APPROACHES TO THE SYNTHESIS OF 2 - (4 - NITROPHENYL) - 4, 6 - DI (4 - METHOXYPHENYL) BENZENE - 1, 3 - QUINONE

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
WILLIAM DAVID WATSON
1973

ABSTRACT

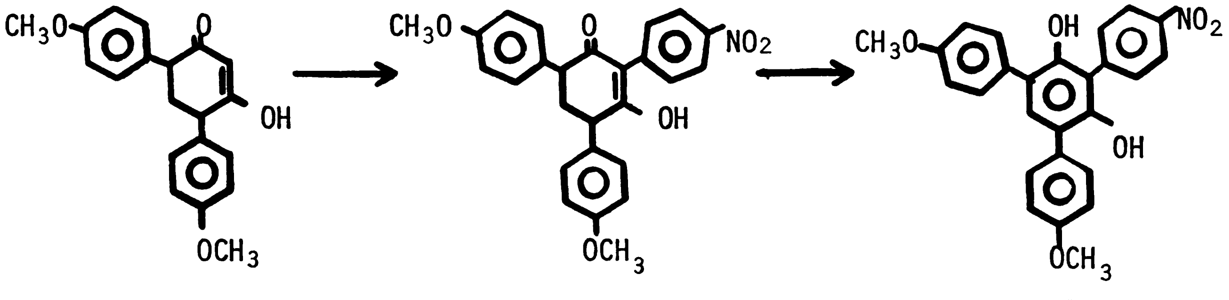
APPROACHES TO THE SYNTHESIS OF 2-(4-NITROPHENYL)-4,6-DI(4-METHOXYPHENYL) BENZENE-1,3-QUINONE

By

William David Watson

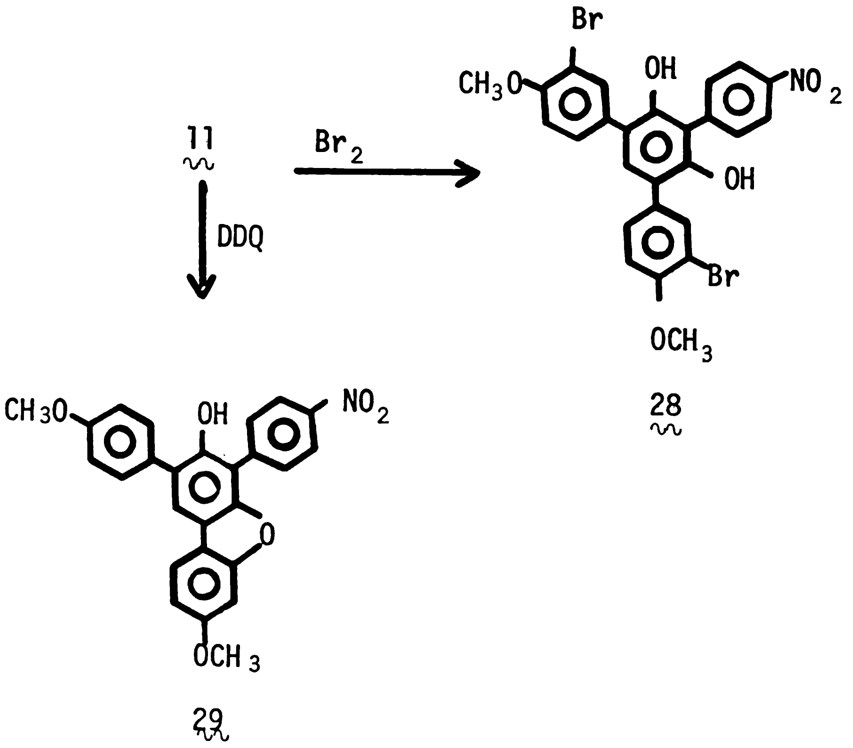
Synthetic approaches to 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl) benzene-1,3-quinone 9 have been investigated. Benzene-1,3-quinone is unknown and is expected to be unstable since there is no uncharged resonance contributor. However molecular orbital calculations indicate that the molecule may be isolable with appropriate stabilizing groups, as noted above.

A key step in the synthesis was arylation of 4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione 15 with 4-fluoronitrobenzene using sodium hydride and hexamethylphosphoramide to give 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione 10. Aromatization of 10 was accomplished by bromination, and rearrangement with spontaneous loss of hydrogen bromide to form 2-(4-nitrophenyl)4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 11.



15 10 11

Attempted oxidation of 11 with bromine did not form 9 but 2-(4-nitrophenyl)-4,6-di(3-bromo-4-methoxyphenyl)-1,3-dihydroxybenzene 28, instead. Oxidation of 11 with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone, DDQ, again did not form 9 but 3-hydroxy-7-methoxy-2-(4-methoxyphenyl)-4-(4-nitrophenyl)dibenzofuran 29, instead.



Other oxidations of 11 are currently under study.

APPROACHES TO THE SYNTHESIS OF 2-(4-NITROPHENYL)-4,6-DI(4-METHOXYPHENYL)BENZENE-1,3-QUINONE

By

William David Watson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Chemistry

1973

DEDICATION

To my Mother and Father who instilled in a young impressionable mind the importance of integrity, the desire to learn, and the ability to work to accomplish one's goals.

To my darling wife, Eva, who has made life meaningful and beautiful to me. It was only through her unselfish love and encouragement that I was able to accomplish this goal in my life. Only now will I be able to devote the time and assistance to her that she deserves.

And finally to Davy, Richy, and Julie, my children, who have had to suffer from a negligent father who "has to go to work tonight and study." No more, kids!

ACKNOWLEDGMENT

The author would like to express his appreciation to Professor Donald G. Farnum for his guidance and helpful assistance during the course of this study.

During my brief stay at East Lansing, my association with the graduate students working in Dr. Farnum's group was most rewarding. Dr. W. T. Suggs who had worked previously on the project was a constant source of consultation and recommended the use of 4-fluoronitrobenzene in the NaH/HMPT system for the arylation reactions described in the text.

The author would also like to thank Dr. A. E. Young of the Dow Chemical Co., Midland, Michigan for helping to arrange my education leave of absence from Dow and who has been a constant source of encouragement.

TABLE OF CONTENTS

Page

INTRODUCTION. 2

RESULTS AND DISCUSSION 10

EXPERIMENTAL 27

- General 27
- Ethyl-4-methoxyphenylacetate **12** 27
- Oxaltoester of ethyl-4-methoxyphenylacetate **13** 28
- Ethyl-2-(4-methoxyphenyl) propenate **14** 28
- 4,6-di(4-Methoxyphenyl)cyclohexane-1,3-dione **15** 29
- 2-(4-Nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione **16**. 30
- 2-(4-Nitrophenyl)-4,6-diphenylcyclohexane-1,3-dione **18**. 30
- 2-(4-Nitrophenyl)-4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione **10** 31
- 2-Bromo-5,5-dimethylcyclohexane-1,3-dione **19** 32
- 2,2-Dibromo-5,5-dimethylcyclohexane-1,3-dione **20** 32
- 2,4-Dibromo-5,5-dimethylcyclohexane-1,3-dione **21** 33
- 2-Bromo-2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione **22** 34
- 4-Bromo-2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione **23** 34
- Bromination of 4-methoxyphenylacetone **24** 35
- 2-Bromo-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene **25** 35
- 2-Bromo-2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione **26** 36
- 2-(4-Nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene **11** 36
- 2-(4-Nitrophenyl)-4,6-di(3-bromo-4-methoxyphenyl)-1,3-dihydroxybenzene **28** 37
- Oxidation of 1,4-dihydroxybenzene with DDQ 38

TABLE OF CONTENTS - Continued

Page

3-Hydroxy-7-methoxy-2-(4-methoxyphenyl)-4-(4-nitrophenyl) dibenzofuran 29 38

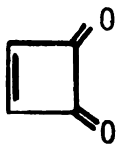
BIBLIOGRAPHY. 40

INTRODUCTION

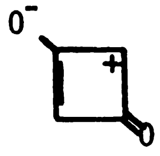
INTRODUCTION

The *ortho* and *para* quinones of benzene are well known systems in organic chemistry. More recently, quinone-like derivatives (**1a**) of cyclobutadiene have been prepared, including the unusual 1,3 or "*meta*" quinone **1b**. It is the purpose of this work to synthesize a six member ring 1,3-quinone.

In the cyclobutadienequinone series there are two possible isomers, a 1,2 (*ortho*)-quinone **1a** and a 1,3 (*meta*)-quinone **1b**.

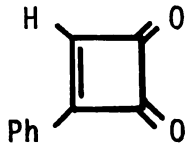


1a

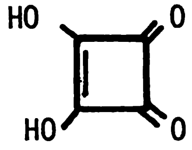


1b

In the 1,2 (*ortho*)-quinone series phenylcyclobutadiene-1,2-quinone[1] **2** and and 3,4-dihydroxycyclobutadiene-1,2-quinone[2] **3** (squaric acid) are known.

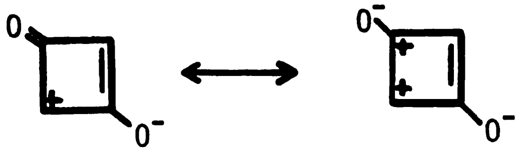


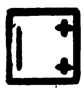
2



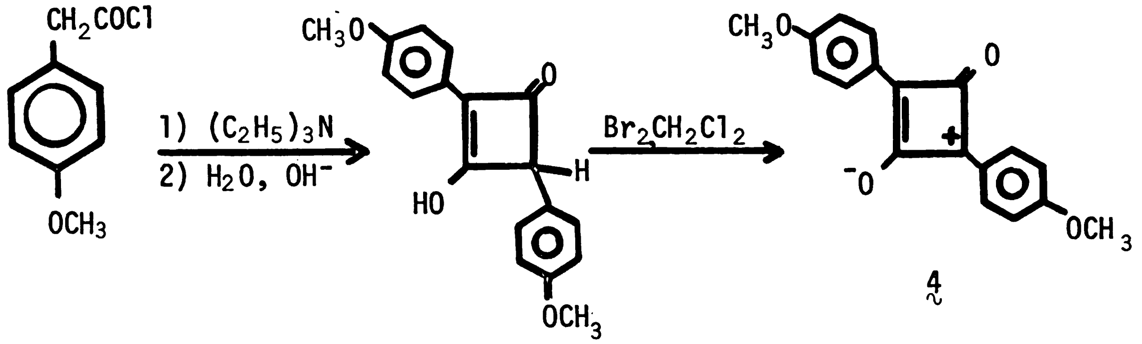
3

1,3 (meta)-quinones are of theoretical interest because of their relationship to the closed shell dication of cyclobutadiene.



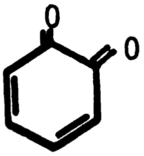


Several cyclobutadiene-1,3-quinones have been reported since 1965.[3-7] However only 2,4-di(4-methoxyphenyl)cyclobutadiene-1,3-quinone 4 has been examined by extensive structure determination[8,9] including crystal structure.[10] 4 was obtained as a high melting purple crystalline solid by the following scheme:

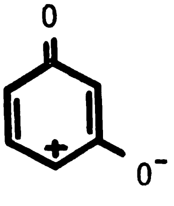


4

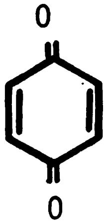
In the benzene series there are three possible isomers, a 1,2-(ortho)-quinone 5a, a 1,3 (meta)-quinone 5b and a 1,4 (para)-quinone 5c.



5a



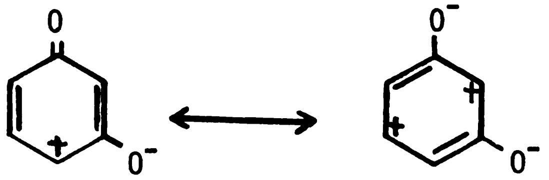
5b

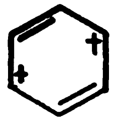


5c

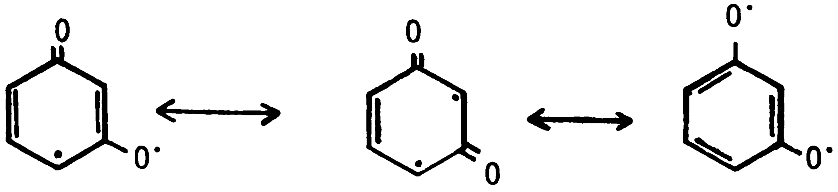
Both the 1,2- and 1,4-benzene quinones have long been known and are relatively stable. Both, however, are reduced quite easily to the corresponding more electronically stable aromatic hydroquinones. Furthermore, they react like α,β-unsaturated ketones, forming 1,4 addition products, rather than like aromatic compounds.

