curves due to the anodic oxidation of reductant were identical with those due to the cathodic reduction of the oxidant of the same system. This fact serves as a very convenient criterion to determine the reversibility of an oxidation–reduction system. For instance we were unable to oxidize lactic acid in a solution of nitric acid at the dropping mercury electrode, using the most positive potential available at this electrode, *viz.*, E_h = +0.65 v. This supports the view that the reversible step $P \rightleftarrows L^*$ is followed by an irreversible process $L^* \longrightarrow L$.

Using Conant's method, Barmore[24] found that lactic acid could be oxidized in acid solution by potassium permanganate which corresponded to an apparent oxidation potential (A. O. P.) of E_h = +1.4 v. However, when he tried to determine the A. R. P. of pyruvic acid by this method he failed, because the most negative reagent he could use, *i. e.*, titanium trichloride (E_h = −0.8 at *p*H 7.2) was not negative enough to bring about a reduction. For such systems, therefore, the polarographic method and Conant's method supplement each other.

(24) M. A. Barmore, "Electrometric Studies on Pyruvic Acid, Lactic Acid, and Glyceric Aldehyde" (unpublished thesis), Stanford University Library, 1929.

This work was aided by a grant from the Rockefeller Foundation.

Summary

1. The application of the polarographic method to the study of keto–enol tautomerism, polymerization and apparent reduction potential is described.

2. Evidence is presented in support of the following facts: (a) The ratio of keto/enol + enolate forms of pyruvate ion becomes unity at *p*H 5.8 and decreases with increase in *p*H and vice versa. (b) Pyruvic acid polymerizes even in fairly dilute solutions and this polymerization increases with increase in acidity and with time. (c) The "polarographic half-wave potential" is equivalent to the "apparent reduction potential" of Conant and represents the E'_0 of the reversible step in an irreversible reaction. (d) The apparent reduction potentials of the various forms of pyruvic acid vary with *p*H.

3. An interpretation of the conflicting data in the literature concerning the keto–enol tautomerism of pyruvate ion is given on the basis of some new facts presented in this paper.

STANFORD UNIVERSITY, CALIF.

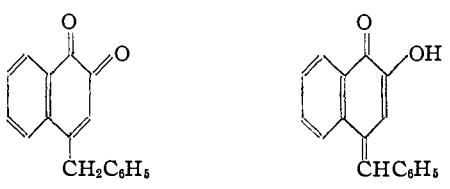
RECEIVED OCTOBER 27, 1938

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

The Synthesis from β-Naphthohydroquinone of a Tautomer of 4-Benzyl-1,2-naphthoquinone

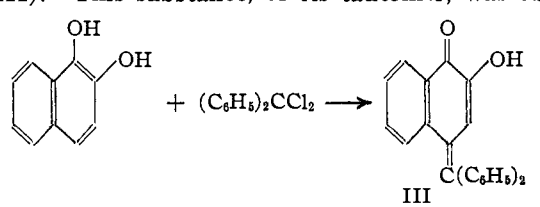
BY LOUIS F. FIESER AND MARY FIESER

In the course of an investigation with Bradsher[1] it was observed in preliminary experiments that 4-benzyl-1,2-naphthoquinone (I) can be converted by treatment with concentrated sulfuric acid or with alkali into a yellow substance which, as shown in the present work, is a monomer isomeric with the starting material. In undertaking a further study of the problem, the possibility was considered that the yellow substance has the structure of the acidic tautomer, II, even though there is no analogy in quinone chemistry for the independent existence of such a compound. It was thought that if this were the structure the substance might be obtainable more readily than through the rather inaccessible quinone I by application of a reaction employed successfully by Fieser and Hartwell[2] for the preparation of a similar compound, 2-hydroxy-1,4-naphthofuchsone-1 (III). This substance, or its tautomer, was ob-



I

II



III

(1) Fieser and Bradsher, THIS JOURNAL, **61**, 417 (1939).

(2) Fieser and Hartwell, *ibid.*, **57**, 1484 (1935).

tained in quantitative yield by heating β-naphthohydroquinone with benzophenone dichloride until hydrogen chloride was no longer evolved.

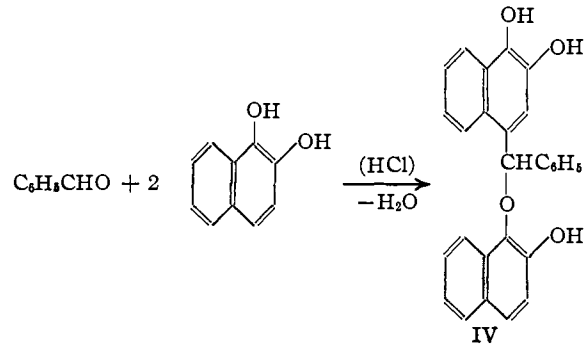
When a mixture of β-naphthohydroquinone and benzal chloride was heated in similar fashion hydrogen chloride was evolved copiously but the product was a very dark oil from which no solid could be isolated. Benzene was then used as solvent with the view of moderating the reaction, and on gentle heating gas was liberated and a reaction product could be caused to separate in the form of nearly colorless, microscopic prisms. The substance proved to be very sensitive and could not be kept for more than a few days without undergoing extensive decomposition. Although tests for halogen were negative, the substance has a very marked vesicant action. Purification proved difficult. The compound dissolves readily in hydroxylic solvents but the solutions rapidly become discolored by oxidation, and it is practically insoluble in hydrocarbon solvents. It forms colorless and comparatively stable solutions in purified ether or dioxane, however, and beautifully crystalline complexes separate from these solvents. The complexes, to be sure, are only slightly less sensitive than the unsolvated substance and exact characterization by analysis proved difficult.

It was next found that the same product can be obtained by condensing β-naphthohydroquinone with benzaldehyde in benzene solution in the presence of dry hydrogen chloride. Other aromatic aldehydes, and at least one aldehyde of the aliphatic series, condense in the same way giving products of varying stability and propensity to crystallize. The product from *p*-chlorobenzaldehyde has properties somewhat more favorable than most of the others studied, and the halogen content is of advantage for purposes of analysis. The percentages of carbon, hydrogen and chlorine all indicate that the ether complex in this case contains two molecules of the solvent combined with the substance $C_{27}H_{19}O_4Cl$. The reaction then must involve the condensation of one molecule of the aldehyde with two molecules of β-naphthohydroquinone with elimination of water.

$$ClC_6H_4CHO + 2C_{10}H_6(OH)_2 \longrightarrow C_{27}H_{19}O_4Cl + H_2O$$

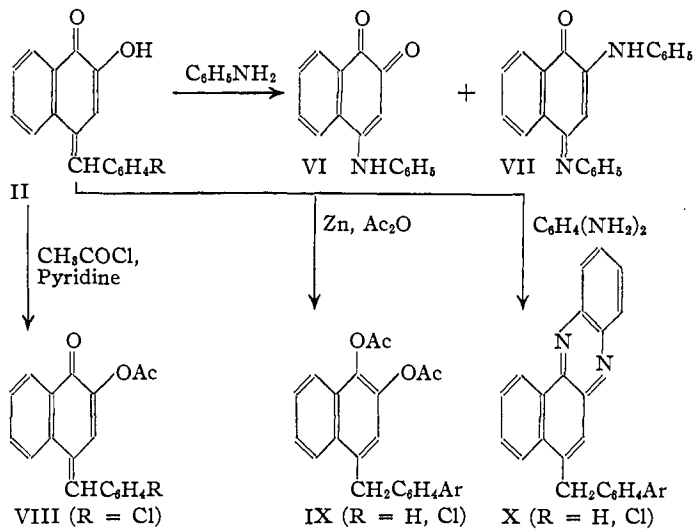
This formulation is in accord with the yields obtained and is supported by the analyses of the acetyl derivatives of the condensation products obtained with *p*-chlorobenzaldehyde, *m*-nitrobenzaldehyde, and *n*-butyraldehyde. These are stable substances which crystallize in an unsolvated form and the analytical data indicate unequivocally that they are all triacetyl derivatives of C_{27}-compounds of the type described above. The condensation products therefore contain three hydroxyl groups, which means that only one of the four original phenolic hydroxyls is involved in the condensation. That the reaction products contain one intact β-naphthohydroquinone residue is shown by the results of oxidation experiments. The crude compounds, or their colorless solvated complexes, are easily oxidized to orange quinones which form azines, indicating that they are ortho quinones. The quinones are sensitive substances, but the *p*-chloro compound was obtained in a pure condition as an ether complex and the parent substance was isolated in an unsolvated form and converted into an azine monoacetate. The analytical figures show that two atoms of hydrogen are removed in the oxidation.

