604. *The Chemistry of the "Insoluble Red" Woods. Part VIII.* The Synthesis of Analogous Anhydro-7-hydroxybenzopyranols and a Note on the Oxidation of Deoxybenzoins.*

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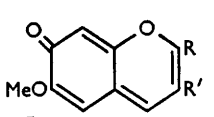
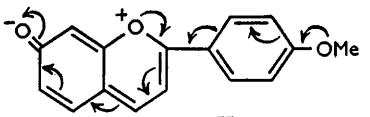
The synthesis of several anhydro-7-hydroxybenzopyranols with structures comparable to the provisional formulæ proposed in Part VI [1] for santalin and santarubin is described. The close similarity between the properties of the synthetic and the natural bases affords collateral evidence in support of the suggested structures.

The oxidation of deoxybenzoins with potassium permanganate or lead tetra-acetate generally yields the corresponding benzils, and not the benzoins as previously reported.[2,3]

In Part VI [1] it was suggested that the complex "insoluble red" wood pigments santalin and santarubin could be provisionally represented by the general anhydro-pyranol structure (I). In view of the scarcity of analytical evidence due to the intractable nature of the pigments the present synthesis of anhydro-pyranols substituted with phenyl groups in both the 2- and the 3-position was carried out for purposes of comparison. Accordingly the condensation of various deoxybenzoins with *o*-hydroxybenzaldehydes, particularly 2 : 4-dihydroxy-5-methoxybenzaldehyde, under the usual conditions has given a number of anhydro-pyranols of type (I) which have been characterised by conversion into the corresponding flavylium salts. The methoxylated synthetical compounds show a marked resemblance to the natural bases, santalin and santarubin, and their derivatives. Thus both groups show some tendency to persist in the amorphous form and can only be crystallised with difficulty when they then show the same tenacious retention of solvent



(I)



(II)

of crystallisation. Further, the methyl ethers of santalin and santarubin could not be crystallised from benzene–light petroleum in the absence of a little methanol; the synthetic anhydro-bases behave in the same manner.

The infrared absorption spectra of the ethers of santalin and santarubin show (*a*) that these ethers have a very close structural similarity with each other and with the synthetic compounds and (*b*) that the ethers of santarubin obtained in various ways (Part VI) are identical. Moreover, the spectra of the natural compounds disclose no new structural or

* Part VII, *J.*, 1957, 542.

[1] Robertson and Whalley, *J.*, 1954, 2794.
[2] Robertson, Suckling, and Whalley, *J.*, 1949, 1571.
[3] Badcock, Cavill, Robertson, and Whalley, *J.*, 1950, 2961.

functional features in santalin or santarubin although the complexity of the finger-print regions of the spectra suggests the presence of at least two, and possibly three, substituted phenyl residues as originally proposed.[1] The infrared absorption spectra of both the natural and the synthetic methoxylated anhydro-bases show extremely weak carbonyl absorption (in Nujol) in the region **1634—1645** cm.$^{-1}$ ($\alpha\beta$: $\alpha'\beta'$-diunsaturated *cyclo*hexadienone) as follows: tri-*O*-methylsantarubin, **1639**; tetra-*O*-methylsantalin, **1639**; anhydro-7-hydroxy-3-(3 : 4-dimethoxyphenyl)-6-methoxy-2-(2 : 4 : 6-trimethoxyphenyl)benzopyranol, **1645**; anhydro-7-hydroxy-2-(2 : 4-dimethoxyphenyl)-3-(3 : 4-dimethoxyphenyl)-6-methoxybenzopyranol, **1637**; and anhydro-7-hydroxy-2-(4-diphenylyl)-3-(3 : 4-dimethoxyphenyl)-6-methoxybenzopyranol, **1634** cm.$^{-1}$. On the other hand anhydro-bases devoid of methoxyl groups exhibit strong absorption in this region, independently of whether the phenyl substituents are in the 2 : 4- or 2 : 3-positions, *e.g.*, anhydro-2-(4-diphenylyl)-7-hydroxy-3-phenylbenzopyranol, **1642**; anhydro-8-ethyl-7-hydroxy-2 : 4-diphenylbenzopyranol, **1641**; and anhydro-6-ethyl-7-hydroxy-2 : 4-diphenylbenzopyranol, **1639** cm.$^{-1}$. The weak carbonyl absorption of the methoxylated anhydro-bases may be ascribed to the tendency of these compounds to exist in the zwitterion forms (II). In confirmation of our conclusion that tetra-*O*-methylsantalin [1] is obtained as a stable hydrate the infrared absorption spectrum of this compound shows hydroxyl group absorption at **3497** cm.$^{-1}$, whilst tri-*O*-methylsantarubin,[1] which is devoid of solvent, does not exhibit absorption in this region.

On hydrolytic fission the synthetic bases give rise to the requisite *o*-hydroxybenzaldehydes in agreement with the absence of a substituent in the 4-position of the pyranol ring. This behaviour is strictly analogous to that of the natural pigments and supports the formulations of Part VI.[1]

Furthermore, unpublished work from this laboratory indicates that anhydro-7-hydroxy-2-phenylbenzopyranols which lack substituents in the 3-, 4-, and 5-positions are very unstable. The stability of tri-*O*-methylsantarubin and tetra-*O*-methylsantalin which we have shown to be devoid of substituents in the 4- and 5-positions indicates the presence of a substituent (phenyl) in the 3-position as required by our tentative formulæ for the pigments.

