Charles Pfizer Company, and Merck and Company for generous samples of 2,5-diethoxytetrahydrofuran, β-ketoglutaric acid, and tropinone, respectively. The microanalyses herein reported are principally by Miss Paula M. Parisius, Mrs. Evelyn G. Peake, and Mr. Byron Baer of the Microanalytical Service Laboratory directed by Dr. William C. Alford. Mr. Harold K. Miller made the infrared measurements, and Mrs. Charles I. Wright, determined the ultraviolet absorption spectra. He is indebted to Mr. Miller and Dr. William R. Nes for helpful interpretations of the infrared absorption spectra.

BETHESDA 14, MD.

[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

Keto Grignard Reagents. Intramolecular Reduction*[1]

REYNOLD C. FUSON AND NORMAN SHACHAT[2]

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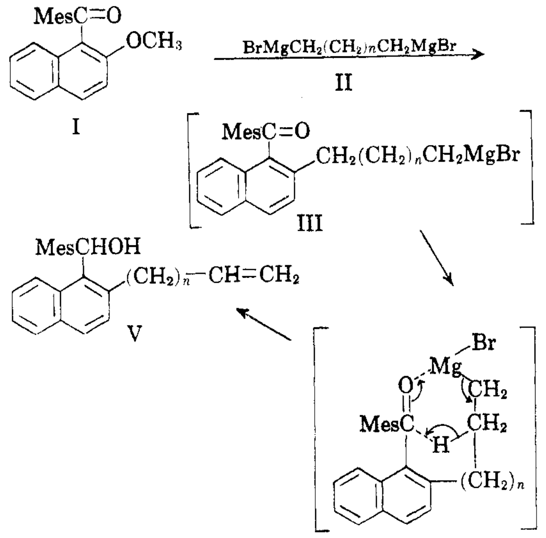
1-Mesitoyl-2-methoxynaphthalene (I) reacts with the dimagnesium derivatives (II) of 1,4-dibromobutane, 1,5-dibromopentane, and 1,6-dibromohexane to yield products that could be derived from intermediate keto Grignard reagents (III). With 1,4-butanedimagnesium dibromide, for example, the principal product is 2-(γ-butenyl)naphthyl-1-mesitylcarbinol (V, $n = 2$). The amount of reduction product decreases progressively as the chain of the Grignard reagent is lengthened. Similarly, duryl 2-methoxyphenyl ketone (X) and the Grignard reagent from 1,4-dibromobutane gave 2-(γ-butenylphenyl)durylcarbinol (XII).

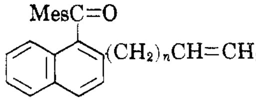
The condensation of esters with certain aliphatic bifunctional Grignard reagents to give cyclic carbinols[3] appears to involve the formation of keto Grignard reagents as transient intermediates. The object of the present study was to determine whether such a keto Grignard reagent could be produced by the action of a dibromomagnesium compound on a hindered *o*-methoxyaryl ketone, a vinylog of an ester.

1-Mesitoyl-2-methoxynaphthalene (I) has been found to react with the Grignard reagent from 1,4-dibromobutane (II, $n = 2$) to give the olefinic carbinol V ($n = 2$) in a yield of 65%. This unexpected product was formed presumably by way of the keto Grignard reagent III ($n = 2$), which may undergo intramolecular reduction by way of a transition state resembling the *quasi*-cyclic system IV ($n = 2$).[4] Since *n*-butylmagnesium bromide displaces the methoxyl group of the methoxy ketone I in 55% yield,[5] the intramolecular reduction of the keto Grignard reagent III ($n = 2$) probably occurs rapidly and quantitatively.

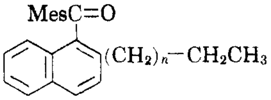
Oxidation with dichromate in glacial acetic acid, by preferential attack of the carbinol function, produced the olefinic ketone VI ($n = 2$), which was hydrogenated catalytically to give 2-*n*-butyl-1-mesitoylnaphthalene (VII, $n = 2$).



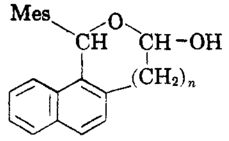
IV



VI



VII



VIII

The terminal position of the double bond in the side chain of the carbinol was established by ozonization. In addition to formaldehyde, a larger frag-

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* This paper is a contribution in honor of Lyndon F. Small, former Editor of the Journal.

