[CONTRIBUTION FROM THE SCHOOL OF CHEMISTRY OF THE UNIVERSITY OF MINNESOTA]

# The Reaction between Quinones and Sodium Enolates. VII. Bromopseudocumoquinone and Sodium Malonic Ester[1]

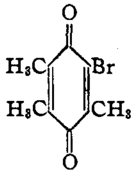
BY LEE IRVIN SMITH AND KENNETH C. JOHNSON[2]

So far, in the work described in this series of papers, two types of quinones have been investigated: (a) completely methylated para benzoquinones, represented by duroquinone[3] and by 2,3-dimethylnaphthoquinone[4]; (b) a quinone with one free position, pseudocumoquinone.[5] In the reactions with sodium enolates, such as sodium malonic ester, quinones of type (a) have behaved as pentad-enol systems and have given coumarin derivatives, while the quinone of type (b) reacted through the conjugated system terminating in the free position, and gave benzofuran derivatives. At the beginning of this work, duroquinone was selected for investigation because a fully substituted quinone, containing no *replaceable* group, was desired in order that the reaction might be with certainty confined to an addition.

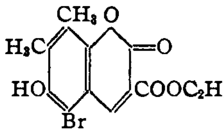
A great variety of active methylene compounds has been used in reactions with halogenated quinones, such as 2,3-dichloro-α-naphthoquinone.[6] In general, one or both of the halogen atoms were replaced, but when only one halogen atom was present this might or might not react, and the reaction has involved the replacement even of an ether group by a malonic ester residue although halogen was available.[7] Moreover, the halogen in 2-bromo-3-mesityl-α-naphthoquinone was inert toward sodium malonic ester.[8]

The mononuclear halogenated quinones also have shown the same irregularities. Chloranil[6a,9] reacted with replacement of two (para) chlorine atoms by malonic ester residues; in the diethers of chloroanilic acid both ether groups were replaced;[10] and in dibromothymoquinone only one halogen (ortho to the methyl group) was replaced by the malonic ester residue, while with aniline, the *methyl group* was replaced by the anilino group.[11]

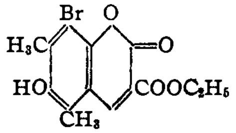
Because of the variety of the reactions shown by halogenated quinones, it was of interest to examine the behavior of bromopseudocumoquinone (I) toward sodium malonic ester. This quinone could react by replacement of the halogen by the malonic ester residue and it also offered the possibility of a reaction of the type (a) quinones already studied which would involve a methyl group and lead to a coumarin derivative. In the latter case, three different coumarins (A, B, C) could result, since the three methyl groups in the quinone were not equivalent (*o*-, *m*- or *p*- to the bromine atom). If only one of the methyl groups were involved, it was hoped that a study of the reaction would yield information concerning the activating effects of the groups upon each other as transmitted through the quinone ring.



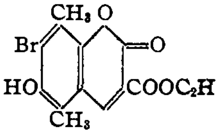
I



A (ortho)



B (meta)
III



C (para)

When bromopseudocumoquinone (I) was added to a solution of sodium malonic ester in absolute alcohol, there resulted a red sodium derivative (II) which, when decomposed by hydrochloric acid, gave a golden-yellow substance (III). Analysis and determination of the molecular weight showed this substance to have the composition $C_{14}H_{13}O_5Br$. The equation which Smith

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[1] Part VI, THIS JOURNAL, **59**, 667 (1937).

[2] Abstracted from a thesis by Kenneth Carl Johnson presented to the Graduate Faculty of the University of Minnesota in partial fulfilment of the requirements for the degree of Doctor of Philosophy, March, 1937.

[3] (a) Smith and Dobrovolny, THIS JOURNAL, **48**, 1693 (1926); (b) Smith and Tenenbaum, *ibid.*, **59**, 667 (1937).

[4] Smith and Webster, *ibid.*, **59**, 662 (1937).

[5] Smith and MacMullen, *ibid.*, **58**, 629 (1936).

[6] Liebermann, (a) *Ber.*, **31**, 2903 (1898); (b) *ibid.*, **32**, 916 (1899); (c) *ibid.*, **33**, 566 (1900); (d) Michel, *ibid.*, **33**, 2402 (1900); (e) Hirsch, *ibid.*, **33**, 2412 (1900).

[7] Liebermann, *ibid.*, **32**, 260 (1899).

[8] Han Chiang Yuan, *J. Chinese Chem. Soc.*, **3**, 141 (1935); from *C. A.*, **29**, 6229 (1935).

[9] Stieglitz, *Am. Chem. J.*, **13**, 38 (1891).

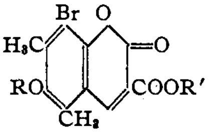
[10] (a) Grindley and Jackson, *Ber.*, **26**, 397 (1893); (b) *Am. Chem. J.*, **17**, 579, 633 (1895); (c) Jackson and Oenslager, *ibid.*, **18**, 1 (1896); (d) Bentley, *ibid.*, **20**, 472 (1898).

