The Structure of o-Quinone Methide Trimer

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The crystalline trimer of o-quinone methide was shown to be an α,β-unsaturated ketone. On the basis of a partial degradation to 1-[β(2-methoxyphenylethyl)]-2-methoxyxanthone and a comparison of spectral data from xanthones of known structure, the constitution of the trimer is proposed as shown in IV. It thus appears to be the product of two successive Diels-Alder reactions.

A study of the chemistry of the very reactive o-quinone methide (III)[1] has shown one of its most facile reactions to be that of trimerization. This report is concerned primarily with evidence bearing on the constitution of the trimer.[2]

The synthesis of o-quinone methide and of the trimer began with salicylaldehyde and entailed transformations shown below. These have since been generalized.[4] A more direct and considerably more efficient approach[5] involving the reduction of
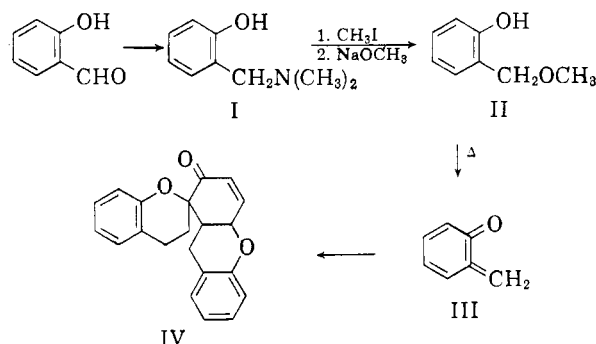
salicylaldehyde to o-hydroxybenzyl alcohol (saligenin) and its subsequent methylation to II proved to be very convenient for large scale preparations. The product of the vapor-phase pyrolysis of II was found to be dependent upon the equipment and

conditions employed; at high concentrations of substrate the trimer was the major product obtained but at low substrate concentrations o-quinone methide (III) itself was the principal product. The latter, trapped at low temperatures, spontaneously trimerized on being warmed ($-20°$). It was found more convenient to use the high concentration technique for the preparation of large quantities of the trimer.

This general approach to the synthesis of quinone methides and their polymers has been found to be quite useful. Thus, 1-methoxymethyl-2-naphthol (V) afforded the previously reported[6] dimer of 1,2-naphthoquinone-1-methide (VI).
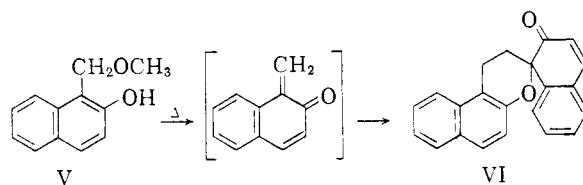
Attempts to prepare p-quinone methides in this manner were unsuccessful. The thermostability of para ethers is illustrated by the parent member of the family, p-methoxymethylphenol (VII), which could not be changed at temperatures up to 900° at residence times used in studies of the ortho ethers.
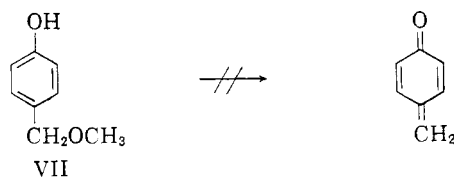
Infrared spectral data on the trimer (IV) suggested the presence of α,β-unsaturated carbonyl functionality (5.94μ) which was confirmed by derivative formation and hydrogenation data. Oximation with excess hydroxylamine consumed two mole-equivalents, one adding conjugatively and the other reacting at the carbonyl in the normal manner. The product is formulated as VIII. The presence of only one double bond was established by quantitative hydrogenation. The product (IX) shows infrared absorption at 5.79μ characteristic of a

(1) P. D. Gardner, H. Sarrafizadeh R., and R. L. Brandon, J. Am. Chem. Soc., 81, 5515 (1959).

(2) The isolation of trimers of several substituted quinone methides has been described.[3] Although these are assumed to be related structurally, most of the data reported are concerned with the trimer of 3,5-dimethylquinone methide.

(3) H. von Euler, E. Adler, and J. O. Cedwall, Ark. Kemi., Min. Geol., 14A, No. 14, 1941; Chem. Abstr., 36, 755 (1942). K. Fries and K. Kann, Ann., 353, 335 (1907). H. von Euler, E. Adler, G. Eklund, and O. Törngren, Ark. Kemi., Min. Geol., 15B, No. 9 (1941); Chem. Abstr., 36, 7182 (1942). H. Civelekoglu, Rev. fac. sci. univ. Istanbul, 18A, 14 (1953). E. Adler, S. Tingstam, and O. Caspersson, Ark. Kemi., Min. Geol., 15B, No. 10 (1941); Chem. Abstr., 36, 7183 (1942). K. Hultzsch, Ber., 74, 898 (1941), K. Hultzsch, J. prakt. Chem., 159, 180 (1941), K. Fries and E. Brandes, Ann., 542, 48 (1939), K. Hultzsch, Ber., 74, 1539 (1941), G. Schiemann and K. Hultzsch, Naturwissenschaften, 35, 124 (1948); Chem. Abstr., 44, 2948 (1950). G. Schiemann, Rev. fac. sci. univ. Istanbul, 17A, 290 (1952).