(1) This investigation was supported in part by a grant from the Office of Ordnance Research, U.S. Army (Contract No. DA-11-022-ORD-874).

(2) Allied Chemical and Dye Corporation Fellow, 1956–1957.

(3) C. D. Nenitzescu and I. Necsoiu, *J. Am. Chem. Soc.*, 72, 3483 (1950).

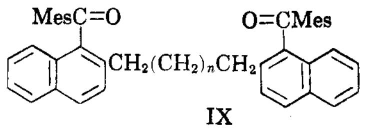
(4) H. S. Mosher and E. La Combe, *J. Am. Chem. Soc.*, 72, 3994 (1950).

(5) R. C. Fuson and S. B. Speck, *J. Am. Chem. Soc.*, 64, 2446 (1942).

ment was isolated which had the composition of the expected hydroxy aldehyde; its infrared spectrum corresponds instead to the seven-membered hemiacetal VIII ($n = 2$). The existence of such a ring is not without precedent.[6] The compound formed a derivative with methone.

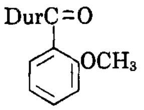
The pentenyl carbinol (V, $n = 3$), obtained in 36% yield by the use of the *di*-Grignard reagent from 1,5-dibromopentane (II, $n = 3$), underwent ozonization to yield the interesting eight-membered hemiacetal (VIII, $n = 3$). In view of the findings of Hurd and Saunders[6c] that simple ω-hydroxy aldehydes capable of forming cyclic hemiacetals of ring size greater than six members exist mainly as the free aldehyde, it is remarkable that in this system (hydroxy aldehyde form of VIII) of much reduced mobility the seven- and eight-membered cyclic hemiacetals are favored. The carbinol was accompanied by the isomeric *n*-pentyl ketone (VII, $n = 3$), which would be formed from the keto Grignard reagent (III, $n = 3$) by hydrolysis.

1,6-Hexanedimagnesium dibromide (II, $n = 4$) gave none of the hexenyl carbinol (V, $n = 4$). It is curious that the amount of the original ketone (I) that was recovered rose from zero for the C_4-reagent to 36% for the C_6-reagent. Also, with the C_5- and C_6-reagents small amounts of di-displacement products were isolated. These correspond to formula IX in which n has the values 3 and 4, respectively.

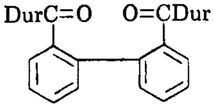


IX

Coupling was the chief reaction when duryl 2-methoxyphenyl ketone (X) was treated with 1,4-butanedimagnesium dibromide; 2,2′-diduroylbiphenyl (XI)[7] was obtained in a yield of 45%. The amount of this diketone remained undiminished even when great care was taken to free the Grignard reagent of magnesium metal. This result is in accord with the observation that reduction of a ketone to the corresponding pinacol may be brought about by a Grignard reagent.[8]

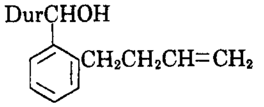


X

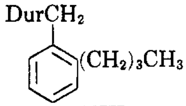


XI

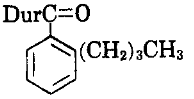
Intramolecular reduction occurred with the duryl ketone (X) also, but the yield of the unsaturated alcohol (XII) was only 8.5%.



XII



XIII



XIV

Hydrogenation of this carbinol gave 2-(*n*-butylphenyl) durylmethane (XIII) in high yield. Reduction of 2-*n*-butylphenyl duryl ketone (XIV), effected with sodium in ethanol, gave the same hydrocarbon.

It is to be noted that three of the four types of products of these several reactions—the olefinic carbinols (V), the alkylated ketones (VII), and the diketones (IX)—are those to be expected from the postulated keto Grignard reagents (III).

