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# Naphthalene-2,3-Dialdehyde: A Synthon to 7,9-Polymethylene-8H- Cyclohepta[B]Naphthalene-8-One and a Study of Their Aromaticity

Edward O. Crapps  
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NAPHTHALENE-2,3-DIALDEHYDE: A SYNTHON TO 7,9-POLYMETHYLENE-  
8H-CYCLOHEPTA[b]NAPHTHALENE-8-ONE AND A STUDY OF  
THEIR AROMATICITY

by

Edward C. Crapps

A Thesis  
Submitted to the  
Faculty of The Graduate College  
in partial fulfillment of the  
requirements for the  
Degree of Doctor of Philosophy  
Department of Chemistry

Western Michigan University  
Kalamazoo, Michigan  
August 1984

NAPHTHALENE-2,3-DIALDEHYDE: A SYNTHON TO 7,9-POLYMETHYLENE-  
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Edward C. Crapps, Ph.D.

Western Michigan University, 1984

This report describes the synthesis of naphthalene-2,3-dialdehyde, and an analytical method for determining its purity by thin layer chromatography. Subsequently, the dialdehyde was condensed with various cyclic ketones to generate a series of polymethylene bridged naphthotropones. It was found that planarity and aromaticity increase with the size of the methylene bridge, although, the bridge must contain six or more methylene groups for the latter to be true. The claim for aromaticity is supported by NMR and IR data, which indicates the positive charge for a perchlorate cation salt is delocalized over the naphthalene and tropone ring system. Furthermore, from the available data, the order of aromaticity for the following tropone derivatives is: tropone > naphthotropone > benzotropone > pyrazolotropone > furotropone.

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AROMATICITY

*Western Michigan University*

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## DEDICATION

My mother has waited a long time for this deserving dedication for partial fulfillment of her dream.

We have gone through a lot of good and bad times together, and it has been very seldom in my life that I have been able to say, "mama everything is okay." It's always been trials and tribulations from place to place in my career, mainly because I am too honest and too fair, to let my mother tell it. But, that's the way I was raised. And I feel that it is only fair and honest to dedicate all my efforts that it took to acquire this degree to you Mama, Lillie Crapps, the sweetest lady I know.

## ACKNOWLEDGEMENTS

It has been an honor to work for Professor Robert E. Harmon, a fine chemist, humanitarian, and friend. Any value and significance of this research is due to his outstanding chemical insight. His comprehensive knowledge of chemistry combined with patience and friendship made this endeavor possible.

The author would like to express his gratitude to Western Michigan University faculty and staff and to his colleagues in the Department of Chemistry for their help and suggestions.

He is especially grateful to his mother and family for their patience, understanding, encouragement, and support during this endeavor.

Edward C. Crapps

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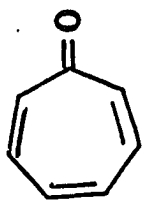
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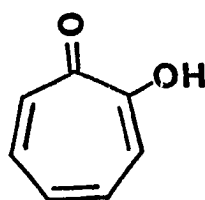
## CHAPTER I

### INTRODUCTION

The tropones 1 and tropolones 2 make up a very important and interesting class of nonbenzenoid aromatic compounds and many of their derivatives were first encountered in several quite different kinds of natural products (1).

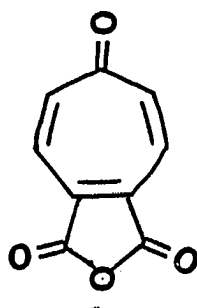


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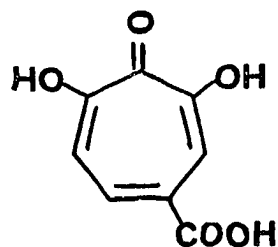


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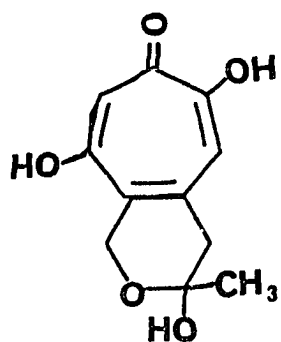
For example, it has been recognized that the tropolone system of the Penicillium Stipitatum, namely, stipitatic 3 (2) acid, puberulic acid 4 (3), and sepedonin 5 (4) are secondary vegetable metabolites.



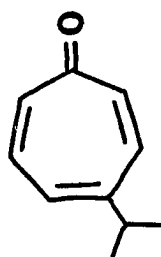
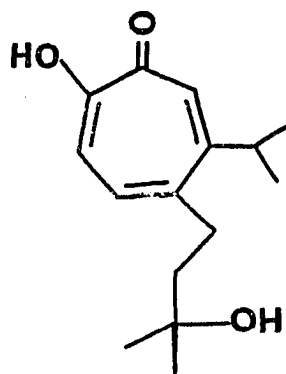
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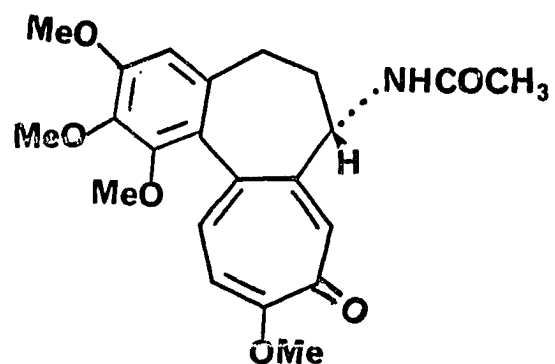
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On the other hand,  $\beta$ -thujaplicin 6 was isolated from the oil of the Formosan cedar and nookatinol 7 is found in the heartwood of various Cupressales (5).

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The alkaloidal tropolones have been given much medical, chemical, and botanical attention, which marks the long history of the active ingredient of Colchicum autumnale L. (Liliaceae). Its most common active component, colchicine 8, has been used for years in the treatment of gout. Although colchicine was reported to arrest mitosis in 1889, little research was done in this area until 1940, because



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scientists did not realize the genetic potentialities and possible therapeutic value of the agent in combating cancer. The biological aspects of colchicine 8 and related compounds have been reviewed (6), as well as the chemistry of colchicine (7,8,9).



## CHAPTER II

### STATEMENT OF THE PROBLEM

This project was undertaken with two objectives in mind:

1. To synthesize naphthalene-2,3-dialdehyde from readily available starting materials, using analytical methods to describe its purity.
2. To synthesize a series of 7,9-polymethylene-8H-cyclohepta-[b]naphthalene-8-ones and several 7,9-polymethylene-8H-cyclohepta[b]-naphthalenium ions, and to describe their abilities to sustain a ring current, depending on the size of the polymethylene bridge, as an indicator of their aromaticity.

CHAPTER III  
REVIEW OF LITERATURE

Aromaticity

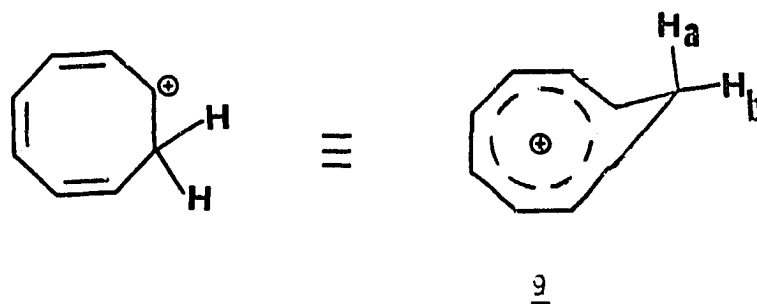
Originally, aromaticity has been associated with the properties of benzene, in terms of its chemical reactivity (10). For example, aromatic hydrocarbons were considered to be unsaturated systems which generally underwent substitution as opposed to addition reactions. Later, thermodynamic stability played an ever increasing role in defining aromaticity. That is to say, benzene has a lower enthalpy than cyclohexatriene (model system); the latter has been attributed to the molecular framework of benzene. Also, benzene is able to sustain a ring current due to its ability to delocalize the electron density over the carbons of the entire molecular ring.

Today, aromaticity is usually expressed in terms of molecular orbital terminology (M.O.T.). That is, structures which have a particular stable series of occupied  $\pi$ -molecular orbitals are called aromatic. This M.O. description of structure and aromaticity results in the Hückel rule. It is derived from simple Hückel molecular orbital (HMO) theory, and states that planar monocyclic completely conjugated hydrocarbons will be aromatic when the ring contains  $4n + 2$   $\pi$ -electrons, such systems have all electrons paired in bonding M.O.'s. This provides the theoretical basis of the Hückel rule.

All attempts to describe just how stable a given aromatic molecule

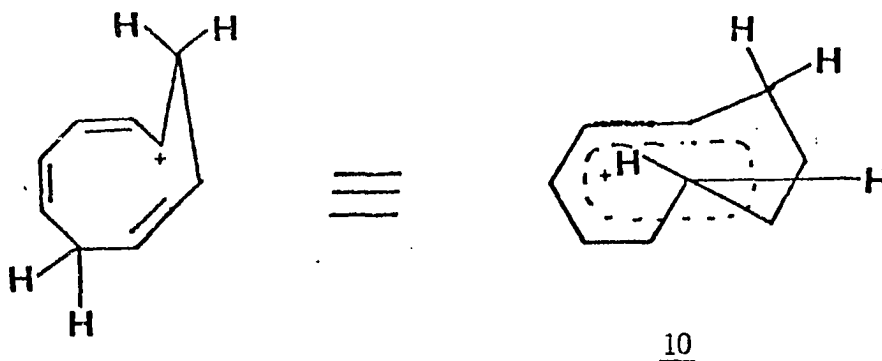
is in terms of simple HMO calculations are based on the delocalization energy. This value for the  $\pi$ -electrons of benzene is  $6\alpha + 8\beta$ , while the value for the hypothetical localized model cyclohexatriene is  $6\alpha + 6\beta$ , the sum of three isolated C=C bonds (11,12). The difference of  $2\beta$  is called the delocalization energy or resonance energy (R.E.). This quantity is often useful for comparing related systems. It is not a real, measurable physical quantity; it is a comparison between a real molecule and a nonexistent one. The resonance energy for benzene lies between 20-40 Kcal/mole.