(4) P. D. Gardner, H. Sarrafizadeh R., and L. Rand, J. Am. Chem. Soc., 81, 3364 (1959).

(5) J. de Jonge and B. H. Bibo, Rec. trav. chim., 74, 1448 (1955).

(6) R. Pummerer, G. Schmidutz, and H. Seifert, Ber., 85, 535 (1952). L. I. Smith and J. W. Horner, Jr., J. Am Chem. Soc., 60, 676 (1938).

saturated ketone and derivative formation proved it to be the only carbonyl group in the molecule. Further reduction with sodium borohydride or lithium aluminum hydride afforded the corresponding alcohol (X).
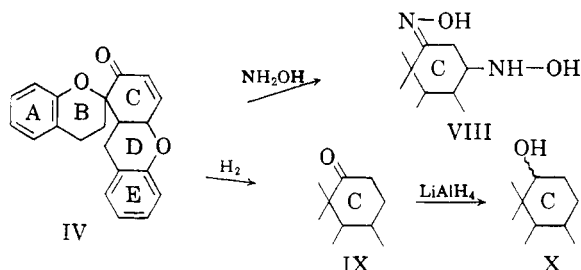

Ultraviolet spectra (95% ethanol) of IV, IX, and X are tabulated in Table I along with values for o-methylanisole. Carbinol X is a suitable choice for comparison with o-methylanisole as its C-ring is devoid of ultraviolet chromophore. It is seen that the correspondence of maxima wave lengths is quite satisfactory and that extinction coefficients of all three maxima of X are about twice those of the model.

TABLE I

Substance	λ_{max} (mμ)	$\epsilon \times 10^{-3}$
IV	216	23.40
	273	3.78
	280	3.66
IX	209	17.90
	274	4.70
	282	4.58
X	217	28.70
	275	4.06
	283	4.39
o-Methyl-	216	13.50
anisole	272	1.82
	278	1.65

Among the various structures with which these data can be reconciled, IV must be included. This assemblage is one of several possible from two successive Diels-Alder reactions of III. The first step of this process finds support both in early
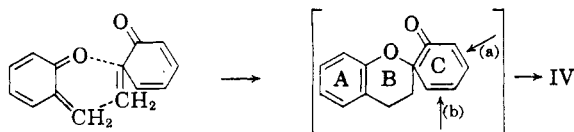
work on the dimerization of 2-methylenecyclohexanone[7] and in studies on the dimerization of quinone methides which are structurally incapable of further reaction.[6,8–10]

(7) M. Mannich, *Ber.*, **74B**, 557 (1941).

(8) K. Fries and F. Hubner, *ibid.*, **39**, 435 (1906).

(9) R. Pummerer and I. Veit, *ibid.*, **86**, 412 (1953).

(10) P. D. Gardner and H. Sarrafizadeh R., *J. Org. Chem.*, **25**, 641 (1960).

Attack of a third molecule of quinone methide on the dimer could occur as shown either by (a) or (b). The presence of α,β-unsaturation in the trimer makes it clear that path (b) is that followed. Precedent for this behavior of a dienone in its reaction as a dienophile is found in the work of Curtin and co-workers[11] on the dimer of 2,6,6-trimethyl-2,4-cyclohexadienone.
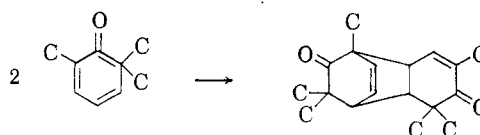
While this reaction course may be electronically controlled, molecular model constructions of transition states required by attack (a) and (b) suggest that the steric requirement about the spiro carbon atom of ring C should be prohibitive in attack (a); the planar ring of the quinone methide molecule would be forced to lie directly over the spiro carbon atom and thus a tight complex could not be formed. The transition state necessary for reaction (b), on the other hand, is entirely free of steric interaction of this nature and a close, parallel geometry of addenda can be accommodated.