One further transformation, achieved at least with the condensation products from the aromatic aldehydes, resulted in the realization of our original goal. On treatment with concentrated sulfuric acid the product from benzaldehyde or its triacetate is converted smoothly into a yellow, acidic substance identical with the compound obtainable under similar conditions from 4-benzyl-1,2-naphthoquinone. As will be shown presently, the yellow substance definitely has the same skeletal structure as the orange quinone. The benzal residue present in the condensation product must, then, be joined directly to the 4-position of one of the β-naphthohydroquinone units, for this carbon–carbon linkage could hardly arise in the cleavage reaction with sulfuric acid. The second unit must be linked to the aldehyde residue through one of the two hydroxyl groups and, assuming for the moment that the α-hydroxyl is the one involved, a plausible structure

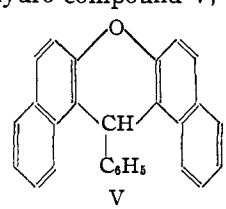


IV

for the condensation product is shown in formula IV. This accords with the analyses and yields of the products, and with the formation of a triacetate, an ortho quinone, and a quinone-azine monoacetate. Further evidence pointing to this type of structure will be given below, and some basis will be offered for preferring the specific formulation IV rather than the alternate one involving the β-hydroxyl group.



Thus far we have been unable to extend the synthetic method by varying the phenolic component. Catechol, α-naphthol, and α-naphthohydroquinone all react in benzene solution with benzal chloride, or with benzaldehyde and hydrogen chloride, but no solid products or crystalline complexes have been isolated. β-Naphthol, treated in benzene solution under the usual conditions with either the aldehyde or chloride, gave the known anhydro compound V, which Mackenzie and Joseph[3] obtained by heating β-naphthol and benzal chloride without solvent. Although the reactions of aldehydes with phenols have been studied extensively, there appears to be no analogy for the type of condensation obtained with β-naphthohydroquinone. Raudnitz and Puluj[4] observed an interesting reaction of benzaldehyde with two molecules of α-naphthohydroquinone in a mixture of acetic and hydrochloric acids, but the resulting substance of as yet unknown structure does not appear to bear any relation to the type of condensation product described in the present work. The substance, which is dark red, stable, and sparingly soluble, was assigned the formula $C_{27}H_{19}O_4Cl$.



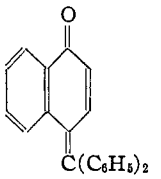
V

Before presenting other evidence concerning the structure of the condensation product it is necessary to consider the properties of the yellow, acidic substance isomeric with 4-benzyl-1,2-naphthoquinone. The above synthesis provides a convenient source of the material, as well as of the chloro and nitro derivatives, and in the further study one or the other of these compounds was employed as found expedient. The analyses all indicate that the parent substance is indeed an isomer of the quinone I, and the following evidence supports the formulation of the compound as a tautomer having the structure II. The substance dissolves in alkali with the formation of a deep red sodium salt, and the presence of a hydroxyl group was established in the chloro series by the isolation of a monoacetate (VIII) from the reaction of the hydroxy compound with acetyl chloride in pyridine. Results of acetylation under other conditions are described below. The *p*-chloro compound, on Schotten–Baumann reaction in dioxane–alkali, also yielded a monobenzoate. In several instances it has been possible to convert the yellow compound II (R = H) into derivatives identical with those obtainable from 4-benzyl-1,2-naphthoquinone. The reaction with aniline in alcohol usually gives both the anilino quinone VI and the anilino quinoneanil VII, the latter resulting from the further reaction of the former with aniline, and the same products were isolated from the *p*-chloro compound. The anilino quinoneanil was obtained previously[1] on similar treatment of the benzylnaphthoquinone. The quinone and the yellow aci-compound both yield the same azine, X (R = H), and on reductive acetylation they both give 4-benzyl-1,2-naphthohydroquinone diacetate, IX (R = H), although with the aci-compound this is accompanied by considerable high melting material probably resulting from bimolecular reduction.

The evidence thus points to the methylenequinonoid structure and the compound is regarded as

(3) Mackenzie and Joseph, *J. Chem. Soc.*, **85**, 793 (1904).
(4) Raudnitz and Puluj, *Ber.*, **64**, 2212 (1931).

2-hydroxy-4-benzal-1-naphthone (II). As far as we are aware this is the first case of the independent existence of both forms of such a tautomer pair. Both forms seem remarkably stable, for each can be crystallized repeatedly without change in the crystalline form or melting point, and neither form shows a tendency to undergo isomerism in the absence of strong acids or bases. It has been reported already that 4-benzyl-1,2-naphthoquinone forms a reversible oxido–reduction system having a normal potential in the expected range.[1] In contrast, the hydroxybenzalnaphthone II does not form with its reductant an electromotively active system under the same conditions and behaves in this respect like 1,4-naphthofuchsone, XI. This is a clear indication



XI

that the substance does not tautomerize to any appreciable extent in dilute alcoholic hydrochloric acid solution. No method has been found, indeed, for reconverting the yellow substance into the orange quinone, and, since it is obtainable from the quinone by treatment with concentrated sulfuric acid or with alkali, the hydroxybenzalnaphthone form would appear to be the more stable of the two. The situation contrasts with that observed[2] with the substance resulting from the condensation of benzophenone dichloride with β-naphthohydroquinone. This gives reactions characteristic of 2-hydroxy-1,4-naphthofuchsone (III), but electrometric titration shows that its solutions contain a considerable proportion of the tautomer 4-diphenylmethyl-1,2-naphthoquinone. 4-Dicarbethoxymethyl-1,2-naphthoquinone also appears to form with its tautomer a mobile tautomeric system,[1] and hence the 4-benzyl compound differs in behavior from closely related quinones.

Two other interesting and probably closely related transformations of the yellow hydroxybenzalnaphthone have been observed. One consists in its conversion on reaction with acetic anhydride in the presence of sulfuric acid, sodium acetate, or pyridine into a colorless substance which proved to be identical with the "abnormal triacetate" obtained by Bradsher[1] from 4-benzyl-1,4-naphthoquinone with the same reagents. A similar product was obtained using propionic anhydride, and colorless triacetates were prepared in the chloro and nitro series. The unsubstituted triacetate, as found in experiments by Bradsher, is converted on hydrolysis with acid or alkali into hydroxybenzalnaphthone, indicating that the acetoxy groups introduced in the acetylation are not attached to the naphthalene nucleus.

A plausible interpretation of the abnormal acetylation was first reached from a study of a second unexpected reaction product. This was encountered in the crystallization from ethyl alcohol of crude hydroxybenzalnaphthone prepared in one experiment (Bradsher) from benzylnaphthoquinone and sulfuric acid and on another occasion (M. F.) by the cleavage of the aldehyde condensation product with sulfuric acid. Instead of the expected yellow needles of II, a new substance separated in the form of brilliant orange plates. In Bradsher's experiment this appeared in mother liquors which had stood for a prolonged period. The formation of the substance was later traced to a reaction of II with ethyl alcohol catalyzed by sulfuric acid present in the crude product. Experimentation with pure II showed that the reaction proceeds slowly and is not a simple esterification, for refluxing gives only tars and in order to obtain the orange substance it is necessary to allow a solution of the reagents to stand at room temperature for a period of days.

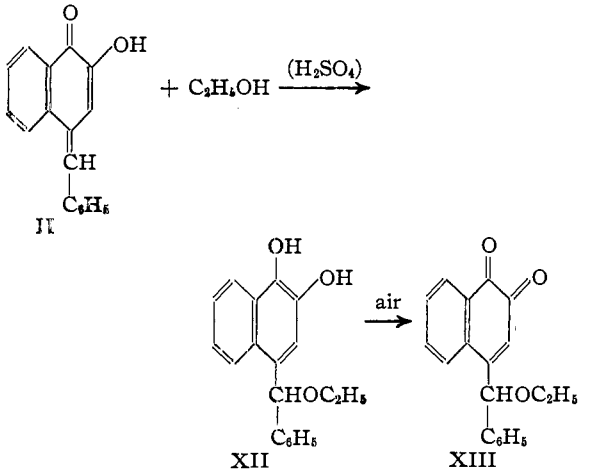
The reaction is a general one, for II and its derivatives may be converted into a series of products by interaction with various alcohols in the presence of a trace of sulfuric acid. The orange substances contain one alkoxyl group (Zeisel), but they are not ordinary ethers of the hydroxy compounds since they contain one atom of oxygen more than expected for such derivatives. The analytical data indicate that the reaction must involve both an addition of the alcohol and a process of oxidation

$$ArC_{11}H_6O_2 + ROH + [O] \longrightarrow ArC_{11}H_5(OR)O_2 + H_2O$$

The nature of the oxidation step became apparent with the recognition that the orange compounds are quinones. The substances can be reduced with hydrosulfite to colorless hydroquinones which are easily reoxidized by the air, and hydroquinone diacetates of the usual type are obtained on reductive acetylation. The orange color is suggestive of an orthoquinonoid structure, and this was established by the formation of yellow azines.