Oxidation of Deoxybenzoins.—In earlier work on the oxidation of selected methoxylated deoxybenzoins with potassium permanganate and lead tetra-acetate,[1,2] it was concluded that the products were benzoins, because, *inter alia*, (*a*) with lead tetra-acetate deoxybenzoin is oxidised almost quantitatively to benzoin [4] (this has been substantiated), (*b*) with methoxylated deoxybenzoins each oxidising agent gave the same product,[3] (*c*) with lead tetra-acetate flavanols are obtained from flavanones,[5] and (*d*) with the same reagent reactive methylene groups usually undergo monoacetoxylation.[6] The corresponding benzil structure for the oxidation products of the methoxylated deoxybenzoins was not entirely excluded [2] but attempts to prepare methoxylated benzils by unequivocal methods, *e.g.*, oxidation of methoxylated deoxybenzoins with selenium dioxide, a procedure applicable to simple deoxybenzoins,[7] has given negative results (unpublished work by one of us, W. B. W.). However, a comparative examination of the infrared absorption spectra (a technique not available to us at the time of our earlier communications) of these oxidation products together with a number of authentic benzoins and benzils, clearly shows the absence of hydroxyl groups in our oxidation products from deoxybenzoins and their presence in authentic benzoins. This result in conjunction with the oxidation of benzoin and anisoin to benzil and anisil respectively clearly defines the oxidation products described in Parts III [2] and IV [3] as benzils, in agreement with the fact that these products have now been found to yield quinoxaline derivatives by more drastic methods than those originally

[4] Cavill, Robertson, and Whalley, *J.*, 1949, 1567.
[5] Cavill, Dean, McGookin, Marshall, and Robertson, *J.*, 1954, 4573.
[6] Dimroth and Schweitzer, *Ber.*, 1923, **56**, 1375.
[7] Riley, Morley, and Friend, *J.*, 1932, 1875.

employed.[2,3] This rationalises our failure to prepare aryl esters of the products or to effect their further oxidation with chromic oxide. Further confirmation of the benzil structure has been provided by the production of 2 : 4 : 2′ : 4′-tetramethoxybenzil by the oxidation of (*a*) 2 : 4 : 2′ : 4′-tetramethoxydeoxybenzoin with lead tetra-acetate, (*b*) the same deoxybenzoin with potassium permanganate, and (*c*) 2-hydroxy-4 : 2′ : 4′-trimethoxydeoxybenzoin with potassium permanganate followed by methylation of the product. The identity of the 2 : 4 : 2′ : 4′-tetramethoxybenzil from these three sources was confirmed by a comparison of the infrared absorption spectra, whilst the structure of the authentic specimen of 2 : 4 : 2′ : 4′-tetramethoxybenzil [8] has been unequivocally established.[9]

It is of interest that the majority of the benzils described in this paper and in Parts III [2] and IV [3] are colourless.

Experimental

Anhydro-2-(4-*diphenylyl*)-7-*hydroxy*-3-*phenylbenzopyranol*.—A solution of 4-phenyldeoxybenzoin (1·3 g.) and β-resorcylaldehyde (0·7 g.) in ethyl acetate (50 ml.) was saturated at 0° with hydrogen chloride and next day the crystalline precipitate was purified from acetic acid containing 1% of hydrochloric acid to give 7-*hydroxy*-3 : 4′-*diphenylflavylium chloride* (0·3 g.) in dark red prisms or orange plates, m. p. 309—310° (decomp.) after darkening from 170° (Found : C, 78·7; H, 5·1; Cl, 8·5. $C_{27}H_{19}O_2Cl$ requires C, 79·0; H, 4·7; Cl, 8·6%). Addition of ether (300 ml.) to the ethyl acetate mother-liquors left after the isolation of this salt gave an amorphous precipitate (1 g.) which, on purification by chromatography from chloroform on neutralised aluminium oxide, followed by elution with the same solvent, furnished *anhydro*-2-(4-*diphenylyl*)-7-*hydroxy*-3-*phenylbenzopyranol* (0·3 g.) which separated from benzene or benzene–light petroleum (b. p. 60—80°), containing a trace of methanol, in red plates or needles, m. p. 210° (decomp.), insoluble in 2N-aqueous sodium hydroxide (Found : C, 84·1, 84·3; H, 5·0, 5·1. $C_{27}H_{18}O_2,0{\cdot}5H_2O$ requires C, 84·6; H, 5·0%).

