trichloro-1,4-dioxaspiro[4,5]deca-7,9-diene-2,6-dione (IV) (infrared bands at 1820 and 1680 cm.$^{-1}$) which could not be purified. Treatment of III with other oxidizing agents such as hydrogen peroxide, ammonium persulfate, and ceric sulfate, did not produce the expected arenone.

Oxidation of 2-hydroxy-3,5-dibromophenoxyacetic acid with silver oxide in benzene likewise gave a crude product with infrared bands at 1825 and 1700 cm.$^{-1}$, characteristic of the *o*-arenone. As in the case of IV, a pure product could not be obtained because of the instability of the incompletely halogenated arenone system.[1]

Experimental

Melting points are uncorrected. The ultraviolet spectra were recorded on a Beckman Model DK-2 spectrometer. The infrared spectra were taken in Nujol mull with a Perkin-Elmer Model 125 spectrometer. The n.m.r. spectra were obtained on a Varian A-60 instrument in deuterioacetone, using tetramethylsilane as internal standard; the chemical shifts are expressed in δ-units.

7,8,9,10-Tetrachloro-1,4-dioxaspiro[4,5]deca-7,9-diene-2,6-dione (II).—In a solution of 5 g. of 2-hydroxy-3,4,5,6-tetrachlorophenoxyacetic acid (I)[3] in 250 ml. of dry ethyl ether CaO (12.5 g.) was suspended and chlorine was bubbled with stirring during 10 min. The solution was stirred for 1 hr., then filtered, and evaporated to dryness. Four grams of residue was obtained, which, crystallized from butanol, yielded pale yellow needles: m.p. 105–107°, infrared (Nujol) 1825 (νC-2=O) and 1708 cm.$^{-1}$ (νC-6=O), δ (CD_3COCD_3) 4.73 (methylene), and $\lambda_{max}^{CCl_4}$ 368 mμ (ϵ 4300).

Anal. Calcd. for $C_8H_2Cl_4O_4$: C, 31.61; H, 0.66; Cl, 46.67. Found: C, 31.70; H, 0.84; Cl, 46.12.

2-Methoxy-4,5,6-trichlorophenoxyacetic Acid.—A solution of 50 g. of 2-methoxy-4,5,6-trichlorophenol,[4] 31 g. of chloroacetic acid, and 22 g. of NaOH in 1000 ml. of water was refluxed for 35 hr. The warm solution was acidified and, after cooling, the precipitate was collected and then dissolved in 0.5 *N* NaOH. The solution was acidified to pH 6.0 and the unreacted phenol was filtered off. The solution was then acidified to pH 1 and the precipitate was collected and crystallized from ethanol–water (1:1) and then from benzene, yielding 15 g. of white needles: m.p. 147°; δ (CD_3COCD_3) 8.25 (singlet, 1H, carboxylic proton), 7.24 (singlet, 1H, aromatic proton), 4.73 (singlet, 2H, methylene), and 3.95 (singlet, 3H, methoxyl).

Anal. Calcd. for $C_9H_7Cl_3O_4$: C, 37.86; H, 2.47; Cl, 37.26. Found: C, 37.72; H, 2.60; Cl, 37.43.

2-Hydroxy-4,5,6-trichlorophenoxyacetic Acid (III).—Ten grams of the above methoxy acid was refluxed in 250 ml. of 48% HBr for 5 hr. On cooling a crop of white needles was obtained, which, crystallized from water and then from toluene, yielded 4 g. of product: m.p. 140–141°; δ (CD_3COCD_3) 8.80 (singlet, 2H, carboxylic and phenolic protons), 7.10 (singlet, 1H, aromatic proton), and 4.85 (singlet, 2H, methylene).

Anal. Calcd. for $C_8H_5Cl_3O_4$: C, 35.39; H, 1.86; Cl, 39.18. Found: C, 35.27; H, 2.00; Cl, 39.60.

2-Hydroxy-3,5-dibromophenoxyacetic Acid.—To a stirred solution of 5 g. of 2-hydroxyphenoxyacetic acid in 50 ml. of dioxane at 60° was gradually added 8 ml. of pyridine together with a solution of 3.2 g. of bromine in 200 ml. of dioxane. The reaction was stirred for 1 hr. after all of the bromine was added. Pyridine hydrobromide was filtered off; the solution was evaporated under vacuum to 50 ml. and then diluted to 500 ml. with 2 *N* HCl to give colorless crystals which were recrystallized from benzene: m.p. 157–158°; δ (CD_3COCD_3) 9.10 (singlet, 2H, carboxylic and phenolic protons), 7.32 (doublet, J = 2.5 c.p.s., 1H) and 7.18 (doublet, J = 2.5 c.p.s., 1H) (two aromatic protons in *meta* position), and 4.85 (singlet, 2H, methylene).

