663. *The Phenolic Resin of the Wood of* Chlorophora excelsa (*Benth. and Hook f.*).

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Chlorophorin, a phenolic resin from *Chlorophora excelsa* (Benth. and Hook f.), has been examined. The results confirm a suggestion by Grundon and King (*Nature*, 1949, **163**, 564) that chlorophorin is a pinosylvin analogue having the partial structure (I).

The wood of *Chlorophora excelsa* (Benth. and Hook f.) is variously known under the names of iroko (the British standard name), mvuli, odum, and kambala, and it has been marketed also under the names of " African teak," " African oak," and " iroko teak." It is one of the best all-round African timbers, and considerable quantities have been exported to Europe. The timber is relatively resistant to decay and to attack by insects, but it is reported to cause skin irritation (Wagner, *Holzmarkt Berl.*, 1938, **55**, 300; Davidson, *Lancet*, 1941, **240**, 38). Our attention was drawn to this wood by Dr. E. G. Manken (private communication) as a result of difficulties experienced by the South African Railways and Harbours in the drying of varnishes applied to it. These difficulties appeared to arise from anti-oxidants present in the wood, since they could be overcome by increasing the proportion of driers in the varnish used.

The only reported chemical examinations of the wood are by Marmasse (" Contribution a l'etude analytique de quelques bois coloniaux," Paris, 1931) and Grundon and King (*Nature*, 1949, **163**, 564).

The brown ethyl-alcoholic and acetone extracts of the wood, on concentration and dilution with water, gave a light-brown powder. From this material there has been obtained a phenolic substance, chlorophorin, which we have not been able to purify completely, though crystalline material has separated from its aqueous diethylene glycol solutions. The crude material, however, readily yielded pure *tetra-acetyl* and *tetrabenzoyl* derivatives and a *tetramethyl ether*, all corresponding in composition to a formula $C_{25}H_{26}(OH)_4$ for chlorophorin.

On distillation with zinc dust crude chlorophorin gave resorcinol, together with a non-aromatic hydrocarbon fraction, b. p. 170—190°. Similarly on alkali fusion, resorcinol was produced, together with vapours smelling strongly like citronellol.

Chlorophorin tetramethyl ether rapidly absorbed bromine from carbon tetrachloride solution, indicating a high degree of unsaturation, and this was confirmed by the fact that both this substance and chlorophorin tetra-acetate absorbed 3 moles of hydrogen to give *hexahydro*-derivatives. On the basis of these observations it seemed possible that the chlorophorin structure contained two dihydric phenol nuclei joined by an aliphatic chain containing three olefinic double bonds. This conclusion was supported by a comparison of the absorption spectrum of hexahydrochlorophorin tetramethyl ether with that of *n*-hexylresorcinol dimethyl ether. The two spectra proved almost coincident when that of the latter (see Fig. 2) was calculated at twice its molecular weight. Since chlorophorin tetramethyl ether gave 2 : 4-dimethoxybenzaldehyde as one product of its oxidation, both with potassium permanganate and with ozone, the nature and mode of union of one of the dihydric phenol nuclei was apparent. That the other aromatic nucleus contained one reactive position was indicated by the fact that hexahydrochlorophorin tetramethyl ether could be titrated with a solution of bromine in carbon tetrachloride; it consumed two moles of bromine under the same conditions as those under which 4-*n*-hexylresorcinol dimethyl ether absorbed one mole : a *dibromohexahydrochlorophorin tetramethyl ether* was formed. Derived from this second aromatic nucleus, a *dicarboxylic acid* $C_9H_8O_6$ has been obtained from chlorophorin tetra-acetate by ozone. This acid corresponds to

Absorption spectra in ethyl alcohol solution.

FIG. 1. FIG. 2.