[11] Hoffmann, *Ber.*, **34**, 1558 (1901).

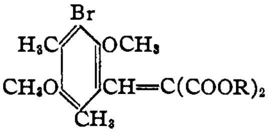
and Dobrovolny[3a] found to hold for the reaction between duroquinone and malonic ester, when applied to I, would lead to a product having the composition of III.

$$\underset{\text{I}}{2C_9H_9O_2Br} + C_7H_{12}O_4 \longrightarrow \underset{\text{III}}{C_{14}H_{13}O_5Br} + C_2H_5OH + C_9H_{11}O_2Br$$

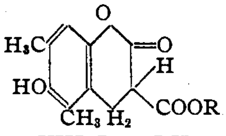
It was obvious at the outset, therefore, that the bromine atom in the quinone I had not reacted, but that one of the methyl groups had been involved and that the product III was undoubtedly one of the coumarin esters A, B and C. The substance III was an ester, for it could be hydrolyzed to an acid (IV). The yellow ester III also contained one hydroxyl group for it could be converted into a white monoacetate (V); likewise the yellow acid IV could be converted into a white monoacetate (VI). Only a single product (VII) could be obtained by methylation of the ester III with methyl sulfate and alcoholic potassium hydroxide, and the same methyl derivative VII was obtained from the acid IV, or from the acetates V and VI. The composition of this methyl derivative was $C_{13}H_{11}O_5Br$—hence the ester grouping in III was hydrolyzed during the methylation, and VII was a monomethyl derivative of IV. Catalytic reduction of the ester III gave a colorless product (VIII) $C_{14}H_{16}O_5$, which contained no bromine. This composition corresponded to that required by reduction of one double bond, and replacement of the bromine by hydrogen, in the ester III.



III, R = H, R′ = $C_2H_5$
IV, R = H, R′ = H
V, R = Ac, R′ = $C_2H_5$
VI, R = Ac, R′ = H
VII, R = $CH_3$, R′ = H



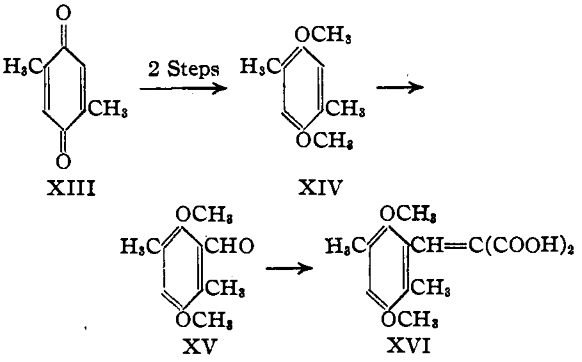
D, R = $C_2H_5$
E, R = H



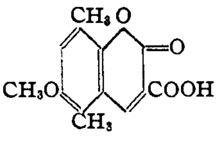
VIII, R = $C_2H_5$
VIIIa, R = H

It was planned to open the coumarin ring by methylation and so obtain the ester D or the acid E which could then be synthesized or degraded to simpler compounds, analogous to the method used by Smith and Dobrovolny[3a] in handling the product from duroquinone. But the replacement of a methyl group by bromine in position 8 of the coumarin rendered the hetero ring surprisingly resistant to opening, and it was not possible to obtain any product other than VII by any of the methods tried.

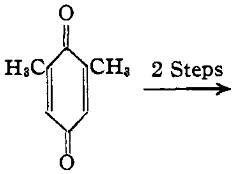
Since it was not possible to degrade the ester III to any simpler compound, it became necessary to synthesize either the ester III or one of its derivatives. At this point nothing about the chemistry of III or its derivatives was known which would point to a choice among the possible structures A, B and C for III, consequently the choice of which of these to synthesize first was governed by the accessibility of the starting materials. Of the three xyloquinones which constituted the starting points for the respective series, the para isomer was most readily obtained; hence the first attempt was directed toward a synthesis of C. *p*-Xyloquinone (XIII) was converted to 1,4-dimethyl-2,5-dimethoxybenzene (XIV) and the latter was converted to 2,5-dimethyl-3,6-dimethoxybenzaldehyde (XV). The aldehyde was difficult to brominate, and when subjected to rather vigorous conditions it gave a product which could not be purified. It was therefore condensed with malonic acid to give the benzalmalonic acid XVI and this, when heated above its melting point, lost methyl alcohol to give 3-carboxy-6-methoxy-5,8-dimethylcoumarin XVII.[3a]