Assuming that the double Diels-Alder origin of IV is well predicated, there remains one structural point for which precedent permitting a choice does not exist. The orientation of III in the formation of the trimer could be such as to give rise to IV or XI. The former might be expected by analogy with structures of quinone methide dimers, but this seemed to be too perilous an extrapolation.
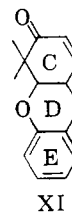
The position of the ring D oxygen atom in question was shown to be as in IV by partial degradation of the trimer. When the dihydro trimer (IX) was heated with palladium-charcoal, there was obtained a degradation product retaining all of the carbon atoms of the trimer and a small quantity of o-cresol. The substance was surmised to be a substituted xanthene because of similarities of its ultraviolet spectrum with those of other xanthenes. Analytical and molecular weight data as well as an examination of derivatives formed by

(11) T. L. Brown, D. Y. Curtin, and R. R. Fraser, *J. Am. Chem. Soc.*, **80**, 4339 (1958).

the substance led to its assignment of structure as 1 - [β(2 - hydroxyphenylethyl)] - 2 - hydroxyxanthene (XII). With dimethyl sulfate it gave a dimethyl ether (XIII) and with 3,5-dinitrobenzoyl chloride a diester. Oxidation of the dimethyl ether (XIII) with potassium permanganate in pyridine provided convincing evidence that the formulation of the degradation product as a xanthene was correct; there was obtained a product resulting from the loss of two hydrogen atoms and the incorporation of an oxygen atom. Spectral and analytical data showed it to be a xanthone and led ultimately to its assignment as 1-[β(2-methoxyphenylethyl)]-2-methoxyxanthone (XIV).

IX $\xrightarrow[\Delta]{\text{Pd-C}}$

XII. R = H
XIII. R = CH₃

XIV
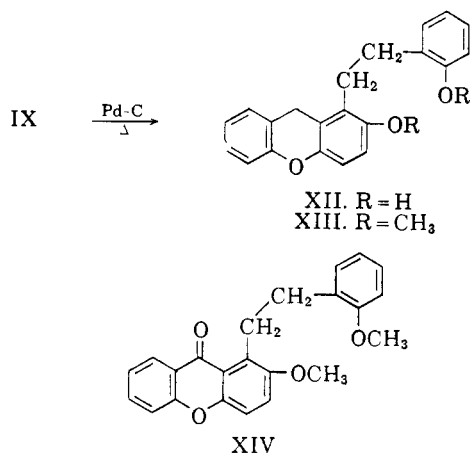
Support for structure XII was found in mass spectral data. The origin of principal peaks in the electron-impact decomposition pattern is shown in the following diagram:

mass 318 (parent ion)

mass 211

mass 197
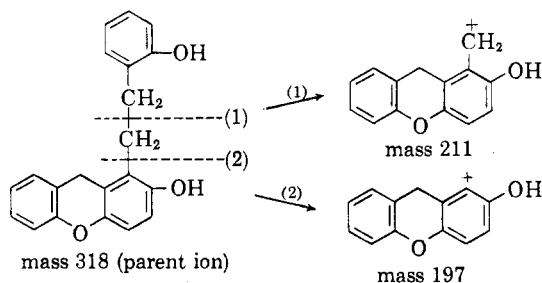
As pointed out earlier, structure XII (and therefore XIV as well) is largely surmised from data thus far presented. Xanthone XIV is the product expected if the formulation of the trimer represented by IV is correct; an isomeric xanthone would result from the degradation of XI. Evidence permitting a choice and at the same time confirming the xanthone assignment to XIV was obtained by comparisons of spectra of XIV with those of 1-
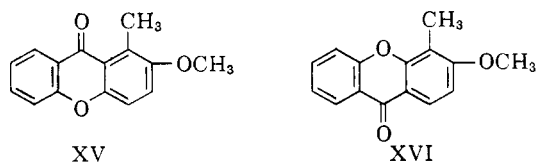
methyl-2-methoxyxanthone (XV) and 3-methoxy-4-methylxanthone (XVI).

The first of these (XV) was prepared from recently reported 1-formyl-2-hydroxyxanthone (XVII).[12]

XVII. R = H
XVIII. R = CH₃
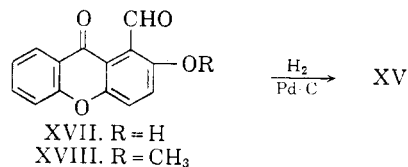
3-Methoxy-4-methylxanthone (XVI) was synthesized as shown in the following sequence. The mono ether of 2-methylresorcinol (XIX) was prepared by partial methylation (dimethyl sulfate) of

→XVI

XX
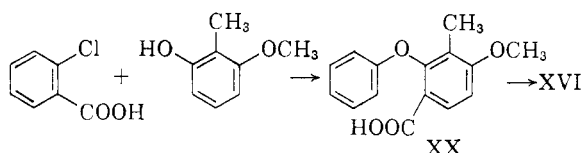
the methyl resorcinol. Its condensation with o-chlorobenzoic acid afforded XX which was then cyclized to XVI using polyphosphoric acid. Some preparations of XVI in which the starting material (XIX) was contaminated with 2-methylresorcinol gave a high-melting product formulated as 12H,-14H - 6 - methyl[1]benzopyrono[3,2 - b]xanthone (XXI). Reduction with lithium aluminum hydride[13] afforded the expected xanthene (XXII).