Prepared by the addition of excess of perchloric acid to a solution of the above anhydro-base in acetic acid or by the condensation of 4-phenyldeoxybenzoin (1·3 g.) and β-resorcylaldehyde (0·7 g.) in ethyl acetate (50 ml.), containing 70% aqueous perchloric acid (2 ml.), with excess of hydrogen chloride at 0° during 24 hr., 7-*hydroxy*-3 : 4′-*diphenylflavylium perchlorate* separated from acetic acid, containing 1% of perchloric acid, in red needles, m. p. 265° (decomp.) (Found : C, 66·9, 67·0, 67·2; H, 4·3, 4·2, 4·3; Cl, 6·7, 6·8. $C_{27}H_{19}O_6Cl,0{\cdot}5H_2O$ requires C, 67·1; H, 4·1; Cl, 7·3%). With picric acid a solution of the anhydro-base in benzene gave 7-*hydroxy*-3 : 4′-*diphenylflavylium picrate*, forming yellow-brown needles, m. p. 220° (decomp.) (Found : C, 65·2, 65·6; H, 3·4, 3·6; N, 7·1. $C_{33}H_{21}O_9N_3$ requires C, 65·3; H, 3·5; N, 7·0%). The *ferrichloride* separated from acetic acid containing hydroferrichloric acid in red needles, m. p. 218—221° (decomp.) (Found : C, 54·9; H, 3·8; Cl, 25·1; Fe, 10·0. $C_{27}H_{19}O_2Cl_4Fe,H_2O$ requires C, 54·8; H, 3·6; Cl, 24·0; Fe, 9·5%).

Methylation of anhydro-2-(4-diphenylyl)-7-hydroxy-3-phenylbenzopyranol (1 g.) in boiling benzene (50 ml.), containing potassium carbonate (10 g.) and excess of methyl sulphate, for 6 hr. gave rise to 2-(4-*diphenylyl*)-7-*methoxy*-3-*phenylbenzopyranol* (1 g.) which could not be satisfactorily crystallised but which separated from benzene as a colourless semi-crystalline solid with an indefinite m. p. (Found : C, 82·5; H, 5·4; OMe, 5·2. $C_{27}H_{19}O_2{\cdot}OMe$ requires C, 82·7; H, 5·4; OMe, 7·6%). The *perchlorate* from this base crystallised from acetic acid containing 1% perchloric acid in red needles, m. p. 235° (decomp.) (Found : C, 68·6; H, 4·2; Cl, 6·8. $C_{28}H_{21}O_6Cl$ requires C, 68·8; H, 4·3; Cl, 7·2%). The chloride, picrate, and ferrichloride did not crystallise.

Anhydro-2-(2 : 4-*dimethoxyphenyl*)-3-(3 : 4-*dimethoxyphenyl*)-7-*hydroxybenzopyranol*.—Interaction of 2 : 4 : 3′ : 4′-tetramethoxydeoxybenzoin (1·6 g.) with β-resorcylaldehyde (0·7 g.) in ethyl acetate (50 ml.) saturated with hydrogen chloride at 0° for 24 hr. gave a clear solution which on dilution with ether (300 ml.) deposited an amorphous red solid (2 g.). A solution of this in chloroform (600 ml.) was chromatographed on neutralised aluminium oxide and eluted with chloroform (100 ml.), giving a red base which did not crystallise and failed to yield a crystalline

[8] Schrauffstätter, *Chem. Ber.*, 1948, **81**, 240.
[9] Whalley, *J.*, 1956, 3213.

chloride or perchlorate. Prepared in benzene, the *picrate* formed crimson prisms, m. p. 194–196° (decomp.), which appeared to contain benzene of crystallisation [Found: C, 61·2, 61·3; H, 4·2, 4·1; N, 6·0, 5·9; OMe, 16·6, 17·3. Calc. for $C_{27}H_{13}O_9N_3(OMe)_4$: C, 57·5; H, 3·9; N, 6·5; OMe, 19·1. $C_{27}H_{13}O_9N_3(OMe)_4,C_6H_6$ requires C, 61·2; H, 4·3; N, 5·8; OMe, 17·1%]. Regenerated from the crystalline picrate by chromatography on aluminium oxide, the anhydro-base was amorphous and, with much difficulty, was converted into crystalline 3-(3 : 4-*dimethoxyphenyl*)-7-*hydroxy*-2′ : 4′-*dimethoxyflavylium perchlorate*, red prisms, m. p. 118—120° (decomp.) (from acetic acid) [Found: C, 52·4, 52·5; H, 5·1, 5·0; Cl, 5·9, 5·8; OMe, 22·0, 22·1. $C_{21}H_{11}O_6Cl(OMe)_4,3H_2O$ requires C, 52·4; H, 5·1; Cl, 6·2; OMe, 21·7%]. The corresponding *chloride* separated from aqueous-alcoholic hydrochloric acid in red needles, m. p. 170—172° (decomp.) [Found: C, 65·7; H, 5·0; Cl, 7·3; OMe, 26·1. $C_{21}H_{11}O_2Cl(OMe)_4$ requires C, 66·1; H, 5·1; Cl, 7·8; OMe, 27·3%]. The ferrichloride did not crystallise.

Prepared from the anhydro-base by the standard method, 2-(2 : 4-*dimethoxyphenyl*)-3-(3 : 4-*dimethoxyphenyl*)-7-*methoxybenzopyranol* separated from benzene as a semicrystalline, colourless solid, m. p. 105—120° [Found: C, 69·5, 69·7; H, 6·0, 6·2; OMe, 35·0. $C_{21}H_{17}O_2(OMe)_5$ requires C, 69·3; H, 5·8; OMe, 34·4%]. The salts from this base did not crystallise.