Anal. Calcd. for $C_8H_6Br_2O_4$: C, 29.47; H, 1.85; Br, 49.05. Found: C, 29.63; H, 1.93; Br, 49.39.

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A Facile Synthesis of 3β-Acetoxy-20-keto-5,14,16-pregnatriene[1]

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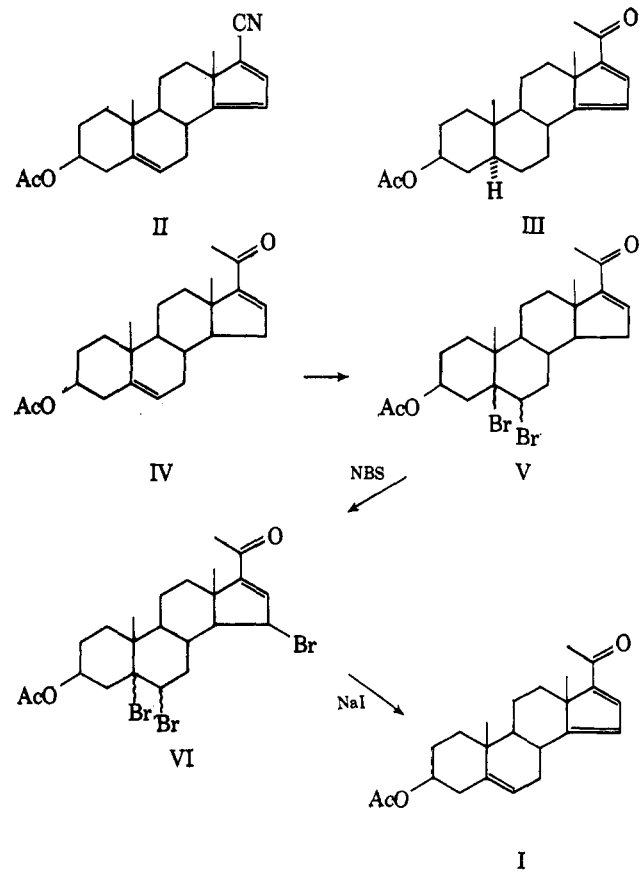
In connection with our projected synthesis of ring-D-bridged analogs of the steroid hormones,[3] it became necessary to secure a supply of 5,14,16-pregnatrien-3β-ol-20-one acetate (I). The only synthesis of I which we have been able to find in the literature involves Grignard addition to 3β-acetoxy-17-cyano-5,-14,16-androstatriene (II).[4] Since, in our previous work,[3] we found the synthesis of II[4] to be difficult and overly long, we decided to seek a more facile path to I.

The synthesis of 3β-acetoxy-20-keto-5α-pregna-14,-16-diene (III) has been reported by a path involving conversion of 3β-acetoxy-5α-pregnan-20-one to its 16-dehydro derivative, followed by bromination at C-15 and subsequent dehydrobromination.[5] Because the separation of III from the intermediate 16-dehydro



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compound proved difficult, the original workers abandoned this synthesis in favor of a path[6] analogous to the one which they used in the synthesis of I.[4] The current availability of 16-dehydro-20-keto steroids appreciably shortens the original synthetic scheme[5] and has thus made its reinvestigation appear attractive.

Bromination of 16-dehydropregnenolone acetate (IV) according to the procedure of Inhoffen[7] resulted in formation of the 5,6-dibromide V. The dibromide was not purified since n.m.r. studies indicated that by-product formation occurred mainly during crystallization. An excess of N-bromosuccinimide was then employed to effect allylic bromination at the 15-position. Subsequently, the tribromide VI was treated with potassium iodide under the conditions specified by the Swiss workers for the regeneration of the 5,6-double bond from tribromide in the synthesis of II.[4] As some spontaneous elimination of the allylic bromide was observed[8] during this process, conditions were modified to effect direct conversion of tribromide to I. The above procedure appreciably shortens the synthesis of 14,16-unsaturated steroids, eliminates the need for preparing and dehydrating cyanohydrins (particularly disagreeable steps both because of the toxicity of the reactants and because of the reversibility of the cyanohydrin formation), and reproducibly affords 3β-acetoxy-20-keto-5,14,16-pregnatriene (I) from 16-dehydropregnenolone acetate in greater than 60% yield.

Experimental[9]

3β-Acetoxy-20-keto-5,14,16-pregnatriene (I).—To a solution of 5.024 g. (0.014 mole) of 3β-acetoxy-20-keto-5,16-pregnadiene in 170 ml. of anhydrous ether was added, with stirring, a solution of 10 g. of anhydrous potassium acetate in 100 ml. of glacial acetic acid. The resulting mixture was thoroughly stirred in an ice bath while 2.25 g. (0.14 mole) of bromine in 50 ml. of acetic acid was added dropwise over a period of 3–3.75 hr. The mixture was stirred in the cold an additional 2 hr. and then at room temperature overnight. The product was partitioned between water and ether. The ether solution was washed twice with water, once with aqueous potassium carbonate solution, and then once with water. The organic phase was dried over magnesium sulfate and filtered; the ether was distilled under reduced pressure. The dibromide, 7.184 g., was obtained as a white foam.