It is reasonable to say that aromaticity is best defined in terms of its stability derived from the delocalization of bonding electrons. An aromatic molecule is characterized by its appreciable stabilization relative to a noncyclic polyene. An antiaromatic system is one that is destabilized relative to a polyene model (13), and the term nonaromatic can be applied to molecules for which the calculated energy and the energy of the polyene model are comparable. On the other hand, homoaromaticity is a term used to describe systems in which a stabilized cyclic conjugated system is formed by bypassing one saturated carbon atom (14). An example is the cyclooctatrienyl cation 9.



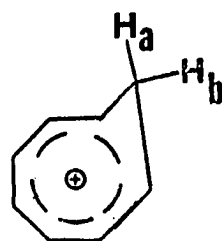
If two saturated carbon atoms were present, the term bishomo-aromatic would apply (15). Stabilization in such systems depends not only on the presence of a favorable electronic system, but also on the ability of the molecule to adopt a geometry favorable for overlap of the  $\pi$ -system.

Ions such as 9 and 10 have been isolated (16) and exhibit aromatic



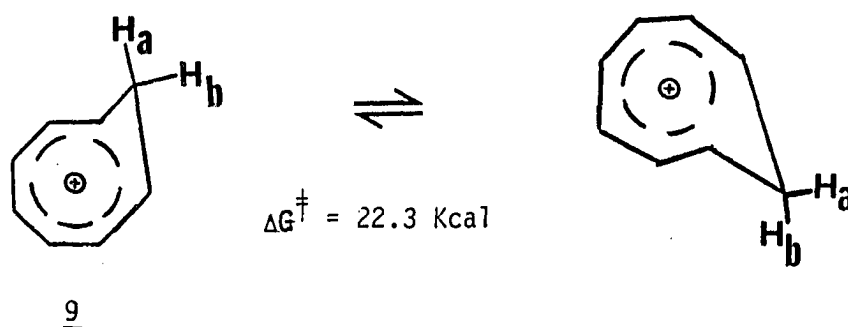
characteristics. Compound 9 illustrates how NMR spectroscopy has been an instrumental tool, capable of assessing aromaticity. Aromatic compounds are characterized by their ability to exhibit a diamagnetic ring current, which is responsible for a large magnetic anisotropy effect in aromatic compounds. The  $H_a$  proton lies above the plane of the ring, in the cone of the shielded region of the diamagnetic ring current, and its signal appears at a relatively high field compared to that of  $H_b$ . The occurrence of these chemical shift phenomena can be taken as evidence for aromaticity. It is not an absolute criterion, however, since model compounds must be used to estimate the chemical shift expected in the absence of a ring current, and a poor choice of a model can give misleading results (17). Thus, protons a and b

exhibit sharply different NMR chemical shifts (16). Proton a appears at  $\Delta-0.68$  while  $H_b$  appears at  $\Delta 5.2$ . This indicates the existence of an aromatic ring current.



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The  $\pi$ -system also contributes to imposing a high barrier to conformational flip of the saturated carbon ( $\Delta G^\ddagger = 22.3$  Kcal), because

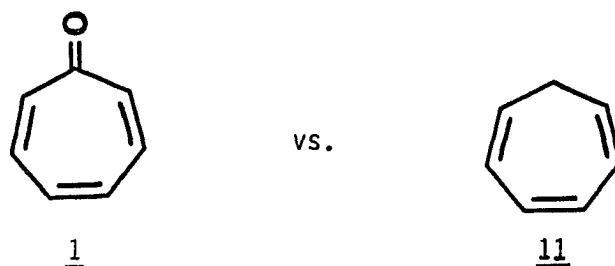


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the molecule would have to temporarily lose planarity required for aromaticity in the region of the  $\pi$ -system carbons for such a conformational change.

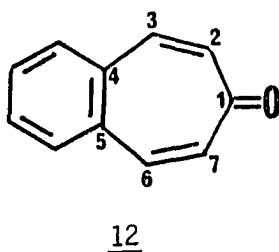
#### Tropones and Benzotropones

Based on NMR studies, one can conclude that tropone 1 is planar and has double bond alternation (18). The IR spectrum gives further support. That is, the carbonyl absorbs at  $1594\text{ cm}^{-1}$ , which is typical



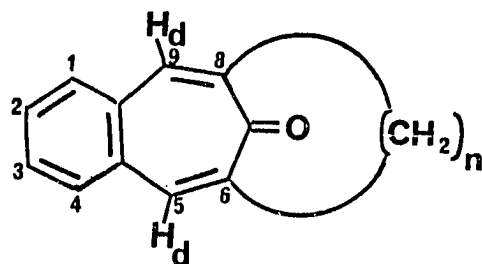
for such conjugated systems (19). Furthermore, the resonance stabilization energy of tropone is 14 Kcal/mole while that of cycloheptatriene 11 is only 8 Kcal/mole (20). This means that tropone is more stable than cycloheptatriene 11 and that the former can sustain a ring current.

X-ray crystallographic analysis of 4,5-benzotropone 12 shows the

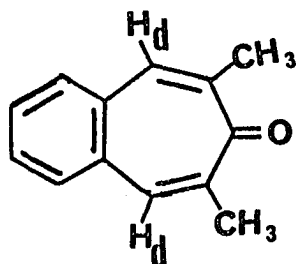


fused ring to be almost planar. Namely, the carbonyl oxygen is displaced out of the plane (of the ring system) by  $0.2\text{\AA}$ , while the carbon is displaced by  $0.1\text{\AA}$  (21). The IR carbonyl absorption occurs at  $1590\text{ cm}^{-1}$ , which is expected for a conjugated ketone 12 able to sustain a ring current.

Kloster-Jensen wanted to confirm the degree of planarity of the tropone ring by forcing the tropone ring out of planarity. This was done by placing a polymethylene bridge across C-6 to C-8, generating a series of 6,8-polymethylenebenzotropones 13 by varying the value of "n". It was found that the tropone ring is planar only if  $n \geq 7$  (22).

13

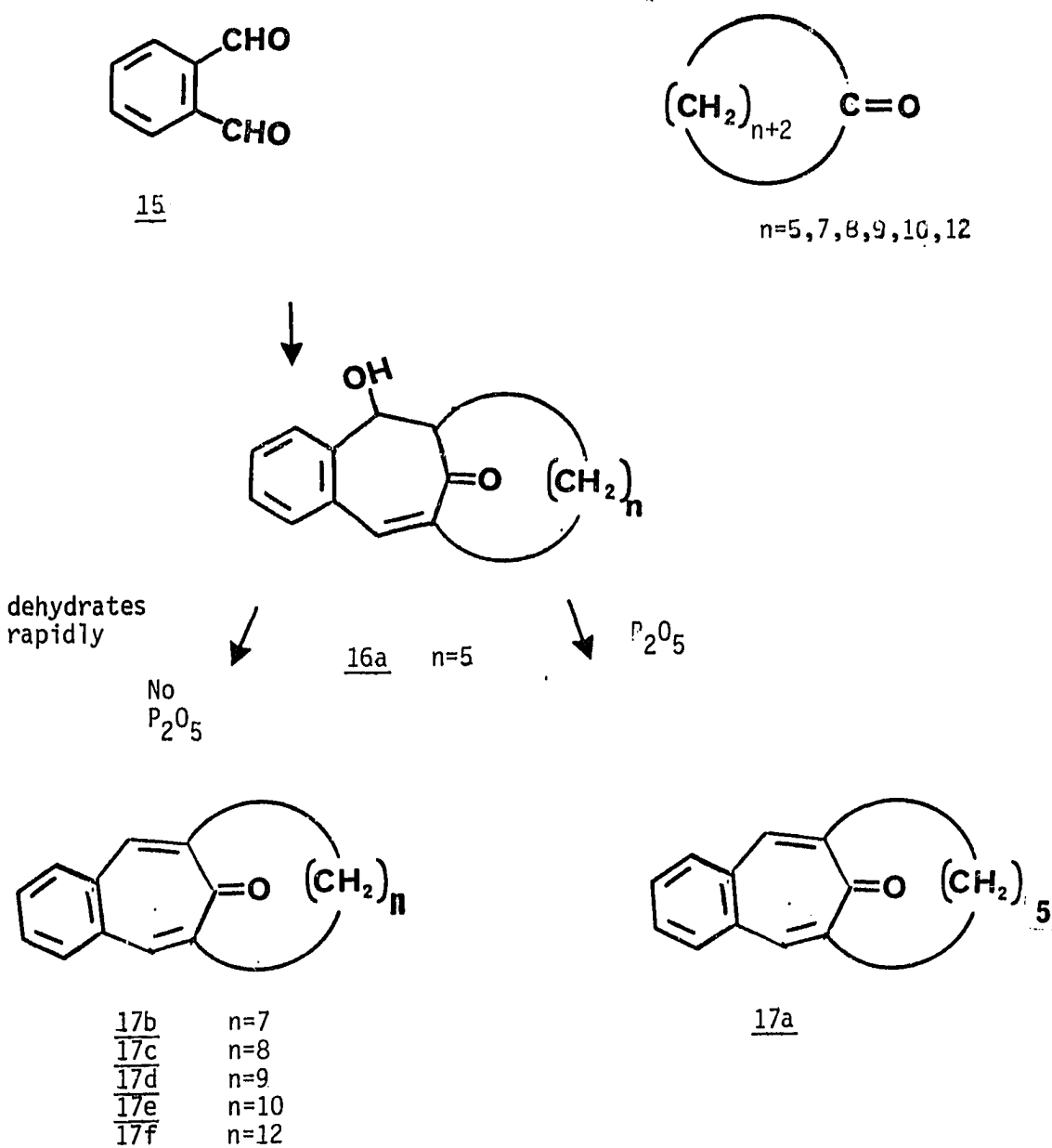
Similar results (23,24) were obtained by Harmon and Suder, and were substantiated by proton NMR. In 2,7-dimethyl-4,5-benzotropone 14,

14

protons  $H_d$  resonate at  $\Delta 7.7$  which is consistent for a planar conjugated system. In contrast to 14, protons  $H_d$  in 13 resonate at  $\Delta 6.78$  when  $n \leq 7$ , indicating that, the tropone ring lacks planarity and cannot as well sustain a ring current. However, when  $n=9$ , the  $H_d$  protons in 13 resonate at  $\Delta 7.81$ . This downfield shift of the  $H_d$  protons in the tropone ring is attributed to an increase in planarity of the tropone ring system. Planarity increases with increasing "n" ( $n \geq 7$ ). Dehydration of the 3-hydroxy precursor is rapid in those cases where  $n \geq 7$ . The driving force is the energy gained by attainment of a planar conjugated system. On the other hand, when  $n \leq 7$ , the intermediate adduct had to be treated with  $P_2O_5$  to accomplish the same results.