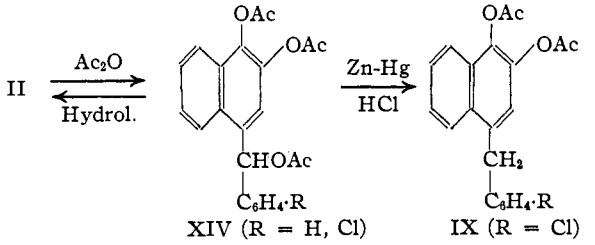
The primary reaction with alcohol therefore may well give the hydroquinone, and this on standing may then undergo air oxidation to the final product. An important completing piece of evidence is that on treatment with cold concentrated sulfuric acid the orange ortho quinones are converted, at least in part, into the original hydroxybenzalnaphthones, showing that the alkoxyl group is not attached to the naphthalene nucleus.

Since the only place left for the alkoxyl group is on the aldehydic carbon atom, the reaction can be formulated as an addition of the alcohol to the conjugated system of II to give the hydroquinone XII, which undergoes air oxidation to α-ethoxy-4-benzyl-1,2-naphthoquinone, XIII. The nature



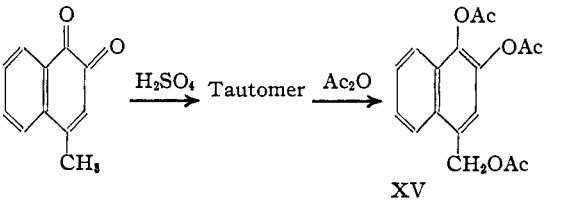
of the cleavage reaction with sulfuric acid is not clear, but since this gives II only in poor yield it may involve a process of disproportionation to give the hydroquinone (XII), followed by the elimination of the elements of alcohol. The other properties of the orange quinone are in entire accord with formula XIII.

If alcohols can add to the conjugated system of II under the influence of a catalyst it seems likely that the reaction with acetic anhydride follows a similar course. The colorless abnormal triacetate obtained both from II and from 4-benzyl-1,2-naphthoquinone would then be assigned the formula XIV (R = H). This is consistent with

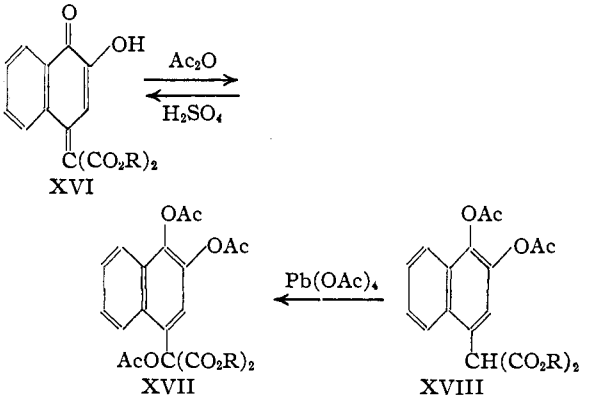


the ready hydrolysis of the compound to II, and the structure is further confirmed by the observation that the triacetate of the chloro series can be converted by Clemmensen reduction and reacetylation into the 4-benzyl-1,2-naphthohydroquinone diacetate (IX, R = Cl). The removal of one acetoxyl group by reduction is good evidence of its location on the α-carbon atom. The formation of the triacetate XIV from 4-benzyl-1,2-naphthoquinone[1] probably is best interpreted as involving a tautomerization to II.

Although no further work has been done with the triacetate obtained by Bradsher[1] from 4-methyl-1,2-naphthoquinone, analogy would indicate the structure XV. In the earlier experi-



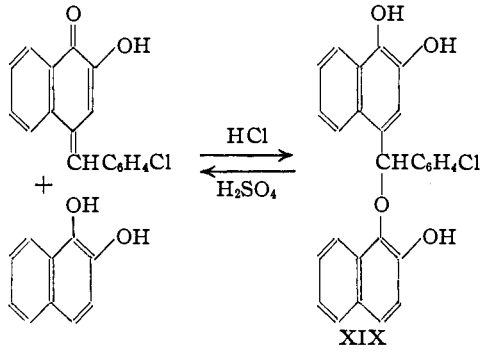
ments[1] it was found that under conditions even somewhat more drastic than required for the conversion of the 4-benzyl and 4-methyl quinones into triacetates, the tautomeric 4-dicarbethoxymethyl-1,2-naphthoquinone, reacting in the aci-form XVI, gives only a monoacetate when warmed with acetic anhydride–sulfuric acid. Reinvestigation has shown that by increasing the amount of catalyst and raising the temperature to the boiling point a colorless triacetate can be obtained.



This can be reconverted to the starting material with sulfuric acid in the usual way and it is regarded as having the structure XVII. A confirmation of the structure, and of the general interpretation of the abnormal acetylations, was found in the preparation of the triacetate XVII by the oxidation of the known hydroquinone di-

acetate[1] XVIII with lead tetraacetate in glacial acetic acid solution. This can hardly be interpreted other than as a replacement of the active hydrogen atom of the malonic ester residue by an acetoxyl group. That the addition of acetic anhydride proceeds more slowly with the 4-dicarbethoxymethyl quinone than with the methyl and benzyl compounds may be because of the accumulation of negative substituents at the carbon atom at the end of the conjugated system. No triacetate has as yet been isolated from 4-diphenylmethyl-1,2-naphthoquinone[2] (or the tautomer III).

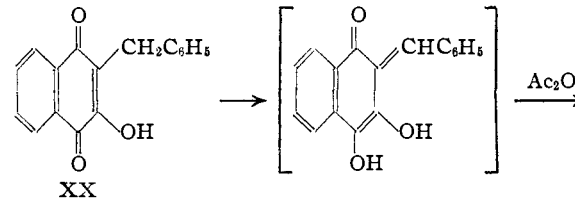
The observed catalytic addition of alcohols to hydroxybenzalnaphthone (II) suggested a possible method for the resynthesis of the condensation product from β-naphthohydroquinone and *p*-chlorobenzaldehyde, XIX. When 2-hydroxy-



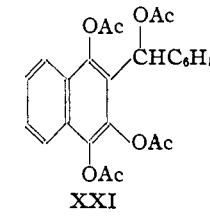
XIX

4-(*p*-chlorobenzal)-1-naphthone was warmed in benzene solution with an equivalent amount of β-naphthohydroquinone in the presence of hydrogen chloride, it did in fact yield the product previously obtained in the condensation reaction. This supports the structure assigned to the condensation products on the basis of other evidence, and the cleavage with concentrated sulfuric acid becomes better understandable in light of the analogous hydrolysis of the above triacetate XIV. In further experiments it was found that, under the same conditions, hydroxybenzalnaphthone (II) does not condense with phenol, catechol, 9-phenanthrol, or β-naphthol, the yellow substance II being recovered unchanged. A reaction very evidently occurred with α-naphthol, but the product failed to crystallize and was not isolated in a pure condition. The qualitatively observed reactivity of a hydroxyl group in the α- but not in the β-position of naphthalene suggests that with β-naphthohydroquinone the ether linkage is probably established through the 1- rather than the 2-hydroxyl group, but a rigid proof of this point is not available.

The elucidation of the abnormal acetylation reactions provides an interpretation of an observation made several years ago by one of us and not previously reported. When 2-benzyl-3-hydroxy-1,4-naphthoquinone[5] (XX) is warmed for a short time with acetic anhydride and sodium acetate it yields the normal, light yellow monoacetate, but when the solution is boiled for about twenty-five minutes there is obtained in fairly good yield a colorless, nicely crystalline product which, from the analysis, appears to be a tetraacetate of the formula $C_{25}H_{22}O_8$. The substance is quite different from the colorless hydroquinone triacetate, and on hydrolysis it yields 2-benzyl-3-hydroxy-1,4-naphthoquinone, apparently without any oxidation step. In analogy with the above reactions it is probable that the substance is an α-acetoxy compound of the structure XXI, formed by the addition of acetic anhydride to the unsaturated system of the tautomeric dihydroxybenzalnaphthone and acetylation of the two phenolic hydroxyl groups.