EXPERIMENTAL[9]

Treatment of 1-mesitoyl-2-methoxynaphthalene (I) *with the di-Grignard reagent from 1,4-dibromobutane.* A solution of the Grignard reagent was prepared from 2.8 g. (0.013 mole) of 1,4-dibromobutane and 1.0 g. (0.041 g. atom) of magnesium in 35 ml. of ether. To it was added, slowly with stirring, a solution of 2.01 g. (0.0067 mole) of the methoxy ketone in a mixture of 15 ml. of benzene and 10 ml. of ether. The red reaction mixture, which contained a precipitate, was heated under gentle reflux for 4 hr., cooled in an ice water bath, and hydrolyzed with 50 ml. of a saturated ammonium chloride solution. The organic layer was washed with 10% sodium bicarbonate solution and water, then dried over anhydrous sodium sulfate. Two recrystallizations from high-boiling petroleum ether yielded 1.2 g. of the colorless product, 2-(γ-butenyl)naphthyl-1-mesitylcarbinol (V, $n = 2$), m.p. 85.5–88.5°.

Anal.[10] Calcd. for $C_{24}H_{26}O$: C, 87.23; H, 7.93. Found: C, 87.38; H, 8.14.

The infrared spectrum[11] (CS_2) shows absorption bands which can be assigned to a hydroxyl function (3570 and 1038 cm.$^{-1}$), a vinyl group (1641, 915, 1005 cm.$^{-1}$), a mesityl group (857 cm.$^{-1}$), and a 1,2-disubstituted naphthalene ring (821 and 747 cm.$^{-1}$).

The crystallization filtrates were concentrated and the residual 0.9 g. of yellow oil was subjected to chromatography with alumina as the adsorbent and cyclohexane-ether mixtures as the eluting solvents. In this way an additional 0.23 g. of product was isolated; total yield 1.43 g. (65%).

Hydrogenation of 2-(γ-butenyl)naphthyl-1-mesitylcarbinol (V, $n = 2$). A solution of 0.33 g. (0.001 mole) of the carbinol in 15 ml. of absolute ethanol was hydrogenated over a palladium-charcoal catalyst at atmospheric pressure and room temperature. After 15.5 hr., the theoretical amount of hydrogen (0.002 mole) had been absorbed. The product, a colorless oil, has an infrared spectrum (CS_2) that is consistent

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[6] (a) H. Pringsheim and S. Kalodny, *Ber.*, **59**, 1135 (1926); (b) B. Helferich and G. Sparmberg, *Ber.*, **64B**, 104, 1151 (1931); (c) C. D. Hurd and W. H. Saunders, Jr., *J. Am. Chem. Soc.*, **74**, 5324 (1952).

[7] R. C. Fuson and R. O. Kerr, *J. Org. Chem.*, **19**, 373 (1954).

[8] W. Theilacker and M. L Wessel, *Ann.*, **594**, 229 (1955).

[9] All melting points are corrected.

[10] The microanalyses were performed by Mr. Joseph Nemeth, Mrs. R. Benassi, Mr. Rolo Nesset, Miss Claire Higham, Mrs. Ruby Ju, and Mrs. M. Stingl.

[11] The infrared spectra were determined by Mr. James Brader, Mrs. Louise Griffing, Mr. Sy Portnow, and Mr. Brian Cloonan.

with the hydrocarbon structure, 2-(n-butyl)naphthyl-1-mesitylmethane; strong absorption bands appear at 2920, 1079, 851, 815, and 749 cm.$^{-1}$. The bands ascribed to the hydroxyl and vinyl groups of the starting material are completely absent.

Transformation of 2-(γ-butenyl)naphthyl-1-mesitylcarbinol (V, n = *2*) *to 2-n-butyl-1-mesitylnaphthalene* (VII, n = 2).

Oxidation. To a solution of 0.5 g. (0.0015 mole) of the carbinol in 20 ml. of benzene and 15 ml. of glacial acetic acid was added dropwise a solution of 1.8 g. of sodium dichromate dihydrate in 3 ml. of concentrated sulfuric acid, 10 ml. of water, and 2 ml. of glacial acetic acid. The dark red reaction mixture was stirred at room temperature for 17 hr. After water and benzene had been added to increase the volume of the layers, the organic solution was washed with water and dried. A yellow oil remained when the solvent was removed. When subjected to chromatography, however, this oil gave only clear colorless oils. An infrared spectrum (CS_2) of this material was consistent with the structure 2-γ-butenyl-1-mesitoylnaphthalene (VI, n = 2).