Benzene-1,3-quinone 5b however is unknown. It is expected to be unstable since no uncharged resonance contributor can be drawn for such a molecule. In fact its dipolar contributor is formally related to the 4π-electron antiaromatic benzene dication as are those of the isomeric quinones.



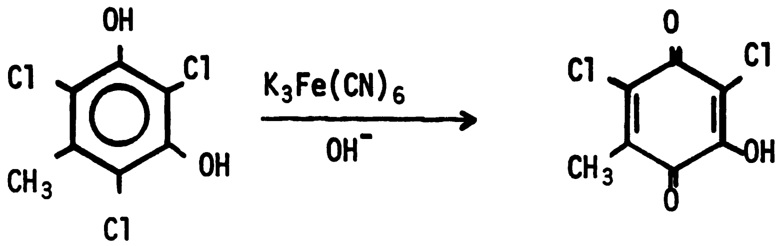


Benzene-1,3-quinone may also be represented as a triplet diradical species, a hypothesis that could easily be tested by esr investigation.

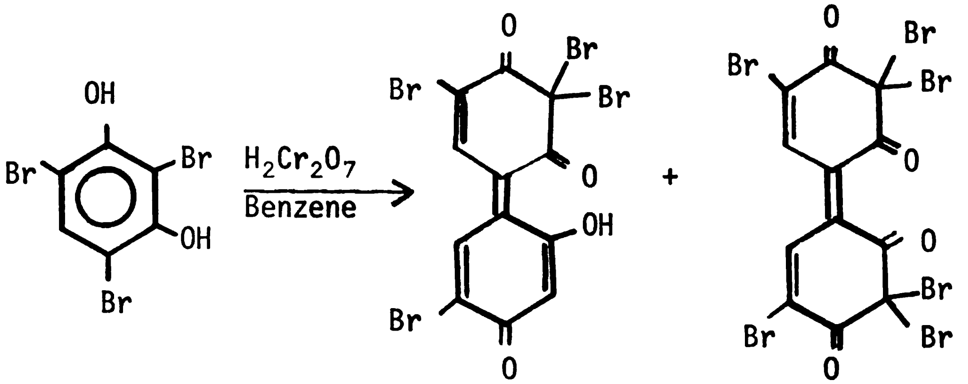


Various methods have been attempted in an effort to prepare a benzene-1,3-quinone. However none have been successful.

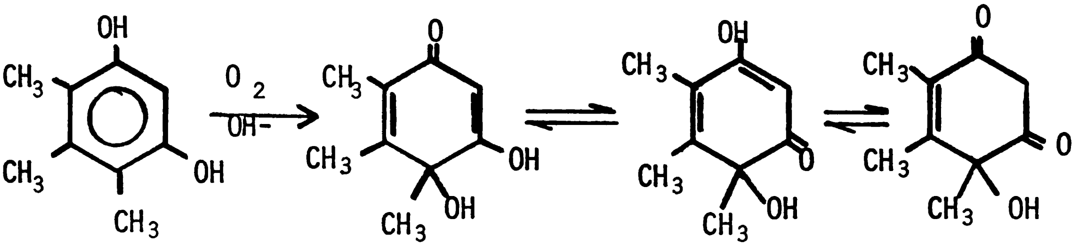
The first method attempted was the oxidation of various substituted 1,3-dihydroxybenzenes. For example 2,4,6-trichloro-5-methyl-1,3-dihydroxybenzene when treated with alkaline potassium ferricyanide produced a 1,4-quinone.[11]



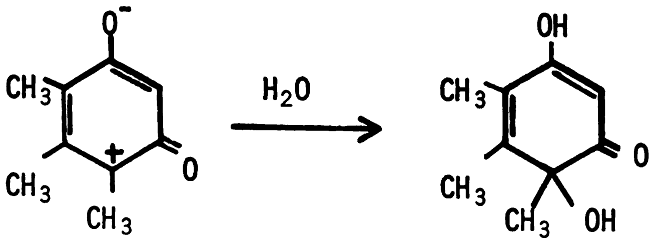
2,4,6-tribromo- and 2,4,6-trichloro-1,3-dihydroxybenzene gave similar results. Oxidation of 2,4,6-tribromo-1,3-dihydroxybenzene with chromic acid in benzene produced two coupled products.[12]



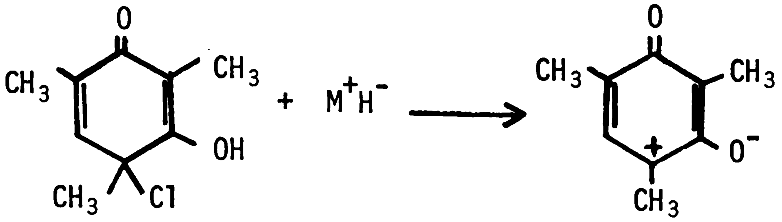
The air oxidation of an alkaline solution of 4,5,6-trimethyl-1,3-dihydroxybenzene produced the following product which exists as various tautomers.[13]



It has been proposed that the above products are formed from the addition of water to a benzene-1,3-quinone.

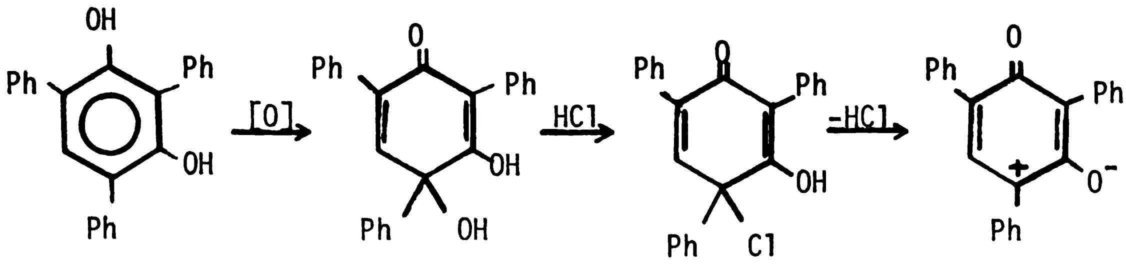


Based on the above, McCarthy approached the synthesis of benzene-1,3-quinone through 2,4,6-trimethyl-4-chloro-3-hydroxy-2,5-cyclohexanedienone **6**, since a reagent that would simultaneously extract both a proton and a chloride ion should form the desired product.[14]



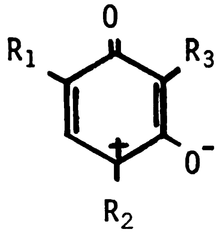
6

However, no direct synthesis of **6** was accomplished. Various attempts to make the tri(t-butyl) analog of **6** also failed. It has also been suggested that the triphenyl analog of **6** could be prepared from 2,4,6-triphenyl-1,3-dihydroxybenzene[15-17] via the following scheme.

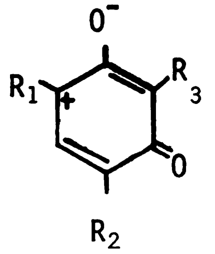


However the work was never completed.

Simple molecular orbit calculations suggest that 7 and 8 are a close approximation to the charge distribution in benzene-1,3-quinone.



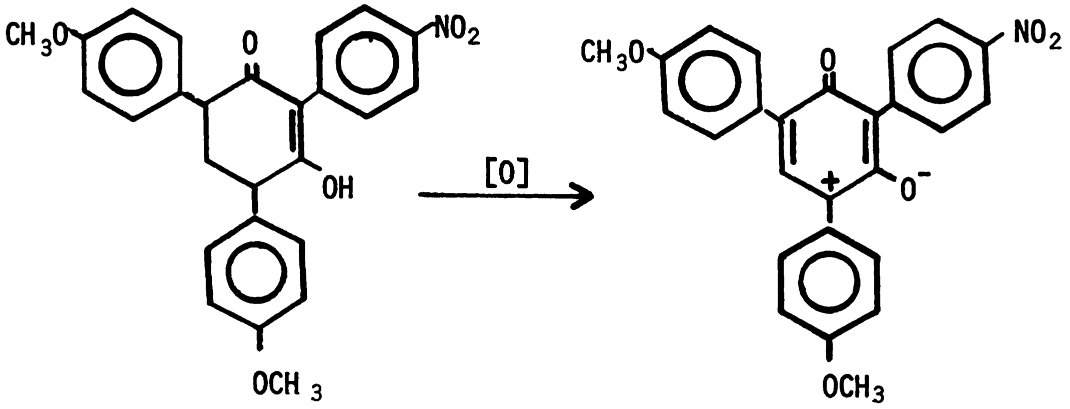
7



8

These structures can be looked at in a simplified view as zwitterionic species with a non-interacting allyl cation and a β-diketone enolate anion. Electron donating groups at the R_1 and R_2 positions should stabilize the allyl cation moeity and an electron withdrawing group at the R_3 position should stabilize the β-diketone enolate anion. Based on the stability of the 2,4-di-(4-methoxyphenyl)cyclobutadiene-1,3-quinone in the four membered 1,3-quinone species it was decided to use R_1=R_2=4-methoxyphenyl and R_3=4-nitrophenyl 9. It was thought that the above substituted benzene -1,3-quinone might be stable enough to be isolatable.

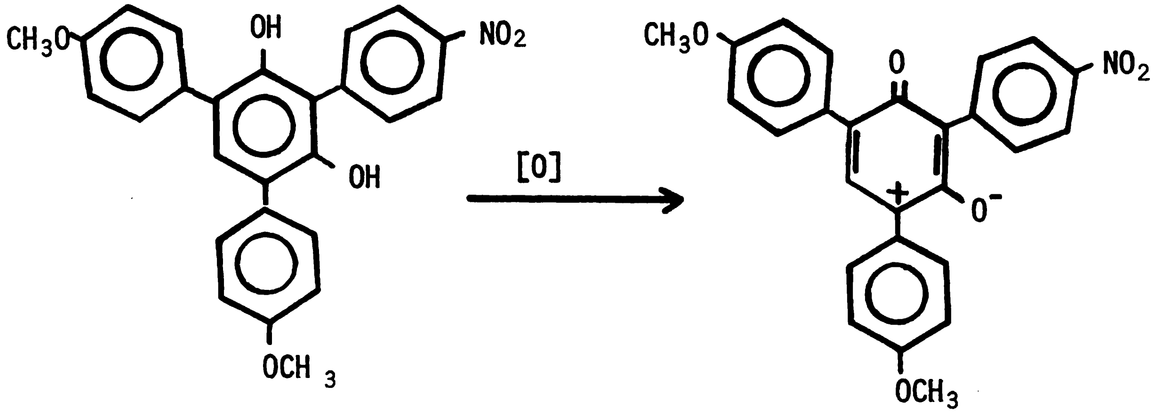
Recent work by Suggs on the oxidation of 2-(4-nitrophenyl)-4,6-di-(4-methoxyphenyl)cyclohexane-1,3-dione 10 has given inconclusive results.[10]



10 9

Using two equivalents of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) per equivalent of dione 10 in refluxing dioxane yielded a black crystalline solid with no definite melting point. The only spectrum that was encouraging was the mass spectrum that showed molecular ions at 443 and 441. 443 is the molecular weight of 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene and 441 is the molecular weight of benzene-1,3-quinone 9. However attempts to purify the black crystals have met with no success.

The route chosen for this work on the preparation of 2-(4-nitrophenyl) -4,6 di(4-methoxyphenyl)benzene-1,3-quinone was based on the oxidation (eg. Br_2, HgO or DDQ) of 2-(4-nitrophenyl)4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 11.