XX

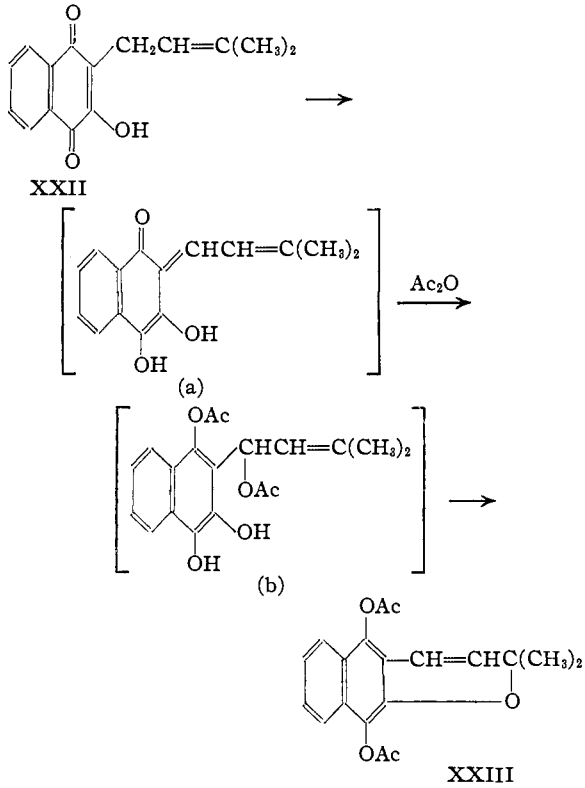


XXI

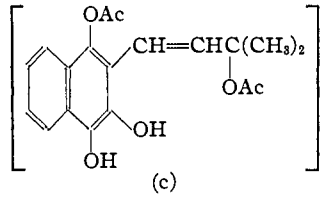
Another remarkable acetylation reaction in the naphthoquinone series was observed by Paternò[6] as early as 1882 in investigating the action of acetic anhydride and sodium acetate upon lapachol (XXII). The yellow quinone is converted by this treatment into a colorless substance which Hooker[7] many years later characterized as the hydroquinone diacetate of dehydro-α-lapachone (Paternò's "isolapachone") of the structure XXIII. The hydroquinone diacetate of the β-isomer is formed simultaneously. A similar behavior on acetylation was noted by one of us[5] with

(5) Fieser, THIS JOURNAL, **48**, 3201 (1926).
(6) Paternò, *Gazz. chim. ital.*, **12**, 337 (1882).
(7) Hooker, THIS JOURNAL, **58**, 1190 (1936).

2-allyl-3-hydroxy-1,4-naphthoquinone. The interpretation suggested by the present results is that lapachol (XXII) reacts in a tautomeric form (a) to which the reagent adds with the formation of an α-acetoxy compound (b). This can yield



the final product XXIII by various possible mechanisms, for example, by addition of the 3-hydroxyl group to the double bond, loss of acetic acid between the α- and β-positions of the side ring, and acetylation of the 4-hydroxyl group. A still simpler route would involve an allylic shift of the acetoxy group from the α- to the γ-position (c) and ring closure by the loss of acetic acid.



Although the exact mechanism remains uncertain, the recognition that alkylnaphthoquinones are often attacked on acetylation in the α-position of the side chain renders understandable the removal of hydrogens from the α,β-position in the heretofore unexplained acetylation of the β,γ-unsaturated alkyl quinones of the lapachol type.

The special acetylations of lapachol and of 2-benzyl-3-hydroxy-1,4-naphthoquinone are thus regarded as correlated phenomena following the same course in the essential initiating step. The hydrogen atom migrating in the tautomeric shift is activated by the double bond of the side chain in the one case and by the phenyl group in the other, and the tautomerization results in the extension of the conjugated system of the nucleus to include the unsaturated group of the side chain. This evidently provides a driving force for the tautomerization, and consequently for the addition of acetic anhydride, for the special acetylation reaction does not occur if the side chain is saturated, for example with hydrolapachol. 4-Alkyl-1,2-naphthoquinones show a greater tendency than 2-alkyl-1,4-naphthoquinones to react through the tautomeric form, and do so even though the alkyl group lacks an activating center of unsaturation. Since para quinones are invariably more stable than ortho quinones, the nature of the difference is easily understandable.

Experimental Part[8]

Condensation Products from β-Naphthohydroquinone and Aldehydes or Dihalides.

Preparation of β-Naphthohydroquinone.—After many trials under different conditions the method of reduction of the quinone with sulfur dioxide[2] was abandoned because of the variable and usually unsatisfactory yields. Reduction with sodium hydrosulfite is more reliable and also more convenient, since the product is obtained in an unhydrated condition. The moist β-naphthoquinone prepared as described[9] from 40 g. of pure 1,2-aminonaphthol hydrochloride was added in lumps to a well stirred solution of 60 g. of sodium hydrosulfite in 500 cc. of water. The suspension of light yellow solid was heated to boiling to coagulate the product, cooled thoroughly, and the solid collected and dried in a vacuum desiccator. The crude, tan material (24.8 g., m. p. 103°) was purified by two distillations in vacuum, giving 20.6 g. of slightly yellow product of m. p. 104°.

Condensation with Benzal Chloride or Benzaldehyde.—A solution of 1 g. of β-naphthohydroquinone and 0.7 cc. of freshly distilled benzal chloride in 6–8 cc. of thiophene-free benzene was heated in a test-tube over a hot-plate while stirring vigorously with a glass rod. Hydrogen chloride was evolved shortly and in about five minutes crystallization of the product could be induced by thorough scratching of the walls of the tube. When the evolution of gas had ceased and no more material separated the pasty mixture was cooled and the solid collected and washed well with cold benzene. The yield was 0.8–0.9 g. of colorless or pale yellow microcrystalline material. This has no characteristic melting point, but darkens on being

(8) Melting points are corrected except as noted.
(9) Fieser, *Org. Syntheses*, **17**, 68 (1937).

heated above 100° and decomposes above 200°. Beilstein and sodium fusion tests for halogen were negative. The substance dissolves in alkali with rapid discoloration. It is readily soluble in alcohol but undergoes rapid change. The solid usually cannot be kept for more than a few days without darkening. When a few particles are dusted onto the skin or the material applied in solution the substance rapidly produces a dark brown stain and a severe blister soon develops.

Material of the same quality was obtained by passing dry hydrogen chloride into a warm solution of 0.8 g. of β-naphthohydroquinone and 0.6 cc. of benzaldehyde in 5 cc. of pure benzene. After five to ten minutes the color deepened and droplets of water began to collect on the walls; on boiling the solution and scratching, the pale yellow microcrystalline solid separated and was collected as before; yield, 0.6–0.7 g.

The condensation product (IV) is very sparingly soluble in benzene or ligroin. It dissolves readily in purified, dry ether, and colorless, diagonal plates of an **ether complex** can be obtained by concentration or by the addition of petroleum ether. Purified samples were observed to decompose with gas evolution at 106–108° and at 112°, giving the unsolvated solid. These crystals can be preserved longer than the unsolvated material. Analyses of samples crystallized in various ways and having about the same appearance and melting point suggested that the substance may crystallize with either one or two molecules of ether, or possibly with two molecules of ether and one of water, but the results are regarded as less decisive than those with the chloro compound described below and will not be reported. The **dioxane complex** separates from dioxane–ligroin as clusters of faintly yellow prisms, m. p. 94–94.5°, but when dried in vacuum at room temperature the crystals wither to a white powder.

Acetylation by any of the three methods described below gave a product closely resembling the triacetates obtained in the other series, but the unsubstituted compound crystallized poorly and was not isolated in a completely pure condition. The best appearing material was obtained as fine, colorless needles, m. p. 229.5–230°, from ether, in which solvent the substance is but sparingly soluble.

The **quinone**, prepared by oxidation of the ether complex by the procedure described below (*p*-chloro series), was obtained as an orange powder. The material is very sensitive to the action of solvents, but small amounts of microscopic orange prisms were obtained from dioxane–ligroin. When introduced into a bath at 235°, the substance decomposes at 244–246°, uncorr. It is soluble in dilute alkali.

Anal. Calcd. for $C_{27}H_{18}O_4$: C, 79.78; H, 4.47. Found[10]: C, 79.84; H, 4.15.

An azine was obtained by heating the quinone with *o*-phenylenediamine in glacial acetic acid solution, but it could not be obtained in a satisfactory crystalline condition. Acetylation of the yellow material gave the **azine monoacetate**, which when purified by crystallization from benzene–ligroin formed pale yellow microprisms, m. p. 284.5–285°.

