{22}$: C, 91.55; H, 8.45. Found: C, 91.52; H, 8.36.

From Ditosylate 10. Treated as above, compound **10** afforded crystals which were identical with those of hydrocarbon **11**, as indicated by mixed melting point and IR and NMR spectra (74% yield, 15% recovered unreacted material).

Preparation of the Cyclic Sulfite 12. A solution of 0.060 g of diol **6** in 1 mL of anhydrous pyridine was treated by a solution of 0.6 mL of freshly distilled thionyl chloride in 1 mL of pyridine. The mixture was left at room temperature for 5 min. After extraction with methylene chloride, the crude reaction product was purified by preparative thin-layer chromatography on silica. Crystallization from hexane afforded crystals of sulfite **12:** mp 70 °C; IR (CCl_4) 1200 cm^{-1}; mass spectrum m/e 340 [M^+].

Acylation of Hydrocarbon 11. A. By Acetyl Chloride. A suspension of 0.370 g (2.8 mmol) of freshy sublimed aluminium trichloride in 15 mL of anhydrous methylene chloride was stirred under nitrogen at room temperature for 30 min. The mixture was cooled to −60 °C and a solution of 0.108 g (1.4 mmol) of acetyl chloride in 30 mL of anhydrous methylene chloride was added over a period of 30 min. After 12 h at −60 °C, a solution of 0.182 g (0.7 mmol) of hydrocarbon **11** in 15 mL of methylene chloride was added. The mixture was left at this temperature, and the reaction mixture was analyzed: 1-mL aliquots were removed, poured into 2 mL of diluted HCl, extracted with CH_2Cl_2 (3 × 2 mL), washed with water, and dried; the solvent was evaporated; the residue was dissolved in a calculated amount of solvent containing benzophenone as internal standard; and the relative amounts of unreacted **11**, monoacyl **13**, and diacyl **14** were determined by VPC (SE-52 5%) at different reaction times.

The rate difference can be graphically estimated as follows. The acetylation of the two phenyl rings of **11** is of the competitive consecutive second-order type

$$A + B \xrightarrow{k_1} C + E$$

$$A + C \xrightarrow{k_2} D + E$$

where B is hydrocarbon **11**, C is monoacetyl **13**, and D is diacetyl derivative **14**. For a rate ratio $r = k_2/k_1$, the concentration of C and D as a function of [B] at any time is given by

$$[C] = \frac{[B]}{r-1}\left[1 - \left(\frac{[B]}{b}\right)^{r-1}\right]$$

$$[D] = b - \frac{[B]}{r-1}\left[r - \left(\frac{[B]}{b}\right)^{r-1}\right]$$

where $b = [B_0]$. From the experimental values of [B] at different reaction times, [C] and [D] were calculated and plotted against time for a series of r values. The experimental plots of the variation of [C] and [D] with time were compared with the calculated curves and found to be very similar to the curve corresponding to $k_1/k_2 = 5$.

To isolate the monoacetyl derivative **13**, the reaction was run as stated previously and stopped after 5 h [VPC analysis: 60% of **13**, 38% of **11**, and a trace (1–2%) of **14**]. After isolation, the mixture was chromatographed on silica. Elution with hexane afforded the unreacted **11** in the first fractions and then the monoacetyl derivative **13**, which was crystallized from ethyl acetate–hexane: mp 74–76 °C; IR ($CHCl_3$) 1690 and 1605 cm^{-1}; NMR ($CDCl_3$) δ 7.95 and 7.30 (q_{AB}, 4 H, J_{AB} = 9 Hz), 7.25 (s, 5 H), 3.50–1.15 (m, 15 H, sharp peak at 2.54 assigned to CH_3).

Anal. Calcd for $C_{22}H_{24}O$: C, 86.80; H, 7.95. Found: C, 86.53; H, 7.80.

The diacetyl derivative **14** was quantitatively obtained by running the reaction at 25 °C for 10 h. Purification by chromatography on silica and crystallization from ethyl acetate–hexane gave white crystals: mp 110–112 °C; IR ($CHCl_3$) 1690 and 1605 cm^{-1}; NMR ($CDCl_3$) δ 7.95 and 7.30 (q_{AB}, 8 H, J_{AB} = 9 Hz), 3.70–1.20 (m, 18 H, sharp peak at 2.58 assigned to CH_3).

Anal. Calcd for $C_{24}H_{26}O_2$: C, 83.20; H, 7.56. Found: C, 83.29; H, 7.49.