Anhydro-2-(2 : 4-dimethoxyphenyl)-7-hydroxy-3-*p*-methoxyphenylbenzopyranol was obtained as an amorphous red solid which gave a *picrate*, forming red prisms, m. p. 220—222° (decomp.), from a benzene solution of picric acid [Found: C, 58·2; H, 3·9; N, 7·0; OMe, 14·8. $C_{27}H_{14}O_9N_3(OMe)_3$ requires C, 58·3; H, 3·7; N, 6·8; OMe, 15·1%]. Regenerated by chromatography of the picrate, the amorphous anhydro-base gave the *chloride* which separated from aqueous-alcoholic hydrochloric acid in red needles, m. p. 125—127° (decomp.) [Found: C, 62·8, 62·7; H, 5·6, 5·4; Cl, 7·4; OMe, 19·5. $C_{21}H_{12}O_2Cl(OMe)_3,2H_2O$ requires C, 62·6; H, 5·4; Cl, 7·7; OMe, 20·2%]. The perchlorate and ferrichloride did not crystallise.

Anhydro-2-(2 : 4-*dimethoxyphenyl*)-3-(3 : 4-*dimethoxyphenyl*)-7-*hydroxy*-6-*methoxybenzopyranol*.—(*a*) Interaction of 2 : 4 : 3′ : 4′-tetramethoxydeoxybenzoin (3·2 g.) and 2 : 4-dihydroxy-5-methoxybenzaldehyde (1·7 g.) in ethyl acetate (200 ml.) saturated with hydrogen chloride, followed by dilution with ether (500 ml.), gave a red precipitate (4 g.) which was chromatographed from chloroform on neutralised aluminium oxide. This purified *anhydro-base* (2·9 g.) separated from benzene–light petroleum (b. p. 60—80°) containing 1% of methanol, in orange-red needles, m. p. 193° [Found: C, 69·7; H, 5·4; OMe, 33·5. $C_{21}H_9O_2(OMe)_5$ requires C, 69·6; H, 5·4; OMe, 34·6%].

(*b*) Condensation of 2 : 4 : 3′ : 4′-tetramethoxydeoxybenzoin (1 g.) and 2 : 4 : 5-trihydroxybenzaldehyde (0·5 g.) in the usual manner followed by chromatography of the product gave a red gum. This was methylated by methyl sulphate–acetone–potassium carbonate, giving anhydro-2-(2 : 4-dimethoxyphenyl)-3-(3 : 4-dimethoxyphenyl)-7-hydroxy-6-methoxybenzopyranol (0·1 g.), m. p. and mixed m. p. 193°, after purification by chromatography. Prepared from this, 2-(2 : 4-*dimethoxyphenyl*)-3-(3 : 4-*dimethoxyphenyl*)-7-*hydroxy*-6-*methoxyflavylium chloride* separated from alcoholic hydrochloric acid in red needles, m. p. 128° (decomp.) [Found: C, 59·9, 59·6; H, 5·6, 5·7; Cl, 6·6, 6·6; OMe, 28·9. $C_{21}H_{10}O_2Cl(OMe)_5,2H_2O$ requires C, 59·9; H, 5·6; Cl, 6·8; OMe, 29·7%], and the *perchlorate* from alcohol containing 1% of perchloric acid in crimson prisms, m. p. 165° (decomp.) [Found, for a specimen dried for 5 hr. at 100° over P_2O_5: C, 55·1, 55·0; H, 4·8, 4·8; Cl, 7·7, 7·5; OMe, 24·9. Found, for a specimen dried for 12 hr. over $CaCl_2$: C, 51·7, 51·5; H, 4·9, 5·3; Cl, 7·1, 7·1; OMe, 23·9. $C_{21}H_{10}O_6Cl(OMe)_5,H_2O$ requires C, 55·1; H, 4·8; Cl, 6·3; OMe, 27·4. $C_{21}H_{10}O_6Cl(OMe)_5,3H_2O$ requires C, 51·8; H, 5·2; Cl, 5·9; OMe, 25·7%]. The *picrate* formed deep red needles, m. p. 175—180° (decomp.), from methanol [Found: C, 56·5; H, 3·9; N, 6·4; OMe, 20·8. $C_{27}H_{12}O_9N_3(OMe)_5$ requires C, 56·7; H, 4·0; N, 6·2; OMe, 22·9%], and the *ferrichloride* from acetic acid, containing hydroferrichloric acid, red needles, m. p. 173—175° (decomp.) [Found: C, 47·8; H, 4·1; Cl, 22·5; OMe, 18·1; Fe, 8·9. $C_{21}H_{10}O_2Cl_4Fe(OMe)_5$ requires C, 48·2; H, 3·9; Cl, 21·9; OMe, 23·9; Fe, 8·6%].