XXI   XXII
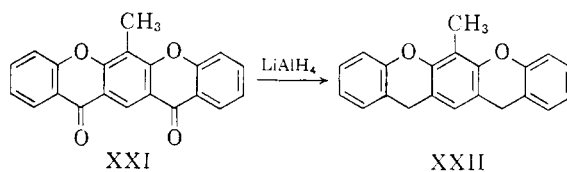
A comparison of the ultraviolet spectrum of the xanthone derived from o-quinone methide trimer (XIV) with those of the two isomeric methyl methoxyxanthones (XV and XVI) is shown in Fig. 1. The marked similarity between spectra of XIV and XV suggested the additional comparison of the spectrum of XIV with that of an equimolar mixture of XV and o-methylanisole. The latter is also shown in Fig. 1. The similarities and dissimilarities evident among these curves coupled with information provided by derivative formation and analytical data make it clear that the degradation product XIV is correctly formulated and that o-quinone methide trimer must be as formulated in IV but not in XI. Data obtained from NMR spectra are in complete accord with this assignment. They were obtained in connection with a study of the structures of trimers of substituted o-quinone methides.[3] These and other data which

XV   XVI

(12) J. S. H. Davies, F. Lamb, and H. Suschitzky, J. Chem. Soc., 1790 (1958).
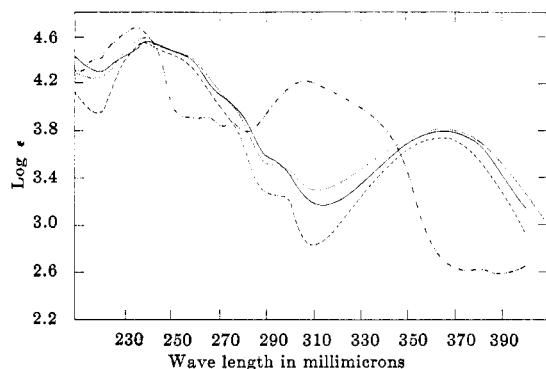(13) A. Mustafa and M. K. Hilmy, ibid., 1343 (1952).

Fig. 1. $\cdots - \cdots$, 3-methyl-4-methoxyxanthone; $— — —$, 1-methyl-2-methoxyxanthone; $\ldots\ldots$, 1-methyl-2-methoxy-xanthone and 2-methylanisole; $———$, 1-[β-(2-methoxy-phenylethyl)]-2-methoxyxanthone

demonstrate that all such trimers have the same basic ring system (IV) will be presented elsewhere.[14]

EXPERIMENTAL

o-Methoxymethylphenol (II). A mixture of 122 g. of distilled salicylaldehyde, 2.5 g. of 10% palladium-charcoal, and 255 g. of 25% aqueous dimethylamine solution was shaken under hydrogen (30 p.s.i.). Reaction was discontinued when the suspension abruptly changed from yellow to nearly colorless—this occurred at slightly more than 1 mole-equiv. uptake of hydrogen. Over-hydrogenation gave substantial quantities of o-cresol. Following removal of catalyst by filtration, the solution was cooled and made acidic with dilute hydrochloric acid. The solution was extracted with several portions of ether and made slightly basic (pH ca. 9) with concentrated aqueous sodium hydroxide solution (cooling) whereupon an oily layer separated. Several extractions with ether, drying with anhydrous sodium sulfate, and removal of ether through a Vigreux column at an aspirator afforded crude o-dimethylaminomethylphenol (I). Distillation through a short column gave 131 g. (86%) of pure I, b.p. 60° (0.2 mm.) [lit.[15] 104° (13 mm.)].

Anal. Calcd. for $C_9H_{13}NO$: C, 71.52; H, 8.60; N, 9.27. Found: C, 71.37; H, 8.57; N, 9.32.

The methiodide was prepared by mixing the amine with methyl iodide in dry ether solution. The precipitate, collected after 12 hr. at 30°, melted at 150° (dec.).

Anal. Calcd. for $C_{10}H_{16}NO$: C, 40.95; H, 5.46; N, 4.7. Found: C, 41.13; H, 5.53; N, 4.4.