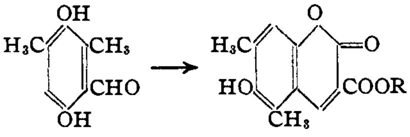
Bromination of XVII to give C was unsuccessful; the product showed only a slight test for halogen and even after several recrystallizations melted over a wide range. But the melting point of XVII, 230°, was 20° higher than that of the bromocoumarin VII, and since all previous experience with these compounds had shown that the introduction of a bromine atom into the ring raised the melting point considerably, it appeared



XVII



XVIII

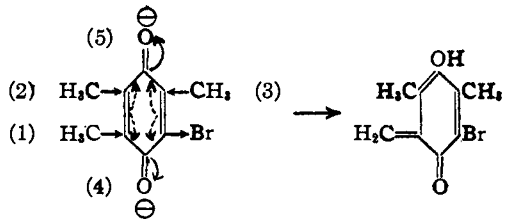


XIX

XX R = H
XXI R = $C_2H_5$

quite certain that the ester III did not belong in the para series (C).

At this point, attention was turned to the meta series and hence to a synthesis of B or some compound derived from it.[12] *m*-Xyloquinone XVIII was prepared by oxidation of mesidine, and by a series of reactions similar to that outlined above the quinone was converted into 2,4-dimethyl-3,6-dihydroxybenzaldehyde (XIX). Condensation of XIX with malonic acid gave 3-carboxy-6-hydroxy-5,7-dimethylcoumarin, (XX). Malonic ester did not condense well with the aldehyde XIX, but the ethyl ester XXI was easily prepared from the acid XX. Bromination of the coumarin acid XX to the bromocoumarin IV was unsuccessful, but when the ethyl ester XXI was catalytically reduced, a dihydro ester resulted which was identical in all respects with the ester VIII prepared by reduction of III. A specimen of VIII prepared by reduction of I gave, when oxidized with ferric chloride, a coumarin acid identical in all respects with the acid XX.



I F

In the quinone I, the electrons tend to shift as shown by the arrows. One-half of the molecule is symmetrical, so that the effects of the methyl groups 1 and 2 are the same. But in the other half of the molecule, the bromine atom has a strong electron affinity and this counteracts the tendency for the electrons to shift to the oxygen atom 4, while the methyl group 3 augments the tendency for the electrons to shift to the oxygen atom (5). As a result of these effects, oxygen atom 5 is more electronegative than 4. Consequently, when enolization occurs in the pentad–enol system, the hydrogen would shift to the more negative oxygen atom (5), and the enol would have structure F in which the methyl group (1) meta to the bromine atom, is part of the new conjugated system.

The substance III obtained from the reaction between bromopseudocumoquinone and sodium malonic ester therefore possesses the structure B and is 3-carbethoxy-6-hydroxy-5,7-dimethyl-8-bromocoumarin. In this reaction the bromine atom of the quinone is unaffected; the quinone behaves as a pentad–enol system and it is the methyl group meta to the bromine which is involved in the reaction. It is proposed to explore the limits of this reaction in a series of brominated alkyl quinones and to discover how far this inertness of the bromine atom extends.

Although the initial experiments on the reaction between the quinone and sodium malonic ester were carried out in alcohol, the yield of product III by this procedure was very low and it was possible to account for but a small fraction of the quinone used. This was due to the action of sodium ethoxide which rather rapidly converted the quinone to tarry products. When the red sodium compound (II) was prepared in benzene, according to the original procedure of Smith and Dobrovolny,[3a] the ester III obtained from it was accompanied by large amounts of a highly fluorescent viscous oil, and the yield of III was low. Better results were obtained when the quinone was added to a suspension of sodium malonic ester (free from alcohol) in ether, but it was possible to account for only about 30% of the starting quinone when this procedure was used. When, however, the quinone was added to an alcoholic solution of malonic ester in which finely divided magnesium ethoxide was suspended, a reddish solid soon precipitated with very little tarry by-product. This magnesium compound (IX) when filtered and dried was light tan in color. Dilute acids readily converted it to the ester III and with dilute hydrochloric acid the reaction was quite vigorous. The yield of coumarin ester III when prepared in this way was approximately the theoretical assuming two moles of quinone necessary to form one mole of III. The alcoholic filtrate from the magnesium compound yielded the fairly stable, brilliant black quinhydrone of I. Practically all of the quinone used was accounted for by ester III and quinhydrone recovered.

