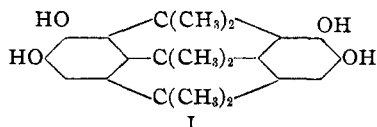


[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

The Condensation of Polyhydric Phenols with AcetoneBY C. HAROLD FISHER,¹ ROBERT W. FURLONG AND MORTON GRANT

It is well known that a comparatively simple product, 2,2-bis-(4-hydroxyphenyl)-propane,² results from the interaction of phenol and acetone, but the nature of the products obtained from certain polyhydric phenols is more obscure. However, in a number of instances,³ it seems well established that two moles of the polyhydric phenol react with three of acetone, with the elimination of three moles of water. There is considerable disagreement, nevertheless, concerning the structure of the resulting products. In most cases, and in a recent report,^{3c} the structures proposed are similar to the one (I) assigned to the catechol-acetone condensation product.^{3a} This type of polycyclic system (I) appears improbable on general grounds, and is definitely objectionable since

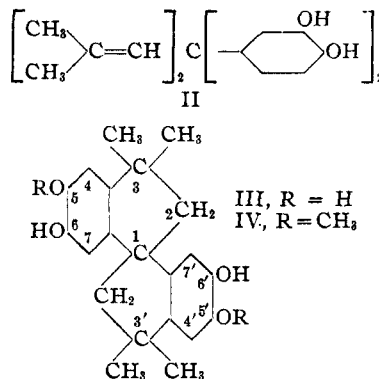


it does not explain the ready formation of polybromo derivatives^{3,4} (tetra- and dibromo derivatives from the catechol-acetone and pyrogallol-acetone products, respectively).

It was shown subsequently that the same catechol-acetone condensation product could be prepared⁵ satisfactorily from phorone and catechol. On the basis of this fact it was believed that the structure was best represented by II, although more than four atoms of bromine should be introduced into this molecule (II) on bromination. Baker⁴ also obtained the catechol-acetone product from phorone, but the structure III was preferred to those previously suggested.

In view of the findings of Baker⁴ and the evidence given below, the bis-1,1'-spirohydrindene structure (III) appears to be correct.

It has been found now that guaiacol also reacts with acetone to give a similar compound, 6,6'-dihydroxy-5,5'-dimethoxy-3,3,3',3'-tetramethylbis-1,1'-spirohydrindene (IV). The condensation



was carried out in the presence of acetic and hydrochloric acids; the same product had been prepared by Sükösd,^{3c} who, probably influenced by the conclusions of Fabinyi and Szeki,³ advanced a formula analogous to I. In the present work, it was found possible to relate the guaiacol-acetone compound (IV) to the catechol-acetone product (III) by complete methylation, the same tetramethyl ether being obtained from both III and IV. An attempt to prepare the tetramethyl ether of III by condensing veratrole with acetone, under the conditions used with catechol and guaiacol, was unsuccessful.

The behavior of the catechol-acetone product (III), and its tetramethyl ether, on oxidation favors the bis-1,1'-spirohydrindene structures. The catechol derivative (III) is oxidized by nitric acid in good yield to a red di-quinone; the ease of oxidation of III, and the stability of the resulting quinone are in accord with the views of Mills and Nixon⁶ concerning the distribution of bonds in hydrindene derivatives. The tetramethyl ether was found to be stable to prolonged treatment with chromic anhydride in acetic acid. This resistance to oxidation would not be anticipated in derivatives of II, and therefore the olefinic type of structure suggested by Ghiglieno⁵ appears to be unworthy of consideration.

It was hoped to get more conclusive evidence of structure by comparing the behavior of III and IV in coupling experiments with that of V which, on account of the location of double bonds, couples⁶ in the 6-position with diazonium compounds. As would be expected in the case of 5-

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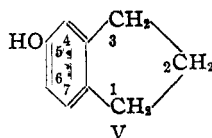
(2) For references see Yohe and Vitcha, *THIS JOURNAL*, **57**, 2259 (1935).

(3) (a) Fabinyi and Szeki, *Ber.*, **38**, 2307 (1905); (b) *ibid.*, **38**, 3527 (1905); (c) Sükösd, *C. A.*, **27**, 1873 (1933).

(4) Baker, *J. Chem. Soc.*, 1678 (1934).

(5) Ghiglieno, *C. A.*, **6**, 2922 (1912).