Prepared from the foregoing pyranol with methyl sulphate and alkali in the usual manner, 2-(2 : 4-*dimethoxyphenyl*)-3-(3 : 4-*dimethoxyphenyl*)-6 : 7-*dimethoxybenzopyranol* separated from benzene as a colourless amorphous solid of indefinite m. p. [Found: C, 67·2; H, 5·9; OMe, 39·2. $C_{21}H_{10}O_2(OMe)_6$ requires C, 67·5; H, 5·9; OMe, 38·7%], which gave a *perchlorate*, forming crimson needles, m. p. 236—238° (decomp.), from acetic acid or methanol containing 1% of perchloric acid [Found: C, 56·0, 56·1; H, 5·0, 5·0; Cl, 6·6; OMe, 29·7, 30·0. $C_{21}H_9O_5Cl(OMe)_6,H_2O$ requires C, 55·8; H, 5·0; Cl, 6·1; OMe, 32·0%], and a *picrate*, red

plates, m. p. 206° (decomp.), from methanolic picric acid [Found: C, 56·9; H, 4·2; N, 6·1; OMe, 26·2. $C_{27}H_{11}O_8N_3(OMe)_6$ requires C, 57·3; H, 4·2; N, 6·1; OMe, 26·9%]. The chloride and ferrichloride did not crystallise.

A solution of anhydro-2-(2 : 4-dimethoxyphenyl)-3-(3 : 4-dimethoxyphenyl)-7-hydroxy-6-methoxybenzopyranol (1 g.) in acetone (100 ml.) was oxidised by the method employed for the corresponding derivatives of santalin and santarubin.[1] The clarified mixture from three oxidations was extracted with ether and then with chloroform, and the ethereal extract washed with 2N-aqueous sodium hydrogen carbonate solution. Evaporation of the chloroform extract left unchanged anhydro-base (0·2 g.) whilst the ethereal solution gave 2 : 4 : 3′ : 4′-*tetramethoxybenzil* forming pale yellow prisms (0·4 g.), m. p. 110°, after purification from alcohol followed by sublimation at 110°/0·001 mm. [Found: C, 65·5; H, 5·5; OMe, 37·6. $C_{14}H_6O_2(OMe)_4$ requires C, 65·5; H, 5·5; OMe, 37·6%]. The *quinoxaline* separated from alcohol in pale yellow prisms, m. p. 152° [Found: C, 71·5; H, 5·5; N, 7·1; OMe, 30·7. $C_{20}H_{10}N_2(OMe)_4$ requires C, 71·6; H, 5·5; N, 7·0; OMe, 30·8%]. The aqueous sodium hydrogen carbonate washings furnished veratric acid (25 mg.) and 2 : 4-dimethoxybenzoic acid (50 mg.).

A solution of the anhydro-base (1 g.) in methanol (50 ml.) containing potassium hydroxide (15 g.) and water (10 ml.) was refluxed for 4 hr. in a stream of nitrogen. The combined hydrolysates from two experiments were cooled, and the alkali-insoluble product (1 g.) was collected, dried, and sublimed at 150°/0·001 mm., giving 2 : 4 : 3′ : 4′-tetramethoxydeoxybenzoin (0·2 g.), m. p. 101° [Found: C, 68·3; H, 6·5; OMe, 39·0. Calc. for $C_{14}H_8O(OMe)_4$: C, 68·3; H, 6·4; OMe, 39·2%]. Purification of the residue from the sublimation by chromatography of a chloroform solution on activated aluminium oxide followed by crystallisation from benzene–light petroleum (b. p. 60—80°), containing 1% of methanol, gave unchanged anhydro-base (40 mg.).

The acidified hydrolysate was exhaustively extracted with ether, and the extract purified by pouring through a column of alumina. Evaporation of the eluate followed by crystallisation of the residue from benzene (charcoal) furnished 2 : 4-dihydroxy-5-methoxybenzaldehyde (0·2 g.), m. p. 150° (Found: C, 57·2; H, 5·0; OMe, 18·7. Calc. for $C_7H_5O_3{\cdot}OMe$: C, 57·1; H, 4·8; OMe, 18·5%).

Anhydro-2-(4-diphenylyl)-7-hydroxy-6-methoxy-3-phenylbenzopyranol.—Prepared from 4-phenyldeoxybenzoin (1 g.) and 2 : 4-dihydroxy-5-methoxybenzaldehyde (1 g.), the *anhydro-base* separated from benzene–methanol in crimson needles or prisms (0·6 g.), m. p. 135° (decomp.) [Found: C, 81·1, 81·2; H, 5·3, 5·2; OMe, 8·3. $C_{27}H_{17}O_2(OMe),0{\cdot}5H_2O$ requires C, 81·3; H, 5·1; OMe, 7·5%]. With hydrochloric acid this gave 7-*hydroxy*-6-*methoxy*-3 : 4′-*diphenylflavylium chloride* which formed brown needles, m. p. 216° (decomp.) (Found: C, 72·5, 72·5; H, 5·4, 5·3; Cl, 7·5, 7·7; OMe, 6·5. $C_{27}H_{18}O_2Cl{\cdot}OMe,H_2O$ requires C, 73·3; H, 5·1; Cl, 7·5; OMe, 6·8%). The corresponding *perchlorate* separated from aqueous acetic acid in crimson prisms, m. p. 259—262° (decomp.) (Found: C, 65·2, 65·6; H, 4·0, 3·9; Cl, 7·3, 7·1; OMe, 5·9. $C_{27}H_{18}O_6Cl{\cdot}OMe,0{\cdot}5H_2O$ requires C, 65·4; H, 4·2; Cl, 6·9; OMe, 6·0%), and the *ferrichloride* from acetic acid in red needles, m. p. 218° (decomp.) (Found: C, 52·6; H, 3·2; Cl, 26·5; OMe, 4·6; Fe, 8·0. $C_{27}H_{18}O_2Cl_4Fe{\cdot}OMe,HCl$ requires C, 52·6; H, 3·3; Cl, 27·7; OMe, 4·8; Fe, 8·8%).