To a suspension of 100 g. of the methiodide of o-dimethyl-aminomethylphenol in 250 ml. of methanol was added 750 ml. of methanol containing 56 g. of potassium hydroxide. This solution was heated under reflux for 30 min., cooled to 0°, and diluted with 1 l. of water. While stirring, cold, dilute hydrochloric acid was added so that the temperature did not rise above 20°. Without delay, the cold, acidic mixture was extracted with three portions of ether and the combined extracts were quickly washed with dilute sodium bicarbonate solution and then with water. They were dried (sodium sulfate) and freed of ether under reduced pressure with use of a Vigreux column. Distillation through a short path system afforded 32.9 g. (70%) of o-methoxymethylphenol (II), b.p. 55° (0.45 mm.), n^{25}_D 1.5315. This substance poly-

merizes readily and it was found that prolonged heating during distillation drastically reduced the yield.

A better synthesis of II has been described.[5] The saligenin required for this synthesis was prepared by the hydrogenation of salicylaldehyde.[16] Samples of II prepared by the two methods were identical in all respects.

Preparation of o-quinone methide trimer (IV). The following was found to be the most efficient procedure for the direct formation of the trimer. The isolation of the monomer was best effected using an entirely different apparatus which will be described elsewhere.

The apparatus consisted of a 100-ml. modified Claisen flask arranged to distil directly into a 0.9-cm. Vycor tube 30 cm. in length. This tube was wrapped with a heating element and sufficient insulation to permit its operation up to 1000°. The distillation flask was outfitted with a nitrogen inlet tube extending to within 1 mm. of the bottom. Nitrogen flow was controlled by a valve positioned at the top of this tube. The exit end of the pyrolysis tube was attached to a serrated trap which could be cooled by raising a cold bath to surround it. The trap was connected to a high-capacity vacuum pump by large-diameter heavy-wall tubing.

o-Methoxymethylphenol (II, 10.0 g.) was placed in the flask and the system was evacuated. The pyrolysis tube was then heated to 750–850° and a slow stream of nitrogen was admitted through the inlet tube. The temperature of the oil bath used to heat the distillation flask was increased until distillation proceeded at the rate of 1–2 drops/5 sec. As the viscous pyrolysate began to collect in the tube at the furnace outlet, it became necessary periodically to sweep with a large surge of nitrogen. At the termination of a run, 1–2 g. of II remained in the flask and the pyrolysate was distributed throughout the trap and lower end of the tube leading from the furnace. It was collected by refluxing chloroform through the disassembled system. Evaporation of solvent to a very small volume followed by the addition of three volumes of acetone and cooling gave the crude trimer. From the 8–9 g. of II actually pyrolyzed, there was obtained 5–6 g. (80–85%) of IV, m.p. 186–191°. Recrystallization from acetone or ethyl acetate or from chloroform-petroleum ether gave colorless needles, m.p. 190–192°.

Anal. Calcd. for $C_{21}H_{18}O_3$: C, 79.22; H, 5.70; Mol. Wt., 318. Found: C, 79.00; H, 5.70; mol. wt., 324 (cryoscopic in benzil).

The infrared spectrum of IV possesses carbonyl absorption at 5.94 μ.

When IV was allowed to reflux in an ethanolic solution of hydroxylamine hydrochloride and pyridine there was formed the oxime of an intermediate hydroxylamine derivative (VIII). It melted with gas evolution at 232–233° after recrystallization from a large volume of ethanol.

Anal. Calcd. for $C_{21}H_{22}N_2O_4$: C, 68.83; H, 6.05; N, 7.65. Found: C, 68.98; H, 6.08; N, 7.64.

Attempted pyrolysis of p-methoxymethylphenol (VII). Using the apparatus described for the preparation of IV, 10.0 g. of p-methoxymethylphenol[5,17] was submitted to pyrolytic conditions described above except that a temperature of 800–900° was employed. The crystalline deposit found in the receiver weighed 7.1 g. and was shown by m.p. and mixture m.p. to be very pure starting material.

Pyrolysis of 1-methoxymethyl-2-naphthol (V). A solution of 5.0 g. of 1-methoxymethyl-2-naphthol[10] in 50 ml. of benzene was added dropwise to a heated 15-cm. unpacked tube. The tube was positioned at a 45° angle so that pyrolysate could run from the tube (250–300°) into a trap. A nitrogen atmosphere was employed. An addition rate of 1–2 drops/sec. gave best results. The gummy product was washed from the system with benzene and chromatographed on alumina in 1:1 benzene-ether. A lemon-yellow fraction separated

(14) P. D. Gardner, A. Merijan, and B. A. Shoulders, manuscript in preparation.