Hydrogenation. A solution of the yellow oil in absolute ethanol was hydrogenated over 30% palladium-on-charcoal at 752 mm. and 32°. The uptake of hydrogen ceased after 2.5 hr.: 23.2 ml. (0.0009 mole) had been absorbed. The product crystallized from ethanol, m.p. 70–72°, yield 0.2 g. (40%). The infrared spectrum (CS_2) of this product is superimposable on that of 2-n-butyl-1-mesitoylnaphthalene (VII, n = 2).[5]

Ozonolysis of 2-(γ-butenyl)naphthyl-1-mesitylcarbinol (V, n = *2*). A solution of 0.5 g. (0.0015 mole) of the unsaturated carbinol in 20 ml. of methanol was treated with ozone at −20 to −30° for 12 min. at a flow rate of approximately 0.171 millimole of ozone/min. To the cold solution of ozonide was added 1.0 g. of sodium iodide and 1.0 ml. of glacial acetic acid. The mixture was allowed to warm to room temperature slowly during 1.5 hr. A 10% solution of sodium thiosulfate was added dropwise to reduce the iodine that formed. The colorless solution was distilled under vacuum, and the distillate was collected in an acetone–Dry Ice trap at −80°. Ether and water were added to the solid residue. The organic layer was dried and the solvent removed. Two recrystallizations from ethanol produced 0.3 g. (60%) of colorless product, m.p. 181–182°.

Anal. Calcd. for $C_{23}H_{24}O_2$: C, 83.10; H, 7.28. Found: C, 83.20; H, 7.33.

The infrared spectrum ($CHCl_3$) of this compound exhibits absorption bands at 3605, 3420, 1091, 1057, 1037, and 855 cm.$^{-1}$.

The *methone derivative* of the major fragment, prepared in the usual manner,[12] was recrystallized from a methanol-water mixture, m.p. 195.5–198.5°. Its infrared spectrum ($CHCl_3$) exhibits a weak broad band at 3160 cm.$^{-1}$, a very strong band at 1621 cm.$^{-1}$, and a weak band at 856 cm.$^{-1}$.

To the distillate was added a slight excess of p-nitrophenylhydrazine. The red solution was heated on a steam bath for 20 min., cooled, and filtered. The reddish-orange solid product was recrystallized several times from an ethanol-water mixture, m.p. 177.5–180.5° (dec.) (reported m.p. 181°), yield 0.05 g. This product exhibits the same infrared spectrum (Nujol) as an authentic sample of formaldehyde p-nitrophenylhydrazone.

Treatment of 1-mesitoyl-2-methoxynaphthalene (I) *with the di-Grignard reagent from 1,5-dibromopentane.* To a solution of 1,5-pentanedimagnesium dibromide prepared from 1.46 g. (0.06 g. atom) of magnesium, 4.6 g. (0.02 mole) of 1,5-dibromopentane, and 50 ml. of ether was added dropwise a solution of 3.04 g. (0.01 mole) of the methoxy ketone in a mixture of 20 ml. of benzene and 10 ml. of ether. The dark red mixture was treated as described for the previous *di*-Grignard reaction. A crystallization from high-boiling petroleum ether gave 0.56 g. of a colorless product, m.p. 95.5–96.5°.

Anal. Calcd. for $C_{25}H_{28}O$: C, 87.16; H, 8.19. Found: C, 87.30; H, 8.39.

The infrared spectrum (CS_2), which is very similar to that of 2-(γ-butenyl)naphthyl-1-mesitylcarbinol, exhibits bands at 3605, 1640, 1034, 1005, 910, 852, 818, and 745 cm.$^{-1}$. These data are consistent with the structure, 2-(δ-pentenyl)-naphthyl-1-mesitylcarbinol (V, n = 3).

The solvent was removed from the crystallization filtrates, and the residual oil was chromatographed. A clear colorless oil, 0.4 g. (11.5%), was eluted in the early fractions. Repeated attempts to effect crystallization were unsuccessful. The infrared spectrum (CS_2) of the oil is very similar to that of 2-n-butyl-1-mesitoylnaphthalene. A Beilstein test was negative with respect to the presence of halogen. Therefore, it is not unreasonable to assign the structure, 1-mesitoyl-2-n-pentylnaphthalene (VII, n = 3) to this material. By combination of fractions and recrystallization from high-boiling petroleum ether, 0.26 g. (8.5%) of starting material was recovered, m.p. 125–127°. A new compound was obtained by elution of the column with 1:4 cyclohexane-ether. Two recrystallizations from ethanol afforded 0.23 g. (7.5%) of the colorless di-displacement product (IX, n = 3), m.p. 148–149°.