Anal. Calcd. for $C_{36}H_{24}O_3N_2$: N, 5.38. Found[11]: N, 4.91.

Condensation with *p*-Chlorobenzaldehyde.—Following the procedure described above, 0.8 g. β-naphthohydroquinone and 0.6 g. of the aldehyde gave 0.8 g. of the condensation product **XIX**. This is similar to the parent compound but is somewhat more stable; it decomposes at about 200–210°. The substance dissolves readily in dioxane but a crystalline complex could not be isolated, the addition of ligroin causing the separation of only oily products. The ether complex separates from ether–petroleum ether in long, slender, glistening, colorless needles. The substance has no m. p. but loses solvent gradually, becoming yellow at about 90° and decomposing at about 210°. Analysis indicates the presence of two molecules of ether of crystallization.

Anal. Calcd. for $C_{27}H_{19}O_4Cl\cdot(C_4H_{10}O)_2$: C, 71.11; H, 6.65; Cl, 6.00. Found[12]: C, 70.81, 70.63, 70.96; H, 6.52, 6.66, 6.30; Cl, 6.03, 5.85, 6.07.

The **triacetate** was prepared by acetylation in the presence of either sulfuric acid, sodium acetate, or pyridine as catalyst. Thus either the crude condensation product or the purified ether complex was suspended in acetic anhydride, a drop of concentrated sulfuric acid (or a little pyridine or sodium acetate) was added, and the mixture allowed to stand at room temperature with occasional shaking. After about one day the solid dissolved, and on further standing the triacetate separated in a crystalline or granular condition. It was collected, washed, dried, and crystallized from ether–petroleum ether, when it formed colorless prisms, m. p. 237.5–238°.

Anal. Calcd. for $C_{33}H_{25}O_7Cl$: C, 69.65; H, 4.43; Cl, 6.23. Found: C, 69.33[11]; H, 4.54[11]; Cl, 6.14.[12]

Various methods were investigated for the preparation of the quinone. Oxidation occurs with lead tetraacetate, ferric chloride, or potassium dichromate, but the cleanest product is obtained with chromic acid. The carefully purified ether complex (2.4 g.) was dissolved in 20–25 cc. of glacial acetic acid and a solution of 1.8 g. of chromic oxide in the least amount of water was added. In a few minutes the solution was diluted with water and the bright orange precipitate coagulated by boiling and collected. The orange solid (1.5–1.6 g.) is soluble in cold alkali and can be reduced with hydrosulfite with discharge of the color. It becomes oily on attempted crystallization from benzene and decomposes in alcoholic solution. The dioxane solutions supersaturate and only a small amount of solid can be recovered. The best method found for purification is by extraction with pure, dry ether in a Soxhlet apparatus. The solubility in ether is slight, but after two to three hours a small crop of small, sword-like plates separates. If the crystals are allowed to remain long in contact with the boiling ether they gradually dissolve and only an oil is obtained on evaporation. It is therefore necessary to stop the extraction every few hours, collect the crystals, and start again with fresh ether. After five such extractions of 1.5 g. of crude material, 0.5 g. of crystalline quinone was obtained from the boiling flask and the residue in the thimble (0.5 g.) had also become crystalline.

(10) Analysis by Mrs. Verna R. Keevil.

(11) Analysis by the Arlington Laboratories.

(12) Analysis by Dr. C. Fitz.

The best material when introduced into a bath at 190° darkened at 200° and decomposed completely at about 210°. A yellow, alkali-soluble azine was obtained but could not be crystallized satisfactorily. According to the following analyses the crystallized quinone contains one molecule of ether.

Anal. Calcd. for $C_{27}H_{17}O_4Cl \cdot C_4H_{10}O$: C, 72.29; H, 5.29; Cl, 6.88. Found[11]: C, 72.29; H, 5.08; Cl, 7.00.

Resynthesis of the Condensation Product XIX.—A benzene solution of 0.28 g. of 2-hydroxy-4-(*p*-chlorobenzal)-1-naphthone (see below) and 0.16 g. of β-naphthohydroquinone was warmed and treated with a stream of hydrogen chloride for about five minutes. On rubbing the walls of the container a colorless powder separated (0.2 g.). This formed an ether complex of the properties listed above, and gave a triacetate, m. p. 234° uncorr., which did not depress the m. p. of the sample prepared from material obtained from *p*-chlorobenzaldehyde and β-naphthohydroquinone.

Condensation with *m*-Nitrobenzaldehyde.—On passing hydrogen chloride into a benzene solution containing 0.8 g. of each component a brown oil separated and on being rubbed it solidified. In the most successful experiments the yield of condensation product was 1–1.1 g. The substance apparently crystallizes from ether in the form of a complex (fine, cream colored needles), but this shows no characteristic m. p. and seems to lose solvent gradually when heated and decomposes above 200°. The **triacetate** crystallizes from ether in fine, colorless needles, m. p. 276.5–277°.

Anal. Calcd. for $C_{33}H_{25}O_9N$: C, 68.38; H, 4.36; N, 2.47. Found: C, 68.10[11]; H, 4.43[11]; N, 2.46.[12]

Condensation with *n*-Butyraldehyde.—From 0.5 g. of β-naphthohydroquinone and 0.2 g. of the aldehyde there was obtained 0.2 g. of colorless condensation product. The **triacetate**, prepared in the usual way with acetic anhydride–sulfuric acid at room temperature, forms fine, colorless needles from benzene–ligroin, m. p. 166.5–167°.

Anal. Calcd. for $C_{30}H_{28}O_7$: C, 71.97; H, 5.64. Found[11]: C, 72.07; H, 6.01.

The action of sulfuric acid on this condensation product was investigated but no pure product was isolated.

2-Hydroxy-4-benzal-1-naphthone (II) and Derivatives

Preparation of II from 4-Benzyl-1,2-naphthoquinone (Experiments by C. K. Bradsher and L. F. Fieser).—When a small sample (5 mg.) of 4-benzyl-1,2-naphthoquinone was heated with dilute alkali to the boiling point the substance soon dissolved to a deep orange-yellow solution and the odor of benzaldehyde became evident. The solution was filtered, acidified, and boiled to coagulate the precipitate, which separated as a granular, dull yellow solid. This was identified by microscopic tests, melting point (176–178°) and mixed m. p. as the substance described in more detail below. This method of isomerization is not practical for larger quantities and the yield is poor.

A better conversion was obtained by dissolving the quinone (0.1 g.) in concentrated sulfuric acid (1 cc.) at 0° and, after three minutes, pouring the deep red solution into water. The crystalline yellow product after recrystallization from alcohol melted at 180°, uncorr. (0.08 g.).

The same substance can be obtained by hydrolysis of the previously described[1] "abnormal triacetate" (XIV, m. p. 139.5–140°, corr.). In one experiment the triacetate (0.3 g.) was heated with alcohol (5 cc.) and 6 *N* sodium hydroxide (3 cc.), and the deep orange-red solution was diluted and acidified. The yellow precipitate on two crystallizations from alcohol formed a mat of hair-fine, yellow needles, m. p. 181–182°, uncorr. In another test the triacetate (1.1 g.) was refluxed with alcohol (10 cc.) and concentrated hydrochloric acid (3 cc.) for twenty minutes, during which time a crop of yellow needles had separated (0.45 g.). The recrystallized product melted at 181–182°, uncorr. The samples obtained in these experiments were found to be identical by mixed m. p. determination.

Anal. Calcd. for $C_{17}H_{12}O_2$: C, 82.22; H, 4.88. Found: C, 82.38,[13] 82.57[14]; H, 5.44,[13] 5.34.[14]

The compound crystallizes from alcohol on the microscope slide in characteristic twisted clusters of curved, pointed blades. When covered with dilute alkali these blades turn red and small granules of the red salt are deposited on the crystals. It is soluble in very dilute alkali in the cold and the red sodium salt separates easily in the presence of excess alkali; it is insoluble in sodium carbonate solution. When heated for some time with alcohol and bisulfite solution, the substance slowly dissolves to a colorless solution.