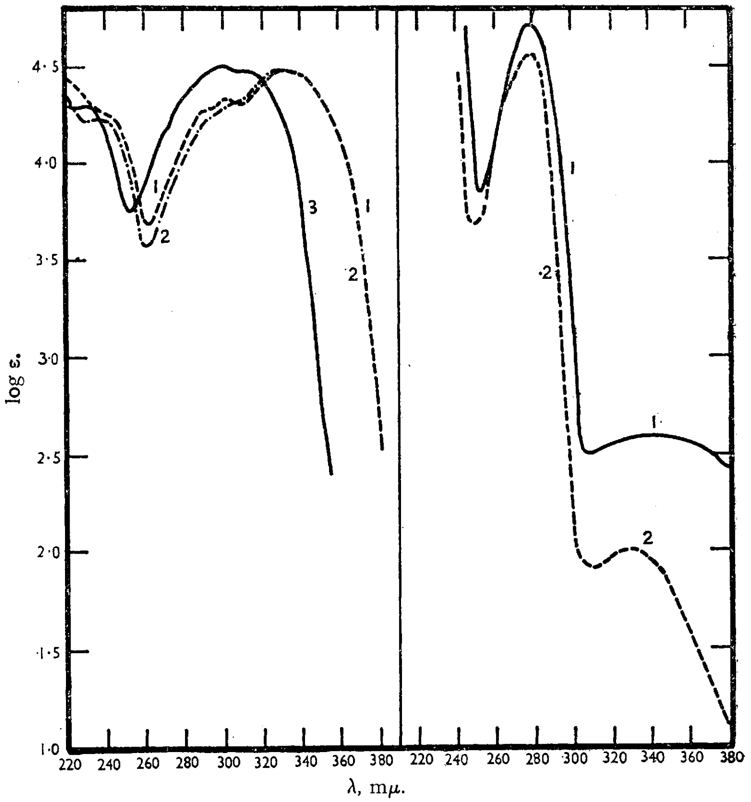


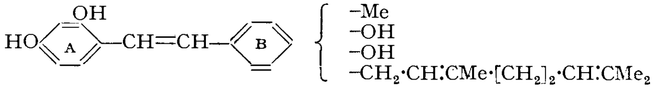
FIG. 1.—1, *Chlorophorin.* 2, *Chlorophorin tetramethyl ether.* 3, *Tetra-acetylchlorophorin.*
FIG. 2.—1, *Hexahydrochlorophorin tetramethyl ether.* 2, n-*Hexylresorcinol dimethyl ether.*
(ε *calculated using double the molecular weight.*)

one compound $C_{11}H_{12}O_6$ formed in the oxidation of chlorophorin tetramethyl ether with potassium permanganate and formulated by Grundon and King provisionally as a dimethoxytoluenedicarboxylic acid. Since Grunden and King are engaged on the further investigation of the structure of this degradation product, we have not pursued these observations further.

In their studies of the aliphatic portion of the molecule, Grundon and King have had considerable success with oxidative degradation of tetrahydro-derivatives of chlorophorin and its tetramethyl ether. After oxidation of the former derivative with alkaline hydrogen peroxide, they isolated an olefinic acid $C_{11}H_{20}O_2$, which on ozonolysis yielded 6-methylheptan-2-one and was formulated by them as $CHMe_2\cdot[CH_2]_3\cdot CMe{:}CH\cdot CH_2\cdot CO_2H$. We oxidised unhydrogenated chlorophorin derivatives. From chlorophorin and chlorophorin tetra-acetate, acetone and malonic acid have been isolated, while qualitative evidence for the formation of lævulic and succinic acid has also been obtained. These observations, in conjunction with those of Grundon and King, demonstrate that the aliphatic residue in chlorophorin is $CMe_2{:}CH\cdot[CH_2]_2\cdot CMe{:}CH\cdot CH_2\cdot$, and that it is the double bond of the *iso*propylidene group which is preferentially hydrogenated in the formation of tetrahydrochlorophorin derivatives. Since chlorophorin tetramethyl ether is inert to maleic anhydride and to sodium and alcohol, it contains no conjugated double bonds, so that a shift in the position of a double bond on hydrogenation is unlikely.

We therefore confirm the suggestion by these authors that chlorophorin is an analogue of pinosylvin (Erdtman, *Annalen*, 1939, **539**, 116) and that it has the partial structure (I) :

(I.)