B. By Benzoyl Chloride. To a mixture of 0.530 g (3.9 mmol) of aluminium trichloride and 0.280 g (2 mmol) of benzoyl chloride in 30 mL of methylene chloride was added dropwise at 0 °C a solution of 0.262 g (1 mmol) of hydrocarbon **11** in 15 mL of methylene chloride. The mixture was stirred at 20 °C for 24 h under nitrogen. The reaction mixture was poured into cold aqueous HCl and extracted with methylene chloride. Subsequent workup gave a residue which was chromatographed over silica gel. Elution with petroleum ether gave the unreacted **11** (0.060 g, 0.23 mmol, 23%). Elution with petroleum ether–ether (80:20) furnished the monobenzoyl derivative **15** (0.250 g; 0.7 mmol; 70%), crystallized from ethanol: mp 107 °C; IR ($CHCl_3$) 1655, 1605 cm^{-1}; NMR ($CDCl_3$) δ 7.95–7.10 (complex m, with one peak 7.25, 14 H), 3.50–1.0 (m, 12 H).

Anal. Calcd for $C_{27}H_{26}O$: C, 88.48; H, 7.15. Found: C, 88.42; H, 7.06.

Further elution furnished the dibenzoyl derivative **16** (0.030 g; 0.07 mmol; 7%), crystallized from ethanol: mp 99°C; IR ($CHCl_3$) 1655, 1605

cm^{-1}; NMR ($CDCl_3$) δ 7.95–7.10 (complex m, 18 H), 3.50–1.0 (complex, 12 H).

Anal. Calcd for $C_{34}H_{30}O_2$: C, 86.77; H, 6.43. Found: C, 86.68; H, 6.38.

C. By Butyric Anhydride. To a mixture of 0.800 g (6 mmol) of aluminium trichloride and 0.510 g (3.25 mmol) of butyric anhydride in 60 mL of methylene chloride was added dropwise at 0 °C 0.773 g (2.95 mmol) of **11** in 30 mL of methylene chloride under a nitrogen atmosphere. The mixture was allowed to react at room temperature for 16 h. The mixture was poured into cold aqueous hydrochloric acid and extracted with methylene chloride. The organic layer was stirred with sodium bicarbonate and worked up in the usual manner to provide a residue which was chromatographed over silica gel. Elution with hexane afforded 0.38 g of unreacted **11** (1.5 mmol; 50%). Elution with hexane–ethyl acetate (8:2) gave 0.437 g of **17** (1.31 mmol; 45%): mp 61 °C; IR ($CHCl_3$) 1680 and 1605 cm^{-1}; NMR ($CDCl_3$) δ 7.85 and 7.30 (AB quartet, 4 H, J = 8 Hz), 7.25 (s, 5 H), 3.5–0.7 (complex, 19 H).

Anal. Calcd for $C_{24}H_{28}O$: C, 86.70; H, 8.49; O, 4.89. Found: C, 86.75; H, 8.43; O, 4.82.

Further elution with hexane–ethyl acetate (8:2) furnished 0.050 g of diacyl **18** (0.050 g; 4%): mp 99 °C; IR ($CHCl_3$) 1680 and 1605 cm^{-1}; NMR ($CDCl_3$) δ 7.85 and 7.30 (AB quartet, 8 H, J = 8 Hz), 3.5–0.7 (m complex, 26 H).

Anal. Calcd for $C_{28}H_{34}O_2$: C, 83.54; H, 8.51; O, 7.95. Found: C, 83.26; H, 8.43; O, 8.31.

Mono- and Diacids 19 and 20. Treatment of 0.41 g (1.3 mmol) of **13** dissolved in 25 mL of dioxane by a solution of 5 g of KOH and 1 mL of bromine in 10 mL of water at 0 °C for 12 h afforded after extraction with methylene chloride 0.40 g of monoacid **19,** which was esterified by diazomethane to give **21:** mp 93°C; IR ($CHCl_3$) 1720 and 1610 cm^{-1}; NMR ($CDCl_3$) δ 7.85 and 7.30 (AB quartet, 4 H, J = 8 Hz), 7.25 (s, 5 H), 3.30 (s, 3 H).

Anal. Calcd for $C_{22}H_{24}O_2$: C, 82.46; H, 7.55; O, 9.99. Found: C, 82.57; H, 7.49; O, 9.94.

A similar treatment of the diacetyl derivative **15** gave quantitatively the diacid **20** which was converted into the diethyl ester **22:** mp 111 °C; IR ($CHCl_3$) 1700 and 1610 cm^{-1}; NMR ($CDCl_3$) δ 7.90 and 7.30 (AB quartet, 8 H, J = 8 Hz), 4.35 (q, 4 H), 3-1 (complex, 18 H).

Anal. Calcd for $C_{26}H_{30}O_4$: C, 76.82; H, 7.44; O, 15.74. Found: C, 76.76; H, 7.32; O, 15.92.