See Scheme 1.

Scheme 1



These polymethylenebenzotropone 17a-f are prepared by condensing phthalaldehyde 15 with various cyclic ketones to give aldol-type



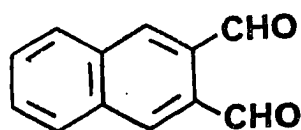
condensation products, which dehydrate (if  $n \geq 7$ ) to form 6,8-poly-methylenebenzotropones 17a-f in 20-84% yields (23,24).

## CHAPTER IV

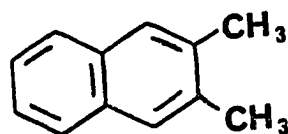
### RESULTS AND DISCUSSION

#### Preparation of Naphthalene-2,3-dialdehyde

Naphthalene-2,3-dialdehyde 18 has been synthesized by several workers (25-29) with varying degrees of difficulty, in fair to poor yields, which do not lend themselves to macrogram scale-up. In the present paper, we report the synthesis of the dialdehyde 18 from readily available 2,3-dimethylnaphthalene, with the potential for macrogram scale-up, which can function as a synthon for the production of various 7,9-polymethylene-8H-cycloalkyl[b]naphthalene-8-ones in yields ranging from 45-71%.

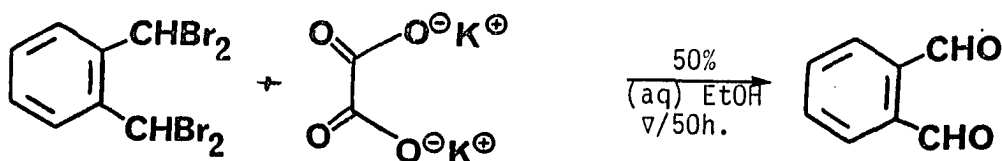


18



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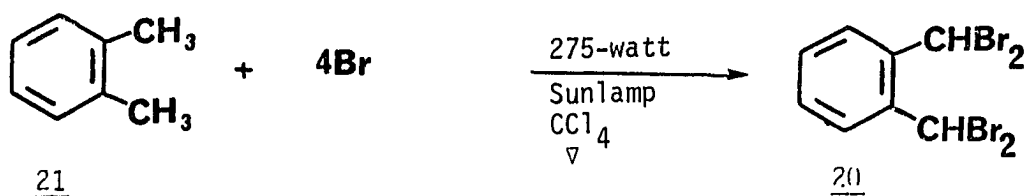
It is known from the literature (30) that phthalaldehyde 15 may be purchased from Aldrich or prepared from  $\alpha,\alpha,\alpha',\alpha'$ -tetrabromo-o-xylene 20 by treating it with potassium oxalate in 50% (aqueous) ethanol at reflux for 50 hours. The product 15 was steam distilled.



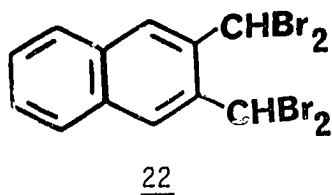
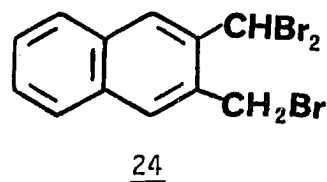
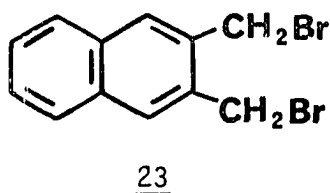
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It is also known that 20 is synthesized from 1,2-dimethylbenzene 21 and bromine in the presence of a 275-watt sun lamp. In an analogous manner, 2,2,3,3-tetrabromodimethylnaphthalene 22 was prepared in 82% yield.

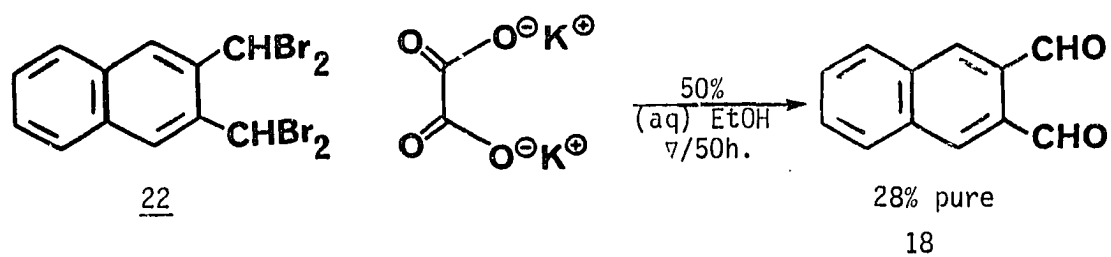


The progress of the reaction was followed by thin layer chromatography (TLC). If monitored, one can isolate the dibromide 23, or the tribromide 24, if the reaction is stopped at either point. Subsequently, 22 was refluxed in the presence of 50% (aqueous) EtOH and potassium oxalate; it was not necessary to steam distill 18 as was the case with phthalaldehyde 15.



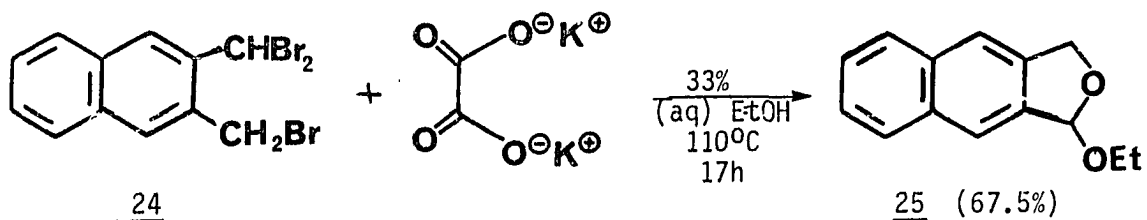
The pure dialdehyde 18 was isolated in 28% yield, plus a mixture of 22 and 18 in a ratio of 90:10 respectively. The latter was

based on analytical TLC. It was presumed that the yield of the dialdehyde 18 could be increased if high pressure were used.



+ Mixture (18 + 22)  
1 : 9

Since we had some of 24 on hand, as a trial run, it was placed into an autoclave along with 33% (aqueous) EtOH and potassium oxalate, and heated at 110°C for 17 hours, to give 25.



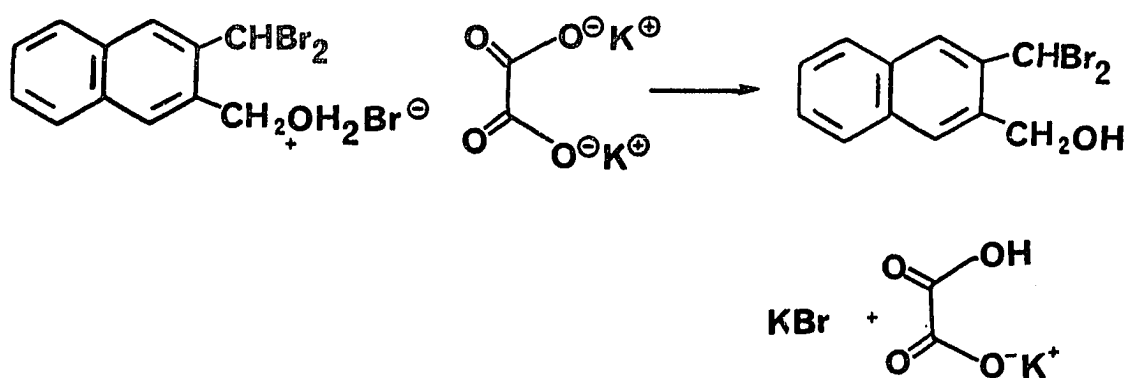
The proposed mechanism for 25 seems to involve two internal nucleophilic displacement reactions. See Scheme 2.

## Scheme 2

1.  $\text{H}_2\text{O}$  displaces  $\text{Br}^-$  in  $\text{S}_{\text{N}}2$  fashion.



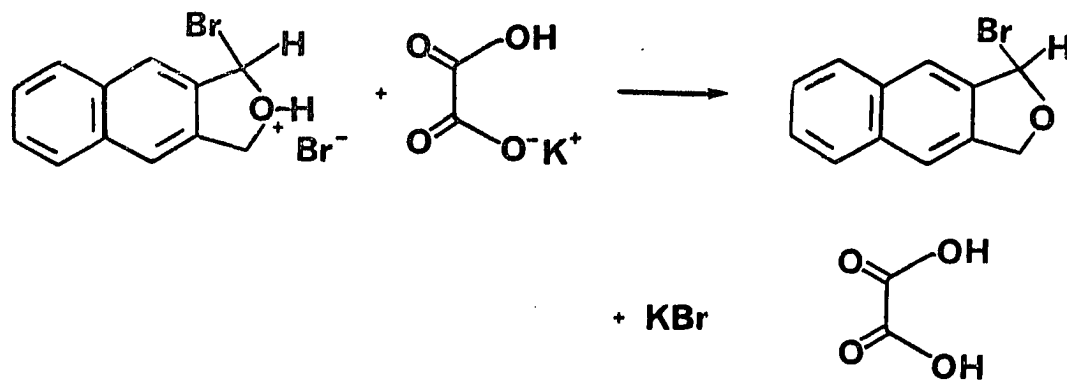
2. Potassium oxalate abstracts a proton.