The asignment of positions to the substituents in the aromatic nucleus B will follow, in large measure, from the study of the acids $C_{11}H_{12}O_6$ and $C_9H_8O_6$ mentioned above, and in view of Grundon and King's work we are not pursuing this problem further.

EXPERIMENTAL.

(Analyses are by Drs. Weiler and Strauss, Oxford.)

Chlorophorin.—This was obtained by extraction of either sawdust or chips of iroko wood, and the yields have proved variable. Although high yields of extracts were obtained from early extractions of sawdust, these were not repeated on later specimens examined. The highest yields recorded were : light petroleum extract, 1·3%; ethyl alcohol extract, 10·3%; acetone extract, 0·34%. Chlorophorin was precipitated from the alcoholic extracts on concentration followed by dilution with water. The precipitate appeared amorphous, but needle-like crystals could be observed under the microscope. The crude product has not been purified completely. It was insoluble in virtually all non-polar solvents, whilst in polar or hydroxylic solvents it dissolved with great ease and once in solution could not be induced to separate again except by precipitation with water. The traces of coloured impurites (probably autoxidation products) with which it was associated could not be removed effectively by the use of charcoals or by chromatographic techniques and no perfectly colourless material has been obtained. Well-defined rosettes of fine needle-shaped crystals could be obtained by cooling solutions of the crude chlorophorin in aqueous diethylene glycol. From their behaviour, however, it is deduced that these crystals probably contained diethylene glycol of crystallisation, and for analytical purposes crystals so obtained were dissolved in alcohol and precipitated by addition of water, in order to remove the associated hygroscopic and high-boiling solvent. A *hydrate* was thus obtained, having m.p. 161—162° [Found : C, 74·0, 74·2, 74·1, 74·2; H, 7·5, 7·4, 7·4, 7·5; *C*-Me (Kuhn–Roth), 7·7. $C_{25}H_{30}O_4,\frac{1}{2}H_2O$ requires C, 74·4; H, 7·7; *C*-Me, 7·4%]. This lost weight only very slowly at 110° in a vacuum, to give the anhydrous substance (Found: C, 76·1; H, 7·3. Calc. for $C_{25}H_{30}O_4$: C, 76·1; H, 7·7%).

Chlorophorin was insoluble in sodium hydrogen carbonate solution, but dissolved in sodium carbonate and sodium hydroxide solutions to give yellow solutions from which the original material was recovered unchanged on addition of acid. It gave no colour reaction with ferric chloride, but coupled with solutions of diazonium salts.

Oxidation of Chlorophorin.—(*a*) *With nitric acid.* Despite repeated experiments under varied conditions, the only product isolated from the oxidation of chlorophorin with nitric acid was oxalic acid.

(*b*) *With aqueous potassium permanganate.* Chlorophorin (5 g.) was dissolved in dilute sodium hydroxide solution, ice was added, and aqueous potassium permanganate (5%) run in with stirring until a faint pink colour persisted in the reaction mixture. The manganese dioxide was filtered off, the filtrate distilled, and the first part of the distillate collected separately. To it was added 2 : 4-dinitrophenylhydrazine reagent, whereupon a yellow 2 : 4-dinitrophenylhydrazone separated, which was recrystallised from aqueous alcohol and identified by m. p. and mixed m. p. as acetone 2 : 4-dinitrophenylhydrazone. After the residue from the distillation had been concentrated to about 500 c.c., it was acidified with dilute sulphuric acid and extracted continuously with ether. The solvent was removed and the crystalline residue crystallised from acetone–benzene. It was identified as oxalic acid by m. p. and qualitative tests. No other product was isolated, though the residue from the ether extraction smelled strongly of acetic acid.