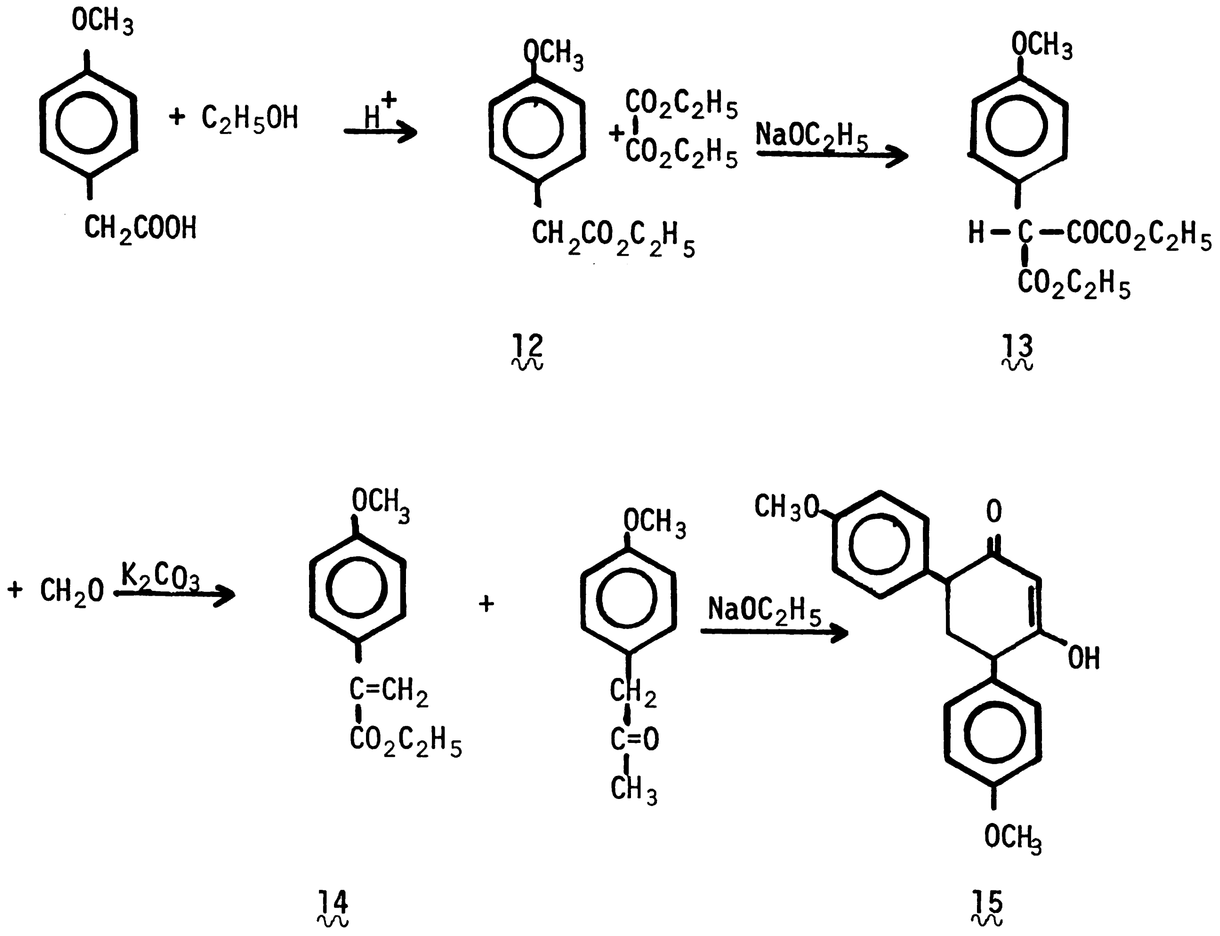


11 9

The general approach to the synthesis of 11 started with the synthesis of 4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione as described by Suggs.[10]

RESULTS AND DISCUSSION

The approach to the synthesis of 4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione as described previously by Suggs is shown below.[10]



The reaction sequence involves esterification of 4-methoxyphenyl-acetic acid with ethanol under acidic conditions to form ethyl-4-methoxyphenyl-acetate **12**. Acetate **12** reacts with diethyloxalate in the presence of sodium ethoxide to form the oxaltoester of ethyl-4-methoxyphenylacetate **13**. This oxaltoester reacts with aqueous formaldehyde in the presence of potassium carbonate to form ethyl-2-(4-methoxyphenyl)propenoate **14**. Reaction of the propenoate with 4-methoxyphenyl acetone in a Michael addition cyclization results in the formation of 4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione. Up to this point the procedure used was identical to that reported by Ames and Davey for the preparation of 4,6-diphenylcyclohexane-1,3-dione.[18]

Previous work by Suggs[10] had shown that acetate 12 was formed in 66%, oxaltoester 13 in 49%, propenoate 14 in 70% and dione 15 in 25% yield. Thus the overall yield of dione 15 was only 5.7%. It was one of the goals of this research to attempt to improve the overall yield.

Using the procedure of Vogel[19] the reaction of 4-methoxyphenylacetic acid with excess ethanol using catalytic amounts of sulfuric acid produced ethyl-4-methoxyphenyl acetate 12, b p 102-105^{o}/1.0mm in 93% yield. Ir, nmr and elemental analysis confirmed the structure.

The preparation of oxaltoester 13 was modified in accordance with Levene and Meyer,[20] and Floyd and Miller.[21] Reaction of equal molar amounts of sodium ethoxide, diethyl oxalate and acetate 12 produced the oxaltoester of ethyl-4-methoxyphenyl acetate 13 m p 50.0-53.0^{o} in 71% yield. Ir, nmr and elemental analysis confirmed the structure.

The reaction of oxaltoester 13 with a four molar excess of aqueous formaldehyde and potassium carbonate yielded ethyl-2-(4-methoxyphenyl) propenoate 14, b p 119-124^{o}/1.5mm, in 75% yield. The structure was verified by ir and nmr. It was observed that upon standing for three months the sample completely polymerized as shown by the disappearance of the vinyl protons in the nmr.

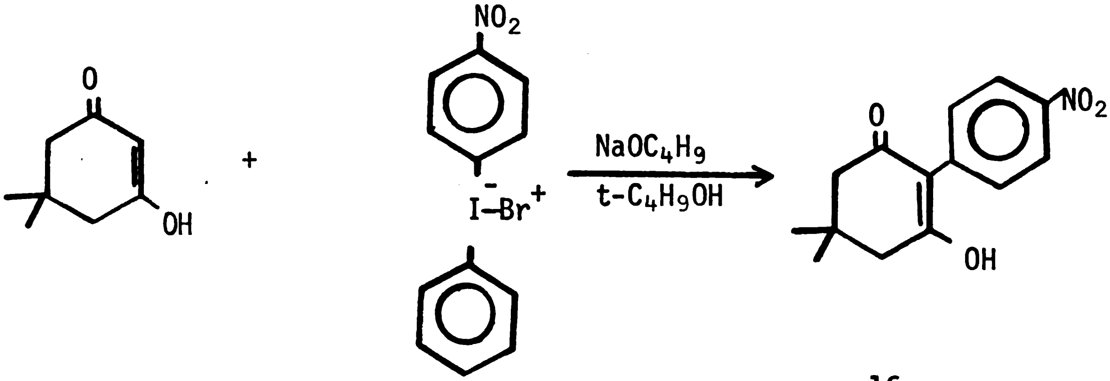
Preparation of 4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione 15 was accomplished in 77% yield by the reaction of a slight excess of sodium ethoxide and propenoate 14 with 4-methoxyphenyl acetone. The dione 15 m.p. 93^{o} was identified by ir, nmr and elemental analysis.

Thus the overall yield of dione 15 was increased from 5.7 to 38%.

The next major synthetic step was arylation of dione 15 in the

C-2 position with a 4-nitrophenyl group. Since dione 15 was in limited supply it was decided to investigate the arylation of 5,5-dimethylcyclohexane-1,3-dione(dimedone), a closely related structure.

Arylations of dimedone described in the literature using aryl iodonium halides and a base/solvent system of sodium t-butoxide/t-butanol have been shown to give poor yields (10%) of 2-(4-nitrophenyl) dimedone 16.[10]



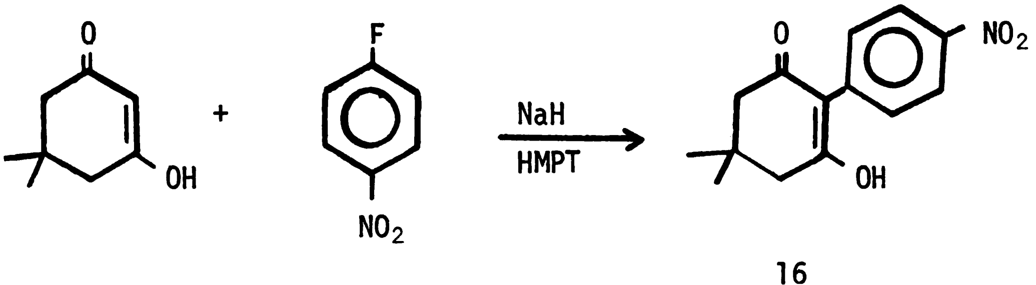
16

However Suggs has shown the attempted arylation of 4,6-diphenylcyclohexane-1,3-dione under the same resulted in recovery of unreacted starting material. The use of a base/solvent system of sodium ethoxide/ethanol or sodium hydride/hexamethylphosphoramide (HMPT) led to similar results.[10]

Some success had been achieved in arylating dimedone with 4-halonitrobenzenes using the sodium hydride/HMPT system.[24] This general reaction has also been described in the literature.[25-28] It was suggested by Suggs[29] that the emphasis on arylations should be done using 4-fluoronitrobenzene in the sodium hydride/HMPT system since the 4-iodo-, bromo-, and chloronitrobenzenes had been shown to give only fair yields of 16 but the reactivity appeared to be Cl>Br>I.

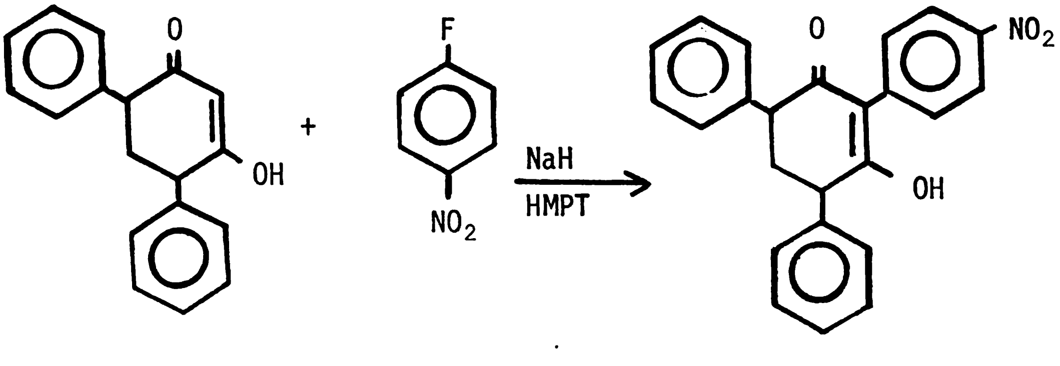
Reaction of dimedone with equivalent amounts of sodium hydride and 4-fluoronitrobenzene afforded a 50% yield of 2-(4-nitrophenyl) dimedone

16 m.p. 236.0-238.0°. Nmr, ir, mass spectra and elemental analysis were consistent with 16.



16

Next 4,6-diphenylcyclohexane-1,3-dione 17 was arylated under similar conditions to determine if the phenyl groups in the 4,6 position had any deleterious effect on the reaction. Equivalent amounts of 17, sodium hydride and 4-fluoronitrobenzene react to form 2-(4-nitrophenyl)-4,6-diphenylcyclohexane-1,3-dione 18 m p 241.0-243.0° in 28% yield.