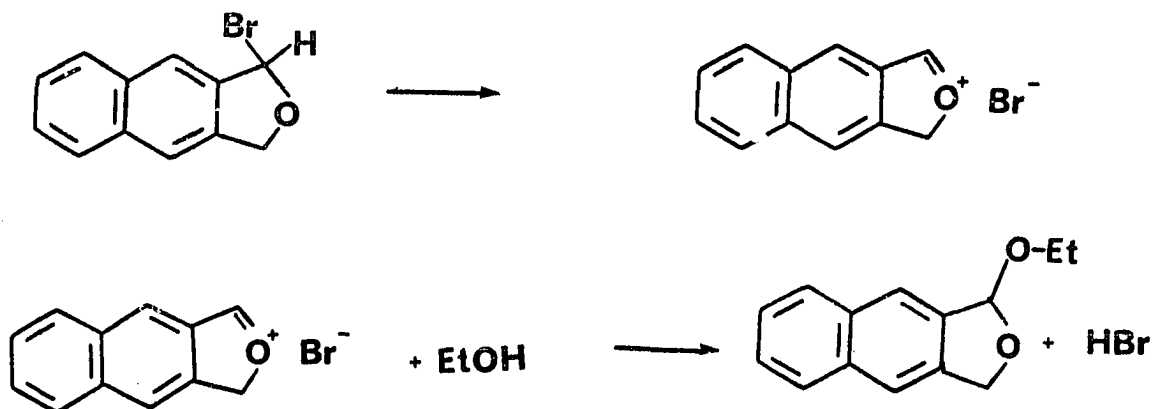
3. Internal nucleophilic displacement of  $\text{Br}^-$  by  $-\text{OH}$  function.



4. Potassium oxalate abstracts a proton.

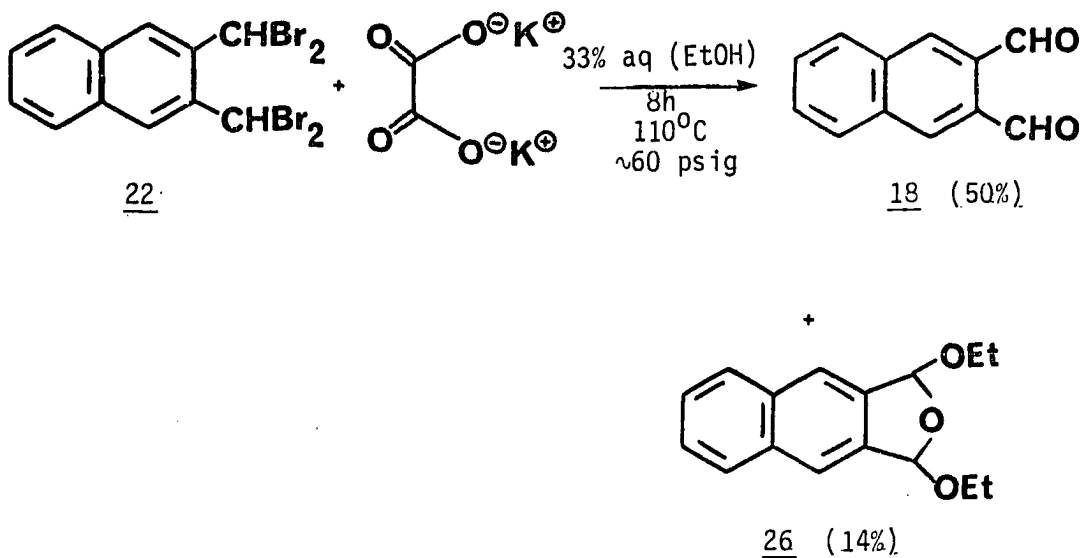


5. Internal displacement of  $\text{Br}^-$  by oxygen, followed by attack of EtOH (hemiacetal would be unstable).



6. HBr reacts with potassium oxalate

With these encouraging results, we proceeded to use an analogous high pressure procedure to the dialdehyde 18, with decreased reaction time. Note: Prolonged heating causes the dialdehyde to discolor. Two products were expected: 26 and 18.

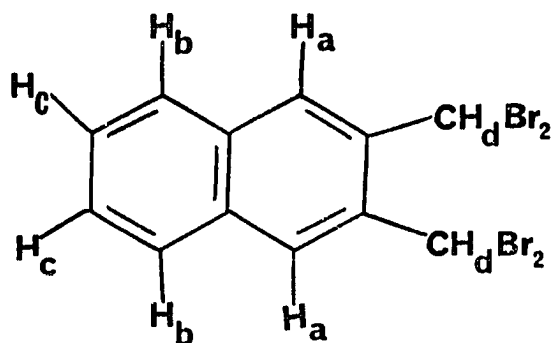


Indeed the expected products were obtained in the yields indicated, although 18 was contaminated with trace amounts of the tetrabromide 22. There was also ~11% of an unidentified oil, which appears to be a mixture of 18 and 26 by NMR. 26 was vacuum distilled away from the latter oil at 130°C and 0.5 mmHg.

It is not practical nor necessary to remove impurities (the tetrabromide 22) in the dialdehyde 18. The latter oxidizes readily on silica gel or in solution in the absence of an inert atmosphere in attempting further purification. The former 22 does not react with the cyclic ketones under the reaction conditions used, although 18 does react with them to give the desired 7,9-polymethylene-8H-cyclo-alkyl[b]naphthalene-8-ones 27a-d. Consequently, it is only necessary to know the amount of impurity 22 present. This was accomplished with analytical TLC, to be discussed later.

#### Spectral Data for the Dialdehyde vs. the Tetrabromide

The NMR spectrum for the tetrabromide 22 shows four distinctly different types of protons.

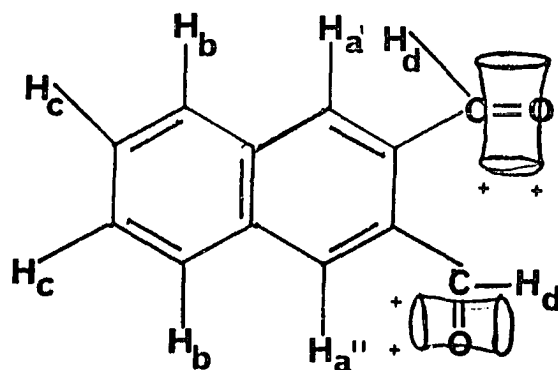


NMR(CDCl<sub>3</sub>): Δ8.1 (s,2Hd), Δ7.6-7.8 (m,2Hc), Δ7.3-7.55 (m,2Hb), Δ7.2

(S, 2Ha), IR (KBr)  $3500-3140\text{ cm}^{-1}$  (w)

Unlike the tetrabromide,  $H_a$  protons are not equivalent in the dialdehyde due to anisotropic effects of the adjacent aldehydic groups.

That is:



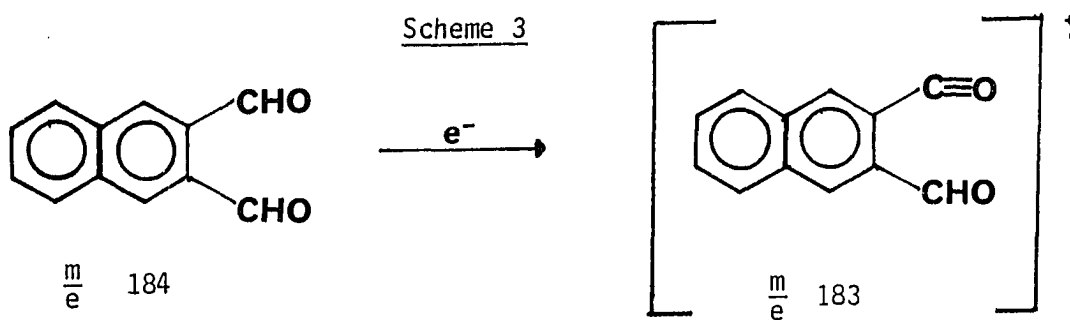
NMR( $\text{CDCl}_3$ ):  $\Delta 8.35$ (S, 2Hd),  $\Delta 7.95$ (m, 2Hc, 1Ha'),  $\Delta 7.65$ (m, 2Hb, 1Ha'')

IR(KBr):  $3500-3300\text{ cm}^{-1}$ , c=O ( $1715-1570$ )  $\text{cm}^{-1}$ , centered at  $1685\text{ cm}^{-1}$

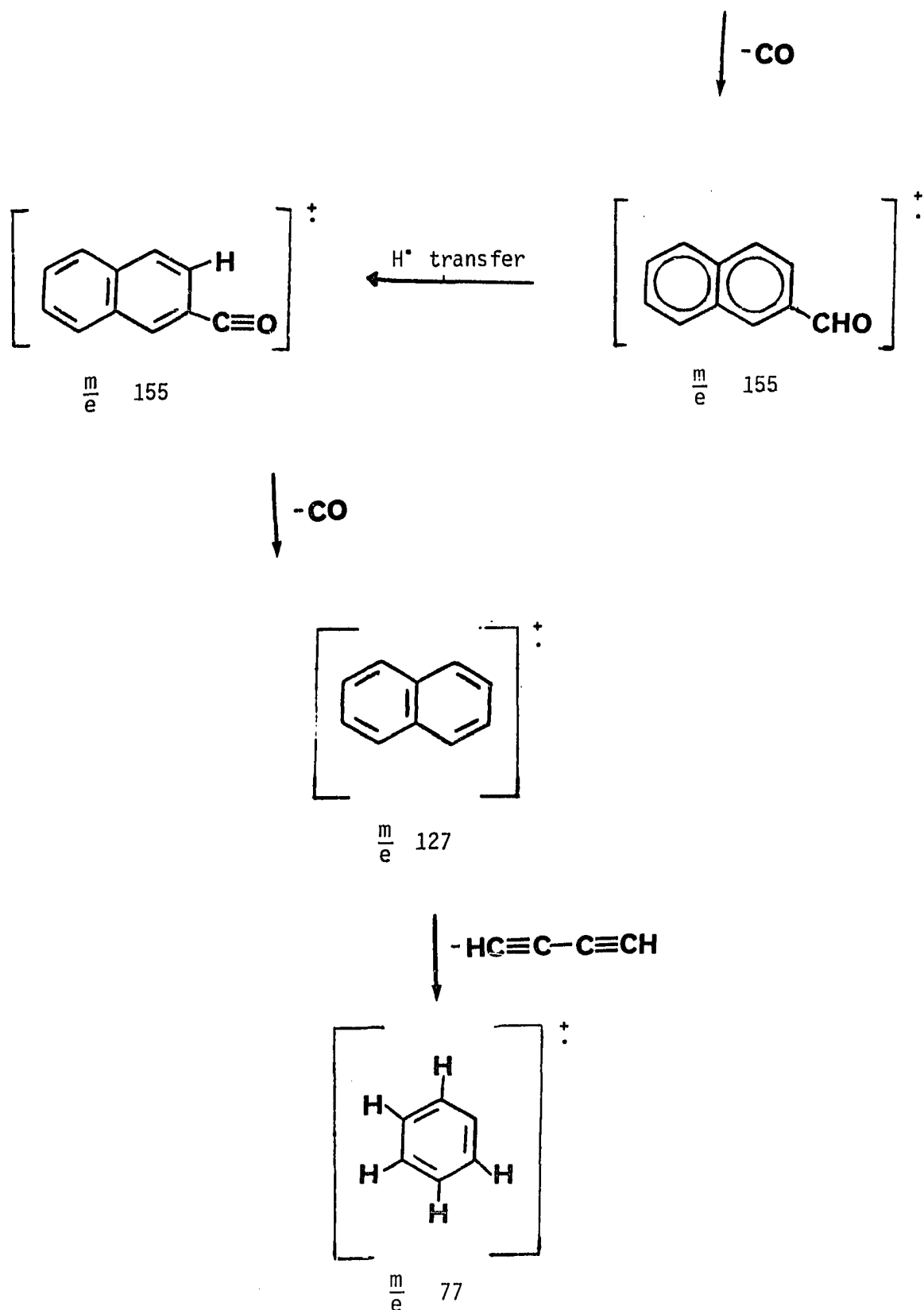
$H_a''$  is shielded to a greater degree than  $H_a'$ , because it is located in a region of high electron density.