Oxidation of the anhydro-base (1 g.) as described previously [1] gave 4-phenylbenzil (50 mg.), m. p. 105° (Found: C, 84·2; H, 5·2. Calc. for $C_{20}H_{14}O_2$: C, 83·9; H, 4·9%), together with benzoic acid as the only identifiable acid, whilst alkali degradation of the base (2 g.) gave 2 : 4-dihydroxy-5-methoxybenzaldehyde (50 mg.) together with unchanged base (10 mg.) and 4-phenyldeoxybenzoin (80 mg.), m. p. and mixed m. p. 148° (Found: C, 88·0; H, 5·6. Calc. for $C_{20}H_{16}O$: C, 88·2; H, 5·9%).

Anhydro-3-(3 : 4-dimethoxyphenyl)-7-hydroxy-6-methoxy-2-(2 : 4 : 6-trimethoxyphenyl)benzopyranol.—Prepared from 2 : 4 : 6 : 3′ : 4′-pentamethoxydeoxybenzoin (3·5 g.) and 2 : 4-dihydroxy-5-methoxybenzaldehyde (1·7 g.), the *anhydro-base* (3·2 g.) separated from benzene–methanol in orange prisms, m. p. 180° [Found: C, 65·8; H, 5·7; OMe, 37·6. $C_{21}H_8O_2(OMe)_6,H_2O$ requires C, 65·3; H, 5·7; OMe, 37·6%], and gave the corresponding *flavylium chloride* which formed scarlet prisms, m. p. 175°, from aqueous-alcoholic hydrochloric acid [Found: C, 59·2, 59·0; H, 5·3, 5·4; Cl, 6·7, 6·9; OMe, 33·0. $C_{21}H_9O_2Cl(OMe)_6,2H_2O$ requires C, 58·8; H, 5·6; Cl, 6·5; OMe, 33·8%]. The *perchlorate* separated from methanol containing 1% perchloric acid in red needles, m. p. 258—260° (decomp.) [Found: C, 53·0, 52·8; H, 4·8, 5·0; Cl, 6·2, 6·5; OMe, 29·5. $C_{21}H_9O_6Cl(OMe)_6,2H_2O$ requires C, 52·7; H, 5·0; Cl, 5·8; OMe, 30·3%], and the

picrate in maroon needles (from benzene–picric acid), m. p. 205° [Found: C, 56·2; H, 4·0; N, 5·9; OMe, 25·4. $C_{27}H_{11}N_3O_9(OMe)_6$ requires C, 56·0; H, 4·1; N, 5·9; OMe, 26·3%].

Oxidation of this anhydro-base (3 g.) gave unchanged base (0·1 g.), and 2 : 4 : 6 : 3′ : 4′-*pentamethoxybenzil* which formed pale yellow prisms (0·2 g.), m. p. 175°, from benzene [Found: C, 63·1; H, 5·8; OMe, 42·4. $C_{14}H_5O_2(OMe)_5$ requires C, 63·3; H, 5·6; OMe, 43·0%], together with veratric acid (50 mg.) as the only identifiable acid. Distillation of the neutral fraction from the mother-liquors remaining after the separation of the benzil gave 1 : 3 : 5-trimethoxybenzene (20 mg.), m. p. 52° [Found: C, 63·7; H, 6·6; OMe, 53·0. Calc. for $C_6H_3(OMe)_3$: C, 64·3; H, 7·2; OMe, 55·4%]. Alkali degradation of the anhydro-base (1 g.) gave unchanged base (0·1 g.), 2 : 4-dihydroxy-5-methoxybenzaldehyde (0·1 g.), m. p. and mixed m. p. 150°, and 2 : 4 : 6 : 3′ : 4′-pentamethoxydeoxybenzoin (0·1 g.), m. p. 110° [Found: C, 66·0; H, 6·5; OMe, 44·6. Calc. for $C_{14}H_7O(OMe)_5$: C, 65·9; H, 6·4; OMe, 44·8%].