Nitration of Hydrocarbon 11. To solution of 1 g (3.8 mmol) of hydrocarbon **11** in 24 mL of acetic anhydride was added dropwise at 0 °C a solution of 0.17 mL of fuming nitric acid in 5 mL of acetic anhydride. After the reaction was stirred for 4 h at 20 °C, the mixture was worked up in the standard manner. Chromatography on silica using hexane as eluent afforded successively 0.30 g (1.15 mmol, 30%) of unreacted **11,** 0.60 g (2 mmol, 51%) of the mononitro derivative **23,** and 0.12 g of a complex unresolued mixture. **23** was crystallized from ethanol: mp 99 °C; IR ($CHCl_3$) 1600 and 1350 cm^{-1}; NMR ($CDCl_3$) δ 8.15 and 7.40 (AB quartet, 4 H, J = 8 Hz), 7.28 (s, 5 H), 3.5–1 (m, 12 H).

Anal. Calcd for $C_{20}H_{21}O_2N$: C, 78.14; H, 6.89; N, 4.56. Found: C, 78.10; H, 6.93; N, 4.57.

Electronic Absorption Spectra. Ultraviolet spectra were recorded on a Cary Model 15 spectrophotometer using 1-cm cells at 25 °C. All the compounds in the series **11–23** were studied and their absorption spectra were found to be identical with those of the corresponding references (phenylcyclopentane or para-substituted toluenes). Compounds **11, 13,** and **23** were examined in the presence of electron acceptors, chloranil and TCNE, in CH_2Cl_2 at equimolar concentrations of both components ($\approx 10^{-2}$ M) and compared to the spectra of the references recorded in the same conditions. No perturbation was detected.

Registry No.—**1**,69867-45-4; **2**, 69867-46-5; **3**, 69867-47-6; **4**, 69867-48-7; **5**, 69867-49-8; **6**, 69867-50-1; **7**, 69867-51-2; **8**, 69867-52-3; **9**, 69867-53-4; **10**, 69867-54-5; **11**, 69867-55-6; **12**, 69867-56-7; **13**, 69867-57-8; **14**, 69867-58-9; **15**, 69867-59-0; **16**, 69867-60-3; **17**, 69867-61-4; **18**, 69867-62-5; **20**, 69867-64-7; **21**, 69867-65-8; **22**, 69867-66-9; **23**, 69867-67-0; thionyl chloride, 7719-09-7.

References and Notes

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Dry Ozonation of Steroids. C-25 Functionalization of Cholestane Derivatives

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The ozonation of substrates adsorbed on dry silica gel is a convenient method to introduce oxygen into unactivated tertiary C–H bonds.[1] This method involves preadsorption of substrate on chromatographic grade silica gel and passing over it ozone at temperatures between −75 and −45 °C, followed by elution with an appropriate solvent. The reactivity of C–H bonds toward ozone depends both on the electronegativity of the C atom and on its steric availability.

As part of our program to synthesize 25-hydroxycholesterol and its derivatives, we have studied the utilization of ozone as a reagent for the hydroxylation of saturated derivatives of cholesterol as a complimentary method to the previously described[2] peracetic acid oxidation.

We have already published[1d] a preliminary report on dry ozonation of 1α,3β-diacetoxy-6,7-dibromo-5α-cholestane (**11**), which led to C-25 hydroxylation. In this study, we describe dry ozonation of other saturated cholestane derivatives substituted at positions 5, 6, or 7 which serve as protecting groups for ring B double bonds. We have chosen cholestan-3β-ol acetate (**1**) as a model compound, which was ozonated on silica at −78 °C, resulting in 74% conversion to a mixture of hydroxylated products from which cholestane-3β,25-diol 3-acetate (**2**) was isolated in 8% yield; the rest of the material was a mixture of other monohydroxylated and dihydroxylated products.

Ozonation of cholestane-3β,5α-diol 3-acetate (**3**) under similar conditions resulted in 80% of hydroxylated products, containing 11% of the 25-hydroxy derivative **4.** This material was converted to 25-hydroxycholesteryl acetate (**5**) on treatment with ferric chloride adsorbed on silica gel.[3]

The yield of hydroxylation was higher on ozonation of the 5,6-dibromide **6,** leading to **7** (15% yield and 70% conversion). Even better results were achieved with the 6,7-dibromide **8** (prepared from the known cholest-6-en-3β-ol acetate[4] by bromination with iodobenzene dibromide), which on ozonation at −65 °C gave its 25-hydroxy derivative **9** as the only isolated product in 32% yield of the converted material (50%). This compound is a convenient precursor for the preparation of 25-hydroxyvitamin D_3 as its dehydrobromination leads to the respective provitamin, the cholesta-5,7-diene-3β,25-diol (**10**).

As mentioned above, ozonation of 6,7-dibromide **11,** possessing an additional acetoxy function at 1α, also led to sub-

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