The IR absorption at  $3500-3300\text{ cm}^{-1}$  is characteristic for the naphthalene ring system.

The proposed structure 18 is further supported by mass spectroscopy data ( $M^+$  @  $\frac{m}{e}$  184). For the fragmentation pattern, see Scheme 3.



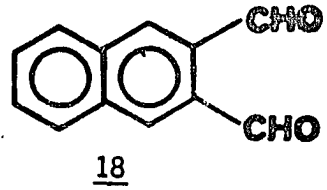
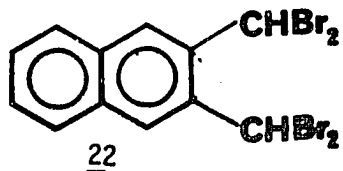




### Analytical Method for Determining Purity of Dialdehyde

The concentration of tetrabromide 22 in the dialdehyde 18 reaction mixture was determined by Analytical Thin Layer Chromatography. The Anatech plates once developed were scanned on a spectrodensitometer equipped with a dual wavelength system. The maximum absorption of the above compounds occurred at 300 m $\mu$ . All peaks were read at this wavelength.

Standard concentration curves were made for both the tetrabromide and the dialdehyde at the concentrations shown below.

<u>Compound</u>	<u>Concentration (<math>\mu\text{g}/\text{spot}</math>)</u>
 <u>18</u>	2.5, 2.0, 1.5, 1.0, 0.5
 <u>22</u>	1.25, 1.0, 0.75, 0.50, 0.25

The tetrabromide 22 will be used to illustrate the procedure; the same procedure was used for the dialdehyde 18. That is, the standards and the unknown samples were spotted in duplicate, and were run on the same plate to minimize experimental error. The tetrabromide migrates with an  $R_f = 0.54$  while that of the dialdehyde is 0.22. Therefore,

any unknown compound which migrates with an  $R_f$  value of 0.54 was assumed to be the tetrabromide 22. The solvent system was 20% EtOAc/79.5% hexane/0.5% isopropanol. Other solvent systems ( $\text{CH}_2\text{Cl}_2$ ; 10% EtOAc/1% isopropanol/89% hexane) were tried so as to correlate the unknown compound with the known standard 22 or 18. Since the unknown  $R_f$  value was 0.54, it was concluded that unknown must be the tetrabromide, which was the same in more than one solvent system. This claim was supported by NMR, IR, and mass spectra data.

The computer plotted area versus concentration for the standard tetrabromide and dialdehyde which generated the following statistical parameters: slope 0.1356, intercept 0.1038, variance 0.3710 and correlation coefficient 0.9952.

Ideally the correlation coefficient should be 1.000, but it is 0.9952, which means that all points fall on a straight line whose intercept is zero. The latter means that our data is good and so is the method.

From these standard curves, the computer determined the amount of tetrabromide in the unknown sample by using the linear regression line model. Since the unknowns were run in duplicates, two concentrations were recorded (1.0977  $\mu\text{g}/\text{spot}$  and 1.1190  $\mu\text{g}/\text{spot}$ ). The average concentration (1.11  $\mu\text{g}/\text{spot}$ ) was used.

#### Calculation

$$1 \text{ spot} = 25\lambda$$

$$1,000\lambda = 1 \text{ mL}$$

The Original Tetrabromide Concentration

2,606  $\mu\text{g/mL}$  0.8 mL of this solution was diluted to 10 mL of solution, resulting in a concentration of 208.48  $\mu\text{g/mL}$ . 6 mL of this solution was diluted to 25 mL of solution, resulting in a concentration of 50.03  $\mu\text{g/mL}$ .

Therefore, to calculate the % yield of tetrabromide in unknown is as follows:

$$\frac{1.11 \mu\text{g}}{\text{spot}} \times \frac{1 \text{ spot}}{25\lambda} \times \frac{1,000\lambda}{\text{mL}} = \frac{44.4\mu\text{g}}{\text{mL}} \text{ tetrabromide in unknown}$$

$$\frac{44.4 \mu\text{g}}{\text{mL}} \times 25 \text{ mL} = X\mu\text{g/mL} \quad (6 \text{ mL})$$

$$X\mu\text{g/mL} = 185$$

$$\frac{185 \mu\text{g}}{\text{mL}} \times 10 \text{ mL} = \frac{Y\mu\text{g}}{\text{mL}} \quad (0.8 \text{ mL})$$

$$Y\mu\text{g/mL} = 2,312.5 \mu\text{g/mL}$$

% Tetrabromide 21 in Unknown

$$\% \text{ tetrabromide } \underline{21} \text{ in unknown} = \frac{2,312.50 \mu\text{g/mL}}{2,606 \mu\text{g/mL}} \times 10^2$$

$$\% \text{ tetrabromide} = 88.74 \%$$

$$\% \text{ dialdehyde} = 8.8 \%$$

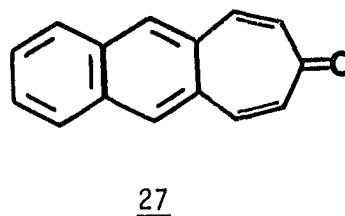
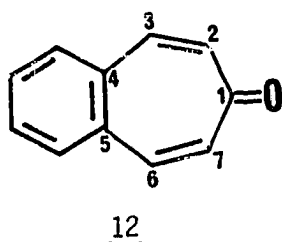
$$\% \text{ unknown residue } (R_f=0.96) = 1.5 \%$$

The above method enables us to determine the composition of any

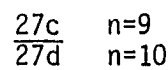
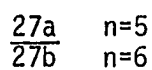
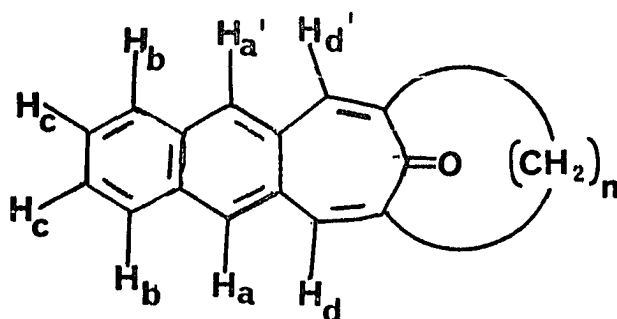
unknown mixture of tetrabromide and dialdehyde. Therefore, we can proceed to synthesis of 7,9-polymethylene-8H-cycloalkyl[b]naphthalene-8-ones 27a-d.

### Synthesis of 7,9-Polymethylene-8H-cyclohepta[b]naphthalene-8-ones

For the sake of brevity these 7,9-polymethylene-8H-cyclohepta[b]naphthalene-8-ones 27a-d will be called 4,5-naphthotropones similar to 4,5-benzotropone 12, which are named after the parent compound tropone 1.



These naphthotropones 27a-d were prepared by condensing naphthalene-2,3-dialdehyde 18 with various cyclic ketones to give aldol-type condensation products in 45-70% yield, similar to benzotropone preparation (31).



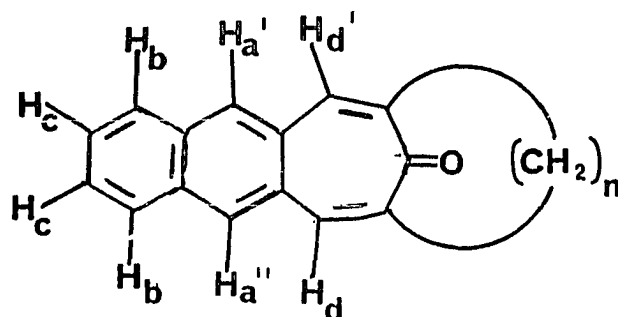
All that remains is to compare naphthotropone's ability to sustain a ring current relative to the benzotropone derivatives (31), as the size of the polymethylene bridge is varied across C-2 and C-7 if named as a tropone. It has already been shown that for 4,5-benzotropones if  $n \geq 7$ , the tropone ring is nearly planar and can sustain a ring current; if  $n \leq 7$ , it cannot. This becomes evident when one looks at the NMR spectra.

If the  $H_d$  protons resonate at  $\Delta 7.2$  or lower field, the tropone ring system must sustain a ring current. See Tables 1, 2, and 3.