Anal. Calcd. for $C_{45}H_{44}O_2$: C, 87.62; H, 7.19. Found: C, 87.39; H, 7.28.

The infrared spectrum (CS_2) exhibits bands which are assignable to a conjugated hindered ketone group (1657 cm.$^{-1}$), a mesityl group (853 cm.$^{-1}$), and a 1,2-disubstituted naphthalene ring (824 and 749 cm.$^{-1}$).

Finally, elution of the column with alcohol gave an additional 0.68 g. of 2-(δ-pentenyl)naphthyl-1-mesitylcarbinol, m.p. 94.5–96°, total yield 1.24 g. (36%).

Ozonolysis of 2-(δ-pentenyl)naphthyl-1-mesitylcarbinol (V, n = *3*). A solution of 1.0 g. (0.0029 mole) of the unsaturated carbinol in 20 ml. of methanol was treated with ozone at −20 to −30° for 24 min. at a flow rate of approximately 0.171 millimole of ozone/min. The work-up was similar to that previously described. The major fragment was purified by recrystallization from an ether–low-boiling petrolum ether mixture, m.p. 108–109°, yield 0.6 g. (60%).

Anal. Calcd. for $C_{24}H_{26}O_2$: C, 83.20; H, 7.56. Found: C, 83.17; H, 7.79.

The infrared spectrum (CS_2) of the compound shows absorption bands at 3600, 3410, 1081, 1023, 1002, 855, 820, and 747 cm.$^{-1}$.

The *methone derivative* of the major fragment, prepared in the usual manner,[12] was recrystallized from low-boiling petroleum ether, m.p. 180–181°. Its infrared spectrum ($CHCl_3$) exhibits a weak band at 3610 cm.$^{-1}$, a very broad weak band at about 2650 cm.$^{-1}$, a very strong band at 1597 cm.$^{-1}$, and a weak band at 855 cm.$^{-1}$.[13]

The p-nitrophenylhydrazone of formaldehyde was isolated from the distillate and identified by its melting point and infrared spectrum (Nujol).

Treatment of 1-mesitoyl-2-methoxynaphthalene (I) *with the di-Grignard reagent from 1,6-dibromohexane.* A solution of 0.01 mole of the ketone in 50 ml. of benzene was added dropwise during a period of 2.5 hr. to the two-layer Grignard system prepared from 2.2 g. (0.09 g. atom) of magnesium,

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[12] E. C. Horning and M. G. Horning, *J. Org. Chem.*, **11**, 95 (1946).

[13] It is interesting that the infrared spectra of the methone derivatives of the hemiacetals VIII (n = 2 and 3) exhibit only a single absorption in the carbonyl region, a very intense band near 1600 cm.$^{-1}$; whereas strong absorption bands at both 1700 and 1605 cm.$^{-1}$ are found in the infrared spectrum of methone itself. (L. J. Bellamy, *The Infrared Spectra of Complex Molecules*, John Wiley and Sons, Inc., New York, 1954, p. 123.) The methone derivative of butyraldehyde (m.p. 134–135°)[12] was prepared for infrared inspection. Its spectrum ($CHCl_3$) also shows a lone, intense carbonyl band at 1595 cm.$^{-1}$.

7.3 g. (0.03 mole) of 1,6-dibromohexane, and 60 ml. of ether. The red reaction mixture was heated under reflux for 2 hr. and hydrolyzed with a cold, saturated ammonium chloride solution. The cloudy organic layer was washed with water and filtered. The colorless solid which collected on the filter was recrystallized several times from a chloroform-ethanol mixture, m.p. 272–274° (bubbles of gas appear at melting point), yield 0.12 g. (4%).

Anal. Calcd. for $C_{41}H_{40}O_4$: C, 82.52; H, 6.76. Found: C, 82.50; H, 6.99.

The infrared spectrum ($CHCl_3$) of this substance exhibits bands at 1636, 1614, 1569, 1264, and 855 cm.$^{-1}$. These data are consistent with a tetrahydrobinaphthyl structure.