(15) J. Decombe, *Compt. rend.*, 196, 866 (1933); *Chem. Abstr.*, 27, 2941 (1933). The value reported was for a product obtained from the reaction of phenol, formaldehyde and dimethylamine.

(16) W. H. Carothers and R. Adams, *J. Am. Chem. Soc.*, 46, 1675 (1924).

(17) B. Dunning, Jr., F. Dunning, and E. E. Reid, *J. Am. Chem. Soc.*, 58, 1565 (1936).

cleanly and upon evaporation of solvent afforded 1.2 g. (29%) of VI as a very viscous yellow liquid. This crystallized on standing, m.p. 142–143°, unchanged on admixture with authentic dimer of 1,2-naphthoquinone-1-methide.[18]

Hydrogenation of o-quinone methide trimer (IV). A suspension of 1.00 g. of IV, 0.30 g. of 10% palladium-charcoal and 50 ml. of ethanol was stirred under 1 atm. of hydrogen at room temperature. The mixture consumed hydrogen steadily during 16 hr. and then stopped at 104% for one double bond. The catalyst and much of the product were filtered with suction and the solid mixture was boiled with several portions of acetone. These extracts were combined with the ethanol filtrate and concentrated to dryness. The residue was dissolved in a large volume of boiling acetone and the solution then concentrated on a steam cone to a volume of 15 ml. (supersaturated) and cooled. There was obtained 0.90 g. (90%) of dihydro trimer (IX) as colorless prisms, m.p. 223–224°. Its infrared spectrum exhibits carbonyl absorption at 5.79 μ which is characteristic of saturated ketones.

Anal. Calcd. for $C_{21}H_{20}O_3$: C, 78.72; H, 6.29. Found: C, 78.56; H, 6.34.

The oxime, prepared in quantitative yield by the pyridine-ethanol method, was crystallized from ethanol, m.p. 229–230° (dec.).

Anal. Calcd. for $C_{21}H_{21}O_3N$: C, 75.19; H, 6.31; N, 4.18. Found: C, 75.30; H, 6.30; N, 4.04.

Further reduction of the dihydro trimer (IX) to the corresponding carbinol (X) was effected with lithium aluminum hydride. To 0.3 g. of the hydride in 40 ml. of purified tetrahydrofuran was added 1.50 g. of IX. After 12 hr. at reflux temperature, the mixture was cooled and the excess hydride destroyed by the cautious addition of water. Acidification followed by the usual processing gave 1.21 g. (81%) of the carbinol (X), m.p. 122–125°. Recrystallization from methanol gave colorless prisms, m.p. 124–126°.

Anal. Calcd. for $C_{21}H_{22}O_3$: C, 78.23; H, 6.88. Found: C, 78.01; H, 7.20.

Dehydrogenation of dihydro o-quinone methide trimer (IX). A finely powdered mixture of 1.5 g. of IX and 0.1 g. of 30% palladium-charcoal[19] was placed in a sublimation apparatus. Air was replaced with nitrogen and the mixture was heated at 300° for 1 hr. Droplets of condensate, later identified as *o*-cresol, appeared on the finger during the process. The cooled mixture was well extracted with benzene-ether (1:1) and this extract was then concentrated to a small volume. The addition of petroleum ether and cooling gave 0.60 g. (40%) of yellow solid, m.p. 155–160° (dec.). Recrystallization from benzene (decolorizing charcoal) gave 0.20 g. of 1-[β-(2-hydroxyphenylethyl)]-2-hydroxyxanthene (XII) as fine colorless needles, m.p. 162–163° (dec.).

Anal. Calcd. for $C_{21}H_{18}O_3$: C, 79.22; H, 5.70. Found: C, 79.33; H, 5.68.

The bis-3,5-dinitrobenzoate, prepared in pyridine, had m.p. 181–182° (dec.) after crystallization from acetone. This substance is sensitive to both light and air.

Anal. Calcd. for $C_{35}H_{22}N_4O_{13}$: C, 59.49; H, 3.14; N, 7.93. Found: C, 59.20; H, 3.12; N, 7.69.

1-[β-(2-Methoxyphenylethyl)]-2-methoxyxanthene (XIII). A mixture comprised of 0.50 g. of the dehydrogenation product (XII), 2.0 g. of anhydrous potassium carbonate, 0.50 g. of dimethyl sulfate, and 50 ml. of acetone was stirred and heated under reflux for 11 hr. It was poured into water (200 ml.) and extracted with ether. Isolation of the product in the usual way and recrystallization from benzene–petroleum ether afforded 0.40 g. (73%) of the dimethyl ether (XIII), m.p. 100–105°. Further purification raised the m.p. to 108–109°. Satisfactory analytical data could be obtained only after chromatography on alumina, m.p. 108–109°.