While the discovery that this magnesium derivative was readily formed and that it could be

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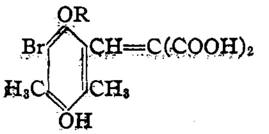
(12) While this synthesis was in progress, Dr. I. M. Webster and Mr. T. A. Geissman of this Laboratory called the attention of the authors to the fact that an application of the electronic principles used extensively by the English School of Organic Chemists [see C. K. Ingold, *Chem. Rev.*, **15**, 225 (1934)] would lead to the prediction that B was the correct structure for III.

converted to III in good yield was of great practical value in these researches, the most interesting and significant property of the substance was the fact that it could be converted into a series of derivatives closely related to, but different from the series of derivatives obtained from the ester III or from the sodium compound II. When the magnesium compound (IX) was decomposed by freshly distilled methyl sulfate in methanol, a *yellow* product (X) melting at 240° was obtained. Analysis of this product X showed a composition closely approximating $C_{13}H_{16}O_6Br$, and it contained one methoxyl group. The substance was unaffected by boiling it in acetone solution with hydrochloric acid, but hydrobromic acid in acetic acid converted it to the coumarin acid IV. The action of acetic anhydride converted X into a colorless acetyl derivative (XII), which was different from any acetate obtained from the ester III or from its derivatives. Methylation of X by methyl sulfate and alkali gave the same methyl ether VII as was obtained by methylation of III. When the magnesium compound IX was subjected to the action of acetyl chloride (distilled from dimethylaniline directly onto the substance) it gave an oily reaction product from which yellow, solid acetyl derivative (XI) was finally isolated.

When methylated, the acetyl derivative XI gave the methyl ether VII; hydrolysis of XI by acetone–hydrochloric acid gave the coumarin acid IV. Because of the formation of a series of products entirely different from those obtained from the coumarins III and IV, it is believed that these substances are derived from the primary metallic derivative formed by 1,4-addition to the conjugated system in F. While much more work remains to be done on this series of compounds, the methyl ether X and the acetate XI are provisionally given the structures shown.[13]



X R = $CH_3$
XI R = Ac

## Experimental Part[13a]

**Synthesis of the Quinone I. 5-Bromo-3,6-dinitropseudocumene.**—A solution of 5-bromopseudocumene (50 g.) in chloroform (200 cc.) was floated on to sulfuric acid (200 cc.). Fuming nitric acid (50 g., d. 1.5) was added dropwise (forty-five minutes) with cooling (−5 to 0°) and stirring. The initial dark color gradually lightened and a solid began to separate. Stirring was continued for thirty minutes after adding the nitric acid; this was followed by stirring for thirty minutes at room temperature. The reaction mixture was a thick emulsion, which did not separate well into layers, but the layers were separated as completely as possible and the acid was extracted once or twice with fresh chloroform. The oil and the chloroform solutions were combined, washed with water, dilute alkali and again with water. Ethanol (300 cc.) was added and the solution concentrated to half its volume. The mixture was cooled to 0°, and the solid was removed, washed with cold alcohol and dried. The white product weighed 61 g. (84%) and melted at 216–217°. When crystallized twice from chloroform–ethanol, the substance melted at 221–222°.[14] From the filtrates about 6 g. more was obtained, bringing the total yield to 93%. The substance could be recrystallized from benzene–alcohol or chloroform–alcohol, but the reaction product, isolated as described, was quite pure.

*Anal.* Calcd. for $C_9H_9O_4N_2Br$: C, 37.37; H, 3.14; Br, 27.6. Found: C, 37.38; H, 3.16; Br, 27.8.

The stannichloride of 5-bromo-3,6-diaminopseudocumene was obtained when a hot solution of stannous chloride (350 g.) in hydrochloric acid (400 cc.) was added quickly to a hot solution of the bromonitro compound (53 g.) in acetic acid (400 cc.). The reaction was vigorous and it was necessary to use a large flask (5 liters). The reaction mixture was cooled to 0°, the solid filtered and washed with alcohol (80 cc.) and ether (60 cc.). The product was contaminated with tin salts; it weighed 85 g. (theory 73 g.).[15]

The amine was isolated by extracting with ether a suspension of the stannichloride in alkali. Crystallized from alcohol, it was almost white (darkened at 150°) and melted at 155° to a black liquid.

*Anal.* Calcd. for $C_9H_{13}N_2Br$: C, 47.16; H, 5.72; Br, 34.9. Found: C, 47.07; H, 5.59; Br, 35.3.

The stannichloride (58 g.) was added to a solution of ferric chloride (275 g.) in water (275 cc.) and hydrochloric acid (25 cc.) in a flask equipped for steam distillation. After standing at room temperature for thirty minutes, the mixture was warmed on the steam-bath for thirty minutes and then steam distilled. The quinone I, isolated from the distillate, weighed 26 g. (82% based on the dinitro compound taken) and melted at 79–80°. It could be crystallized from alcohol in golden-yellow needles, but the crude product was sufficiently pure for most purposes.

*Anal.* Calcd. for $C_9H_9O_2Br$: C, 47.16; H, 3.97; Br, 34.9. Found: C, 47.43; H, 4.02; Br, 34.9.

When the quinone (0.2 g.) in alcohol (25 cc.) was added to the hydroquinone (0.2 g.) in alcohol (50 cc.) and the yellow solution concentrated on the steam-bath until the color darkened, there resulted the black, stable quinhydrone melting at 148.5–149.5°.