(6) Mills and Nixon, *J. Chem. Soc.*, 2510 (1930); see also ref. 4.

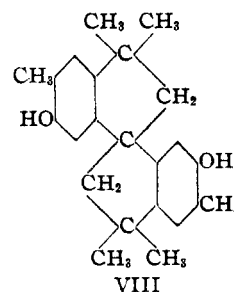
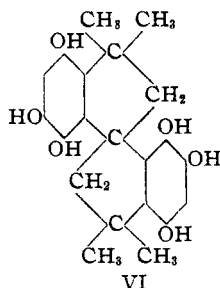
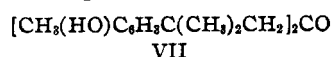


hydroxyhydrindenes having the susceptible position blocked, it was found that the bis-1,1'-spirohydrindenes (III and IV) did not couple with diazonium salts prepared from sulfanilic acid and from *p*-nitroaniline. Unfortunately, the evidence from the coupling experiments is not entirely satisfactory, since side reactions and some discoloration (the latter occurred even in the absence of diazonium solutions) could not be prevented. Discoloration has been observed⁷ also in other coupling experiments employed to indicate structure. It is worthy of note that 2,3-dihydroxynaphthalene has been observed⁸ to couple readily with diazonium salts.

The present communication describes also the product obtained by condensing acetone and hydroxyhydroquinone. This condensation had been carried out earlier by Sükösd,^{3c} who assigned to the product a structure similar to I. In the present work it was found more convenient to prepare the hydroxyhydroquinone-acetone product by condensing hydroxyhydroquinone triacetate, instead of the parent phenol, with acetone. The triacetate reacted to give the Sükösd compound directly; whether or not hydrolysis of the acetyl groups preceded the reaction with acetone is not known. The acetyl, propionyl and benzoyl derivatives of the product obtained from hydroxyhydroquinone triacetate were found to melt at the temperatures given by Sükösd^{3c} as the melting points of the corresponding derivatives of his hydroxyhydroquinone-acetone product. It appeared likely that the hydroxyhydroquinone-acetone compound was really a bis-1,1'-spirohydrindene (VI), and to obtain evidence for this view the general method of Baker⁴ was employed. It was found that the same product (VI) was formed when phorone, instead of acetone, was used in the condensation; it is claimed by Baker⁴ that bis-1,1'-spirohydrindenes are formed when two moles of a phenol react in this manner with phorone with the elimination of one mole of water.

It is interesting to note that, under different conditions, Niederl and Casty⁹ have effected a condensation between two moles of *o*-cresol and

phorone without the loss of water. Presumably, the product (VII) is an intermediate in the formation of a compound (claimed by Sükösd^{3c} to



have a structure analogous to I) from the interaction of *o*-cresol and acetone. It appears probable that the *o*-cresol-acetone product of Sükösd is VIII in reality, and that it is formed by the elimination of water from VII. If the plausible assumption is made that the bis-1,1'-spirohydrindenes described in this paper were formed from intermediates similar to VII, then the hydroxyl and methoxyl substituents may be assigned to definite positions with some confidence (as illustrated in IV, VI and VIII).

It has been claimed¹⁰ that hydroquinone and acetone react in the presence of hydrochloric acid and small amounts of ferric chloride to give a 92% yield of a condensation product (not described). Only oils were obtained in the present work when an attempt was made to condense acetone with hydroquinone, and with toluhydroquinone, in acetic and hydrochloric acids under conditions found successful in the case of catechol. However, resorcinol and pyrogallol reacted with acetone, and with methyl ethyl ketone, in the presence of acetic and hydrochloric acids to give high-melting solids. As yet these products have not been well characterized.

Experimental

Preparation of Bis-1,1'-spirohydrindenes.—The tetrahydroxy-bis-1,1'-spirohydrindene (III) was made from acetone and catechol by the method of Baker⁴ in yields corresponding with those claimed. The compound crystallizes unsatisfactorily unless special precautions are observed; the following method is preferred to those previously used. A hot alcoholic solution of the crude material is treated with small amounts of sodium bisulfite and acetic acid, followed by enough water to cause saturation. Small crystals are formed on slow cooling.

Guaiacol and acetone were condensed by the same method; the reaction proceeded more slowly than in the

(7) Fieser and Lothrop, *THIS JOURNAL*, **57**, 1459 (1935).

(8) Friedländer and v. Zakrzewski, *Ber.*, **27**, 763 (1894).