The clear organic layer was dried and concentrated. Ether was added to the residual red oil, and the solution was cooled. Crystals of starting material (0.39 g.) were removed by filtration and recrystallized from high-boiling petroleum ether, m.p. 125–128°. The remaining product mixture was subjected to chromatography. The first fraction (pure cyclohexane) contained a trace of an oily solid which was submitted for infrared analysis. The spectrum (CS_2) almost bare except for one very intense band in the carbon-hydrogen stretching region (2900 cm.$^{-1}$), suggests that the substance is a long-chain hydrocarbon. Next, 0.94 g. (26.3%) of a clear colorless oil was eluted (4:1 cyclohexane-ether). Repeated attempts to effect crystallization were unsuccessful. The infrared spectrum (CS_2) of this material is almost identical with the spectra of 2-*n*-butyl-1-mesitoylnaphthalene (VII, $n = 2$) and 1-mesitoyl-2-*n*-pentylnaphthalene (VII, $n = 3$). A Beilstein test showed that the substance does not contain halogen. Therefore, the structure 2-*n*-hexyl-1-mesitoylnaphthalene (VII, $n = 4$) was assigned to the compound.

Anal. Calcd. for $C_{26}H_{30}O$: C, 87.10; H, 8.44. Found: C, 86.70; H, 8.71.

Elution of the column with 3:2 and 1:1 cyclohexane-ether yielded an additional 0.7 g. of 1-mesitoyl-2-methoxynaphthalene, m.p. 126–128°, total yield 1.09 g. (36%).

The colorless di-displacement compound (IX, $n = 4$) was eluted with 1:4 cyclohexane-ether and recrystallized from ethanol, m.p. 135–137°, yield 0.1 g. (3.2%). It exhibits an infrared spectrum (CS_2) which is almost identical with that of the analogous product of the previous *di*-Grignard reaction (eluted with 1:4 cyclohexane-ether).

Anal. Calcd. for $C_{46}H_{46}O_2$: C, 87.58; H, 7.35. Found: C, 87.68; H, 7.51.

In one experiment, a trace (0.05 g.) of a colorless compound was isolated and recrystallized from a chloroform-ethanol mixture, m.p. 276.5–278°.

Anal. Calcd. for $C_{42}H_{38}O_4$: C, 83.14; H, 6.31. Found: C, 83.93; H, 6.41.

The infrared spectrum ($CHCl_3$) exhibits an intense band at 1654 cm.$^{-1}$ which can be assigned to a conjugated hindered carbonyl function, a band at 876 cm.$^{-1}$ attributable to a lone aromatic hydrogen atom, and a band at 845 cm.$^{-1}$ assignable to a mesityl group. These data suggest a binaphthyl structure.

A dark red oil (0.5 g.) was eluted from the column with methanol and subjected to infrared analysis (CS_2). By comparison with the spectra of the olefinic carbinols V ($n = 2$ and 3), it was concluded that 2-(ϵ-hexenyl)naphthyl-1-mesitylcarbinol (V, $n = 4$) is present, if at all, in only a slight trace. Therefore, this oil was not treated further.

In view of the large amount of recovered starting material, the experiment was repeated several times under different conditions. One variation involved a much longer period of reflux, and another, an increase in the ratio of benzene to ether. Initially, the experiment was carried out under conditions identical with the previous *di*-Grignard reaction. These modifications, however, did not effectively alter the quantities of products; approximately 30% of the starting material was recovered in each instance.

Treatment of duryl 2-methoxyphenyl ketone (X) *with 1,4-butanedimagnesium dibromide.* A solution of 4.36 g. (0.02 mole) of 1,4-dibromobutane in 60 ml. of ether was added slowly to 0.97 g. (0.04 g. atom) of magnesium under nitrogen. The two-layer system of 1,4-butanedimagnesium dibromide was heated under reflux for 1 hr. with stirring. A few pieces of magnesium remained unchanged. During a period of 0.5 hr., a solution of 5.36 g. (0.02 mole) of duryl 2-methoxyphenyl ketone[7] in 50 ml. of dry ether was added. The reaction mixture turned orange, brown, green, blue-green, and finally dark blue. After addition was complete, the solution was allowed to remain at room temperature for 1 hr. Carbonation was effected by dropping the mixture into a slurry of 100 g. of Dry Ice in 100 ml. of ether. When room temperature had been reached, the solution was hydrolyzed with dilute hydrochloric acid. The organic layer was extracted with three 25-ml. portions of 5% sodium hydroxide. Acidification of the basic extract produced a cloudy aqueous solution; even when cooled, however, this solution gave no solid acid. The organic layer was washed, dried, and concentrated to a semi-solid mass. When a hot ethanol solution of the residue was cooled, an egg-shell white powder formed, m.p. 216–235°. Several recrystallizations from a chloroform-ethanol mixture afforded 1.65 g. of colorless crystals, m.p. 247.5–251°. The infrared spectrum (CS_2) of this material is identical with that of 2,2′-diduroylbiphenyl (XI). Furthermore, a mixture melting point with an authentic sample of that diketone was not depressed.