Anhydro-3-(3 : 4-*dimethoxyphenyl*)-2-(4-*diphenylyl*)-7-*hydroxy*-6-*methoxybenzopyranol*.—Prepared from 3′ : 4′-dimethoxy-4-phenyldeoxybenzoin (2 g.) and 2 : 4-dihydroxy-5-methoxybenzaldehyde (1 g.), the *anhydro-base* (1·6 g.) formed crimson prisms, m. p. 159—160° [Found: C, 74·9, 75·1; H, 5·3, 5·4; OMe, 18·2. $C_{27}H_{15}O_2(OMe)_3,H_2O$ requires C, 74·7; H, 5·4; OMe, 19·3%]. The flavylium chloride separated from aqueous-alcoholic hydrochloric acid as a *hydrate* in deep red needles, m. p. 198° (decomp.) [Found: C, 69·0, 69·1; H, 5·2, 5·2; Cl, 6·8, 6·6; OMe, 17·1. $C_{27}H_{16}O_2Cl(OMe)_3,H_2O$ requires C, 69·4; H, 5·2; Cl, 6·8; OMe, 17·9%], the perchlorate as a *dihydrate* in crimson prisms, m. p. 274° (decomp.), from acetic acid [Found: C, 59·5, 59·7; H, 4·3, 4·0; Cl, 6·0; OMe, 15·0. $C_{27}H_{16}O_6Cl(OMe)_3,2H_2O$ requires C, 60·0; H, 4·8; Cl, 5·9; OMe, 15·5%], and the *picrate* from benzene–picric acid in red prisms, m. p. 238° (decomp.) [Found: C, 62·0; H, 3·8; N, 6·2; OMe, 12·5. $C_{33}H_{18}O_9N_3(OMe)_3$ requires C, 62·2; H, 3·9; N, 6·0; OMe, 13·4%]. Oxidation of this base (3 g.) gave 3′ : 4′-*dimethoxy*-4-*phenylbenzil* (0·15 g.), m. p. 176° [Found: C, 76·5; H, 5·4; OMe, 18·5. $C_{20}H_{12}O_2(OMe)_2$ requires C, 76·3; H, 5·2; OMe, 17·9%], together with diphenyl-4-carboxylic acid (50 mg.), m. p. 225°, and veratric acid (10 mg.), m. p. 170°. Hydrolytic degradation of the base (1 g.) furnished 2 : 4-dihydroxy-5-methoxybenzaldehyde (50 mg.), m. p. 150°, together with 3′ : 4′-dimethoxy-4-phenyldeoxybenzoin (0·25 g.), m. p. 119° [Found: C, 79·8; H, 6·2; OMe, 18·3. Calc. for $C_{20}H_{14}O(OMe)_2$: C, 79·5; H, 6·0; OMe, 18·7%], and unchanged base (0·2 g.).

Oxidation of Deoxybenzoin.—A solution of deoxybenzoin (1 g.) in acetic acid (20 ml.), containing lead tetra-acetate (2 g.), was kept at 120° until a test portion no longer gave a colour with moist starch–potassium iodide paper (*ca.* 1 hr.) and then diluted with water. On isolation with ether benzoin acetate (1·1 g.) separated from methanol in needles, m. p. and mixed m. p. 83° (Found: C, 76·1; H, 5·3. Calc. for $C_{16}H_{14}O_3$: C, 75·6; H, 5·6%). Hydrolysis of the acetate (0·5 g.) with 2N-sulphuric acid (5 ml.) in alcohol (10 ml.) for 2 hr. at the b. p. gave benzoin in needles, m. p. and mixed m. p. 130° after purification from alcohol.

2 : 4-*Dimethoxybenzil*.—(*a*) A solution of potassium permanganate (2·5 g.) in water (50 ml.) was added during 30 min. to one of 2 : 4-dimethoxydeoxybenzoin (1 g.) in acetone (75 ml.). Isolated in the usual manner, the neutral product was purified from alcohol, giving 2 : 4-*dimethoxybenzil* (0·5 g.) in pale yellow prisms, m. p. 104°, identical with the product previously designated as 2 : 4-dimethoxybenzoin [3] [Found: C, 71·0; H, 5·2; OMe, 22·9. $C_{14}H_8O_2(OMe)_2$ requires C, 71·1; H, 5·2; OMe, 23·0%]. The *quinoxaline*, formed in boiling alcohol during 30 min., separated from alcohol in yellow prisms, m. p. 124—125° [Fouud: C, 76·9; H, 5·4; N, 7·9; OMe, 19·6. $C_{20}H_{12}N_2(OMe)_2$ requires C, 77·2; H, 5·3; N, 8·2; OMe, 18·1%].

(*b*) A solution of potassium permanganate (2·5 g.) in water (50 ml.) was added in portions (10 ml.) during 3 hr. to 2-hydroxy-4-methoxydeoxybenzoin (1 g.) in acetone (75 ml.); on addition of the first portion the mixture was heated to the b. p. to initiate the oxidation which subsequently proceeded without heating. On isolation the non-acidic fraction was purified from alcohol, giving 2-*hydroxy*-4-*methoxybenzil* (0·4 g.) in yellow needles, m. p. 86°; this is readily soluble in 2N-aqueous sodium hydroxide, gives an intense red colour in alcohol with ferric chloride, and does not exhibit an absorption band in the free hydroxyl region of the infrared spectrum either in chloroform solution or in Nujol mull (Found: C, 72·3; H, 4·8; OMe, 12·3. $C_{14}H_9O_3{\cdot}OMe$ requires C, 70·3; H, 4·7; OMe, 12·1%). Methylation of this benzil by methyl sulphate–acetone–potassium carbonate gave 2 : 4-dimethoxybenzil, m. p. and mixed m. p. 104°, identical with a product obtained by route (*a*).