Table 1  
Physical Data of Naphthotropones

Compound	n	NMR (CDCl <sub>3</sub> ) $\Delta$						% Yield
		$H_d$	$H_c$	$H_b$	$H_{a''}$	$H_{d'}$	$H_{a'}$	
27a	5	7.9	7.7	7.37	7.37	5.35	6.62	62
27b*	6	7.81	7.75	7.41	7.02	----	----	48
27c*	9	7.88	7.78	7.45	7.29	----	----	77
27d*	10	7.95	7.80	7.40	7.40	----	----	49

\*  $H_d = H_{d'}$  when  $n \geq 6$

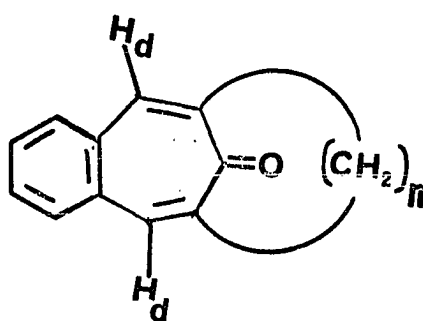


27 n=0

Table 2  
Physical Data of Benzotropones (23,24)

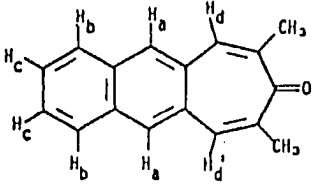
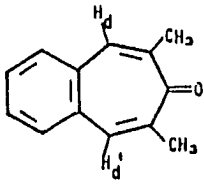
Compound	n	NMR (CDCl <sub>3</sub> ) Δ	
		H <sub>d</sub>	Aromatic
17	0	7.60	7.58
17a	5	6.78	7.05-7.60
17*	6	-----	-----
17d	9	7.31	7.48
17e	10	7.27	7.44

\*Was not prepared



17 n=0

Table 3  
Physical Data of Benzotropone Versus Naphthotropone

							
<u>29</u>						<u>14</u>	
n	*NMR (CDCl <sub>3</sub> ) Δ					n	*NMR (CDCl <sub>3</sub> )
	H <sub>d</sub>	H <sub>c</sub>	H <sub>b</sub>	H <sub>a</sub>	% Yield		H <sub>d</sub>
0	8.0	7.8	7.5	7.5	58.5	0	7.7

$$*H_d = H_d'$$

In all cases, when  $n \geq 6$  in naphthotropones,  $H_d$  resonates at a field below  $\Delta 7.2$ , whereas, the same is true for benzotropones only if  $n \geq 7$ . On the other hand, in naphthotropones, when  $n \leq 6$  27a, the  $H_d$  protons are unequivalent, one resonates at a higher field than the other, and thus the tropone ring has been forced out of planarity, the more stable situation. Similar results were obtained in benzotropone series for  $n \leq 7$ . The above NMR spectra data seem to imply that the additional benzene ring in naphthotropone enhances the system's ability to sustain a ring current over benzotropone. In all cases, the  $H_d$  proton in naphthotropone resonates at a lower field than the  $H_d$  in benzotropone, which is further supported by the  $H_d$  resonance in 29 and 14. Consequently, one could conclude that naphthotropones sustain a

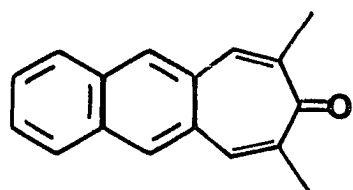


ring current better than benzotropones because the former is more planar, therefore, naphthotropone is more aromatic than benzotropone. Similar ideas have been alluded to by other workers (21,32), namely, tropone is more aromatic than benzotropone which is more aromatic than furotropone.

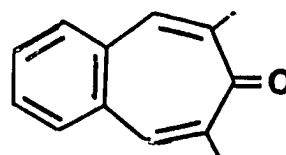
It has also been demonstrated with IR spectroscopy that the carbonyl absorption occurs at  $1590\text{ cm}^{-1}$  for conjugated ketones, which can sustain a ring current like benzotropones 17b-f with  $n \geq 7$ . The IR data found in Table 4 illustrates that the above is true for naphthotropones 27b-d as well.

Table 4  
Physical Data of Naphthotropones Versus Benzotropones

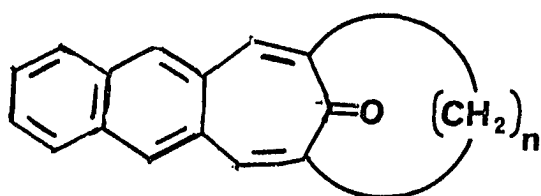
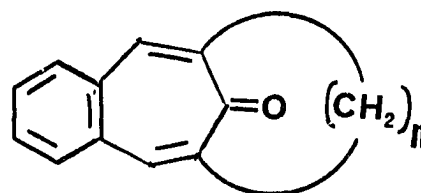
Compound	n	IR(KBr) c=O ( $\text{cm}^{-1}$ )	Compound	n	IR(Nujol) c=O ( $\text{cm}^{-1}$ )
29	0	1587	14	0	1596
27a	5	1665	17	0	1596
27b	6	1645	17a	5	1697
27c	9	1605	17c	9	1610
27d	10	1580	17d	10	1610



29

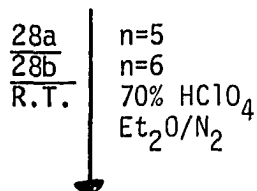
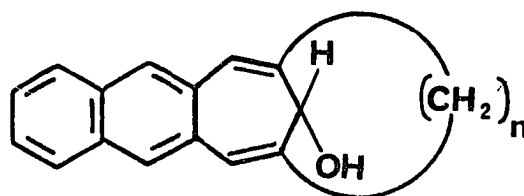
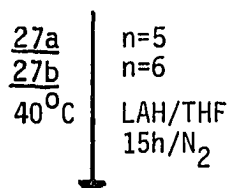
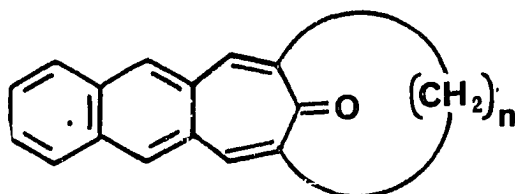


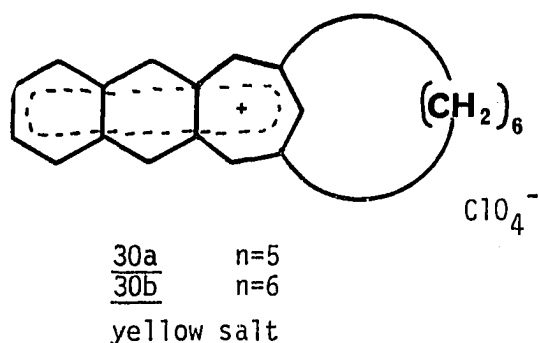
14

27a-d17a-d

## Naphthotroponium Ions

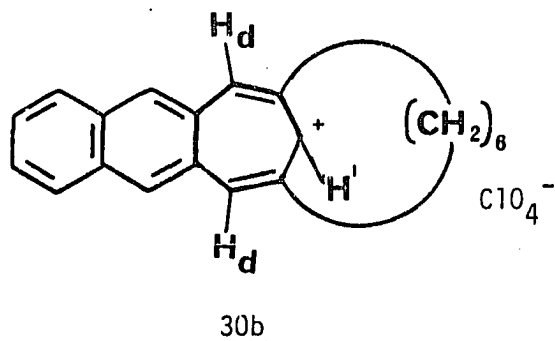
Naphthotropones 27a and 27b are converted to the alcohol by reduction of the carbonyl function with lithium aluminum hydride (LAH) in tetrahydrofuran (THF) in 61% and 87% yields, respectively.





Perchlorate 30 was isolated while 30b was not. This is not surprising since 6,8-polymethylene-4,5-benzotropylium perchlorates have been isolated only if  $n=10$  or  $12$  (31). The inability to isolate these perchlorates with lower values of  $n$  have been attributed to slight deviations in planarity of the tropone ring (31). In essence, the positive charge cannot be sufficiently stabilized if the ring system is not absolutely planar, resulting in an inhibition of formation of a stable perchlorate salt. Although 30b has an  $n$  value less than 7, the positive charge is sufficiently stabilized to enable its isolation. This supports the claim that naphthotropones are more aromatic than benzotropones.

Further NMR evidence was collected on the perchlorate 30b. The



$H_d$  protons, in 30b, give an NMR signal at  $\delta 8.3$  while  $H'$  absorbs at

Δ7.2. All the unsaturated ring protons in 30b absorb in the aromatic region of the NMR spectrum.

## CHAPTER V

### EXPERIMENTAL

#### Instrumentation

##### General

Melting points (uncorrected) were determined on a Thomas-Hoover Unimelt instrument, and are expressed in degrees Celsius. Compounds were identified by IR, NMR, and MS. IR spectra were run as KBr pellets on a Perkin-Elmer 1320 Infrared Spectrophotometer. Proton NMR spectra were recorded in  $\text{CDCl}_3$  solution with TMS as internal standard using a Varian EM 390 Spectrometer. Mass spectra were obtained at 70 eV on a Finnigan MAT CH7. The plates for analytical TLC were spotted with a multispotter (Analytical Instrumental Specialty Company, TLC, multiscanner). These plates were read on a Shimadzu Dual Wavelength GLC Scanner Model CS-910, equipped with CR 1A<sup>o</sup> Chromatopac Data Processor which is connected to a Harris Computer. Micro-analyses were carried out at Midwest Microlab, Ltd., Indianapolis, IN. TLC on silica gel plates (Merck, 60, F<sub>254</sub>, precoated, 0.2 mm) was usually used to follow the reactions and to control the purity of the products.

##### Materials

Aldrich supplied the cycloalkylketones and the 2,3-dimethylnaphthalene. No purification was necessary. All solvents were reagent

grade.

### Preparations

#### Naphthalene-2,3-dialdehyde

A suspension containing 11.75 g ( $2.78 \times 10^{-2}$  mole) of 2,2,3,3-tetrabromodimethylnaphthalene, 10.0 g ( $5.43 \times 10^{-2}$  mole) of potassium oxalate in 150 mL of 33% aqueous ethanol was placed into an autoclave at 60 psig and  $110^{\circ}\text{C}$  for 8 hours. The autoclave was allowed to cool to room temperature before venting. The product was removed with acetone. The resulting mixture was filtered, the filtrate was concentrated in vacuo to leave an oil which solidified. The latter was filtered and washed with cold heptane, and was recrystallized from acetone/heptane. The dialdehyde was isolated 2.74 g (50%), shown to be the same as authentic sample by TLC. NMR ( $\text{CDCl}_3$ ):  $\Delta 8.35(\text{s}, 2\text{H})$ ,  $\Delta 7.95(\text{m}, 3\text{H})$ ,  $\Delta 7.65(\text{m}, 3\text{H})$ . IR(KBr): 3500-3300 (w)  $\text{cm}^{-1}$ . Mass Spectrum:  $\text{M}^+$  (observed) 184 calculated for  $\text{C}_{12}\text{H}_8\text{O}_2$ : 184.0522. Other ions at  $\frac{m}{e}$  183, 156, 155, 154, 128, 127, 126, 77, and 51.

