The crude material melted poorly and proved to be a mixture. Recrystallized from acetic anhydride, it yielded 1.25 g. of yellow needles of the anhydride melting at 310–315° (literature, 312°[8] and 322°[2]), and 6.0 g. of colorless needles of the acid, melting at 249–250° (literature[8] 250°). The acid was converted to methyl phenanthrene-9-carboxylate, white needles from methanol, m. p. 115–116° (literature[9] 116°).

(8) Werner and Kunz, *Ann.*, **321**, 327 (1902).
(9) Mosettig and van de Kamp, THIS JOURNAL, **52**, 3704 (1930).

Summary

1. The synthesis of phenanthrene-9,10-dicarboxylic anhydride and phenanthrene-9-carboxylic acid by ring closure of ethyl 2-biphenyloxalylacetate is described.

2. The method described constitutes a new synthesis of phenanthrene derivatives.

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[CONTRIBUTION FROM THE SCHOOL OF CHEMISTRY AND PHYSICS OF THE PENNSYLVANIA STATE COLLEGE]

Sterols. LXXXVII. Cholesterol and Sitosterol Derivatives

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Inasmuch as most of the oxidation studies on the sterols have been made with chromic anhydride in acetic acid, it seemed of interest to study the action of potassium permanganate in acetic acid on some of these substances. It is well known that potassium permanganate in alkaline medium oxidizes cholesterol to a cholestanetriol-3,5,6,[1,2,3] the reagent under these conditions apparently having no tendency to oxidize the secondary alcohols to ketones. The resulting triol differs from that obtained by the hydroxylation of cholesterol with hydrogen peroxide. That this difference is due to the configuration of the tertiary hydroxyl group at C-5 is indicated by the fact that the two triols on oxidation with chromic anhydride yield different cholestanol-5-diones-3,6.

In acetic acid solution cholesterol with potassium permanganate yields a cholestanol-5-dione-3,6 which is very probably identical with that obtained by oxidizing with chromic anhydride the alkaline permanganate oxidation product of cholesterol. With cholesteryl acetate a 3-acetoxy-5-hydroxy-6-ketocholestane was obtained. Similar results were obtained with sitosterol and sitosteryl acetate. The same products were obtained when the oxidations were conducted at room temperature or at 55°, there apparently being little tendency for ring B to open between C-5 and C-6.

The oxidation of cholestanol-3(β) with potassium permanganate in acetic acid solution at room temperature gave a good yield of cholestanone. At a temperature of 55° both cholestanone and 2,3-cholestane dicarboxylic acid were obtained. The oxidation of neocholestene at room temperature gave largely 2,3-cholestane dicarboxylic acid.

The preparation of 7-ketositosteryl chloride has been carried out by the chromic anhydride oxidation of sitosteryl chloride.[4] The substance undergoes reactions analogous to those of 7-ketocholesteryl chlorides.[4,5]

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Experimental Part

Oxidation of Cholesterol and Sitosterol Derivatives with Potassium Permanganate.—(a) **Cholesterol.**—To a solution of 2 g. of cholesterol in 150 cc. of acetic acid was added 75 cc. of 1 *N* aqueous potassium permanganate and 75 cc. of acetic acid. After standing for six hours at room temperature the mixture was diluted with water and the solid taken up with ether. The ethereal extract was washed with water and dilute sodium carbonate solution and the ether evaporated to yield approximately 1.6 g. of crystalline residue. This was crystallized from acetone to give compact white crystals, m. p. 248–251°.

Anal. Calcd. for $C_{27}H_{44}O_3$: C, 77.8; H, 10.65. Found: C, 78.0; H, 10.7.

(b) **Cholesteryl Acetate.**—To a solution of 2 g. of cholesteryl acetate in 210 cc. of acetic acid heated at 45–50° was added 50 cc. of 1 *N* aqueous potassium permanganate over a period of thirty minutes and the mixture was heated at 50° for an additional thirty minutes. The product was worked up and crystallized from acetone as described above to give white plates, m. p. 231–233°.

Anal. Calcd. for $C_{29}H_{48}O_4$: C, 75.6; H, 10.5. Found: C, 75.8; H, 10.7.

Similar results were obtained when the oxidation was conducted at room temperature.

(1) Windaus, *Ber.*, **40**, 257 (1907).
(2) Pickard and Yates, *J. Chem. Soc.*, **93**, 1678 (1908).
(3) Pimone, *Gazz. chim. ital.*, **62**, 1101 (1932).
(4) Marker, *et al.*, THIS JOURNAL, **59**, 619 (1937).
(5) Marker and Rohrmann, *ibid.*, **61**, 3022 (1939).

With hydroxylamine acetate the product yielded an *oxime* which was crystallized from aqueous methanol, m. p. 204–206°.

Anal. Calcd. for $C_{29}H_{49}O_4N$: C, 73.2; H, 10.4. Found: C, 73.5; H, 10.4.