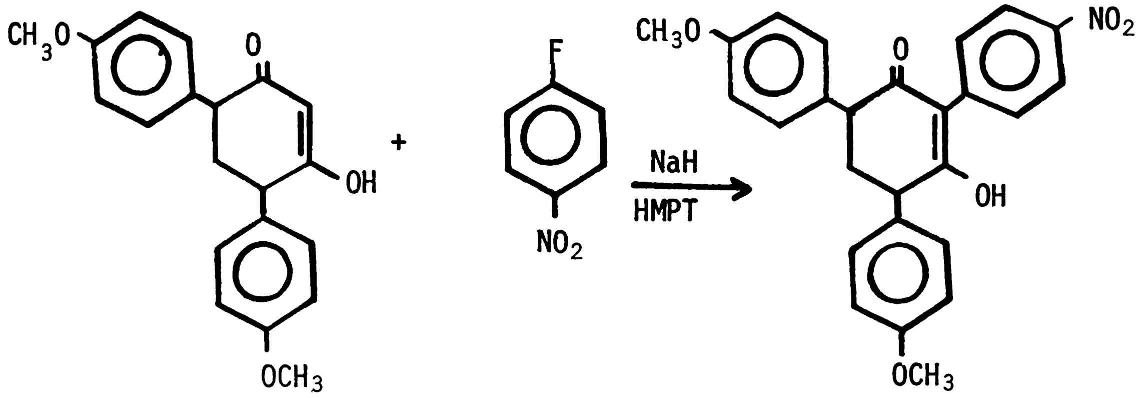


17

18

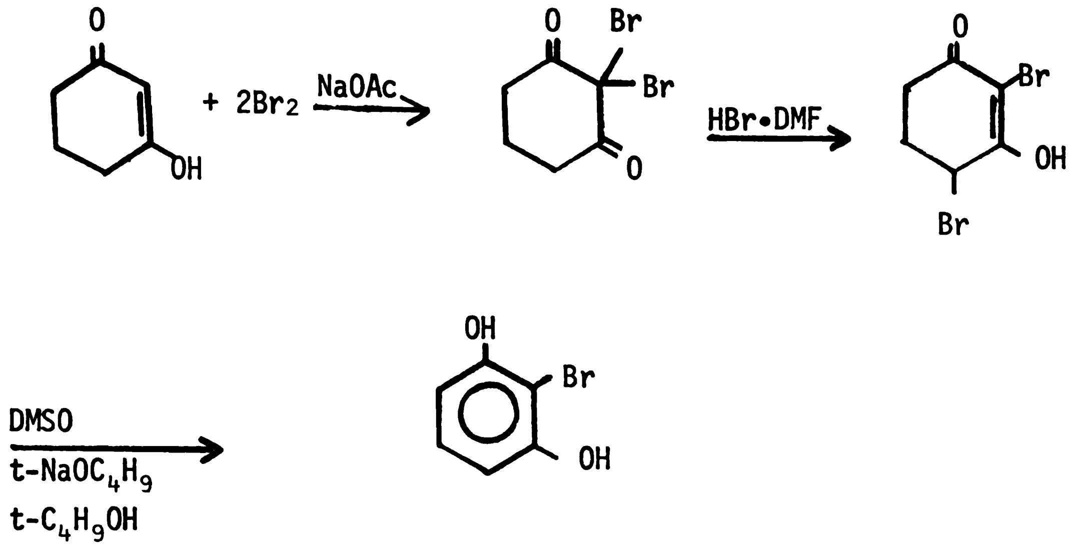
The procedure was somewhat complicated by a HMPT/dione **18** complex that formed during the work up procedure. However the complex was readily destroyed by dissolving it in aqueous sodium bicarbonate and reprecipitating by adding concentrated hydrochloric acid. Ir, nmr, mass spectra and elemental analysis confirmed the structure of dione **18**.

The final arylation, of course, was with 4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione **15**. Equivalent amounts of dione **15**, sodium hydride and 4-fluoronitrobenzene produced 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione **10** m.p. 197.0-198.5° C in 35% yield. Ir, nmr, mass spectra and elemental analysis confirmed the structure of dione **10**.

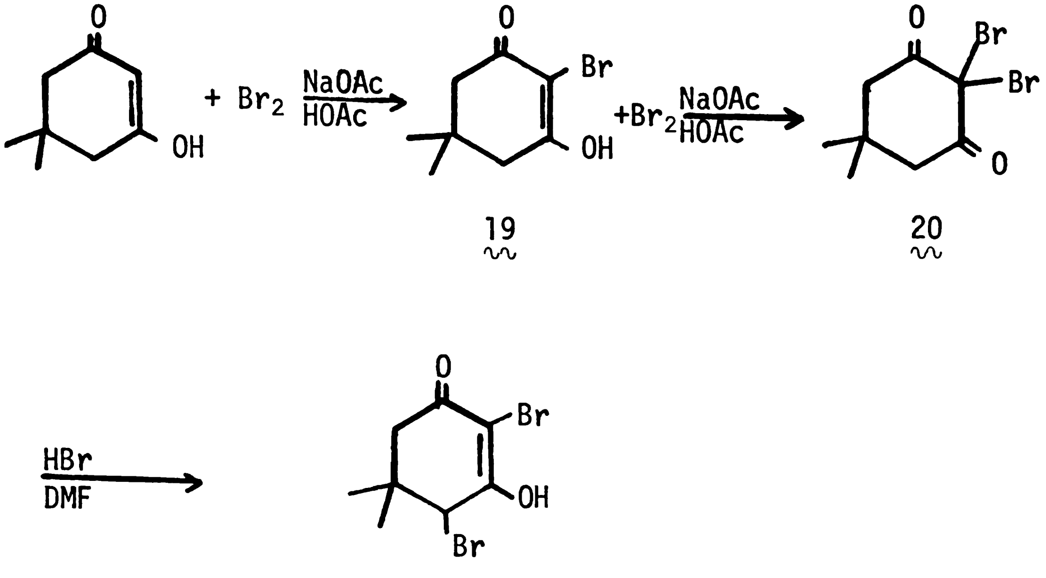


10

Now that dione **10** was prepared, the next step was to aromatize it to the corresponding 1,3-dihydroxybenzene. Various methods are reported in the literature for carrying out this general reaction.[30-34] However, the method chosen to attempt this aromatization was a bromination, rearrangement and dehydrobromination[35-36] procedure originally described by Schamp and De Pooter for the preparation of 2-bromoresorcinol.[37]



In an effort to become familiar with this reaction before attempting it on dione 10 various reactions of dimedone and bromine were carried out in the presence of sodium acetate as a hydrogen bromide acceptor and glacial acetic acid as a solvent. After dibromination the product was rearranged with 20% hydrogen bromide in dimethylformamide (DMF).



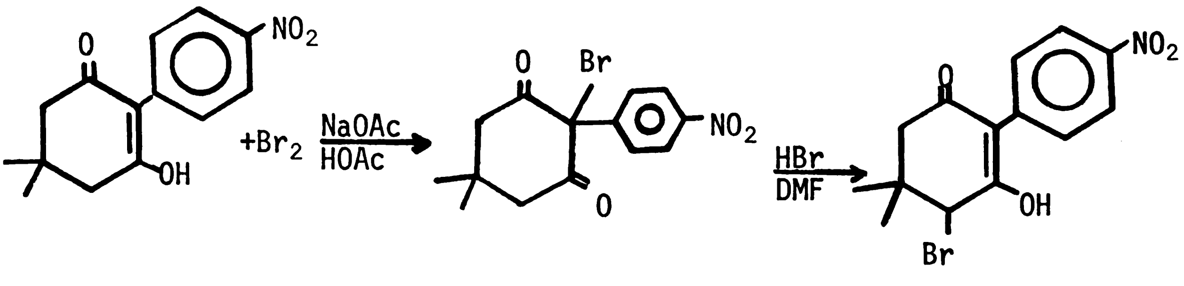
19

20

21

Using the above procedure 2-bromodimedone 19 m p 178.0-180.0^0 was obtained in 66% yield. Dibromination of dimedone led to formation of 2,2-dibromodimedone 20 m p 151.5-153.0^0 in 83% yield. Rearrangement of 20 with 20% hydrogen bromide in DMF resulted in formation of 2,4-dibromodimedone 21 m p 146.5-147.5^0 in 56% yield. Each samples identification was supported by ir, nmr,and elemental analysis.

To insure further that no problems would be encountered in the bromination and rearrangement of dione 10, 2-(4-nitrophenyl)dimedone 16 was brominated with bromine in the presence of sodium acetate and glacial acetic acid. The resulting 2-bromo-2(4-nitrophenyl)cyclohexane-1,3-dione 22 m p 140.0-143.0^0 was obtained in 78% yield. Dione 22 was rearranged with 20% hydrogen bromide in DMF to yield 54% 2-(4-nitrophenyl)-4-bromodimedone 23 m p 205^0 (with decomposition).

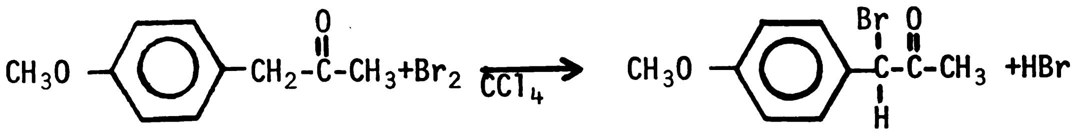


22

23

The structure of 22 and 23 were confirmed by ir, nmr, and elemental analysis.

Since methoxy groups are known activating <u>ortho/para</u> directors in electrophilic aromatic substitution it was of some concern as to whether bromine would attack dione 10 at the <u>ortho</u> position in the 4-methoxyphenyl ring or at the C-2 position in the cyclohexane-1,3-dione. To answer this question two reactions were run. First 4-methoxyphenyl acetone was brominated in carbon tetrachloride with one equivalent of bromine. The only product was 1-bromo-1-(4-methoxyphenyl) acetone 24 obtained in quantitative yield.

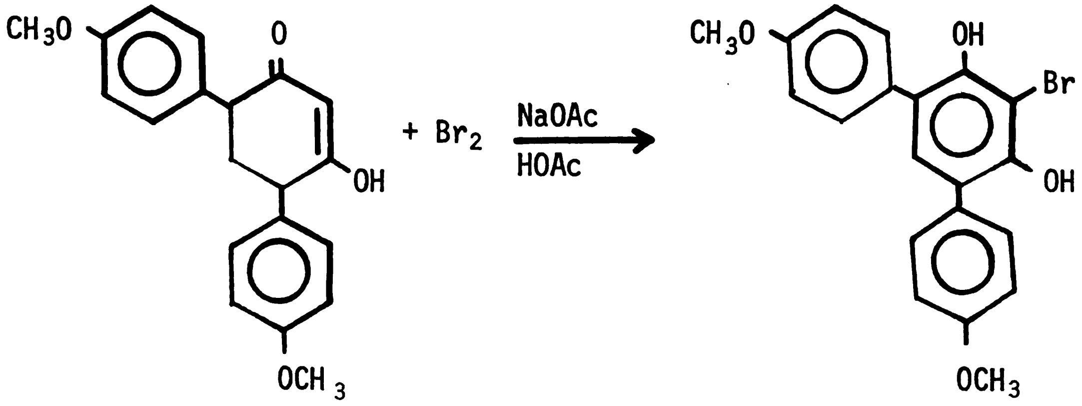


24

Evidence for the formation of 24 was found in the nmr spectra. The aromatic A_2B_2 quartet remained intact thus showing *para* substitution in the product. The methylene protons at 3.50 ppm of the starting material were no longer present in the final product which had a singlet equivalent to one hydrogen at 5.28 ppm corresponding to the H-C-Br methine proton.

The second reaction run to confirm where bromine would attack dione 10 was bromination of 4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione 15 with bromine in the presence of sodium acetate and glacial acetic acid. The results obtained were unexpected. After the bromine was added, copious amounts of hydrogen bromide were evolved. The product had a mass spectra with equal intensity peaks at 402 and 400 (M^+) consistent with the presence of one bromine. The ir showed a broad hydroxy absorbance at 3430 cm^{-1} and no carbonyl absorbance between 1600 to 1800 cm^{-1} indicating an aromatic hydroxy group. The nmr consisted of a singlet for the methoxy at 3.80 ppm (6H), a singlet at 7.13 ppm (1H) and an A_2B_2 quartet at 7.23 ppm

$\Delta\nu$=23, J=8 (8H). These data are consistent with 2-bromo-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 25 mp 153.0-154.0^{o}, which was recovered in 42% yield after recrystallization from methanol.

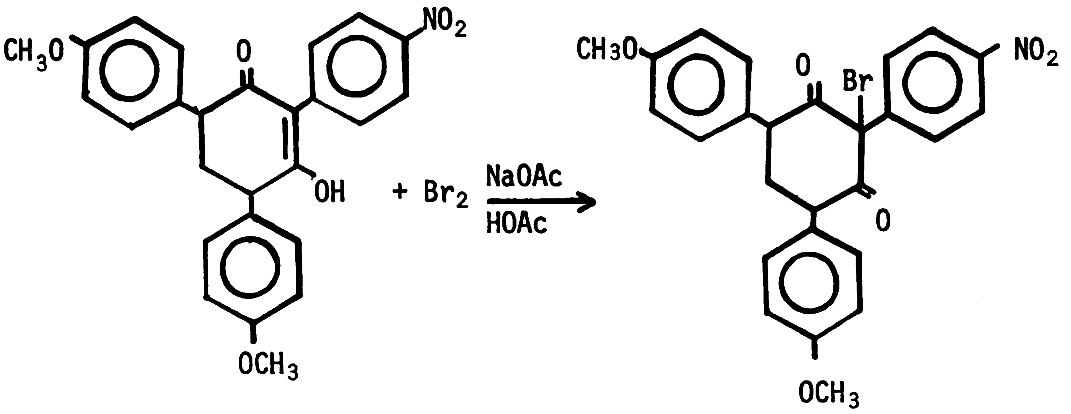


25

Similar results as above were obtained when two equivalents of bromine were used except the yield of 25 was 86.0% and the mass spectra showed the presence of some dibrominated material which apparently lowered the melting point to 149.0-151.0^{o}.