(9) Niederl and Casty, *Monatsh.*, **51**, 86 (1920).

(10) Müller, *Chem.-Ztg.*, **45**, 632 (1921).

catechol condensation, and the yield was much lower. The m. p., 266–267°, is identical with that previously reported³⁰ for this substance.

The hexahydroxy-bis-1,1'-spiro-hydrindene (VI) resulted from the reaction of 40 g. of hydroxyhydroquinone triacetate with 14 g. of acetone in the presence of 42 cc. of acetic acid and 32 cc. of concd. hydrochloric acid. The mixture was warmed on a steam cone for a few minutes to dissolve the triacetate, and then allowed to stand for twenty hours at room temperature. The solid which had separated was collected, washed with water and crystallized from acetone, water being added to give diminished solubility. The yield was 20.5 g.; the product melted at 265–267° with decomposition.

The acetyl, propionyl and benzoyl derivatives of VI were prepared and found to melt, respectively, at 205–206°, 175–177° and 237–238.5°. The melting points given by Sükösd³⁰ for these derivatives are 205–206, 172.5 and 239–240°.

The hexahydroxy derivative (VI) was prepared also from 17 g. of hydroxyhydroquinone triacetate, 4 g. of phorone, 10 cc. of acetic acid and 16 cc. of concd. hydrochloric acid. The melting point of the product was 264–266° with decomposition. The acetyl derivative melted at 205–207°; admixture with the acetyl derivative of the acetone-hydroxyhydroquinone product caused no depression.

Tetramethyl Ether of III.—The ether was prepared from the catechol-acetone product by the method of Baker,⁴ and also from the guaiacol-acetone product as follows. The dimethoxy-bis-1,1'-spiro-hydrindene (3 g.), 3 cc. of methyl alcohol, and 4.5 cc. of dimethyl sulfate were shaken with excess 20% potassium hydroxide, added in portions; further quantities of dimethyl sulfate (4.5 cc.) were added, and the mixture was allowed to boil. The solid which separated was collected and washed with water; yield 3 g. After repeated crystallization from ethyl alcohol and from benzene-ligroin, the m. p. was 155–156°; there was no lowering of the m. p. when the product was mixed with the tetramethyl ether prepared from the catechol-acetone product.

Attempted Oxidation.—The tetramethyl ether (4 g.) of III was heated for twenty hours with 70 cc. of acetic acid and 2 g. of chromic anhydride, and then allowed to stand

at room temperature for six days. The solution did not change in color, and 3.2 g. of the starting material was recovered unchanged.

The Diquinone.—The catechol-acetone product (III) was oxidized to the diquinone in good yield by the directions of Baker.⁴ The quinone reacted readily with Thiele's reagent (acetic anhydride and sulfuric acid), but the identity of the product was not established. Another *o*-quinone with substituents in the 4 and 5 positions has been observed⁴¹ to react with Thiele's reagent.

Coupling Experiments.—A solution, prepared by adding 3.7 g. of sodium nitrite to 10.5 g. of sulfanilic acid and 3.8 g. of anhydrous sodium carbonate in 100 cc. of water, was added to 7 cc. of concd. hydrochloric acid and 50 g. of ice. The precipitate which formed was filtered, washed with a small amount of cold water and redissolved in cold water; a pinch of urea was added. A red dye was obtained when this solution was added to β -naphthol in alkaline solution; when the solution was added to 0.5 g. of the catechol-acetone product dissolved in 30 cc. of 2% sodium hydroxide solution, a dark brown solution resulted, with considerable foaming. Acidification gave a small amount of a dirty-brown, gummy substance.

A similar result was obtained in an attempt to couple the guaiacol-acetone product with diazotized sulfanilic acid. Equally unsuccessful attempts were made to couple the phenols in acetic acid solution with diazotized *p*-nitroaniline.

Summary

The products obtained by condensing acetone with catechol, and with guaiacol, have been shown to be related by conversion of both substances into the same tetramethyl ether. Evidence that these compounds are derivatives of bis-1,1'-spiro-hydrindene is presented. Another product of this type, 4,6,7,4',6',7'-hexahydroxy-3,3,3',3'-tetramethyl-bis-1,1'-spiro-hydrindene, has been prepared by condensing hydroxyhydroquinone triacetate with acetone, and with phorone.

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(11) Private communication from Professor L. F. Fieser.