The solvent was removed from the combined crystallization filtrates, and the remaining oil was subjected to chromatography. The first compound that was eluted was a colorless crystalline solid, which was recrystallized several times from a chloroform-ethanol mixture, m.p. 273.5–276.5°, yield 0.10 g.

Anal. Found: C, 89.06; H, 8.04. Calcd. Empirical Formula $C_{38}H_{40}O$.

The infrared spectrum (CS_2) of this compound is similar to that of 9,10-didurylphenanthrene.[7] Prominent absorption bands appear at 736, 761, 872, 1010, 1022, 1387, and 2908 cm.$^{-1}$.

The second material to be eluted was a colorless oil that slowly crystallized from ethanol, m.p. 38–39.5°, yield 0.15 g.

Anal. Calcd. for $C_{25}H_{34}O$: C, 85.66; H, 9.78. Found: C, 85.36; H, 10.08.

The infrared spectrum (CS_2) of this product is almost identical with that of 2-*n*-butylphenyl duryl ketone (XIV)[14] (m.p. 96.5–97°). The band ascribed to the carbon-hydrogen stretching frequency (2900 cm.$^{-1}$), however, is more intense in the spectrum of the product than in that of the butylated ketone (XIV). Thus, the compound was identified as duryl 2-*n*-octylphenyl ketone.

Next, 0.48 g. of 2,2′-diduroylbiphenyl was eluted; total yield 2.13 g. (45%).

The column was flushed with methanol, and the eluted material was dissolved in hot ethanol. From the cooled solution, 0.15 g. of a highly insoluble substance was removed by filtration. The solid was recrystallized from a chloroform-ethanol mixture, m.p. 260–262°. Its infrared spectrum was identical with that of 2-duroyl-2′-(durylbiphenyl)carbinol.[15] The ethanol filtrate was allowed to remain in the refrigerator for about 2 months. A colorless crystalline compound was removed by filtration and recrystallized from ethanol, m.p. 80–82°, yield 0.5 g. (8.5%).

Anal. Calcd. for $C_{21}H_{26}O$: C, 85.66; H, 8.90. Found: C, 85.53; H, 8.77.

The infrared spectrum (CS_2) exhibits bands assignable to a hydroxyl function (3470 and 1020 cm.$^{-1}$), a vinyl group (1639, 1000, and 913 cm.$^{-1}$), and an *ortho*-disubstituted benzene ring (756 cm.$^{-1}$). The data are consistent with the structure, 2-(γ-butenylphenyl)durylcarbinol (XII).

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(14) This ketone and its infrared spectrum were kindly supplied by Mr. J. R. Larson.

(15) R. C. Fuson and C. Hornberger, Jr., *J. Org. Chem.*, **16**, 637 (1951).

In a subsequent experiment, in which the excess magnesium was removed from the *di*-Grignard reagent by filtration before the duryl 2-methoxyphenyl ketone was added, the coupling products were isolated in undiminished yields.

Hydrogenation of 2-(γ-butenylphenyl)durylcarbinol (XII). A solution of 0.38 g. (0.0013 mole) of the carbinol in 25 ml. of ethanol was hydrogenated over 0.04 g. of 30% palladium-on-charcoal at atmospheric pressure (748 mm.) and room temperature (31°). The theoretical uptake of hydrogen (0.0026 mole) had occurred after about 1 hr.; however, the treatment was continued for an additional 3 hr. The catalyst was removed by filtration and the solvent by distillation. The product, recrystallized from ethanol, formed colorless needles, m.p. 81–83°, yield 0.31 g. (86%). A pure sample melted at 83–84°.