(18) R. Pummerer and E. Cherbuliez, *Ber.*, **52B**, 1392 (1919).

(19) N. D. Zelinski and M. B. Turowa-Pollak, *Ber.*, **58**, 1295 (1925).

Anal. Calcd. for $C_{23}H_{22}O_3$: C, 79.74; H, 6.40; OMe, 17.91. Found: C, 79.46; H, 6.53; OMe, 17.21.

1-[β-(2-Methoxyphenylethyl)]-2-methoxyxanthone (XIV). The methyl ether described above (XIII) (0.21 g.) was dissolved in a solution of 1.2 g. of potassium permanganate in 50 ml. of anhydrous pyridine. The resulting solution was heated, while stirring, at 70° for 3 hr. and then cooled and treated with saturated aqueous oxalic acid to the disappearance of purple. The product was obtained by ether extraction and the usual processing of the extract. Recrystallization from ether–petroleum ether gave 0.13 g. (59%) of the xanthone (XIV), m.p. 156–158°. Another crystallization raised the m.p. to 160–161°.

Anal. Calcd. for $C_{23}H_{20}O_4$: C, 76.65; H, 5.59. Found: C, 76.46; H, 5.68.

Infrared absorption (6.07 μ) exhibited by XIV is typical of xanthones. The ultraviolet spectrum is shown in Fig. 1.

1-Formyl-2-methoxyxanthone (XVII). To a solution of 3.0 g. of 1-formyl-2-hydroxyxanthone[12] in 150 ml. of anhydrous acetone was slowly added, with stirring, 15.0 g. of anhydrous potassium carbonate. An orange salt precipitated. Dimethyl sulfate (4.0 g.) in 50 ml. of acetone was added and the resulting mixture was stirred under reflux for 14 hr. Removal of most of the solvent under reduced pressure followed by the addition of 200 ml. of water gave a flocculent tan precipitate. This was isolated by extraction with benzene. Removal of most of the solvent under reduced pressure and crystallization from benzene–petroleum ether gave 2.0 g. (63%) of light tan solid, m.p. 186–200°. Further purification in this manner gave the sample for analysis, m.p. 208–209°.

Anal. Calcd. for $C_{15}H_{10}O_4$: C, 70.86; H, 3.97. Found: C, 70.97; H, 3.94.

1-Methyl-2-methoxyxanthone (XV). To a presaturated suspension of 0.5 g. of 10% palladium-charcoal in 20 ml. of 95% ethanol was added 0.201 g. of 1-formyl-2-methoxyxanthone (XVII). The mixture was stirred under 1 atm. of hydrogen for 2.75 hr. when 2 mole-equivalents of gas were consumed. Removal of catalyst and evaporation of solvent under reduced pressure gave the crude product. Recrystallization from ethanol afforded 0.15 g. (75%) of 1-methyl-2-methoxyxanthone (XV) as colorless needles, m.p. 154–155°. Its infrared spectrum exhibits xanthone carbonyl absorption at 6.05 μ. The ultraviolet spectrum is shown in Fig. 1.

Anal. Calcd. for $C_{15}H_{12}O_3$: C, 74.98; H, 5.04. Found: C, 75.30; H, 5.22.

2-Methylresorcinol methyl ether (XIX). The procedure described here, although unsatisfactory, is the best found. To a solution of 124 g. of 2-methyl resorcinol (technical grade) in 500 ml. of dry acetone was added 138 g. of anhydrous potassium carbonate. While stirring, 64.0 g. of dimethyl sulfate was added during 30 min. and the mixture was stirred under reflux for an additional 7 hr. Stirring was continued while most of the solvent was removed under reduced pressure. The residue was treated cautiously with 500 ml. of cold 10% sulfuric acid and ether was added to increase the bulk of the organic phase. This phase was separated and extracted with 500 ml. of 10% aqueous potassium hydroxide. Following washing with ether, the aqueous solution was acidified and extracted with ether. The extract was dried, freed of solvent and fractionally distilled through an efficient column. There was obtained 11.0 g. (8%) of the methyl ether (XIX), b.p. 64–65° (1.5 mm.).

Anal. Calcd. for $C_8H_{10}O_2$: C, 69.54; H, 7.30. Found: C, 69.25; H, 7.35.