**Bromopseudocumohydroquinone.**—To the quinone (1 g.) suspended in alcohol (5 cc.) was added a solution of stannous chloride (2 g.) in dilute hydrochloric acid (25

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[13] Farmer, Ghosal and Kon [*J. Chem. Soc.*, 1804 (1936)] have recently obtained two types of metallic derivatives by the addition of sodium malonic esters to α-β acetylenic esters. These two types of metallic derivatives are closely related, but each gives its own series of alkyl derivatives.

[13a] Microanalyses by J. W. Opie.

[14] Fittig [*Ann.*, **147**, 14 (1868)] reports the m. p. as 214–215°.

[15] Nietzki and Schneider, *Ber.*, **27**, 1428 (1894).

cc.). The mixture was warmed until the color disappeared, and the product appeared on cooling. Crystallized from dilute alcohol containing a little stannous chloride and hydrochloric acid, the product formed white needles (0.9 g.), darkened at 170° and melted at 185° (dec.).

**The dimethyl ether** resulted when the hydroquinone (0.5 g.) in methanol (5 cc.) and methyl sulfate (3 cc.) was warmed and treated with small portions of saturated potassium hydroxide in methanol until the reaction mixture was strongly alkaline. The solution was acidified, the solid was removed and crystallized from methanol. The yield of white product, melting at 71–72°, was nearly quantitative.

*Anal.* Calcd. for $C_{11}H_{15}O_2Br$: C, 50.97; H, 5.83; Br, 30.9. Found: C, 51.79; H, 6.04; Br, 30.8.

**The diacetate,** prepared in the usual way, and crystallized from alcohol, formed white needles which melted at 178–179°.

*Anal.* Calcd. for $C_{13}H_{15}O_4Br$: C, 49.52; H, 4.79; Br, 25.4. Found: C, 49.92; H, 4.92; Br, 25.4.

**The dibenzoate,** prepared by the Schotten–Baumann method and crystallized from chloroform–alcohol, was white and melted at 253–255°.

*Anal.* Calcd. for $C_{23}H_{19}O_4Br$: C, 62.87; H, 4.37; Br, 18.2. Found: C, 63.28; H, 4.56; Br, 18.1.

**Addition of Malonic Ester to the Quinone I. (a) In Alcohol.**—A solution of the quinone (11.5 g.) in dry alcohol (100 cc.) was added dropwise to a solution of malonic ester (8 g.) and sodium ethoxide in dry alcohol (1.5 g. sodium, 50 cc. alcohol). The color became bluish-violet at once, then changed to red and a dark solid began to separate within ten minutes. After standing for thirty minutes the solution was poured onto ice (500 g.) and hydrochloric acid (50 cc.). The precipitate gradually collected together into a dark spongy mass which solidified on standing overnight. The dark solid was dissolved in hot alcohol and the solution was filtered. The cooled filtrate deposited 2 g. (25%) of **3-carbethoxy-6-hydroxy-5,7-dimethyl-8-bromocoumarin** (III) in the form of dark yellow needles melting at 200°. The rest of the reaction product was a dark oil from which no other solids could be isolated.

*Anal.* Calcd. for $C_{14}H_{13}O_5Br$: C, 49.26; H, 3.84. Found: C, 48.93; H, 4.26.

**(b) In Ether.**—Sodium (0.5 g.) was dissolved in dry alcohol (10 cc.) and after ethyl malonate (3.5 g.) was added the solvent was removed under reduced pressure. The residual white powder was suspended in ether (150 cc.) and a solution of quinone I (1 g.) in ether was added. After refluxing on the steam-bath for twelve hours, the red sodium compound (II) was filtered, washed with ether and dried. Decomposition of the sodium compound with acids gave III melting at 200° in about 25% yield and from the ethereal filtrates some quinone could be recovered.

**(c) In Benzene.**—The procedure of Smith and Dobrovolny[3a] was followed, but the yield of III was very low. Apparently the prolonged heating (eight days) in the presence of alkali largely destroyed both the quinone and the product.

**(d) Using Magnesium Malonic Ester.**—Magnesium ethoxide (6 g., freshly pulverized) was refluxed with malonic ester (6 g.) and dry alcohol (250 cc.). The quinone I (8 g.) in alcohol was added dropwise while a current of air was bubbled through the reaction mixture. Refluxing was continued, with air passing through, for twelve hours longer. The tan solid IX was filtered and washed with ether; the first crop of material weighed 10.8 g., and from the filtrate and washings 1.6 g. more was obtained. The substance was contaminated with magnesium ethoxide and it was not analyzed. When decomposed by hydrochloric acid the magnesium compound IX (1 g.) gave slightly more than 0.4 g. of the coumarin III melting at 200°. The ether filtrates when evaporated gave a dark oil consisting of malonic ester and quinhydrone.