Therefore the above two experiments show that aromatic ring bromination does not occur and that bromination occurs exclusively at the C-2 position of cyclohexane-1,3-diones. It was also found that we might expect spontaneous loss of hydrogen bromide and thus aromatization when dione 10 was brominated.

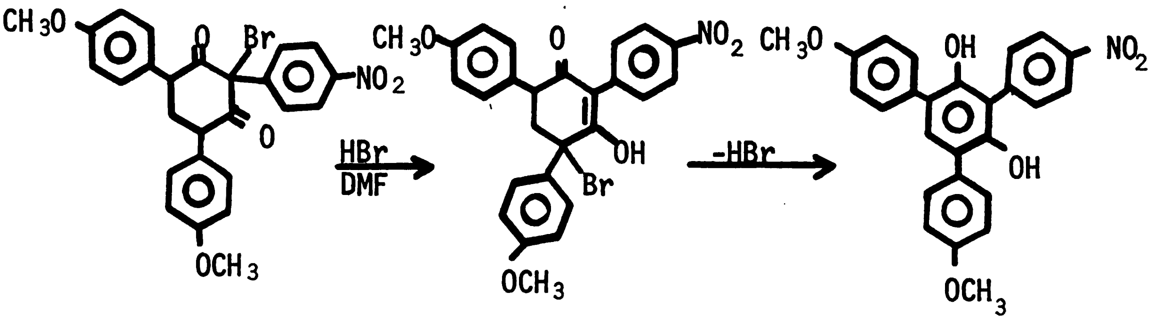
Reaction of 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione 10 with bromine in the presence of sodium acetate and glacial acetic acid gave a 90% yield of 2-bromo-2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione 26 mp 125.5^{o} (with decomposition).



26

The mass spectra of 26 does not exhibit a parent peak but does have a peak at M/e 443 corresponding to the parent peak minus hydrogen bromide. There are also very large peaks at 80 and 82 in a one to one ratio corresponding to hydrogen bromide. The ir shows a broad carbonyl absorption at 1745 to 1715 cm^{-1} which is consistent with an α-bromoketone.[38] The nmr consists of the 2 methylene protons at 2.53-2.82 ppm (m), the 6 methoxy protons at 3.95 ppm (s), the two methine protons at 4.32-4.63 ppm (m), the 8 aromatic protons on the 4-methoxyphenyl group in a A_2B_2 quartet at 7.13 ppm, $\Delta\nu=15$, J=8 and the 4 protons on the 4-nitrophenyl group at 7.48 to 8.47 ppm (m). Elemental analysis is also consistent with 26. 26 slowly decomposes in two to three months.

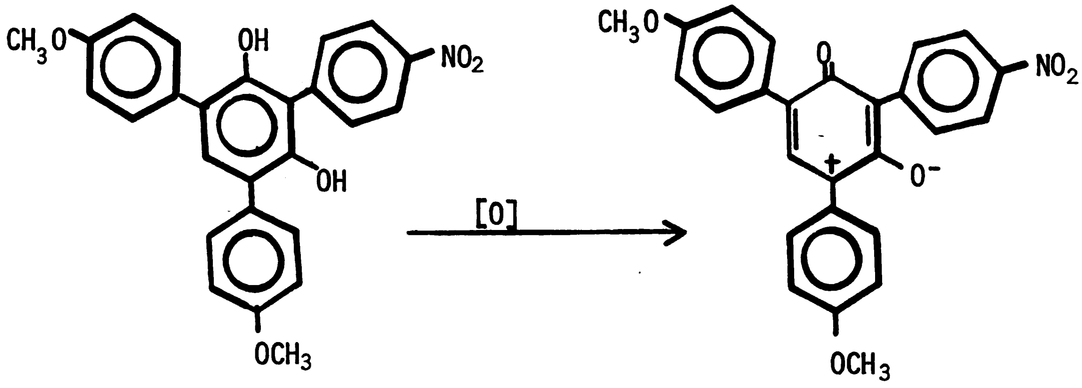
Bromodione 26 was then reacted with 20% hydrogen bromide in DMF in an attempt to rearrange the C-2 bromine to the C-4 position. However instead of isolating the rearranged product 27, 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 11 mp 184.0-185.8° was obtained in 66% yield as a bright yellow solid. Formation of 11 presumably proceeds via spontaneous liberation of hydrogen bromide from 27.



27 11

The mass spectra of 11 consists of the base peak at m/e 443 (M^+) and very little fragmentation indicating a molecule of high stability. The ir shows a sharp hydroxy absorption at 3540 cm^{-1} and no carbonyl absorption between 1600 to 1800 cm^{-1}. The nmr shows the 6 methoxy protons as a singlet at 3.80 ppm, the 2 hydroxy protons as a singlet at 7.12 ppm, the one aromatic proton as a singlet at 7.18 ppm, the 8 protons on the 4-methoxyphenyl rings as a A_2B_2 quartet at 7.23 ppm, $\Delta\nu=22$, $J=9$ and the 4 protons on the 4-nitrophenyl ring as a A_2B_2 quartet at 8.03 ppm, $\Delta\nu=23$, $J=9$. Elemental analysis is also consistent with the 11.

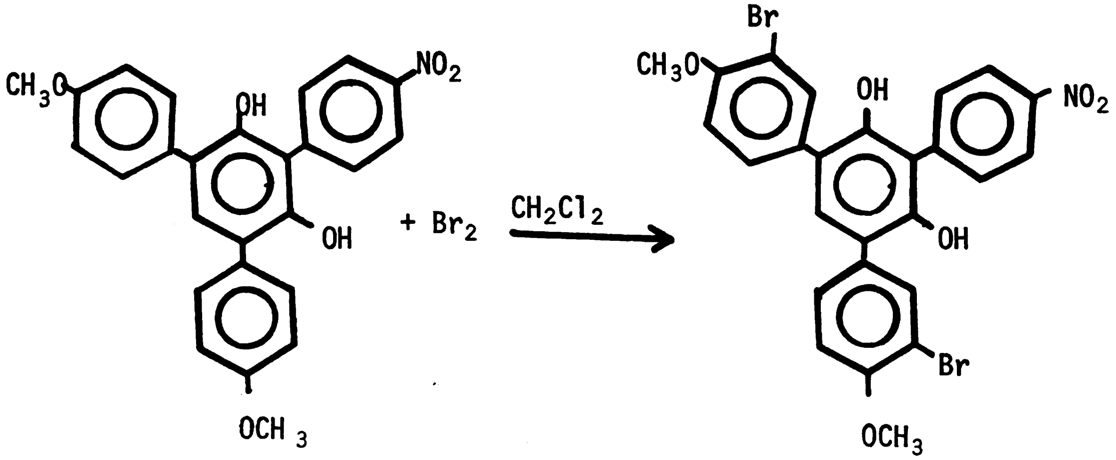
Now that 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 11 was prepared, the final step was oxidation of 11 to the benzene-1,3-quinone 9.



11 9

There are a great variety of oxidizing agents that have been employed in converting dihydroxybenzenes into quinones.[39] This work will deal only with bromine and 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) as oxidizing agents.

Bromine was the first oxidizing agent used in this work since it had been successful in preparing the cyclobutadiene-1,3-quinone 4 as described by Farnum *et. al.*[9] Treatment of dihydroxybenzene 11 with excess bromine in dichloromethane however produced a quantitative yield of 2-(4-nitrophenyl)-4,6-di(3-bromo-4-methoxyphenyl)-1,3-dihydroxybenzene 28.

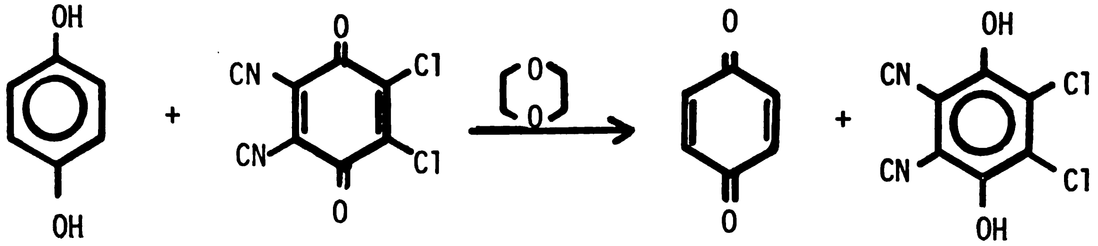


11 **28**

The mass spectra of **28** exhibits peaks at 599, 601 and 603 in a ratio of 1:2:1, the expected pattern for 2 bromine atoms. The mass spectra is very simple indicating a very stable molecule. The ir shows a strong hydroxy absorbance at 3490 cm^{-1} and no carbonyl absorbance between 1600 and 1800 cm^{-1}. The nmr shows the A_2B_2 quartet of the 4 protons on the 4-nitrophenyl ring have not changed significantly from the starting 1,3-dihydroxybenzene **11**. However the A_2B_2 quartet for the protons on the 4-methoxyphenyl rings in **11** is completely destroyed and replaced by a complex multiple. Ortho substitution to the methoxy function is strongly suggested since the methoxy group is an ortho/para director and in this case the para position is already occupied. The upfield shift of the aromatic protons to as low as 6.52 ppm also suggests ortho substitution to the methoxy groups. Elemental analysis is also consistent with **28**.

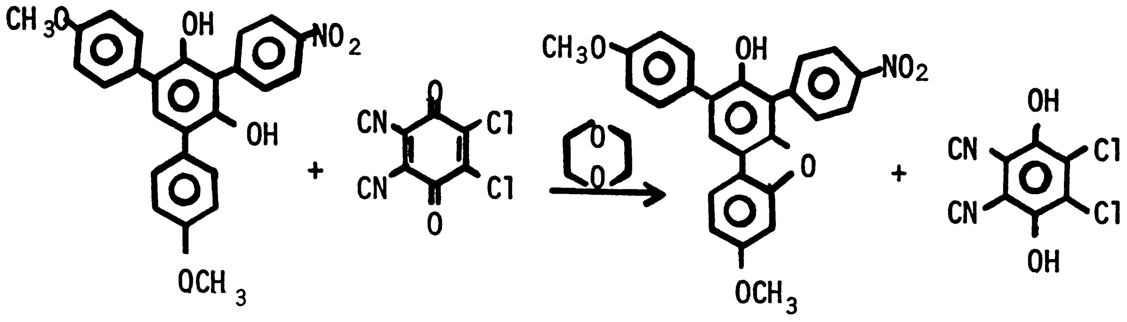
At first it was somewhat surprising the reaction would essentially stop after only two equivalents of bromine reacted with **11** since a ten to one molar ratio of bromine to **11** was used. However this behavior of substituted anisoles has been observed previously and has been attributed to steric inhibition of resonance.[40]

The use of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone, DDQ, as an oxidizing agent was reviewed by Walker and Hiebert in 1967.[41] However, no mention was made in the review on the oxidation of 1,2- or 1,4-dihydroxybenzenes to 1,2- or 1,4-benzoquinones. Therefore to confirm this very plausible oxidation, 1,4-dihydroxybenzene was reacted with one equivalent of DDQ in refluxing dioxane to give a 50% yield of 1,4-benzoquinone.[42] No evidence for the coupling products obtained from monohydroxylic phenols[41]



was found.

2-(4-Nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene $\underset{\sim}{11}$ was reacted with one equivalent of DDQ in refluxing dioxane. White crystals of 2,3-dichloro-5,6-dicyano-1,4-dihydroxybenzene, mp 315° (with decomposition),[43] were recovered in 92% yield by filtering the crude product. Evaporation of the remaining dioxane solution yielded a dark green solid. The mass spectrum showed no peak at 443 corresponding to $\underset{\sim}{11}$ but a strong parent peak at 441 and a small parent peak at 228 which corresponded to 2,3-dichloro-5,6-dicyano-1,4-dihydroxybenzene. Recrystallization of this dark green solid from acetonitrile or glacial acetic acid gave a yellow-green crystalline solid mp 232.0-233.0° in 90 and 61% yield, respectively. This yellow-green solid has been identified as 3-hydroxy-7-methoxy-2-(4-methoxyphenyl)-4-(4-nitrophenyl) dibenzofuran $\underset{\sim}{29}$, not the benzene-1,3-quinone $\underset{\sim}{9}$.