Preparation of II from the Condensation Product IV.—Only a partial conversion to II was accomplished by triturating the crude condensation product from β-naphthohydroquinone and benzaldehyde or benzal chloride with cold concentrated sulfuric acid, followed by precipitation with water, the difficulty apparently being that the condensation product dissolves with difficulty in acid. Mixtures of sulfuric acid with either glacial acetic or methanol (cold) were tried without improvement in the yield. It was then found that the triacetate dissolves readily in ice-cold sulfuric acid and is converted smoothly into II, and that this is true also of the readily prepared dioxane or ether complex of the condensation product. In a typical experiment 1.6 g. of the dioxane complex was stirred with 15 cc. of concentrated sulfuric acid under ice cooling until completely dissolved (five minutes), and the brilliant crimson solution, after standing for ten minutes, was poured onto ice. The brown-yellow solid which precipitated was coagulated by boiling the suspension, collected, and washed with water and with dilute sodium bicarbonate solution. A final washing with cold alcohol largely removed a reddish impurity, and the dried solid (0.5–0.6 g.) was nearly pure yellow, m. p. 177–179°. It is advisable to crystallize the material at this point from benzene, rather than alcohol, since the latter sometimes leads to the formation of the orange quinone XIII. The best material, however, is obtained by final crystallization from alcohol, which gives fine, yellow needles, m. p. 182.5–182.8°. This gave no depression when mixed with samples prepared from 4-benzyl-1,2-naphthoquinone.

Anal. Calcd. for $C_{17}H_{12}O_2$: C, 82.22; H, 4.88. Found[10]: C, 81.90, 82.06; H, 5.11, 4.84.

Reductive Acetylation.—In order to minimize the formation of the triacetate XIV, it is advisable to add the sodium

(13) Analysis by Mrs. G. M. Wellwood.
(14) Analysis by C. K. Bradsher.

acetate only after reduction has occurred. Zinc dust was added to a solution of hydroxybenzalnaphthone (0.5 g.) in acetic anhydride and after refluxing for a short time the solution became colorless. Sodium acetate (0.5 g.) was added, refluxing continued for ten minutes, and the solution was filtered and poured into water. The precipitated, colorless solid on crystallization from benzene–ligroin gave successive crops of a sparingly soluble substance which formed small prisms decomposing at 260–265°. This is probably a product of dimolecular reduction (Calcd. for $C_{42}H_{34}O_8$: C, 75.65; H, 5.14. Found[14]: C, 75.10; H, 5.28). After removing this material as completely as possible the mother liquors on evaporation yielded a yellowish oil which gave 0.09 g. of colorless crystals from ether–petroleum ether. The more soluble substance formed colorless prisms, m. p. 94°, and gave no depression when mixed with **4-benzyl-1,2-diacetoxynaphthalene**[1] (IX, m. p. 96–96.5°).

Reaction with Amines.—Attempts to prepare an azine from hydroxybenzalnaphthone with *o*-phenylenediamine hydrochloride and sodium acetate in acetic acid were unsuccessful. The reaction proceeded smoothly, however, when 0.25 g. of the yellow compound and 0.3 g. of free *o*-phenylenediamine were dissolved in hot glacial acetic acid and a drop of concentrated sulfuric acid was added. The diamine sulfate precipitated and was collected after boiling for five minutes, and the mother liquor on being concentrated and cooled deposited 0.2 g. of a yellow solid, m. p. 193°. Crystallization from alcohol gave yellow needles, m. p. 195.5–196°. This did not depress the m. p. of the **phenazine derivative X** prepared by Bradsher[1] from 4-benzyl-1,2-naphthoquinone.

Anal. Calcd. for $C_{28}H_{16}N_2$: C, 86.21; H, 5.04. Found[11]: C, 85.98; H, 5.00.

A reaction with aniline was brought about by refluxing an alcoholic solution of 0.4 g. of hydroxybenzalnaphthone and 4 cc. of the amine for seven hours, the color changing to deep red as the reaction progressed. After some concentration 0.1 g. of glistening red plates (m. p. 256–257°) separated, and the mother liquor then yielded 0.2 g. of feathery red needles, m. p. 179–180°. The less soluble product on recrystallization from methanol melted at 265–266°, and there was no depression on admixture with a sample of **4-anilino-1,2-naphthoquinone** (VI) prepared from 1,2-naphthoquinone-4-sulfonate.

Anal. Calcd. for $C_{16}H_{11}O_2N$: C, 77.09; H, 4.35. Found[12]: C, 77.23; H, 4.42.

The lower melting reaction product on purification melted at 182.5–183° and was found identical (mixed m. p.) with authentic **2-anilino-1,4-naphthoquinone-4-anil** (VII) and with the sample obtained from the quinone I by Bradsher.[1]

Anal. Calcd. for $C_{22}H_{16}ON_2$: N, 8.64. Found[12]: N, 8.49.

2-Hydroxy-4-(*p*-chlorobenzal)-1-naphthone.—In preparing this substance by the acid cleavage of the condensation product from β-naphthohydroquinone and *p*-chlorobenzaldehyde it is not necessary to use the ether complex. The crude condensation product in this case dissolves fairly readily in cold concentrated sulfuric acid and on collecting the material precipitated by pouring the red solution into water and washing it with water and then with a little alcohol a clean yellow product is obtained, m. p. 183–185°; the yield from 1.3 g. of starting material is 0.7–0.9 g. The purified substance crystallizes from alcohol in fine yellow needles, m. p. 190–190.5°.

Anal. Calcd. for $C_{17}H_{11}O_2Cl$: Cl, 12.55; mol. wt., 283. Found: Cl, 12.37[12]; mol. wt. (in benzene), 291.[14]

Monoacetate (VIII).—This was obtained by adding acetyl chloride to a pyridine solution of hydroxy-*p*-chlorobenzalnaphthone, allowing the solution to stand for several hours at room temperature, and adding water. The substance decomposed on attempted crystallization from alcohol but formed small yellow plates from benzene, m. p. 219.5–220°.

Anal. Calcd. for $C_{19}H_{13}O_3Cl$: C, 70.26; H, 4.04. Found[11]: C, 70.46; H, 3.86.

The **monobenzoate** was obtained by adding benzoyl chloride to a stirred solution of the substance in dioxane–alkali; it crystallizes from benzene–ligroin in fine, bright yellow needles, m. p. 229.5–230°.

Anal. Calcd. for $C_{24}H_{15}O_3Cl$: C, 74.51; H, 3.91. Found[10]: C, 74.58; H, 4.24.

The **phenazine derivative**, prepared as above, formed yellow plates, m. p. 243–244°, from acetic acid. The *p*-chloro compound reacts with aniline exactly as described for the parent substance, giving VI and VII.

4-(*p*-Chlorobenzyl)-1,2-diacetoxynaphthalene (IX, R = Cl) was obtained by reductive acetylation of the naphthone (0.6 g.), along with a less soluble (dimolecular?) substance (0.3 g.) which did not melt at 280°. The less soluble reaction product crystallized from ether–petroleum ether as large, colorless plates, m. p. 134.5–135°.

Anal. Calcd. for $C_{21}H_{17}O_4Cl$: C, 68.38; H, 4.65. Found[10]: C, 68.20; H, 4.80.

2-Hydroxy-4-(*m*-nitrobenzal)-1-naphthone.—The condensation product from *m*-nitrobenzaldehyde dissolves satisfactorily in sulfuric acid and the use of a solvated complex is not necessary, although the cleavage does not proceed as well as in the cases above. The precipitated and washed material (0.9 g. from 1.5 g.) melted at 200–202°; purified by crystallization from benzene–ligroin the compound formed clusters of deep yellow micro needles, m. p. 214–214.5°.

Anal. Calcd. for $C_{17}H_{11}O_4N$: C, 69.61; H, 3.78. Found[12]: C, 70.06; H, 3.90.

1,2,α-Triacetoxy-4-benzylnaphthalene (XIV) and Related Compounds

The preparation of the parent compound (XIV, R = H) from 4-benzyl-1,2-naphthoquinone has been described in the paper with Bradsher.[1] The same substance, identified by m. p. (139.5–140°) and mixed m. p., was obtained by the action of acetic anhydride on hydroxybenzalnaphthone in the presence of various catalysts in 85–95% yield. In attempting, in the chloro series, to control the acetylation and isolate the monoacetate, which was later obtained with use of acetyl chloride, the reaction was conducted under controlled conditions but only the triacetate resulted. Even when stirred with acetic anhydride and a trace of sulfuric acid under ice cooling, the yellow substance rapidly dissolved to give a colorless solution of the

triacetate. In the presence of a small amount of sodium acetate or pyridine the yellow color of the starting material disappeared on very gentle warming.

1,2,α-Triacetoxy-4-(*p*-chlorobenzyl)-naphthalene (XIV, R = Cl).—Prepared from the chloro compound with acetic anhydride–sulfuric acid, this substance crystallized from ether–petroleum ether as large, colorless prisms, m. p. 138.9–139.2°. On treatment with cold sulfuric acid the substance is cleaved and converted into the starting material.