**3 - Carbethoxy - 6 - acetoxy - 5,7 - dimethyl - 8 - bromocoumarin (V).**—The ester III (1 g.) was boiled with acetic anhydride (20 cc.) and sulfuric acid (5 drops). After thirty minutes the solution was poured into water and the mixture made alkaline with ammonia. The solid was dissolved in chloroform, the solution filtered, alcohol added and the filtrate and the solvents evaporated to a small volume. The solid was removed and recrystallized from alcohol. It was white, weighed 0.9 g. (88%) and melted at 160–161°.

*Anal.* Calcd. for $C_{16}H_{15}O_6Br$: C, 50.13; H, 3.95. Found: C, 50.36; H, 4.15.

**3 - Carboxy - 6 - hydroxy - 5,7 - dimethyl - 8 - bromocoumarin (IV).**—The ester III (0.5 g.) was dissolved in acetone (25 cc.) and refluxed for three hours with hydrochloric acid (25 cc.) and water (25 cc.). The hot solution was filtered and the filtrate on cooling deposited a yellow solid. Crystallized from benzene, the substance weighed 0.3 g. (65%) and formed bright yellow needles melting at 250°.

*Anal.* Calcd. for $C_{12}H_9O_5Br$: C, 46.00; H, 2.90. Found: C, 46.41; H, 2.99.

**3 - Carboxy - 6 - acetoxy - 5,7 - dimethyl - 8 - bromocoumarin (VI).**—Acetylation of the acid IV gave white cottony needles of VI melting at 223°.

*Anal.* Calcd. for $C_{14}H_{11}O_6Br$: C, 48.32; H, 3.12. Found: C, 48.35; H, 3.29.

**3 - Carboxy - 6 - methoxy - 5,7 - dimethyl - 8 - bromocoumarin (VII).**—To the ester III (0.5 g.) in boiling methanol (10 cc.) and methyl sulfate (4 g.) was added dropwise an excess of a saturated solution of potassium hydroxide in methanol. The reaction mixture was diluted with water, acidified with hydrochloric acid, and extracted with ether. Evaporation of the ether left a yellow oil which solidified when rubbed with cold methanol. The product, crystallized from methanol, was almost white. It weighed 0.1 g. and melted at 210°. Methylation of the acid IV or the acetate V also gave VII.

*Anal.* Calcd. for $C_{13}H_{11}O_5Br$: C, 47.71; H, 3.40; $OCH_3$, 9.5. Found: C, 47.98; H, 3.63; $OCH_3$, 9.4.

**3 - Carbethoxy - 6 - hydroxy - 5,7 - dimethyl - 3,4 - dihydrocoumarin (VIII).**—The ester III (0.2 g.) was dissolved in ethanol (100 cc.) and a palladium catalyst[16] (0.2 g.) was added, and the mixture was shaken for two hours under hydrogen at 42 pounds (2.8 atm.) pressure. The catalyst was removed, the filtrate concentrated under

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[16] Busch and Stöve, *Ber.*, **49**, 1064 (1916).

reduced pressure and then diluted with water until precipitation started. After standing in the icebox for two hours, the solid was removed and recrystallized from dilute ethanol. The substance formed silvery white needles melting at 142–143°.

*Anal.* Calcd. for $C_{14}H_{16}O_5$: C, 63.61; H, 6.06. Found: C, 63.31; H, 5.75.

**Synthesis of XVII from *p*-Xyloquinone (XIII).**—*p*-Xyloquinone (XIII) was prepared in 40% yield by oxidation of pseudocumidine-5 by chromic acid. It was isolated by steam distillation from the reaction mixture. The melting point was 124–125°.[17] Reduction of the quinone by stannous chloride and hydrochloric acid in aqueous alcohol gave the **hydroquinone** in nearly quantitative yield. Crystallized from water, the white needles melted at 215–216°.[18]

**1,4-Dimethyl-2,5-dimethoxybenzene (XIV)** was obtained in good yield by methylating the hydroquinone in methanol with methyl sulfate and methyl alcoholic potassium hydroxide. The product, steam distilled and crystallized from methanol, melted at 110–111°.[19]

**2,5-Dimethyl-3,6-dimethoxybenzaldehyde (XV).**—The dimethyl ether XIV (3.1 g.) was dissolved in benzene (200 cc.). Zinc cyanide[20] (4.5 g.) was added, the mixture was strongly cooled and dry hydrogen chloride was passed in with stirring for four hours. At this point aluminum chloride (5 g.) was added, and hydrogen chloride again passed in for eight hours. The temperature was then allowed to rise to 25° and the gas was passed in for twelve hours longer. The reaction mixture was then kept at 60° for eight hours, then allowed to stand overnight at room temperature. The benzene was decanted and the oily solid washed with dry benzene. Dilute hydrochloric acid was added and the mixture was steam distilled. The waxy solid in the distillate was crystallized from dilute methanol. The aldehyde (3 g., 83%) formed yellow needles melting at 59–60°. It could be purified by dissolving it in bisulfite, filtering off any insoluble material and acidifying the filtrate.