#### 2,2,3,3-Tetrabromodimethylnaphthalene

In a 1-L three-necked flask equipped with an oil-lubricated Trubore stirrer, a dropping funnel, a thermometer extending nearly to the bottom of the flask, and a reflux condenser attached to a gas absorption trap were placed 2,3-dimethylnaphthalene (25.0 g,  $16.0 \times 10^{-2}$  mole) and 300 mL carbontetrachloride. A General Electric R.S. Reflector Type 275-watt sun lamp was placed approximately 1 cm from the flask so as to

admit the maximum amount of light. The stirrer was started, and reaction solution was heated with the aid of the sun lamp at or near reflux temperature.

A total of 114.9 g ( $72.0 \times 10^{-2}$  moles) of bromine was added in portions from the dropping funnel to the reaction flask at such a rate that the bromine color is removed as fast as it is added. Otherwise, the reaction mixture will become too vigorous and some of the bromine will be lost with the evolved hydrogen bromide. After all the bromine had been added (10-14 hours), the reaction was allowed to stir overnight in the presence of the sun lamp. The reaction solution was allowed to cool to room temperature (R.T.); a tan product was filtered and washed with excess cold heptane.

The crude product was analytically pure, but if not, it may be recrystallized from heptane, or flash chromatographed on silica gel with methylene chloride. The total yield of 2,2,3,3-tetrabromodimethylnaphthalene, m.p. 158-158.5<sup>0</sup>, was 61.9 g (82%). NMR (CDCl<sub>3</sub>):  $\Delta$ 8.1(S, 2H),  $\Delta$ 7.6-7.8(m,2H),  $\Delta$ 7.3-7.55(m,2H),  $\Delta$ 7.2(S,2H). IR(KBr): 3500-3300 (aromatic ring) cm<sup>-1</sup>.

Anal. Calculated for C<sub>12</sub>H<sub>8</sub>Br<sub>4</sub>: C, 30.54; H, 1.71; Br, 67.75

Found: C, 30.18, H, 1.78, Br, 68.02

#### 7,9-Pentamethylene-8H-cyclohepta[b]naphthalene-8-one

A solution containing 0.46 g ( $2.34 \times 10^{-3}$  moles) of naphthalene-2,3-dialdehyde, 0.32 g ( $2.54 \times 10^{-3}$  moles) of cyclooctanone, and 75 mL of absolute ethanol, and 15 mL of saturated sodium hydroxide in methanol

was heated at reflux for 1/2 hour. The reaction was shown to be complete by TLC (silica gel; solvent:  $\text{CH}_2\text{Cl}_2$ ). The solvent was then removed in vacuo and 100 mL of water was added to the residue. This mixture was extracted with ether, dried ( $\text{MgSO}_4$ ), filtered, and evaporated in vacuo. The crude product was chromatographed on silica gel and eluted with methylene chloride, to yield 0.4 g (61%) of pure compound (m.p.  $203^\circ$  sharp). NMR( $\text{CDCl}_3$ ):  $\Delta 7.9(\text{s}, 1\text{H})$ ,  $\Delta 7.7(\text{m}, 2\text{H})$ ,  $\Delta 7.37(\text{m}, 3\text{H})$ ,  $\Delta 6.62(\text{s}, 1\text{H})$ ,  $\Delta 5.35(\text{d}, 1\text{H})$ ,  $\Delta 2.77(\text{b}, 2\text{H})$ ,  $\Delta 2.34(\text{b}, 3\text{H})$ ,  $\Delta 2.05-1.55(\text{b}(\text{s}), 5\text{H})$ . IR(KBr):  $1665(\text{c}=\text{o}) \text{ cm}^{-1}$ .

7,9-Hexamethylene-8H-cyclohepta[b]naphthalene-8-one

A solution containing 0.93 g ( $4.74 \times 10^{-3}$  moles) of naphthalene-2,3-dialdehyde, 0.72 g ( $5.13 \times 10^{-3}$  moles) of cyclononane, and 150 mL of absolute ethanol, and 20 mL of saturated sodium hydroxide in methanol was heated under reflux and nitrogen for 1/2 hour. The reaction was shown to be complete by TLC (silica gel; solvent: 1.5% EtOAc/ $\text{CH}_2\text{Cl}_2$ ). The solvent was then removed in vacuo and 100 mL of water was added to the residue. This mixture was extracted with ether, dried ( $\text{MgSO}_4$ ), filtered, and evaporated in vacuo. The crude product was chromatographed on silica gel and eluted with methylene chloride, to yield 0.41 g (48%) pure compound (m.p.  $168^\circ$  sharp). NMR( $\text{CDCl}_3$ ):  $\Delta 7.81(\text{s}, 2\text{H})$ ,  $\Delta 7.75(\text{m}, 2\text{H})$ ,  $\Delta 7.41(\text{m}, 2\text{H})$ ,  $\Delta 7.02(\text{s}, 2\text{H})$ ,  $\Delta 3.23(\text{b}, 2\text{H})$ ,  $\Delta 2.51(\text{b}, 2\text{H})$ ,  $\Delta 1.13-2.02(\text{b}(\text{s}), 8\text{H})$ . IR(KBr):  $1645(\text{c}=\text{o}) \text{ cm}^{-1}$ .

Anal. calculated for  $\text{C}_{21}\text{H}_{20}\text{O}$ : C, 87.46; H, 6.99

Found: C, 87.27; H, 7.00



7,9-Nonamethylene-8H-cyclohepta [b] naphthalene-8-one

A solution containing 0.40 g ( $2.03 \times 10^{-3}$  moles) of naphthalene-2,3-dialdehyde, 0.35 g ( $1.92 \times 10^{-3}$  moles) of cycloundecanone, and 75 mL of absolute ethanol, and 15 mL of saturated sodium hydroxide in methanol was heated under reflux and nitrogen for 2 hours. The reaction was shown to be complete by TLC (silica gel; solvent: 1.5% EtOAc/ $\text{CH}_2\text{Cl}_2$ ). The solvent was then removed in vacuo and 100 mL of water was added to the residue. This mixture was extracted with ether, dried ( $\text{MgSO}_4$ ), filtered, and evaporated in vacuo.

The crude product was chromatographed on silica gel and eluted with methylene chloride, to yield 0.49 g (77%) pure compound (m.p.  $151.5\text{--}152.5^\circ$ ). NMR( $\text{CDCl}_3$ ):  $\Delta 7.88(\text{s}, 2\text{Hd})$ ,  $\Delta 7.78(\text{m}, 2\text{HC})$ ,  $\Delta 7.45(\text{m}, 2\text{Hb})$ ,  $\Delta 7.29(\text{s}, 2\text{Ha})$ ,  $\Delta 3.6(\text{m}, 2\text{H})$ ,  $\Delta 2.3\text{--}1.1(\text{m}, 16\text{H})$ . IR(KBr):  $3600\text{--}3300\text{ cm}^{-1}$ ,  $2900\text{--}2990\text{ cm}^{-1}$ ,  $2860\text{ cm}^{-1}$ , and  $1605(\text{c}=\text{o})\text{ cm}^{-1}$ . Mass spectrum:  $\text{M}^+$  (observed) 330, calculated for  $\text{C}_{24}\text{H}_{26}\text{O}$ , 330.1977. Other ions at  $\frac{\text{m}}{\text{e}}$  331, 302, 254, 247, 246, 245, 231, 208, and 205.

7,9-Decamethylene-8H-cyclohepta [b] naphthalene-8-one

A solution containing 0.27 g ( $1.37 \times 10^{-3}$  moles) of naphthalene-2,3-dialdehyde, 0.33 g ( $1.68 \times 10^{-3}$  mole) of cyclododecanone, 75 mL of absolute ethanol, and 15 mL of saturated sodium hydroxide in methanol was heated under reflux and nitrogen for 1 hour. The reaction was shown to be complete by TLC (silica gel; solvent: 2% EtOAc/ $\text{CH}_2\text{Cl}_2$ ). The solvent was then removed in vacuo and 100 mL of water was added to the residue. This mixture was extracted with ether, dried ( $\text{MgSO}_4$ ),

filtered, and evaporated in vacuo.

The crude product was chromatographed on silica gel and eluted with methylene chloride, to yield 0.23 g (49%) pure compound (m.p. 153-154<sup>0</sup>). NMR(CDC1<sub>3</sub>): Δ7.95(s,2H), Δ7.80(m,2H), Δ7.40(m,4H), Δ3.05-2.60(b(s),3H), Δ1.80-1.50(m,5H), Δ1.2 (u(s),12H). IR(KBr): 3600-3300 cm<sup>-1</sup>, 2900-2990 cm<sup>-1</sup>, 1580 (c=o) cm<sup>-1</sup>, 1430-1460 cm<sup>-1</sup>. Mass spectrum: M<sup>+</sup> (observed) is 344. Calculated for C<sub>25</sub>H<sub>28</sub>O is 344.2133. Other ions  $\frac{m}{e}$  345, 316, 215, 208, 207, 205, 202, 191.