Anal. Calcd. for $C_{21}H_{28}$: C, 89.94; H, 10.06. Found: C, 89.68; H, 10.04.

The infrared spectrum (CS_2) contains bands at 2905, 1600, 1383, 868, and 757 cm.$^{-1}$ which are consistent with the hydrocarbon structure 2-(*n*-butylphenyl)durylmethane (XIII).

Reduction of 2-n-butylphenyl duryl ketone (XIV) *with sodium and ethanol.* To a boiling solution of 0.1 g. (0.00034 mole) of the ketone in 10 ml. of absolute ethanol was added, slowly with stirring, 1.0 g. of sodium in small pieces. After all the sodium had reacted, the hot solution was poured into a mixture of 15 ml. of concentrated hydrochloric acid and 30 g. of ice. The organic material was extracted from the cloudy aqueous solution with benzene. The benzene solution was washed, dried, and concentrated; the residual yellow oil crystallized from an ethanol-water mixture in slightly yellow crystals, yield 0.0264 g. (28%), m.p. 77–80°. A mixture melting point with the product of the previous reaction was 78–81°. In addition, the infrared spectrum (CS_2) is identical with that of the product of the previous reaction.

URBANA, ILL.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF ROCHESTER]

The Synthesis of Some Linear Tetracyclic Substances*[1]

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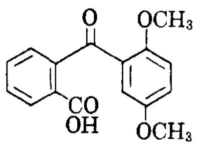
Several synthetic paths leading to linear tetracyclic substances have been investigated, and a dihydroxydioxomethylhexahydronaphthacene has been prepared.

With a view toward assembling large molecules which might have some of the chelating properties associated with the tetracyclines, we have prepared some linear tetracyclic substances bearing several oxygenated functional groups. Our approach has been through *o*-(2,5-dimethoxybenzoyl)benzoic acid (I),[3] readily available by the condensation of *o*-carbomethoxybenzoyl chloride with hydroquinone dimethyl ether.[4] This substance was converted to 3-methyl-3-(2,5-dimethoxyphenyl)phthalide (II) in high yield by the action of methyl magnesium iodide. Reduction of the phthalide II with zinc and ammonia[5] yielded the corresponding acid III which readily cyclized in high yield on treatment with sulfuric acid to give 1,4-dimethoxy-10-methyl-9-anthrone (IV).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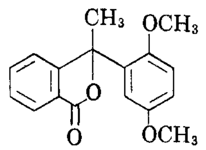
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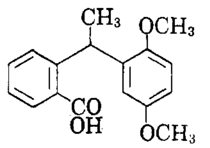
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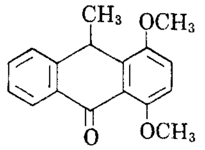
IV

We had hoped to extend the linear annulation of IV by the addition of butadiene or substituted butadienes to the 1,4-quinone corresponding to IV. This approach has the merit of converting the aromatic hydroquinone ring of IV to a hydroaromatic ring corresponding to ring B of the tetracyclines. The deep red quinone VI was readily prepared in high yield from IV by demethylation with aluminum bromide followed by oxidation with ferric chloride, but proved to be too unstable for successful use in the Diels-Alder reaction.

On the assumption that the instability of the quinone was largely the result of the acyl substituent, an attempt to prepare the ethylene thioketal of V prior to its oxidation to the quinone was made, but only unreacted starting material was obtained.

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* This paper is a contribution in honor of Lyndon F. Small, former Editor of the Journal.

(1) Taken from the Ph.D. dissertation of Clifford L. Dickinson, Jr., the University of Rochester, 1955.

(2) E. I. du Pont de Nemours Fellow, 1954–1955.

(3) K. Lagodzinski, *Ber.*, **28**, 116 (1895).

(4) C. Dufraisse and A. Allais, *Bull. Soc. Chim.*, [5], **11**, 531 (1944). This method was preferred to the simpler one using phthalic anhydride since it would allow structural specificity with substituted phthalic acid derivatives, *e.g.* the 3-methoxy derivative, whose use was contemplated in extending this synthesis to more highly oxygenated substances.

(5) The procedure was based on that of Bergmann for the similar reduction of 3-methyl-3-phenyl phthalide. *cf.* E. Bergmann, *J. Org. Chem.*, **4**, 1 (1939).