*Anal.* Calcd. for $C_{11}H_{14}O_3$: C, 67.99; H, 7.27. Found: C, 67.57; H, 7.09.

**The oxime**, prepared in the usual way and crystallized from dilute alcohol, formed white needles melting at 118–119°.

*Anal.* Calcd. for $C_{11}H_{15}O_3N$: C, 63.12; H, 7.23. Found: C, 63.35; H, 7.23.

**2,5 - Dimethyl - 3,6 - dimethoxybenzalmalonic Acid (XVI).**—The aldehyde XV (1 g.) and malonic acid (0.6 g.) were dissolved in methanol (10 cc.) and piperidine (0.6 g.) was added. After warming for four days at 65°, the reaction mixture was acidified with dilute hydrochloric acid and the solid was removed and crystallized from dilute methanol. It formed white needles, melting at 195° with evolution of a gas and the melt, on cooling, solidified to a bright yellow solid which remelted at about 215° (XVII).

*Anal.* Calcd. for $C_{14}H_{16}O_6$: C, 59.97; H, 5.76. Found: C, 59.67; H, 5.60.

**3 - Carboxy - 6 - methoxy - 5,8 - dimethylcoumarin (XVII).**—The coumarin was obtained by fusion of the acid XVI, but it also resulted by prolonged heating of the aldehyde XV (0.1 g.) with malonic acid (0.1 g.) in ethanol (5 cc.) and piperidine. Each day for a period of four days, 3 drops of piperidine was added and the mixture was warmed on the steam-bath for six hours, then allowed to stand overnight. The deep yellow solution was acidified with hydrochloric acid, and the solid was removed and crystallized from dilute methanol. The yellow needles weighed 0.1 g. and melted at 229–230°.

*Anal.* Calcd. for $C_{13}H_{12}O_5$: C, 62.88; H, 4.87. Found: C, 62.13; H, 4.81.

**Synthesis of XX from *m*-Xyloquinone (XVIII).**—The quinone XVIII was prepared by oxidation of mesidine[21] in dilute sulfuric acid by chromic acid.[17] The quinone was isolated by steam distillation and ether extraction of the distillate. Crystallized from dilute methanol it formed light orange needles melting at 74–75°. The yield was 40%. Reduced by stannous chloride in hydrochloric acid, the quinone (1 g.) was converted to the hydroquinone (0.9 g.) which, after crystallization from water, melted at 147–148°.[17]

**2,4 - Dimethyl - 3,6 - dihydroxybenzaldehyde (XIX).**—The aldehyde group was introduced into the hydroquinone by the same procedure as that used for the preparation of the aldehyde XV. The aldehyde, crystallized from dilute methanol, was yellow and melted at 145°. It was soluble in bisulfite solution.

*Anal.* Calcd. for $C_9H_{10}O_3$: C, 65.09; H, 6.07. Found: C, 65.35; H, 5.93.

**3 - Carboxy - 6 - hydroxy - 5,7 - dimethylcoumarin (XX).**—The aldehyde XIX (0.1 g.) and malonic acid (0.1 g.) were dissolved in ethanol (5 cc.). Piperidine (3 drops) was added and the mixture was allowed to stand for three days at room temperature. The deep red solution was acidified with dilute hydrochloric acid, precipitating a yellow solid. Crystallized from dilute methanol, this weighed 0.15 g. and melted at 235–236°.

*Anal.* Calcd. for $C_{12}H_{10}O_5$: C, 61.54; H, 4.30. Found: C, 61.90; H, 4.43.

**3 - Carbethoxy - 6 - hydroxy - 5,7 - dimethylcoumarin (XXI).**—The coumarin acid XX (0.1 g.) was esterified by refluxing it with dry ethanol (100 cc.) and sulfuric acid (5 drops) for three days. Crystallized from dilute ethanol, the substance melted at 165–166°.

*Anal.* Calcd. for $C_{14}H_{14}O_5$: C, 64.12; H, 5.38. Found: C, 64.11; H, 5.33.

When hydrolyzed by boiling acetone–hydrochloric acid, the ester XXI gave the acid XX.

**3 - Carbethoxy - 6 - hydroxy - 5,7 - dimethyl - 3,4 - dihydrocoumarin (VIII).**—When the ester XXI was reduced catalytically using the palladium catalyst, the product was the ester VIII, melting point and mixed melting point 140–143°. Specimens of the ester VIII prepared by two methods gave on oxidation with ferric chloride the coumarin acid XX, melting point and mixed melting point 233°.

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[17] Nölting and Baumann [*Ber.*, **18**, 1151, 2667 (1885)] reported the melting point as 123–124°.