2 : 4 : 6-*Trimethoxybenzil*.—The oxidation of 2 : 4 : 6-trimethoxydeoxybenzoin (1 g.) in boiling acetone (75 ml.) with a solution of potassium permanganate (2·5 g.) in water (50 ml.)

gradually added in 30 min., furnished 2 : 4 : 6-*trimethoxybenzil* (0·6 g.) which formed prisms, m. p. 135°, from alcohol [Found : C, 68·0; H, 5·1; OMe, 30·9. $C_{14}H_7O_2(OMe)_3$ requires C, 68·0; H, 5·4; OMe, 31·0%]. This compound is identical with the product [3] prepared by oxidation of 2 : 4 : 6-trimethoxydeoxybenzoin with lead tetra-acetate and designated as 2 : 4 : 6-trimethoxybenzoin. The *quinoxaline* separated from alcohol in prisms, m. p. 136° [Found : C, 74·2; H, 5·4; N, 7·6; OMe, 24·6. $C_{20}H_{11}N_2(OMe)_3$ requires C, 74·2; H, 5·4; N, 7·5; OMe, 25·0%]. A mixture of this and the parent benzil had m. p. *ca.* 116—121°.

2 : 4 : 3′ : 4′-*Tetramethoxybenzil.*—Oxidation of 2 : 4 : 3′ : 4′-tetramethoxydeoxybenzoin (1 g.) with potassium permanganate (2·5 g.) gave 2 : 4 : 3′ : 4′-tetramethoxybenzil (0·4 g.), forming pale yellow prisms, (0·3 g.), m. p. and mixed m. p. 110°, after repeated purification from alcohol to remove unchanged deoxybenzoin, the last trace of which was difficult to remove [Found : C, 65·7; H, 5·7; OMe, 37·9. Calc. for $C_{14}H_6O_2(OMe)_4$: C, 65·5; H, 5·5; OMe, 37·6%]. Badcock *et al.*[3] record m. p. 94° for the compound prepared by the oxidation of 2 : 4 : 3′ : 4′-tetramethoxydeoxybenzoin with lead tetra-acetate; repetition of this process followed by prolonged purification of the product from alcohol gave 2 : 4 : 3′ : 4′-tetramethoxybenzil identical with that prepared by the permanganate method. The benzil was characterised as the quinoxaline, m. p. and mixed m. p. 152°.

2 : 4 : 6 : 3′ : 4′-*Pentamethoxybenzil.*—Prepared by the method of Badcock *et al.*,[3] the product designated 2 : 4 : 6 : 3′ : 4′-tetramethoxybenzoin is 2 : 4 : 6 : 3′ : 4′-tetramethoxybenzil which formed pale yellow prisms, m. p. and mixed m. p. 175°, from benzene (Found : C, 63·2; H, 5·6. Calc. for $C_{19}H_{20}O_7$: C, 63·3; H, 5·6%). This gave a *quinoxaline* which separated from alcohol in plates, m. p. 176° [Found : C, 69·5; H, 5·8; N, 6·5; OMe, 35·5. $C_{20}H_9N_2(OMe)_5$ requires C, 69·4; H, 5·6; N, 6·5; OMe, 35·9%]; a mixture of this derivative and the parent benzil had m. p. *ca.* 159—160°.

3′ : 4′-*Dimethoxy*-4-*phenylbenzil.*—Condensation of homoveratroyl chloride (from 10 g. of acid) and diphenyl (7·75 g.) with aluminium chloride (15 g.) in nitrobenzene (50 ml.) during 24 hr. gave 3′ : 4′-*dimethoxy*-4-*phenyldeoxybenzoin* (5 g.) which separated from alcohol in needles, m. p. 120° [Found : C, 79·8; H, 6·1; OMe, 17·6. $C_{20}H_{14}O(OMe)_2$ requires C, 79·5; H, 6·1; OMe, 18·7%]. Oxidation of this deoxybenzoin (1 g.) with potassium permanganate (2·5 g.) furnished 3′ : 4′-dimethoxy-4-phenylbenzil (0·6 g.), forming prisms, m. p. and mixed m. p. 176°, from alcohol [Found : C, 76·4; H, 5·4; OMe, 18·3. Calc. for $C_{20}H_{12}O_2(OMe)_2$: C, 76·3; H, 5·2; OMe, 17·9%]. The *quinoxaline* separated from alcohol in prisms, m. p. 146° [Found : C, 80·5; H, 5·5; N, 6·9; OMe, 14·9. $C_{26}H_{16}N_2(OMe)_2$ requires C, 80·4; H, 5·3; N, 6·7; OMe, 14·8%]. The acidic fraction from this oxidation gave diphenyl-4-carboxylic acid, m. p. and mixed m. p. 225°.

With lead tetra-acetate (2·2 g.) in acetic acid at 100° for 30 min. 3′ : 4′-dimethoxy-4-phenyldeoxybenzoin (1 g.) gave 3′ : 4′-dimethoxy-4-phenylbenzil (0·6 g.), m. p. and mixed m. p. 176°.

Oxidation of Anisoin.—The oxidation of *p*-anisoin (1 g.) with potassium permanganate (1·25 g.) furnished *p*-anisil (0·8 g.), the *quinoxaline* from which formed needles, m. p. 149°, from alcohol [Found : C, 77·4; H, 5·4; N, 8·2; OMe, 17·9. $C_{20}H_{12}N_2(OMe)_2$ requires C, 77·2; H, 5·3; N, 8·2; OMe, 18·1%]. Similarly benzoin furnished benzil.

The analyses were carried out by Mr. A. S. Inglis, M.Sc., and his associates of this Department.

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