(*c*) *By fusion with alkali in the presence of air.* Chlorophorin (5 g.) was heated with fused potassium hydroxide (20 g.) with stirring. Much frothing occurred in the initial stages of the reaction, and vapours smelling strongly of citronellol were evolved. After two hours' heating at 220—230°, the reaction mass was dissolved in water, acidified, and the products dissolved in ether. The ethereal solution was then extracted successively with sodium hydrogen carbonate, sodium carbonate, and sodium hydroxide solutions. The sodium hydroxide extract was the only one to yield an identifiable product. It was a thick viscous liquid, which crystallised after distillation in a vacuum (yield, 1 g.). The product of benzoylation was identified (mixed m. p.) as resorcinol dibenzoate.

(*d*) *With ozone.* Chlorophorin (8·0 g.) was dissolved in acetic acid and subjected to prolonged (8 hours) treatment with ozonised oxygen (about 5%). The products were then decomposed by addition of hydrogen peroxide and gentle warming on the water-bath. Evaporation to dryness of the resultant mixture gave a yellow viscous residue. This was dissolved in dry alcohol (100 c.c.), sulphuric acid (2 c.c.) was added, and the solution boiled under reflux for 3 hours. The neutral products of the reaction were isolated and distilled. There was obtained about 1·5 g. of distillate (*A*), b. p. 192—200°/650 mm., followed by a smaller fraction (*B*), b. p. 200—225°/650 mm. Fraction (*A*) (saponification equivalent, about 73) was inert to ketonic reagents, though it gave a trace of unidentified product with 2 : 4-dinitrophenylhydrazine. Further the aqueous solution obtained after saponification of this ester with alkali, gave an immediate precipitate of iodoform in the cold on addition of iodine—a reaction very similar to that given by lævulic acid. Fraction *A* was therefore saponified and the resultant solution acidified and continuously extracted with ether. From the resultant extract a white crystalline mass separated on evaporation, which was identified as malonic acid, by mixed-m. p. determination after crystallisation from acetone–benzene. In the crude state the malonic acid gave a faint fluorescein reaction, which was more intense with the material recovered similarly from fraction (*B*), and which was possibly due to associated succinic acid.

Distillation of Chlorophorin with Zinc Dust.—Chlorophorin (2·11 g.) was mixed with zinc dust (30 g.) in a test-tube which was then drawn out to provide direct delivery of the distillate into a second test-tube cooled in ice. On gradual heating of the mixture, vapours passed over and were condensed in the test-tube receiver in two approximately equal layers. These were separated and distilled. The upper layer proved to be hydrocarbon-like (b. p. about 180°/650 mm.) and from its ultra-violet absorption spectrum was non-aromatic in character. It was not further investigated. The lower layer crystallised and was readily identified as resorcinol. In one experiment the resorcinol formed was estimated, by titration with bromide–bromate solution, after separation from associated materials by extraction from ethereal solution with alkali (Found : resorcinol, 0·34 g. Calc. for $C_{25}H_{20}O_4$, if one resorcinol nucleus present per mol., 0·59 g.).

Chlorophorin Tetra-acetate.—Crude chlorophorin was warmed with an excess of acetic anhydride on a water-bath for 1·5 hours and the excess of acetic anhydride destroyed by careful addition of water. After treatment with decolorising charcoal, more water was added, and the acetate separated. It crystallised from alcohol in needle-shaped crystals, m. p. 135° [Found : C, 70·2; H, 6·5; Ac, 30·0, 32·3; *M*, 558. $C_{25}H_{26}(OAc)_4$ requires C, 70·5; H, 6·8; Ac, 29·9%; *M*, 565]. It was optically inactive.