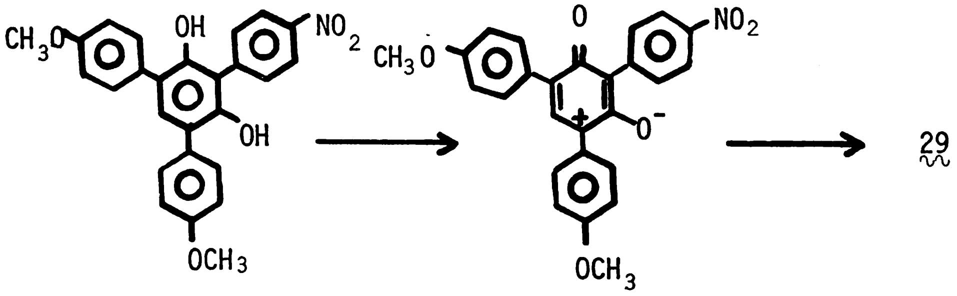
11 29

The mass spectrum consists of a strong parent peak at 441, a base peak at 411 corresponding to either M^+ -2 CH_3 or M^+ - NO, and essentially very little fragmentation. The ir of 29 consists of a sharp phenolic absorbance at 3540 cm^{-1} and no absorbance at 1610 to 1800 cm^{-1}. It was not possible to identify the dibenzofuran ether linkage because of the methoxy C-O and hydroxy C-O absorbances in the 1200 to 1275 cm^{-1} region. The nmr consists of the four protons of the 4-nitrophenyl group as an A_2B_2 quartet at 8.17 ppm $\Delta\nu$=18, J=9, the four protons of the A_2B_2 quartet of the 4-methoxyphenyl group at the C-2 position at 7.30 ppm $\Delta\nu$=22, J=9, the one phenolic proton as a singlet at 7.87 ppm, the one proton at the C-1 position as a doublet at 7.25 ppm, the three protons at the C-6, C-8 and C-9 positions as a multiplet at 6.83 to 8.02 ppm, and the six methoxy protons as a singlet at 3.80 ppm. The phenolic proton was identified by the disappearance of the peak at 7.87 ppm with the addition of D_2O. The identification of the C-1 proton at 7.25 ppm was based on the similar chemical shift (7.18 ppm) of the C-5 proton in 11. Elemental analysis was also consistent with 29.

The above DDQ oxidation run in benzene or in dioxane with 1.5 and 2.0 equivalents of DDQ gave similar results.

The deep green color of the crude product from the oxidation of 1,3-dihydroxybenzene 11 with one equivalent of DDQ made us think that possibly the benzene-1,3-quinone 9 was present in small amounts (<10%). Therefore an attempt was made to reduce the crude mixture back to either 11 or possibly to 2-(4-aminophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 30. This technique had been used to confirm the structure of the cyclobutadiene-1,3-quinone 4.[9] The green product was partially dissolved in trifluoroacetic acid and concentrated hydrochloric acid to give an intense deep green solution. When stannous chloride was added the green color disappeared immediately. However the mass spectra of the products obtained gave a strong m/e at 441 corresponding to dibenzofuran 29 and did not give a m/e at 443 corresponding to 1,3-dihydroxybenzene 11 or at 413 corresponding to the reduced form 30. Therefore we do not have any chemical proof that benzene-1,3-quinone 9 was formed during the reaction of 11 with DDQ.

There is the possibility that dibenzofuran 29 could be formed from 9.



11 9

However, other ionic mechanisms as well as free radical mechanisms can be used to explain the formation of **29**.[41]

Oxidation of 1,3-dihydroxybenzene **11** with other oxidizing agents such as chloranil, 1,4-benzoquinone, mercuric oxide and dinitrogen tetraoxide, as well as electrochemical oxidations, are currently under investigation.

EXPERIMENTAL

General. All melting points were taken on a Thomas-Hoover apparatus and are uncorrected. Infrared spectra were recorded either as neat films or as mulls in Nujol and/or Fluorolube on either a Perkin-Elmer 137 or 457 spectrophotometer. Nuclear magnetic resonance spectra were taken on the Varian T-60 spectrometer. All spectra were taken at ambient temperatures, and are recorded in delta (δ) values relative to tetramethylsilane (TMS, δ=0). Coupling constants (Δν, J) were recorded in Hertz (Hz). An Hitachi RMU-6 spectrometer was used to obtain all mass spectra. Elemental analysis were performed by Chemalytics, Inc., 2330 S. Industrial Park Drive, Tempe, Arizona; and the Analytical Laboratory, The Dow Chemical Company, Midland, Michigan. Bromine analysis were done at the Dow Chemical Company by neutron activation analysis. All reagents and solvents were distilled in glass before use to insure dryness and purity.

Ethyl-4-methoxyphenylacetate **12**. 4-Methoxyphenylacetic acid (100.0 g, .602 m), absolute ethanol (350 ml, 282 g, 6.15 m) and concentrated sulfuric acid (6.6 ml) were refluxed for 5 hours. The excess ethanol was then distilled in 1.5 hr. The residue was poured into 500 ml water. The oil layer was separated and the aqueous portion extracted with 2 x 25 ml portions of carbon tetrachloride. The combined oil and carbon tetrachloride portions were washed with 100 ml of saturated sodium bicarbonate and then with 200 ml of water. The aqueous wash was extracted with 2-25 ml portions of carbon tetrachloride and combined with the original oil and previous carbon tetrachloride extraction. The carbon tetrachloride was distilled at atmospheric pressure and the main product (107.7 g, .555 m, 92.5%) distilled at 102-105^{o} (1.0mm) as a colorless oil. Ir (film) 2980, 1735, 1615, 1515, 1465, 1370, 1300, 1250, 1180, 1155, 1035, 820 cm^{-1}; nmr δ(CCl_4) 6.87 (4 H, A_2B_2 q, Δν=14, J=8), 4.05 (2 H, q, J=6.5), 3.70 (3 H, s), 3.42 (2 H,d), 1.20

(3H, t, J=7).

Anal. Calcd. for $C_{11}H_{14}O_3$: C, 68.0, H, 7.22. Found: C, 68.2: H, 7.38.

Oxaltoester of ethyl-4-methoxyphenylacetate 13. Sodium ethoxide was prepared by dissolving sodium (11.5 g, .500 m) in absolute ethanol (250 ml) at reflux. Diethyl oxalate (73.0 g, .500 m) was added in 1 min at 55°. Ethyl-4-methoxyphenylacetate (97.0 g, .500 m) was added in 3 min and the mixture stirred at 55-60° for 6 min at which time a precipitate formed and the reaction mixture was cooled in 1 hr. The light yellow solid was slurried with 400 ml ethyl ether and filtered. The filter cake was washed with 2-200 ml of ethyl ether and air dried. The sodium salt (165.4 g) was dissolved in 400 ml water, filtered and precipitated with 200 ml of dilute sulfuric acid (29 ml concentrated sulfuric acid in 500 ml water). The yellow oil was separated and the aqueous portion extracted with 3-50 ml portions of ethyl ether. The oil and ethyl ether extracts were dried ($MgSO_4$), filtered and the ethyl ether removed on a roto-vap. The product thus obtained (104.7 g, .356 m, 71.2%) was a light yellow oil that slowly solidified mp 50.0-53.0°. Ir (film) 2990, 1755, 1730, 1615, 1515, 1470, 1445, 1370, 1305, 1250, 1180, 1060, 1030, 835 cm^{-1}; nmr $\delta(CCl_4)$ 6.95 (4 H, m), 5.13 (1 H, s), 4.17 (4 H, m), 3.73 (3 H, s), 1.15 (6 H, m).

Anal. Calcd for $C_{15}H_{18}O_6$: C, 61.2; H, 6.12. Found: C, 61.2; H, 6.22.

Ethyl-2-(4-methoxyphenyl)propenoate 14. The oxaltoester (121.0 g, .412 m) was added to solution of 37.3% aqueous formaldehyde (131.5 g, 1.63 m). To this solution at 15° was added potassium carbonate (56.7 g, .411 m) in 100 ml water in 10 min. This solution was stirred vigorously for

3.75 hr at 20°. The two phase system was extracted with 2 x 100 ml of ethyl ether. The ethyl ether solution was dried (Na_2SO_4), filtered and the ethyl ether removed on a roto-vap to yield 85.5 g of crude product. Distillation at 119-124° (1.5 mm) in the presence of a trace of *para*-hydroquinone yielded a colorless oil (63.9 g, .310 m, 75.3%). Ir (film) 3030, 1730, 1626, 1621, 1515, 1290, 1256, 1190, 1093, 1036, 840 cm^{-1}; nmr δ(CCl_4) 7.12 (4 H, A_2B_2 q, $\Delta\nu$=23, J=9), 6.15 (1 H, d, J=2), 5.72 (1 H, d, J=2), 4.20 (2 H, q, J=7), 3.72 (3 H, s), 1.27 (3 H, t, J=7). (Elemental analysis was not performed on the sample because it had polymerized.)

4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione **15**. Sodium ethoxide was prepared by dissolving sodium (2.3 g, .10 m) in ethanol (50 ml) at reflux under nitrogen. A solution of ethyl-2-(4-methoxyphenyl)propenoate (20.6 g, .10 m) and 4-methoxyphenylacetone (15.0 g, .089 m) was added rapidly to the sodium ethoxide at 62-70°. After 2 min the solution began to gel at which time it was cooled over 1 hr to 25°. The gel was sluried with 80 ml ethyl ether and filtered. The filter cake was washed with an addition 100 ml of ethyl ether leaving 33.7 g of the sodium salt. The salt was dissolved in 100 ml of water and filtered. The aqueous layer was acidified to pH of 3 with dilute sulfuric acid and allowed to digest for 30 min. The white crystalline material was filtered, washed with 50 ml water and dried in a dry pistol. The resulting product (22.2 g, .069 m, 77.0%) was a white crystalline solid mp 93-100°. Ir (Fluorolube, Nujol) 3000, 2930, 2840, 1755, 1720, 1510, 1440, 1300, 1250, 1210, 1175, 1030, 830, 720 cm^{-1}; nmr δ(acetone-d_6) 7.02 (8 H, q, J=8), 5.63 (1 H, s), 3.83 (2 H, t, J=8), 3.77 (6 H, s), 2.43 (2 H, m).

Anal. Calcd. for $C_{20}H_{20}O_4$: C, 74.1; H, 6.17. Found: C, 73.9; H, 6.29.

2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione 16. A 57% oil dispersion of sodium hydride (1.0130 g, .0241 m) was slurried with hexamethylphosphoramide, HMPT, (40 ml) at 15° under nitrogen. A solution of 5,5-dimethylcyclohexane-1,3-dione, dimedone, (2.8008 g, .0200 m) in HMPT (20 ml) was added in 15 min while maintaining the temperature at 15°. There was considerable gas evolution (H_2) during the addition. The contents were stirred for an additional 30 min and then a solution of 4-fluoronitrobenzene (2.8317 g, .0200 m) in HMPT (15 ml) was added rapidly. The reaction mixture was heated to 80° for 9 hr. The red purple solution was cooled to room temperature and hydrolyzed with ice water (450 ml). The pH was adjusted from 7 to 1 with concentrated hydrochloric acid during which time a light yellow precipitate formed. The mixture was cooled to 0° for 1 hr and filtered. The filter cake was washed with water and dried at 60° in a vacuum pistol. Crude yellow product (3.6592 g, .0140 m, 70.0%) mp 225-233 was obtained. This yellow powder recrystallized from methanol-benzene (5 ml, 50/50 v) to yield a light yellow powder (2.5887 g, .0099 m, 49.5%) mp 236.0-238.0°. Ir (Fluorolube, Nujol) 2970, 2870, 1600, 1565, 1510, 1410, 1365, 1340, 1285, 1260, 1145, 1030, 850, 760, 730, 700 cm^{-1}; nmr δ(DMSO-d_6, CCl_4) 7.75 (4 H, A_2B_2 q, $\Delta\nu=40$, J=8), 2.36 (4 H, s), 1.13 (6H, s); m/e 261 (M^+), 246, 231, 205, 188, 168, 149, 131, 111, 103, 83, 77, 71, 69, 67, 57, 53, 43.

Anal. Calcd. for $C_{14}H_{15}NO_2$: C, 64.4; H, 5.75; N, 5.36. Found: C, 64.6; H, 6.09; N, 5.68.