Anal. Calcd. for $C_{23}H_{19}O_6Cl$: C, 64.71; H, 4.49; Cl, 8.31. Found: C, 64.84[10]; H, 4.57[10]; Cl, 8.49.[12]

Clemmensen Reduction.—A mixture of 1.4 g. of 1,2,α-triacetoxy-4-(*p*-chlorobenzyl)-naphthalene, 75 cc. of alcohol, 20 g. of amalgamated mossy zinc, and 15 cc. of concentrated hydrochloric acid was refluxed for four days, with the addition of 80 cc. more acid during this period. An oil separated on cooling, and after dilution this was extracted with ether and the ethereal solution was dried and partially evaporated. A slight yellow color developed, evidently due to air oxidation of the free hydroquinone. Acetic anhydride was therefore added and on shaking the solution with a little zinc dust the color was discharged. Sodium acetate was added and the solution was refluxed for ten minutes to complete the acetylation and poured into water. A white precipitate separated, and on crystallization from ether–petroleum ether there was obtained 0.5 g. of colorless prisms, m. p. 134.5–135°. This did not depress the m. p. of the **4-(*p*-chlorobenzyl)-1,2-diacetoxynaphthalene (IX, R = Cl)** described above. There was no trace of the high-melting dimolecular product obtained as a companion substance in the acetylative reduction of the hydroxybenzalnaphthone; this eliminates the possibility that in the present reaction reduction is preceded by hydrolysis of the triacetate.

1,2,α-Tripropionoxy-4-(*p*-chlorobenzyl)-naphthalene.—On adding a drop of concentrated sulfuric acid to a suspension of 0.25 g. of the hydroxy compound in 5 cc. of propionic anhydride the solid dissolved at once. After short warming the pale yellow solution was poured into water. Large, colorless prisms (0.1 g.) were deposited from ether–petroleum ether, m. p. 89–89.5°.

Anal. Calcd. for $C_{26}H_{25}O_6Cl$: C, 66.58; H, 5.38; Cl, 7.56. Found[11]: C, 66.49; H, 5.40; Cl, 7.81.

1,2,α-Triacetoxy-4-(*m*-nitrobenzyl)-naphthalene forms faintly yellow prisms from benzene–ligroin, or stout needles from alcohol, m. p. 139.5–140°.

Anal. Calcd. for $C_{23}H_{19}O_8N$: C, 63.15; H, 4.38. Found[11]: C, 63.52; H, 4.35.

The **tripropionate** forms large prisms from ether–petroleum ether, m. p. 142.5–143°.

1,2,α-Triacetoxy-4-dicarbethoxynaphthalene, XVII (Experiments by L. F. F.). (a) **By Acetylation.**—A suspension of 0.5 g. of 4-dicarbethoxymethyl-1,2-naphthoquinone[1] (or tautomer XVI) in 5 cc. of acetic anhydride was treated in the cold with 3 drops of concentrated sulfuric acid, which caused the solid to dissolve promptly (the monoacetate can be isolated at this point, or even after very brief heating). The light yellow solution was then heated at the boiling point until the color changed to a distinct brown, which took about five minutes, and the excess anhydride was then decomposed, after cooling, with water. The crude product was tan and rather gummy, but one crystallization from dilute alcohol gave nearly pure material, m. p. 138–140°, in good yield. The thoroughly purified substance separates slowly from a slightly diluted alcoholic solution in colorless, prismatic needles, m. p. 140.5–141°.

Anal. Calcd. for $C_{28}H_{24}O_{10}$: C, 59.99; H, 5.26. Found[15]: C, 60.16; H, 5.38.

A sample was dissolved in concentrated sulfuric acid (frothing) and the red-brown solution poured into water. Crystallization of the precipitate from alcohol gave yellow plates, m. p. 105–106°, identical with the starting material.

(b) **By Lead Tetraacetate Oxidation.**—A solution of 0.4 g. of 4-dicarbethoxymethyl-1,2-diacetoxynaphthalene[1] (XVIII) and 0.6 g. of lead tetraacetate in 12 cc. of glacial acetic acid was heated on the steam-bath for three hours and diluted with water. The crude product was at first gummy, but after four crystallizations from dilute alcohol it formed colorless, prismatic needles, m. p. 139–140°. There was no depression when mixed with the above sample.

α-Alkoxy-4-benzyl-1,2-naphthoquinones

Preparation.—After recognizing that these substances arise from the reaction of the hydroxybenzalnaphthones with an alcohol under the influence of a trace of sulfuric acid, numerous trials were made in an effort to obtain satisfactory yields. Hydrogen chloride was tried as catalyst without success, and increasing the amount of sulfuric acid or refluxing to hasten the reaction led only to the formation of tarry products. The best procedure found consisted in adding one drop of concentrated sulfuric acid to a suspension of 0.5–1 g. of the yellow hydroxy compound in 15–25 cc. of absolute methyl or ethyl alcohol, heating gently to bring the solid into solution, and allowing the red solution to stand at room temperature for two or three days. When the mixture was worked up after only twenty-four hours the sole product isolated was the starting material. If yellow crystals separated on standing more alcohol was added and they were brought into solution. A part of the reaction product sometimes separated as brilliant orange plates, and these were collected separately. After the period specified the solution was diluted with water and the oily precipitate taken into ether and washed with water and with sodium carbonate solution. After drying and concentrating the ethereal solution, petroleum ether was added. The alkoxy derivative usually separated as brilliant orange or orange-red plates; occasionally some starting material was found in the mother liquor, and there usually was dark tar. The yields were rather irregular, even in duplicate experiments with the same reagents. In a few cases the conversion was as high as 70–80%, but more often the products were obtained in 30–50% yield.

α-Ethoxy-4-benzyl-1,2-naphthoquinone (XIII) formed orange plates from alcohol and melted at 154.5–155°.

Anal. Calcd. for $C_{19}H_{16}O_3$: C, 78.08; H, 5.51. Found: C, 78.10,[14] 77.68[11]; H, 5.49,[14] 5.59.[11]

(15) Analysis by Herbert S. Wight.

The corresponding **α-methoxy compound** formed orange needles, m. p. 133.5–134°.

Anal. Calcd. for $C_{18}H_{14}O_3$: C, 77.67; H, 5.07. Found[11]: C, 77.56; H, 5.07.

α-Methoxy-4-(*p*-chlorobenzyl)-1,2-naphthoquinone crystallized from alcohol in orange plates, m. p. 172.5–173°.

Anal. Calcd. for $C_{18}H_{13}O_3Cl$: C, 69.12; H, 4.19; Cl, 11.35; OCH_3, 9.92. Found[11]: C, 69.09; H, 4.18; Cl, 11.48; OCH_3, 9.97.

The **phenazine derivative**, prepared with *o*-phenylenediamine in glacial acetic acid, formed long, slender, yellow needles from this solvent and melted at 202–202.5°.

Anal. Calcd. for $C_{24}H_{17}ON_2Cl$: N, 7.28; Cl, 9.22. Found[11]: N, 7.45; Cl, 9.23.

α-Methoxy-4-(*p*-chlorobenzyl-1,2-diacetoxynaphthalene.—The above orange quinone (0.26 g.) was submitted to reductive acetylation in the usual way and the product extracted and dried in ether. Petroleum ether was added and, after obtaining seed by cooling in carbon dioxide–ether, the substance crystallized in a satisfactory form, giving 0.2 g. of product. The diacetate forms colorless needles, m. p. 134–134.5°.

Anal. Calcd. for $C_{22}H_{19}O_5Cl$: C, 66.24; H, 4.80; Cl, 8.89. Found[11]: C, 66.38; H, 4.75; Cl, 8.86.

α-Ethoxy-4-(*p*-chlorobenzyl)-1,2-naphthoquinone was obtained as orange plates, m. p. 144–144.5°. It was analyzed as the **phenazine**, obtained as pale yellow, feathery needles from glacial acetic acid, m. p. 203–203.5°.

Anal. Calcd. for $C_{25}H_{19}ON_2Cl$: N, 7.03; Cl, 8.89. Found[11]: N, 6.84; Cl, 8.62.

Acid cleavage of the α-ethoxy quinone of the chloro series was accomplished by dissolving 0.2 g. of the material in 2 cc. of concentrated sulfuric acid and, after fifteen minutes, pouring the red solution into water. The yellow precipitate was very crude (m. p. 150°), but after several crystallizations from benzene–ligroin it afforded bright yellow needles, m. p. 188°; a mixture with 2-hydroxy-4-(*p*-chlorobenzal)-1-naphthone melted at 188–189°.