Oxidation of Chlorophorin Tetra-acetate with Ozone.—Chlorophorin tetra-acetate (16·5 g.) was dissolved in chloroform (300 c.c.), the solution cooled in ice, and ozonised oxygen passed through for 12 hours. The reaction mixture was left in the ice-chest for several days whereupon a white crystalline mass separated, was filtered off, and decomposed with amalgamated aluminium and alkali. The solution was then acidified and tested for lævulic acid (cf. Pummerer *et al.*, *Ber.*, 1931, **64**, 809) with negative results. The chloroform filtrate from the ozonisation was shaken with water to decompose ozonides, the solvent removed, and the residue continuously extracted with ether. The extract was boiled with absolute alcohol and sulphuric acid to esterify carboxylic acids, and the esters recovered, after thorough extraction with alkali to remove associated phenolic material. Distillation of the final product gave a fraction, b. p. 190—200°/650 mm., exactly similar to that obtained from the ozonisation of chlorophorin itself. The crystalline product of ozonisation was transferred directly to aqueous alkaline solution and decomposed with aluminium amalgam. The reaction mixture also showed no reaction for lævulic acid when tested with 2 : 4-dinitrophenylhydrazine, but on acidification and continuous extraction with ether a crystalline product was isolated : this gave a purple colour with ferric chloride and, on recrystallisation from water, had m. p. 293° [Found : C, 51·2; H, 4·0%; Ac, 0; equiv., 103·7. $C_9H_8O_6$ (dibasic) requires C, 51·0; H, 3·8%; equiv., 106].

Oxidation of Hydrolysed Chlorophorin Tetra-acetate with Potassium Permanganate.—Chlorophorin tetra-acetate was hydrolysed with alcoholic potassium hydroxide, the alcohol removed by passage of steam, and the residual alkaline solution oxidised with potassium permanganate, as described for chlorophorin. Acetone and oxalic acid were obtained from the products of this oxidation.

Chlorophorin Tetrabenzoate.—Crude chlorophorin was dissolved in pyridine, excess of benzoyl chloride added, and the mixture left overnight. On addition of water to the mixture, a dark oil separated which was washed free from pyridine and benzoic acid and then treated with alcohol. It crystallised from this solvent in radiating clusters of colourless needles, m. p. 164·5—165·5° [Found : C, 78·0; H, 5·7. $C_{25}H_{26}(OBz)_4$ requires C, 78·5; H, 5·7%].

Chlorophorin Tetramethyl Ether.—A solution of crude chlorophorin (10 g.) in methyl alcohol (100 c.c.) was treated with methyl sulphate and potassium hydroxide solution (50%), added alternately and in equivalent amounts, until further additions produced no apparent decrease in the amount of alkali-soluble material present. The product was taken up in ether, washed free from methyl alcohol with water and of acidic material with alkali, and the extracts dried and the ether evaporated. The residue was distilled in a vacuum, and the distillate (b. p. 280—290°/1 mm.) crystallised on being left in the receiver. It was recrystallised from methyl alcohol from which it separated as a felted mass of colourless needles,

m. p. 76—77° [Found : C, 77·0; H, 8·4; *C*-Me (Kuhn–Roth), 6·1; *M*, 418. $C_{25}H_{26}(OMe)_4$ requires C, 77·3; H, 8·5; 2*C*-Me, 6·7%; *M*, 451].

Since this product was inert to acetic anhydride, it was concluded that the methoxyl groups were not completely reactive in the Zeisel determination. The same non-stoicheiometric behaviour was also observed in Zeisel analyses of degradation products such as 2 : 4-dimethoxybenzaldehyde, and 2 : 4-dimethoxybenzoic acid, as well as in the analysis of hexahydrochlorophorin tetramethyl ether.

In some preparations the distillate from the vacuum distillation failed to crystallise and was clearly a mixture, presumably formed by isomerisation of part of the material under the conditions of reaction. Chlorophorin tetramethyl ether failed to react with maleic anhydride in boiling benzene or xylene, though it gave an orange-yellow coloration on mixing of the reagents. This coloration was also given on mixing *n*-hexylresorcinol dimethyl ether with maleic anhydride.

Oxidation of Chlorophorin Tetramethyl Ether with Potassium Permangante.—From oxidations carried out in acetone only a trace of acidic material was isolated, and the main product was a viscous oil which readily yielded a 2 : 4-dinitrophenylhydrazone. This was crystallised from xylene, from which it separated in orange-red elongated plates (Found : N, 16·3. Calc. for $C_{15}H_{14}O_6N_4$: N, 16·2%). It was identified (mixed m. p.) as 2 : 4-dimethoxybenzaldehyde 2 : 4-dinitrophenylhydrazone. An acidic product of the reaction crystallised from aqueous acetic acid in colourless prisms, m. p. (with sublimation and darkening) 284° [Found : C, 55·2; H, 5·25%; equiv., 120. $C_{11}H_{12}O_6$ (dibasic) requires C, 55·0; H, 5·0%; equiv., 120].