(c) **Neocholestene.**—A suspension of 2 g. of neocholestene in 250 cc. of acetic acid was mixed with a solution of 1.5 g. of potassium permanganate in 200 cc. of 90% acetic acid. After standing at room temperature for seven hours the mixture was worked up as described previously. There was very little neutral material. The acidic fraction from the sodium carbonate washing was crystallized from aqueous acetic acid to yield white crystals, m. p. 193–195°. This gave no depression with an authentic sample of the 2,3-cholestane dicarboxylic acid, m. p. 193.5–195°.

(d) **Cholestanol.**—Oxidation of β-cholestanol at room temperature under the above conditions gave a product which crystallized from aqueous acetone as white needles, m. p. 126–128°. This gave no depression with a sample of cholestanone, m. p. 126.5–128°. There was no appreciable acid fraction.

When the oxidation was carried out at 55° for three hours using twice as much permanganate as in the room temperature oxidation approximately equal amounts of cholestanone and of the 2,3-diacid of cholestane were obtained.

(e) **Sitosterol.**—Sitosterol was oxidized as described for cholesterol. The neutral fraction was crystallized from acetone as compact white crystals, m. p. 240°.

Anal. Calcd. for $C_{29}H_{48}O_3$: C, 78.3; H, 10.9. Found: C, 78.3; H, 11.2.

(f) **Sitosteryl Acetate.**—This was oxidized as described for cholesterol. The product was crystallized from acetone as white needles, m. p. 251°.

Anal. Calcd. for $C_{31}H_{52}O_4$: C, 76.15; H, 10.75. Found: C, 76.1; H, 10.8.

$\Delta^{4,5}$-Cholestenedione-3,6 from Cholestanol-5-dione-3,6.—A mixture of 600 mg. of cholestanol-5-dione-3,6 and 12 g. of powdered potassium bisulfate was heated in high vacuum at 150–180°. The sublimate was crystallized from aqueous acetone as white plates, m. p. 121–123°.

Anal. Calcd. for $C_{27}H_{42}O_2$: C, 81.3; H, 10.6. Found: C, 81.3; H, 10.6.

7-Ketositosteryl Chloride.—To a well-stirred solution of 25 g. of sitosteryl chloride in 500 cc. of glacial acetic acid heated at 55° on a water-bath was added a solution of 20 g. of chromic anhydride in 30 cc. of 50% acetic acid during one hour. A small amount of ethanol was then added, the mixture evaporated *in vacuo* to a volume of 250 cc. and 20 cc. of water added to the residual solution. The solution was cooled at 0° for twenty hours. The product was washed with 75% acetic acid and 95% ethanol, and crystallized from acetone to give white plates, m. p. 155–156°.

Anal. Calcd. for $C_{29}H_{47}OCl$: C, 77.85; H, 10.6. Found: C, 77.7; H, 10.5.

7-Hydroxysitosteryl Chloride.—A solution of 1 g. of 7-ketositosteryl chloride and 1 g. of aluminum isopropylate in 45 cc. of dry isopropyl alcohol was refluxed for twelve hours. The residual material was diluted with water and extracted with ether. Evaporation of the ether gave a crystalline residue which was recrystallized from methanol–acetone to give white plates, m. p. 138–139°.

Anal. Calcd. for $C_{29}H_{49}OCl$: C, 77.5; H, 11.0. Found: C, 77.7; H, 10.8.

7-Ketositosterylene.—A mixture of 200 mg. of 7-ketositosteryl chloride, 9 cc. of 95% ethanol, 0.5 cc. of water and 300 mg. of potassium hydroxide was refluxed for ninety minutes. The solution was diluted with water and the precipitated solid extracted with ether. Evaporation of the ether gave a residue which was crystallized from acetone–ethanol as pale yellow plates, m. p. 106–107°.

Anal. Calcd. for $C_{29}H_{46}O$: C, 84.8; H, 11.3. Found: C, 84.7; H, 11.2.

7-Ketositostyl Chloride.—A mixture of 2 g. of 7-ketositosteryl chloride, 700 mg. of Adams catalyst and 100 cc. of ether was shaken with hydrogen at 3 atm. pressure at room temperature for six hours. The mixture was filtered and the filtrate evaporated. The residue was crystallized from acetone–ethanol as white plates, m. p. 128–129°.

Anal. Calcd. for $C_{29}H_{49}OCl$: C, 77.5; H, 11.0. Found: C, 77.7, 77.4; H, 10.9, 11.0.

This product was recovered unchanged after heating for two hours at 60° with chromic anhydride.

A mixture of 150 mg. of 7-ketositostyl chloride, 300 mg. of Adams catalyst and 100 cc. of glacial acetic acid was shaken with hydrogen at 3 atmospheres pressure for five hours at room temperature. The product was crystallized from acetone–methanol to give white needles, m. p. 107–109°. This gave no depression with a sample of sitostyl chloride, m. p. 107–109°.

Anal. Calcd. for $C_{29}H_{51}Cl$: C, 80.0; H, 11.8. Found: C, 79.7; H, 11.8.

Summary

A short study has been made of the action of potassium permanganate in acetic acid on cholesterol and sitosterol compounds.

The preparation and some reactions of 7-ketositosteryl chloride are reported.

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