[18] Conant and Fieser, THIS JOURNAL, **45**, 2194, 3348 (1923).

[19] Nölting [*Ber.*, **23**, 3251 (1890)] reported the melting point as 108°.

[20] Adams and Levine, THIS JOURNAL, **45**, 2373 (1923).

[21] The mesidine used for this preparation was prepared by A. C. Keyl from bromomesitylene.

**Derivatives of the Magnesium Compound (IX).**—The magnesium derivative IX (2 g.) was heated with methanol (20 cc.) and methyl sulfate (5 g.). The hot solution was filtered and the dark yellow filtrate, on cooling, deposited fine yellow needles. Crystallized from acetic acid, the product (X) weighed 0.9 g. and melted at 240–241°.

*Anal.* Calcd. for $C_{13}H_{13}O_6Br$: C, 45.22; H, 3.80; $OCH_3$, 9.0. Found: C, 45.75; H, 3.90; $OCH_3$, 9.7.

The substance X was unchanged after refluxing for three hours with acetone–hydrochloric acid, but when refluxed with acetic acid (15 cc.) and hydrobromic acid (5 cc., 40%), X gave the coumarin acid IV, melting point and mixed melting point 250°. Acetylation of X by warming it with acetic anhydride and a drop of sulfuric acid gave a white substance (XII) which melted at 187–188° after crystallization first from dilute acetic acid and then from methanol. The substance was analyzed but the analysis did not correspond to that required for any simple acetyl derivative of IX.

**The yellow acetyl derivative** XI resulted when the magnesium compound IX (1 g.) was warmed with pure acetyl chloride (freshly distilled from dimethylaniline). Crystallized from acetic acid, the product formed yellow needles which melted at 231–232°.

*Anal.* Calcd. for $C_{14}H_{13}O_7Br$: C, 45.04; H, 3.50. Found: C, 45.08; H, 3.87.

When the yellow acetyl derivative XI was methylated by methyl sulfate and methyl alcoholic potassium hydroxide, the product was the methyl derivative VII, melting point and mixed melting point 210°.

## Summary

1. Sodium and magnesium ethoxides have been used as condensing agents for the addition of malonic ester to bromopseudocumoquinone leading to the formation of a sodium and a magnesium derivative, respectively.

2. Both metallic derivatives were converted by acids to the same substance, 3-carbethoxy-6-hydroxy-5,7-dimethyl-8-bromocoumarin (III), the structure of which was proved by conversion to the bromine-free coumarin acid (XX) and synthesis of the latter from *m*-xyloquinone.

3. The chemical properties of the coumarin ester III and many of its derivatives have been described.

4. In the reaction with the enolates of malonic ester, the bromine atom of the bromoquinone was unaffected. The quinone behaved as a pentad–enol system, the methyl group meta to the bromine atom reacting.

5. The magnesium compound gave rise to two series of derivatives: one identical with the series of derivatives obtained from the sodium compound and the other closely related to, but different from, this series.

6. Starting with *p*-xyloquinone, 3-carboxy-6-methoxy-5,8-dimethylcoumarin (XVII) was synthesized.

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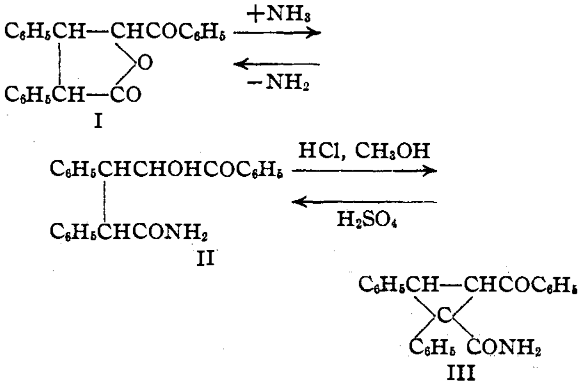
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF MCGILL UNIVERSITY]

# The Action of Alkaline Reagents on Diphenylbenzoylbutyrolactone

BY C. F. H. ALLEN, E. E. MASSEY[1] AND R. V. V. NICHOLLS

The γ-lactone ring is usually opened by alkaline reagents with the consequent formation of a salt of a γ-hydroxy acid; upon acidification an equilibrium mixture is formed, which is usually preponderantly in the lactone form. This behavior is exhibited by α,β-diphenyl-γ-benzoylbutyrolactone I, but if the alkaline solution is not acidified immediately it becomes yellow and deposits a mixture of solids and oil when treated with acids. The new substances are obviously secondary products resulting from the action of alkalies on the highly substituted salt obtained on ring opening. The nature of these products varies to some extent with the reagent used, and hence it is convenient to describe separately the action of each basic substance.

The lactone is insoluble in ammonium hydroxide but gradually dissolves in alcoholic ammonia to give a substance, the properties of which are in best agreement with the open chain hydroxy amide structure II. Thus, analysis shows that



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