A mixture of 7.104 g. (0.014 mole) of dibromide, 4.84 g. (0.028 mole) of N-bromosuccinimide, 75 ml. of carbon tetrachloride, and 20 mg. of 2,2′-azobisisobutyronitrile was stirred and heated under reflux in a nitrogen atmosphere for 1 hr. After the mixture had cooled to room temperature, it was filtered and the solvent was distilled under reduced pressure. The foam which resulted was mixed with 9.548 g. (0.064 mole) of sodum iodide and 75 ml. of acetone and heated under reflux under a nitrogen atmosphere for 3.5 hr. The acetone was then removed under reduced pressure. The residue was partitioned between chloroform and aqueous sodium thiosulfate solution. The chloroform layer was washed with aqueous sodium thiosulfate solution until it was free from iodine, then dried over magnesium sulfate, filtered, and evaporated to dryness under reduced pressure. The crude product, which was obtained as 4.85 g. of brown solid, was chromatographed over 122 g. of Merck acid-washed alumina.

The column was developed using *n*-hexane, benzene, and ethyl acetate as eluents. The fractions eluted by benzene and by 10:1 benzene–ethyl acetate contained a total of 3.43 g. of solid which was crystallized from acetone to give 3.25 g. of 3β-acetoxy-20-keto-5,14,16-pregnatriene as pale yellow rectangular plates: m.p. 158–159°, λ_{max}^{EtOH} 309 mμ (ε 10,650). Recrystallization from acetone afforded an analytical sample: m.p. 159–160°; λ_{max}^{EtOH} 309 mμ (ε 11,270); $[\alpha]^{24}D$ +287°, +284° (c 0.217, 0.315, $CHCl_3$) [lit.[4] m.p. 153–154°, $[\alpha]^{17}D$ +369°, λ_{max} (of 3β-hydroxy compound) 307 mμ (log ε 4.23)][10]; $\lambda_{max}^{CCl_4}$ 5.76, 6.0 (sh), 6.05, 6.57, and 8.07 μ; n.m.r. ($CDCl_3$) δ_{TMS} 1.16 and 1.20 (singlets, 18- and 19-methyl protons), 2.05 (singlet, acetate protons), 2.35 (singlet, C-21 protons), 5.48 (C-6 proton), 6.05 (C-15 proton), and 7.26 (doublet, J = 2 c.p.s., C-16 proton).

Anal. Calcd. for $C_{23}H_{30}O_3$: C, 77.93; H, 8.53. Found: C, 78.07; H, 8.38.

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(10) The optical rotation and extinction coefficient which we determined are in better agreement with the values reported in the literature for related systems than are the values reported for I in ref. 4. For example, the Swiss workers[6] report a log ε of 4.1 for III and, based on the rotation which they report for III, one can calculate, by the method of molecular rotation differences, $[\alpha]D$ +262° for I. In addition, a material balance on a Diels–Alder reaction of I indicates purity of 90% for this substance.

The Thermal Isomerization of 1,1-Dicyclopropylbutadiene

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The rearrangement of vinylcyclopropanes to cyclopentenes is now a well-documented reaction.[1-5] However, there is little data on the thermal isomerization of 1-cyclopropyl-1,3-butadiene (**1**) and its derivatives, a system which might be expected to yield seven-membered rings. Doering has reported, without details, that both the *cis* and *trans* forms of **1** rearrange only to 3-vinylcyclopentene and that no cycloheptadiene is observed.[6] The transitory formation of a seven-membered ring in such a system has, however, been postulated by Vogel to explain the equilibrium at 180° between the antipodes of benzonorcaradiene.[7]

The study of **1** is made difficult by the necessity of separating the *cis* (**1a**) and *trans* (**1b**) isomers. Unless the bond between carbons 1 and 2 loses all π character in the transition state so that free rotation can occur, only **1a** can exist in a conformation in which the cyclopropyl group and terminal vinyl are suitably placed for formation of a seven-membered ring. The probability of such a favorable conformation occurring is, however, greater in the rearrangement of 1,1-dicyclopropyl-1,3-butadiene (**2**) where the problem of *cis* and *trans* isomers does not exist. The isomerization of this compound has therefore been investigated.

As in the case of 1,1-dicyclopropylethylene,[5] rearrangement involving one cyclopropyl group of **2** should lead to a new vinylcyclopropane system which could undergo further rearrangement. There are consequently four products which can be predicted.

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