2-Carboxy-2′-methyl-3′-methoxydiphenyl ether (XX). To a 500-ml., three-neck flask equipped with a stirrer, water separator, thermometer, and reflux condenser were placed, with stirring, 60 g. of anisole, 12.3 g. of 2-chlorobenzoic acid, 0.2 g. of copper-bronze (pre-treated with a 5% solution of iodine in acetone), and 11.0 g. of 2-methylresorcinol methyl ether. The mixture was heated to 70° and 40 g. of anhydrous potassium carbonate was added. The temperature was then slowly raised to 155–160° (frothing) where it was maintained (stirring) for 4 hr. Solvent was then removed by steam dis-

tillation. The aqueous solution was washed with several portions of ether and then cautiously acidified by the addition of cold 50% sulfuric acid. Isolation of the product was effected by ether extraction followed by crystallization from benzene–petroleum ether or from 95% ethanol. There was obtained 3.2 g. (16%) of the acid (XX), m.p. 144–147°. Further purification from ethanol raised the m.p. to 154–155°.

Anal. Calcd. for $C_{15}H_{14}O_4$: C, 69.76; H, 5.46. Found: C, 70.08: H, 5.72.

3-Methoxy-4-methylxanthone (XVI). A mixture of 1.5 g. of 2-carboxy-2'-methyl-3'-methoxydiphenyl ether (XX) and 15 g. of polyphosphoric acid was stirred and heated on a steam cone. Stirring was continued until it became homogeneous and the flask was then stoppered and heated, with occasional swirling, for an additional 30 min. Isolation of the product in the usual manner and recrystallization from 95% ethanol gave 1.0 g. (72%) of the xanthone (XVI) as colorless fibrous solid, m.p. 177–178°.

Anal. Calcd. for $C_{15}H_{12}O_3$: C, 74.98; H, 5.04. Found: C, 75.22; H, 5.15.

This substance exhibits carbonyl absorption in the infrared at 6.04 μ. Its ultraviolet spectrum is shown in Fig. 1.

When preparations of 2-methylresorcinol methyl ether used in this sequence were not carefully fractionated, substantial quantities of 2-methylresorcinol persisted as a contaminant. Utilization of such material in the two-step process described above, without isolation of the intermediate acid, gave varying quantities of a high-melting by-product. Purification by recrystallization from ethanol gave a pure sample as pale yellow needles, m.p. 377–380°. Analytical data, spectral data, and its high melting point suggested it to be a bis condensation product, 12H,14H-6-methyl[1]benzopyrono[3,2-b]xanthone (XXI).

Anal. Calcd. for $C_{21}H_{12}O_4$: C, 76.82; H, 3.69. Found: C, 76.50; H, 3.80.

Lithium aluminum hydride reduction of this substance exactly as described in the general method of Mustafa and Hilmy[13] gave a virtually quantitative yield of 12H,14H-6-methyl[1]benzopyrono[3,2-b]xanthene (XXII). Several recrystallizations from petroleum ether gave very pale yellow needles, m.p. 177–178°.

Anal. Calcd. for $C_{21}H_{14}O_2$: C, 83.97; H, 5.37. Found: C, 84.08; H, 5.42.

Some Reactions of 2-Furyllithium[1]

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The reactivity of 2-furyllithium toward carbon dioxide, aldehydes, ketones, esters, nitriles, and alkyl halides has been studied. Carbinols and ketones containing 2-furyl groups as well as 2-n-butylfuran and 2-furoic acid have been prepared in high yields.

Very little has been published in the literature about the carbanions of furan and its derivatives. Metallic derivatives of furan were first prepared by Gilman and Breuer.[2] Furan was metalated by reaction with sodium, diethylmercury, diphenylmercury, and dibenzylmercury. Dibenzylmercury gave the best results as shown by the formation of 2-furoic acid in 58% yield on subsequent carbonation. Carbonation of the reaction product(s) of furan, sodium sand, and n-amyl chloride gave furan-2,5-dicarboxylic acid (6.5%) in addition to 2-furoic acid (27%), indicating that the furan had probably been converted to its dianion to a small extent.[3] Earlier a 40% yield of 2-furoic acid was obtained by the metalation of furan with phenyllithium while only 7.5% of the acid was obtained with methyllithium as the metalating agent.[4]

Derivatives containing germanium and silicon have been prepared by the reaction between 2-furyllithium and germanium tetrabromide[5] and trimethylchlorosilane, respectively.[6] Sulfur dioxide was absorbed by 2-furyllithium leading to lithium 2-furylsulfinate.[7,8] Carbinols have been obtained by treating 2-furyllithium with 1-alkyl-4-piperidones.[9]

The present work deals with a study of the reactivity of 2-furyllithium toward several different types of compounds including carbon dioxide, alkyl halides, nitriles, aldehydes, ketones, and esters.

Furan (one equivalent) was metalated in high yield by reaction with n-butyllithium (one equivalent) in refluxing ether for four hours as evidenced by the fact that carbonation gave 2-furoic acid in

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