2-(4-nitrophenyl)-4,6-diphenylcyclohexane-1,3-dione 18. A 57% oil dispersion of sodium hydride (.5060g, .0120 m) was slurried with HMPT (20 ml) under nitrogen. A solution of 4,6-diphenylcyclohexane-1,3-dione (2.6422 g, .0100 m) in HMPT (10 ml) was added in 25 min at 15° and stirred for 15 min until gas evolution ceased. A solution of 4-fluoronitrobenzene (1.4150 g, .0100 m) in HMPT (5 ml) was added rapidly and the solution was heated to 80° for 14 hrs. After cooling the deep purple-red solution was hydrolyzed in ice water (400 ml). The pH was adjusted from 7 to 1 with concentrated hydrochloric acid and cooled to 0° overnight. The tacky solid was filtered and heated on a steam bath with a saturated solution of sodium bicarbonate (150 ml). After cooling the basic solution was filtered and acidified to pH 1 with concentrated hydrochloric acid. The crude product (2.6630 g, mp 192-207°) was recrystallized from methanol-benzene (15 ml, 50/50 v) to yield a cream colored solid (1.0930 g, .0028 m, 28.4%) mp 241.0-243.0°. Ir (Fluorolube, Nujol) 3030, 2940, 1640, 1615, 1595, 1510, 1490, 1450, 1410, 1340, 1260, 970, 855, 740, 700 cm^{-1}; nmr δ(acetone-d_6/DMSO-d_6) 7.73 (4 H, A_2B_2 q, Δν=29, J=9), 7.32 (10 H, s), 4.06 (2 H, m, J=7), 2.50(2 H, d, J=9); m/e 385 (M^+), 355, 281, 251, 235, 178, 115, 103, 91, 77, 69.

Anal. Calcd for $C_{24}H_{19}NO_4$: C, 74.8; H, 4.94; N, 3.63. Found: C, 74.5; H, 4.98; N, 3.78.

2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione **10**. A 57% oil dispersion of sodium hydride (2.64 g, .063 m) was slurried with HMPT (150 ml) under nitrogen. A solution of 4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione (20.00 g, .062 m) in HMPT (125 ml) was added at 15° in 1 hr with considerable gas evolution. A solution of 4-fluorobenzene (8.70 g, .062 m) in HMPT (20 ml) was added dropwise in 15 min and the solution was heated to 80° for 13.5 hr. The deep purple solution was poured into ice water (1500 ml) and acidified to pH 2 with concentrated hydrochloric acid. The light yellow sticky solid was filtered and heated to 80° with a saturated solution of sodium bicarbonated (750 ml). After cooling and filtering, the aqueous bicarbonate was acidified with concentrated hydrochloric acid. After filtering and air drying, the crude product (22.18 g) was recrystallized from benzene (100 ml) and dried in a drying pistol at 72^{o} for 22 hrs to give a yellow solid (9.63 g, .0216 m, 34.9%) mp 197.0-198.5^{o}. Ir (Fluorolube, Nujol) 3030, 2940, 1640, 1610, 1510, 1445, 1370, 1345, 1245, 1180, 1110, 1030, 970, 830, 820, 720, 680 cm^{-1}; nmr δ(DMSO-d_6) 7.75 (4 H, A_2B_2 q, $\Delta\nu$=33, J=8), 6.97 (8 H, A_2B_2 q,$\Delta\nu$=11, J=9), 4.02 (2 H, t, J=8), 3.68 (6 H, s), 2.46 (2 H, m); m/e 445 (M^+), 415, 385, 324, 311, 296, 281, 266, 253, 223, 211, 190, 175, 161, 148, 134, 121, 104, 82.

Anal. Calcd for $C_{26}H_{23}NO_6$: C, 70.1; H, 5.16; N, 3.15. Found: C, 70.0; H, 5.28; N, 2.86.

2-Bromo-5,5-dimethylcyclohexane-1,3-dione **19**. 5,5-Dimethylcyclohexane-1,3-dione (1.40 g, .010 m) was dissolved in glacial acetic acid (20 ml). Sodium acetate (.82g, .010 m) was slurried in this solution and then bromine (1.60 g, .010 m) in acetic acid (10 ml) was added in 30 min at 25-30^{o}. The bromine color disappeared immediately when added. After all the bromine was added the solution was stirred for 40 min at 25-30^{o} and a white precipitate (NaBr) formed. The light yellow slurry was heated on a steam bath and filtered hot. The acetic acid was evaporated on a roto-vap and the resulting white crystals were recrystallized from methanol (13 ml) and water (13 ml) to yield white crystals (1.44 g, .00657 m, 65.7%) mp 178.0-180^{o}. Ir (Fluorolube) 2980, 1585, 1380 cm^{-1}; nmr δ(acetone-d_6) 2.52 (4 H, s), 1.12 (6 H, s).

Anal. Calcd. for $C_8H_{11}BrO_2$: C, 43.8; H, 5.02; Br, 36.5. Found: C, 43.6; H, 5.10; Br, 36.7.

2,2-Dibromo-5,5-dimethylcyclohexane-1,3-dione **20**. 5,5-dimethylcyclohexane-

1,3-dione (1.40 g, .010 m) was dissolved in glacial acetic acid (25 ml) and sodium acetate (1.60 g, .020 m) was added. Bromine (3.20 g, .020 m) in acetic acid (10 ml) was added in 25 min at 25-30^{0}. The bromine color disappeared as soon as the bromine solution was added. After stirring for 45 min the slurry was evaporated to dryness on the roto-vap. The white product was completely dissolved in methanol (40 ml) and precipitated by addition water (18 ml) and cooling to 0^{0}. White crystals (2.48 g, .00832 m, 83.2%) were obtained after drying, mp 151.5-153.0^{0}. Ir (Fluorolube) 2990, 1730, 1590; nmr δ(acetone-d_6) 3.12 (4 H, s), 1.03 (6 H, s).

Anal. Calcd for $C_8H_{10}Br_2O_2$: C, 32.2; H, 3.36; Br, 53.7. Found: C, 32.2; H, 3.46; Br, 53.7.

2,4-Dibromo-5,5-dimethylcyclohexane-1,3-dione 21. 2,2-Dibromo-5,5-dimethylcyclohexane-1,3-dione (.90 g, .0030 m) was heated for 45 min at 80^{0} with a 20% solution of hydrogen bromide in dimethyl formamide (1.25 ml, .0031 m). The solution color changed during the course of the reaction from red-orange to yellow. The acid solution was cooled and the pH adjusted from 1 to 9 with a saturated solution of sodium carbonate. This alkaline solution was extracted with ethyl ether (2 x 2 ml). The alkaline solution was acidified with concentrated hydrochloric acid and extracted with ethyl ether (2 x 10 ml). The ether was dried ($MgSO_4$), filtered and evaporated on a roto-vap. The resulting oil was dissolved in acetic acid (3 ml) and precipitated with water (2 ml). After drying a white crystalline solid (.50 g, .0017 m, 56%) was obtained, mp 142.0-142.5^{0}. Two additional recrystallizations from methanol raised the mp to 146.5-147.5^{0}. Ir (Fluorolube) 2985, 1660, 1585, 1370 cm^{-1}; nmr δ(acetone-d_6) 4.60 (1 H, m), 2.63 (2 H, m), 1.25 (6 H, s).

Anal. Calcd. for $C_8H_{10}Br_2O_2$: C, 32.2; H, 3.36; Br, 53.7. Found: C, 32.4; H, 3.52; Br, 53.6.

2-Bromo-2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione **22**. 2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione (1.30 g, .00498 m) was slurried in glacial acetic acid (10 ml). Sodium acetate (0.41 g, .0050 m) was added. Bromine (.80 g, .0050 m) in acetic acid (5 ml) was added in 7 min at 26° during which the bromine color disappeared as soon as it was added. After stirring for 8 min at 25° the acetic acid was evaporated on the roto-vap. The residue was dissolved in hot methanol (20 ml) and precipitated by adding water (5 ml) and cooling to 0° C. After filtering and drying overnight in a drying pistol light yellow crystals (1.32 g, .00388 m, 77.6%) were obtained, mp 140.0-143.0°. Ir (Fluorolube) 2975, 1755, 1725, 1620, 1600, 1530, 1380, 1355; nmr δ(acetone-d_6) 7.87 (4 H, A_2B_2 q, $\Delta\nu$=34, J=9), 3.03 (4 H, q, J=14), 1.10 (6 H, s).

Anal. Calcd for $C_{14}H_{14}BrNO_4$: C, 49.4; H, 4.12; Br 23.5; N, 4.12. Found: C, 49.5; H, 4.23; N, 4.25 (Insufficient sample for Br analysis).

4-Bromo-2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione **23**. 2-Bromo-2-(4-nitrophenyl)-5,5-dimethylcyclohexane-1,3-dione (1.00 g, .00294 m) was heated for 13 hr with a 20% solution of hydrogen bromide in dimethyl formamide (1.20 ml, .00296 m). The reaction solution turned from a deep red color at the beginning of the reaction to a light yellow color at the end. The reaction product was dissolved in diethyl ether (5 ml) and a saturated solution of sodium carbonate was added until the pH was 9. This alkaline solution was extracted with ether (2 x 10 ml), then acidified to pH 1 with concentrated hydrochloric acid and extracted with ether (3 x 10 ml). The final ether extract was dried ($MgSO_4$), filtered and the ether removed on a roto-vap. The crude product was recrystallized from methanol (5 ml) and water (2 ml) to yield a light yellow crystalline solid (.539 g, .00158 m, 53.9%), mp 205^{o} (with decomposition). Ir (Fluorolube) 2950, 1610, 1575, 1520, 1490, 1410, 1380, 1365, 1340 cm^{-1}; nmr δ(DMSO-d_6) 7.92 (4 H, A_2B_2 q, $\Delta\nu$=35, J=8), 4.63 (1 H, s), 2.53 (2 H, m (overlap with DMSO-d_5)), 1.28 (3 H, s), 1.22 (3 H, s).

Anal. Calcd for $C_{14}H_{14}BrNO_4$: C, 49.4; H, 4.12; Br, 23.5; N, 4.12. Found: C, 50.9; H, 4.46; Br, 21.5; N, 4.54.

Bromination of 4-methoxyphenylacetone 24. 4-Methoxyphenylacetone (.17 g, .001 m) was dissolved in carbon tetrachloride (10 ml) and .1M bromine (10 ml, .001 m) in carbon tetrachloride was added in 5 min. The reaction initiated after approximately 5 ml of the .1M bromine solution was added as evidenced by the disappearance of the bromine color and the evolution of hydrogen bromide. After all the bromine solution was added the clear solution was heated on a steam bath for 2 min. Approximately half of the carbon tetrachloride was evaporated off on the roto-vap. The only product as observed in the nmr had the following spectra: nmr δ(CCl_4) 7.10 (4 H, A_2B_2 q, $\Delta\nu$=22, J=8), 5.28 (1 H, s), 3.83 (3 H, s), 2.27 (3 H, s).

2-Bromo-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 25. 4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione (3.24 g, .010 m) and sodium acetate (.82 g, .010 m) were dissolved in glacial acetic acid (25 ml). Bromine (1.60 g, .010 m) in glacial acetic acid (10 ml) was added at 25-30^{o} in 12 min and the solution was allowed to stir for 45 min. A strong odor of hydrogen bromide was noted during this time. The solution was filtered and the glacial acetic acid was removed on the roto-vap at reduced pressure. The remaining solid was recrystallized from methanol (70 ml) to yield a white solid (1.6745 g, .0042 m, 41.8%) mp 153.0-154.0^{o}. Ir (Fluorolube, Nujol) 3430 (broad), 1600, 1580, 1515, 1475, 1445, 1430, 1400, 1325, 1290, 1240, 1180, 1140, 1110, 1030, 845, 830, 805, 725, 680, 655, 620 cm^{-1} ; nmr δ(acetone-d_6) 7.23 (8H, A_2B_2 q, $\Delta\nu$=23, J=8), 7.13 (1 H, s), 3.80 (6 H, s); m/e 400 (M^+), 385, 322, 307, 278, 235, 204, 189, 178, 165, 161, 152, 89, 77, 76.

Anal. Calcd for $C_{20}H_{17}BrO_4$: C, 59.8; H, 4.24; Br, 19.9. Found: C, 60.2; H, 4.53; Br, 19.1.

2-Bromo-2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl) cyclohexane-1,3-dione 26. 2-(4-Nitrophenyl)-4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione (.8900, .00200 m) and sodium acetate (.1657 g, .00200 m) were mixed with glacial acetic acid (40 ml). .1M Bromine solution (20 ml, .00200 m) was added at 25° in 15 min and the stirred at 25° for 1 hr. The acetic acid was evaporated on a roto-vap. The residue was dissolved in boiling methanol (50 ml) and precipitated by adding water (40 ml) and cooling to 0° overnight. The light yellow crystals were filtered, washed with water and dried in a vacuum pistol for 2 hr. Light yellow crystals (.9435 g, .00180 m, 90.0%) were obtained, mp 125.5° (with decomposition). Ir (Fluorolube, Nujol) 2940, 1745, 1715, 1650, 1515, 1450, 1350, 1255, 1180, 1030, 850, 830, 825, 795, 720, 695 cm^{-1} ; nmr δ(acetone-d_6, DMSO-d_6) 8.47-7.48 (4 H, m), 7.13 (8 H, A_2B_2 q, $\Delta\nu$=15, J=8), 4.63-4.32 (2 H, m), 3.95 (6 H, s), 2.82-2.53 (2 H, m) ; m/e 443 (M^+-HBr), 413, 400, 385, 322, 307, 293, 179, 151, 135, 121, 104, 94, 80, 57, 55, 50, 40, 36.