#### 2,7-Dimethyl-4,5-Naphtho[b] tropone

A solution containing 0.21 g (1.06 x 10<sup>-3</sup> moles) of naphthalene-2,3-dialdehyde, 0.95 x 10<sup>-3</sup> g (1.10 x 10<sup>-3</sup> moles) of 3-pentanone, and 75 mL of absolute ethanol, and 15 mL of saturated sodium hydroxide in methanol was heated under reflux and nitrogen for 2 hours. The reaction was shown to be complete by TLC (silica gel; solvent 1% EtOAc/CH<sub>2</sub>Cl<sub>2</sub>). The solvent was then removed in vacuo and 100 mL of water was added to the residue. This mixture was extracted with ether, dried (MgSO<sub>4</sub>), filtered, and evaporated in vacuo. The crude product was chromatographed on silica gel and eluted with 2-L of methylene chloride, then 5% EtOAc/CH<sub>2</sub>Cl<sub>2</sub>, to yield 1.45 x 10<sup>-1</sup> g (58%) pure compound (m.p. 190-192<sup>0</sup>). NMR(CDC1<sub>3</sub>): Δ8.0(s,2H), Δ7.8(m,2H), Δ7.5(m,4H), Δ2.3(s,6H). IR(KBr): 3550-3300 cm<sup>-1</sup> and 1587 (c=o) cm<sup>-1</sup>.

Anal. calculated for C<sub>17</sub>H<sub>14</sub>O: C, 87.15; H, 6.02

Found: C, 86.97; H, 6.07

1-Ethoxy-1,3-dihydronaphtho[2,3-c]furan

A suspension containing 26.48 g ( $6.73 \times 10^{-2}$  moles) of 2,2,3-tribromodimethylnaphthalene, 21.98 g ( $1.19 \times 10^{-1}$  moles) of potassium oxalate in 150 mL of 33% aqueous ethanol was placed into an autoclave at 60 psig and  $110^{\circ}$  for 17 hours. The autoclave was allowed to cool to room temperature before venting. The product was removed with acetone. The resulting mixture was filtered, the filtrate was concentrated in vacuo to an oil which solidified. The crude product was recrystallized from  $\text{CH}_2\text{Cl}_2$ -heptane to yield 9.74 g (68%) pure compound (m.p.  $129-130^{\circ}$ ). NMR( $\text{CDCl}_3$ ):  $\Delta 7.78(\text{m}, 4\text{H})$ ,  $\Delta 7.38(\text{m}, 2\text{H})$ ,  $\Delta 6.3(\text{s}, 1\text{H})$ ,  $\Delta 5.22(\text{q}, 2\text{H})$ ,  $\Delta 3.80(\text{m}, 2\text{H})$ ,  $\Delta 1.30(\text{t}, 3\text{H})$ . IR(KBr):  $3500-3300 \text{ cm}^{-1}$ , and  $2970 \text{ cm}^{-1}$ .

Anal. calculated for  $\text{C}_{14}\text{H}_{14}\text{O}_2$ : C, 78.48, H, 6.59

Found: C, 78.25; H, 6.61

Mass spectrum:  $\text{M}^+$  (observed) is 214. Calculated for  $\text{C}_{14}\text{H}_{14}\text{O}_2$ : is 214.099. Other ions at  $\frac{m}{e}$  185, 170, 169, 142, 141, 139, 129, 115, and 85.

7,9-Pentamethylenecyclohepta[b]naphthalene-8-ol

A suspension containing 0.12 g ( $4.45 \times 10^{-4}$  moles) of 7,9-pentamethylene-8H-cyclohepta[b]naphthalene-8-one 27a, 0.15 g ( $3.95 \times 10^{-3}$  moles) of lithium aluminum hydride, and 10 mL of dry tetrahydrofuran (THF) was stirred for 17 hours at  $40^{\circ}$ , under nitrogen. The reaction was shown to be complete by TLC (silica gel; solvent: 4% MeOH/25% EtOAc/71%  $\text{CH}_2\text{Cl}_2$ ). The reaction mixture was cooled in an ice bath, and

cold water was added slowly, with stirring. The reaction mixture was filtered and THF removed in vacuo. The resulting aqueous layer was extracted with methylene chloride, dried ( $\text{MgSO}_4$ ), filtered, and concentrated in vacuo to give a white solid. The alcohol was recrystallized (from  $\text{CH}_2\text{Cl}_2$ /heptane) to give  $7.5 \times 10^{-2}$  g (61%) (m.p. 116-117<sup>o</sup>).  
 NMR( $\text{CHCl}_3$ ):  $\Delta 7.93(\text{s}, 1\text{H})$ ,  $\Delta 7.72(\text{m}, 2\text{H})$ ,  $\Delta 7.39(\text{m}, 3\text{H})$ ,  $\Delta 6.40(\text{s}, 1\text{H})$ ,  $\Delta 4.8$  (d, 1H),  $\Delta 4.2(\text{d}, 1\text{H})$ ,  $\Delta 2.80-1.10(\text{m}, 12\text{H})$ . IR(KBr): 3600-3100  $\text{cm}^{-1}(\text{s})$ , 2875  $\text{cm}^{-1}$  and 1110  $\text{cm}^{-1}$ .

7,9-Hexamethylenecyclohepta [b]naphthalene-8-one

A suspension containing 0.32 g ( $1.77 \times 10^{-3}$  moles), 7,9-hexamethylene-8H-cyclohepta [b]naphthalene-8-one 27b, 0.21 g ( $5.53 \times 10^{-3}$  moles) of lithium aluminum hydride, and 10 mL of dry tetrahydrofuran (THF) was stirred for 17 hours at 40<sup>o</sup>, under nitrogen. The reaction was shown to be complete by TLC (silica gel; solvent:  $\text{CH}_2\text{Cl}_2$ ). The reaction mixture was cooled in an ice bath, and cold water was added slowly, with stirring. The reaction mixture was filtered and THF removed in vacuo. The resulting aqueous layer was extracted with methylene chloride, dried ( $\text{MgSO}_4$ ), filtered and concentrated in vacuo to give a white solid, 0.45 g (93%), recrystallization was not necessary, but acetone can be used to recrystallize alcohol. NMR( $\text{CDCl}_3$ ):  $\Delta 7.7(\text{unres}(\text{s}) \text{ over a m}, 4\text{H})$ ,  $\Delta 7.3(\text{m}, 2\text{H})$ ,  $\Delta 6.4(\text{s}, 2\text{H})$ ,  $\Delta 4.1(\text{s}, 1\text{H})$ ,  $\Delta 2.8(\text{b}, 2\text{H})$ ,  $\Delta 2.3(\text{b}, 3\text{H})$ ,  $\Delta 1.9-1.2(\text{b}, 6\text{H})$ . IR(KBr): 3600-3200 (s) (-OH)  $\text{cm}^{-1}$ , 3030  $\text{cm}^{-1}$ , 2970  $\text{cm}^{-1}$ , and 1100  $\text{cm}^{-1}$ .

2,7-Pentamethylenecyclohepta [4,5-b] naphthotropylium perchlorate

A solution containing  $7.5 \times 10^{-2}$  g ( $2.71 \times 10^{-4}$  moles) of 7,9-pentamethylenecyclohepta [b] naphthalene-8-ol 28a was dissolved in 25 mL anhydrous ether at  $5^{\circ}\text{C}$ , 1 mL of 70%  $\text{HClO}_4$  was added slowly. The reaction solution turned yellow, TLC (silica gel; solvent:  $\text{CH}_2\text{Cl}_2$ ) showed the reaction was complete. The ether layer was isolated and dried ( $\text{MgSO}_4$ ), filtered, and concentrated in vacuo to a dark oil, which was flash chromatographed on silica gel with methylene chloride. No product was isolated.

2,7-Hexamethylenecyclohepta [4,5-b] naphthotropylium perchlorate

A solution containing 0.45 g ( $1.55 \times 10^{-3}$  moles) of 7,9-hexamethylenecyclohepta [b] naphthalene-8-ol was dissolved in 25 mL of anhydrous ether at  $5^{\circ}\text{C}$ , 1 mL of 70%  $\text{HClO}_4$  was added slowly. The reaction solution turned yellow, TLC (silica gel, solvent:  $\text{CH}_2\text{Cl}_2$ ), showed the reaction was complete. The ether layer was isolated and dried over  $\text{MgSO}_4$ , filtered, and concentrated in vacuo to an oil, which was flash chromatographed on silica gel with methylene chloride. A gold solid was isolated. NMR( $\text{CDCl}_3$ ):  $\Delta 8.3(\text{s}, 2\text{H})$ ,  $\Delta 7.9(\text{q}, 2\text{H})$ ,  $\Delta 7.4(\text{d}, 2\text{H})$ ,  $\Delta 7.3(\text{q}, 2\text{H})$ ,  $\Delta 7.2(\text{s}, 1\text{H})$ ,  $\Delta 3.0(\text{q}, 3\text{H})$ ,  $\Delta 2.0-1.2(\text{m}, 9\text{H})$ . IR(KBr):  $3350-3600 \text{ cm}^{-1}$ ,  $2920 \text{ cm}^{-1}$ ,  $1450 \text{ cm}^{-1}$ ,  $920 \text{ cm}^{-1}$ , and  $740 \text{ cm}^{-1}$ . Mass spectrum:  $\text{M}^+$  (observed) is 273. Calculated for the cation  $\text{C}_{21}\text{H}_{21}$  is 273.1638. Other ions at  $\frac{m}{e}$  275, 274, 270, 245, 232, 216, 215, 213, 207, 205, and 203.

## CHAPTER VI

### CONCLUSION

This report gives a reasonable synthesis of naphthalene-2,3-dialdehyde 18 from readily available starting materials at an affordable price in two steps, with the potential for macrogram production. Furthermore, an analytical method was devised for analyzing the purity of the dialdehyde 18.

The above enabled a series of 7,9-polymethylene-8H-cycloalkyl [b]naphthalene-8-ones 27b-d to be prepared, which made it possible to study the effect of the polymethylene bridge on the aromaticity and the planarity of the naphthotropylium ions. The former 27b-d were prepared by the condensation of various cyclic ketones and the dialdehyde 18, which enabled confirmation that the tropone ring system is planar if  $n \geq 6$ , thus implying that naphthotropones are more aromatic than benzotropones since the latter is planar only if  $n \geq 7$ . Reduction of the naphthotropones with lithium aluminum hydride gave the corresponding alcohols, which were converted to the naphthotropylium perchlorates, and are isolatable only if  $n \geq 6$ . This salt forms only if the tropone ring is planar as was supported with proton NMR data, which indicates the positive charge is delocalized over the naphthalene and tropone ring system 30b if  $n \geq 6$ . In short, from the available data, the order of aromaticity for the following tropone derivatives is: tropone > naphthotropone > benzotropone > pyrazolotropone (33) > furotropone.

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