Action of Ozone on Chlorophorin Tetramethyl Ether.—Chlorophorin tetramethyl ether (5·0 g.) was dissolved in glacial acetic acid (75 c.c.) and ozonised oxygen (about 5%) passed through the solution for 5 hours. Chromic acid (5·0 g.) in water (5 c.c.) was then added slowly to the mixture which warmed considerably. The solution was left overnight, the glacial acetic acid was then distilled off under vacuum, and the residue was diluted with water and exhaustively extracted with ether. From the ethereal extracts acidic products were then extracted with sodium hydroxide solution. (*a*) The neutral products (1·3 g.) were recovered by evaporation of the ether solution, and were distilled in a vacuum giving a fraction (0·7 g.), b. p. 173—175°/2 mm., which crystallised completely on cooling; and a fraction (0·6 g.), b. p. about 200°/0·5 mm., which partly crystallised on cooling. From both fractions the same product, m. p. 68—69°, was recovered as long stout colourless needles on crystallisation from light petroleum. It was identified by mixed m. p. as 2 : 4-dimethoxybenzaldehyde [Found : C, 65·4; H, 6·1; OMe, 24·9. Calc. for $C_9H_{10}O_3$: C, 65·0; H, 6·1; OMe, 34·4% (the Zeisel determination was carried out with the addition of ammonium iodide at 350°)]. (*b*) Acidic products (0·9 g.) were recovered by acidification of the alkaline extracts above and continuous extraction with ether. They formed a semi-solid mass which was difficult to handle, but gave a crystalline product, m. p. 107·5—108°, on extraction with light petroleum (b. p. 90—100°). This was identified by mixed m. p. as 2 : 4-dimethoxybenzoic acid (Found : C, 59·4; H, 5·5. Calc. for $C_9H_{10}O_4$: C, 59·3; H, 5·5%).

Hexahydrochlorophorin Tetramethyl Ether.—When chlorophorin tetramethyl ether in ethyl acetate was shaken with hydrogen in the presence of a palladium–calcium carbonate catalyst three mols. of hydrogen were absorbed. The catalyst was filtered off, the solvent evaporated, and the residue cooled in the ice-chest. After crystallisation had begun the product was recrystallised from methyl alcohol containing a small amount of water from which it separated as a felted mass of colourless needles, m. p. 49—49·5° [Found : C, 76·2; H, 9·4. $C_{25}H_{32}(OMe)_4$ requires C, 76·3; H, 9·7%].

For the light-absorption spectrum of this compound, see Fig. 2.

Dibromohexahydrochlorophorin Tetramethyl Ether.—Hexahydrochlorophorin tetramethyl ether (0·202 g.) in carbon tetrachloride was titrated with a standard solution of bromine in carbon tetrachloride. Bromine equivalent to 2 mols. was absorbed, whilst in a titration of *n*-hexylresorcinol dimethyl ether, under analogous conditions, bromine equivalent to one mol. was absorbed.

The carbon tetrachloride was evaporated from the solution resulting from the first titration. The residue crystallised when kept, and was recrystallised from ethyl alcohol from which it separated in dense prismatic crystals, m. p. 75° (Found : C, 56·2; H, 6·6; Br, 26·7. $C_{29}H_{42}O_4Br_2$ requires C, 56·6; H, 6·9; Br, 26·0%).

Hexahydrochlorophorin Tetra-acetate.—This *compound* was prepared in a manner similar to that described for the hexahydrochlorophorin tetramethyl ether. It crystallised from ethyl alcohol as a felted mass of very fine needles, m. p. 60—60·5°, which tended to be gelatinous under certain conditions (Found : C, 69·4; H, 7·5. $C_{33}H_{44}O_8$ requires C, 69·7; H, 7·8%).

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