Anal. Calcd for $C_{26}H_{22}NO_6Br$: C, 59.5; H, 4.24; Br, 15.2; N, 2.67. Found: C, 59.6; H, 4.28; Br, 14.5 ; N, 3.14.

2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene 11. 2-Bromo-2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)cyclohexane-1,3-dione (1.0510 g, .00200 m) was heated in an oil bath at 75° for 2 hrs with a 20% solution of hydrogen bromide in dimethylformamide (1.0 ml, .0025 m). Very little color change occured during the reaction period. The contents of the reactor were cooled and neutralized with an ice cold solution of sodium bicarbonate. The resulting sticky solid was extracted with diethyl ether (2 x 10 ml) dried ($MgSO_4$), filtered and the ethyl ether removed on a roto-vap. The residue was dissolved in methanol (50 ml) and precipitated by adding water (20 ml) and cooling to 0° C. The deep yellow crystals were filtered, washed with water and dried in a drying pistol under vacuum. (.5860 g, .00132 m, 66.1%) mp 184.0-185.8°. Ir (Fluorolube, Nujol) 3540, 2950, 1600, 1515, 1520, 1465, 1435, 1390, 1340, 1250, 1240, 1180, 1145, 1030, 1020, 860, 835, 810, 765, 735, 720 cm^{-1}; nmr δ(acetone-d_6) 8.03 (4 H, A_2B_2 q,$\Delta\nu$=23, J=9), 7.23 (8 H, A_2B_2 q, $\Delta\nu$=22, J=9), 7.18 (1 H, s), 7.12 (2 H, s), 3.80 (6 H, s); m/e 443 (M^+), 428, 413, 397, 149, 104, 76, 57, 50.

Anal. Calcd for $C_{26}H_{21}NO_6$: C, 70.4; H, 4.78; N, 3.16. Found: C, 70.4; H, 4.83; N, 3.67.

2-(4-nitrophenyl)-4,6-di(3-bromo-4-methoxyphenyl)-1,3-dihydroxybenzene **28**. 2-(4-nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene (.11 g, .25 mm) was mixed with .1M bromine solution (25 ml, 2.5 mm) in dichloromethane for 15 hr at 25°. During this time hydrogen bromide was liberated. The solution was heated to reflux for 1.5 hr and then the dichloromethane was removed on a roto-vap. The crude product was recrystallized from acetone (20 ml) and water (10 ml) to yield a light yellow-green crystalline solid (.15 g, .25 mm, 100%) mp 226.0-228.0°. Ir (Fluorolube, Nujol) 3490, 1600, 1510, 1505, 1345, 1315, 1290, 1255, 1055, 1020, 890, 845, 815, 740, 725, 700; nmr 7.97 (4 H, A_2B_2 q, $\Delta\nu$=21, J=9), 7.75 to 6.52 (9 H, m), 3.87 (6 H, s); m/e 599 (M^+) (2Br), 584 (2 Br) 571 (2 Br), 554 (2 Br) 521 (1 Br), 491, 355, 281, 221, 207, 161, 147, 111, 105, 104, 97, 76, 71, 57, 55.

Anal. Calcd for $C_{26}H_{19}Br_2NO_6$: C, 51.9; H, 3.16; Br, 26.6; N, 2.33. Found: C, 51.7; H, 3.52; Br, 25.3; N, 2.92.

Oxidation of 1,4-dihydroxybenzene with DDQ.- 1,4-dihydroxybenzene (1.10 g, .010 m) and 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (2.27 g, .010 m) were dissolved in dioxane (25 ml). The solution immediately turned a deep green color. After refluxing for 5 hr the solution was cooled and filtered to yield white crystals (2.95 g). The remaining dioxane was evaporated on the roto-vap and the solid was sublimed in a vacuum oven at 80^o and 1-2 mm. Light yellow crystals (.55 g, .005 m, 50%) were obtained mp 113.0-114.5^o. Ir (Nujol) 1765, 1680, 1650 (broad), 1590, 1365, 1310, 1085, 1075, 940, 895; nmr δ (CCl_4) 6.78 (s).

3-Hydroxy-7-methoxy-2-(4-methoxyphenyl)-4-(4-nitrophenyl)dibenzofuran 29.- 2-(4-Nitrophenyl)-4,6-di(4-methoxyphenyl)-1,3-dihydroxybenzene (.4301 g, .971 mm) and 2,3-dichloro-5,6-dicyano-1,4-benzoquinone, DDQ, (.2293 g, 1.01 mm) were dissolved in dioxane (10.0 ml) and heated to reflux for 25 hrs. At the end of this time there was a shiny precipitate present. The product was cooled to room temperature and allowed to crystallize for 2 days. The crystals were filtered, washed with dioxane (3-5 ml) and dried for 36 hrs at 75^o at 1mm to yield white crystals (.2127 g, .933 mm, 92.4%) mp 315^o (with decomposition). Ir (Nujol, Fluorolube) 3210 (broad), 2260, 1575, 1310, 1280, 1190, 1075, 890, 780, 750 cm^{-1}; nmr δ (DMSO-d_6) 10.17 (s); m/e 228 (M^+, 2 Cl), 200 (2 Cl), 137, 110, 101, 87, 78, 77, 38, 36.

The remaining dioxane solution was evaporated on the roto-vap to yield a deep green solid (.4393 g) mp 225-227^o.

The deep green solid (.100 g) was recrystallized from hot glacial acetic acid (100 ml) by allowing the solution to slowly evaporate to a final volume of 50 ml. After drying at 80^o for 8 hr at 1-2 mm a yellow-green solid (.0612 g, 61.2%) was obtained mp 232.0-233.0^o.

The deep green solid (.050 g) was recrystallized from hot acetonitrile (15 ml) by allowing the solution to cool overnight. After drying at 85^o for 8 hr at 1-2 mm a yellow green solid (.0450 g, 90.0%) was obtained mp 232.5-233.0^o.

The spectra of the two products isolated above were identical. Ir (Nujol, Fluorolube) 3540, 1610, 1510, 1440, 1395, 1350, 1330, 1270, 1260, 1190, 1180, 1150, 1105, 1030, 1010, 945, 860, 835, 800, 750, 695 cm^{-1}; nmr δ (DMSO-d_6) 8.17 (4 H, A_2B_2 q, $\Delta\nu$=18, J=9), 7.87 (1 H, s), 7.30 (4 H, A_2B_2 q, $\Delta\nu$=22, J=9), 7.25 (1 H, d), 8.02-6.83 (3 H, m), 3.80 (6 H, s); m/e 441 (M$^+$), 426, 411, 396, 378, 126, 113, 77, 57, 56, 55.

Anal. Calcd for $C_{26}H_{19}NO_6$: C, 70.7; H, 4.31; N, 3.17. Found: C, 70.4; H, 4.39; N, 3.40.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. E. J. Smutny and J. D. Roberts, *J. Amer. Chem. Soc.*, **77**, 3420 (1955).
2. S. Cohen, J. Lacher, and J. Park, *J. Amer. Chem. Soc.*, **81**, 3480 (1959).
3. A. Treibs and K. Jacob, *Angew. Chem., Internat. Ed.*, **4**, 694 (1965).
4. H. Sprenger and W. Ziegenbein, *Angew. Chem., Internat. Ed.*, **6**, 553 (1967).
5. W. Ziegenbein and H. Sprenger, *Angew. Chem., Internat. Ed.*, **5**, 893 (1966).
6. H. Sprenger and W. Ziegenbein, *Angew. Chem., Internat. Ed.*, **5**, 894 (1966).
7. A. Treibs and K. Jacob, *Liebigs Ann. Chem.*, **699**, 153 (1966).
8. A. D. Wolf, M. S. Thesis, Michigan State University, East Lansing, Michigan, 1968.
9. D. G. Farnum, B. Webster and A. D. Wolf, *Tetrahedron Lett.*, **48**, 5003 (1968).
10. W. T. Suggs, Ph.D. Thesis, Michigan State University, East Lansing, Michigan, 1973.
11. J. Stenhouse, *Chem. Ber.*, **13**, 1305 (1880).
12. T. Davis and J. Hill, *J. Amer. Chem. Soc.*, **51**, 493 (1929); T. Davis and V. Harrington, *J. Amer. Chem. Soc.*, **56**, 129 (1934).
13. H. Musso, D. Massen, and D. Bohrmann, *Chem. Ber.*, **95**, 2837 (1962).
14. N. J. McCarthy, Ph.D. Thesis, Cornell University, Ithaca, N.Y., 1968.
15. H. Güsten, G. Kirsche, and D. Schulte-Frohlinde, *Tetrahedron*, **24**, 4393 (1968).
16. H. Budzikiewicz and W. Meslesics, *J. Org. Chem.*, **24**, 1125 (1959).
17. P. Charbrier, J. Seyden-Penne, and A. M. Fouace, *Compt. Rend.*, **245**, 174 (1957).
18. G. R. Ames and W. Davey, *J. Chem. Soc.*, 1794 (1958).

19. A. I. Vogel, "A Text-Book of Practical Organic Chemistry," 3rd ed, John Wiley and Sons, Inc., New York, N.Y., 1962, p. 780.

20. P. A. Levene and G. M. Meyer in "Organic Syntheses, Collective Volume II," A. H. Blatt, Ed., John Wiley and Sons, Inc., New York, N.Y., 1943, p. 288.

21. D. E. Floyd and S. E. Miller in "Organic Synthesis, Collective Volume IV," N. Rabjohn, Ed., John Wiley and Sons, Inc., New York, N.Y. 1963, p. 141.

22. F. Beringer, **et. al**., *J. Amer. Chem. Soc*., **75**, 2705 (1953).

23. F. Beringer, M. Forgione, and M. Yudis, *Tetrahedron*, **8**, 49 (1960).

24. H. Normant, *Angew. Chem., Internat. Ed*., **6**, 1046 (1967).

25. H. Normant and T. Cuvigny, *Bull. Soc. Chim. France*, 1866, 1972, 1881 (1965).

26. J. R. Campbelle, J. Org. Chem., **29**, 1830 (1964).

27. U. S. Rubber Co., British Patent 839420 (1960); *Chem. Abstr*., **54**, 24549*g* (1960).

28. J. Bourdais and C. Mahieu, *C. R. Acad. Sci. Paris*, Ser. C, **84**, 263 (1966).

29. W. T. Suggs, Michigan State University, personal communication, 1972.

30. M. Beringer and E. J. Geering, *J. Amer. Chem. Soc*., **75**, 2633 (1953).

31. M. M. Boudakian, *U. S. Dept. Com., Office Tech. Serv*., P. B. Rept. 148, 483 (1961); *Chem. Abstr*., **57**, 16459*h* (1962).

32. E. C. Horning and M. G. Horning, *J. Amer. Chem. Soc*., **69**, 1359 (1947).

33. W. von E. Doering and F. M. Beringer, *J. Amer. Chem. Soc*., **71**, 2221 (1949).

34. L. F. Fieser and M. Fieser, "Reagents for Organic Synthesis," John Wiley and Sons, Inc., New York, N.Y., 1967, p. 125 and 215.

35. H. Stetter and H. J. Sandhagen, *Chem. Ber*., **100**, 2837 (1967).

36. H. DePotter and N. Schamp, *Bull. Soc. Chim. Belges*, **75**, 391 (1966).

37. N. Schamp and H. DePotter, *Bull. Soc. Chim. Belges*, **75**, 391 (1966).

38. L. J. Bellamy, "The Infra-Red Spectra of Complex Molecules," John Wiley and Sons, Inc., New York, N.Y., 1966, p. 132.

39. C. A. Buehler and D. E. Pearson, "Survey of Organic Syntheses," Wiley-Interscience, New York, N.Y., 1970, p. 730.

40. L. M. Stock, "Aromatic Substitution Reactions," Prentice-Hall, Inc., Englewood Cliffs, N. J., 1968, pp. 54-55.

41. D. Walker and J. D. Hiebert, *Chem. Rev.*, **67**, 153 (1967).

42. N. A. Lange, "Handbook of Chemistry," tenth ed., McGraw-Hill Book Co., New York, N.Y., 1967, p. 692.

43. P. W. D. Mitchell, *Can. J. Chem.*, **41**, 550 (1963).