Acetylation of 2-Benzyl-3-hydroxy-1,4-naphthoquinone[16]

When a mixture of 1.6 g. of the quinone, 0.5 g. of sodium acetate, and 10 cc. of acetic anhydride was heated at the boiling point for a minute or two until the red color was discharged and poured into water, there was obtained 1.7 g. of a light yellow product having the properties of the normal monoacetate and crystallizing from benzene in flat needles, m. p. 120–121°, uncorr. A product of further reaction, regarded as 1,3,4,α-tetraacetoxy-2-benzylnaphthalene, XXI, was obtained when the heating was continued for a longer period. In a typical experiment a mixture of 5 g. of the quinone, 5 g. of sodium acetate, and 60 cc. of acetic anhydride was refluxed for twenty-five minutes, the color changing during this time from red through yellow and dark brown to green. The crude product obtained after treatment with water gave 6 g. of somewhat brown material, m. p. 183–186°, on initial crystallization from benzene. After repeated crystallization from benzene–ligroin or dilute alcohol the substance formed small, colorless plates melting constantly at 193.5–194°, uncorr.

Anal. Calcd. for $C_{26}H_{22}O_6$: C, 66.65; H, 4.93; mol. wt., 450. Found[17]: C, 66.57, 66.77, 66.60; H, 5.06, 5.02, 4.92; mol. wt.[18] (Rast), 412.

On heating the colorless substance with alcoholic alkali in an atmosphere of nitrogen a brilliant purple color developed and then changed to red. The material precipitated by acidification was yellow and on crystallization melted at 173.5–174.5°, uncorr., and did not depress the m. p. of 2-benzyl-3-hydroxy-1,4-naphthoquinone.

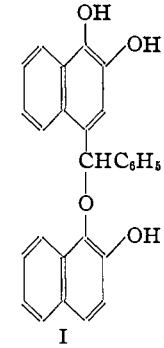
When refluxed in the same way with acetic anhydride and sodium acetate, hydrolapachol was converted only into the normal monoacetate and the methyl ether of 2-benzyl-3-hydroxy-1,4-naphthoquinone (prepared with diazomethane, m. p. 83–83.5°) was recovered unchanged.

1,3,4-Triacetoxy-2-benzylnaphthalene, prepared by reductive acetylation of the quinone, crystallized from dilute acetic acid as small, colorless microcrystals, m. p. 179–180°, uncorr., and gave a depression when mixed with the above tetraacetate.

Anal. Calcd. for $C_{23}H_{20}O_6$: C, 70.39; H, 5.14. Found[17]: C, 70.36; H, 5.32.

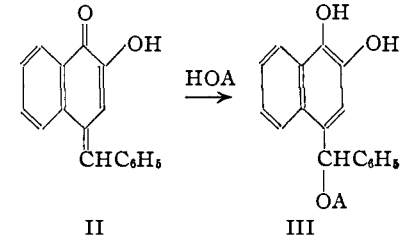
Summary

β-Naphthohydroquinone enters into a remarkable condensation with benzal chloride, or with benzaldehyde and hydrogen chloride, giving a



I

crystalline but sensitive substance which is assigned the structure I. This is uncertain only with respect to the specific hydroxyl group involved in the ether linkage. The substance is cleaved by sulfuric acid into 2-hydroxy-4-benzal-1-naphthone, II, a stable compound obtainable by the isomerization of 4-benzyl-1,2-naphthoquinone



II III

with the same reagent or with alkali. This qui-

(16) Experiments by L. F. Fieser and Evalyn W. Brodie at Bryn Mawr College, 1926–1927.

(17) Analyses by L. F. Fieser.

(18) Determined by E. W. Brodie.

none and the stable tautomer II can be converted into the same derivatives, but the acidic substance has not been reconverted into the quinone. Hydroxybenzalnaphthone (II) enters into various reactions involving a primary addition to the ends of the conjugated system. β-Naphthohydroquinone adds to give the condensation product I; an alcohol reacts to give a hydroquinone III, which is converted by air oxidation to the corresponding orthoquinone. The addition of acetic anhydride results in the formation of 1,2,α-triacetoxy-4-benzylnaphthalene, and the same product is obtained from 4-benzyl-1,2-naphthoquinone, evidently through tautomerism to II. It is suggested that a similar reaction is responsible for the abnormal acetylation of lapachol leading to the formation of a derivative of the substance characterized by Hooker as dehydro-α-lapachone (Paternò's "isolapachone").

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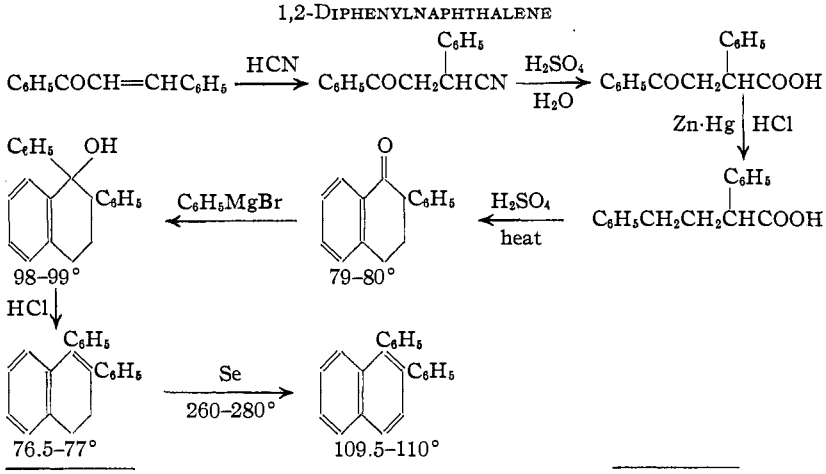
The Diphenylnaphthalenes[1]

BY H. MARJORIE CRAWFORD

There has been reported only one of the four possible diphenylnaphthalenes in which the phenyl groups are in the same ring. Franssen[2] reported the melting point of 1,4-diphenylnaphthalene as 308°, but it has since been shown by Weiss, Abeles and Knapp[3] to melt at 135–137° and by Allen and Gilman[4] to melt at 134–136°.

This paper reports the preparation of 1,2-, 1,3- and 2,3-diphenylnaphthalenes which were needed as reference compounds in connection with another problem. The series of reactions used in the preparation of these compounds is shown, followed by the descriptions of the procedures. The compounds whose melting points are indicated in the equations are described for the first time.

1,2-DIPHENYLNAPHTHALENE



α-Phenyl-β-benzoylpropionitrile was made in 90% yields by the addition of hydrocyanic acid to benzalacetophenone.[5]

α-Phenyl-β-benzoylpropionic acid was prepared in 95% yields by the hydrolysis of the nitrile with sulfuric acid.[6] Thirty to forty grams of the nitrile was hydrolyzed at one time.

α,γ-Diphenylbutyric acid was made by a Clemmensen reduction of the keto acid. Twenty grams of the keto acid was boiled for eighteen hours with 200 g. of amalgamated zinc and 260 cc. of concd. hydrochloric acid. The hydrochloric acid was added in several portions. Extraction of the cooled mixture with petroleum ether and evaporation of the solvent gave 14.5 g. (76%) of the saturated acid. It melted at 75° as reported by Kohler and Kimball[7] and not at 110° as reported by Ali, Desai, Hunter and Muhammad.[8]

1-Oxo-2-phenyl-1,2,3,4-tetrahydronaphthalene was prepared by heating 10 g. of α,γ-diphenylbutyric acid with 42 cc. of concd. sulfuric acid and 14 cc. of glacial acetic acid on the steam-bath for one and one-half hours. The mixture was stirred mechanically. After cooling, the mixture was extracted with ether. The ether solution was then extracted with a solution of potassium hydroxide to remove unchanged acid. Evaporation of the ether solution gave

(1) Reported at the fall meeting of The American Chemical Society at Milwaukee, Wis., in September, 1938.
(2) Franssen, *Bull. soc. chim.*, **37**, 902 (1925).
(3) Weiss, Abeles and Knapp, *Monatsh.*, **61**, 162 (1932).
(4) Allen and Gilman, THIS JOURNAL, **58**, 937 (1936).
(5) *Org. Syntheses*, **10**, 80 (1930).
(6) Lapworth and Wechsler, *J. Chem. Soc.*, **97**, 42 (1910).
(7) Kohler and Kimball, THIS JOURNAL, **55**, 4637 (1933).
(8) Ali, Desai, Hunter and Muhammad, *J. Chem. Soc.*, 1016 (1937).