PART I
THE SYNTHESIS OF HIGHLY SUBSTITUTED PERI-METHYLATED ANTHRACENES

PART II
MISCELLANEOUS

Dissertation for the Degree of Ph. D.
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JACK BAU-CHIEN JIANG
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thesis entitled

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Jack B. Jiang

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Harold Hart

Major professor

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ABSTRACT

PART I

THE SYNTHESIS OF

HIGHLY SUBSTITUTED PERI-METHYLATED ANTHRACENES

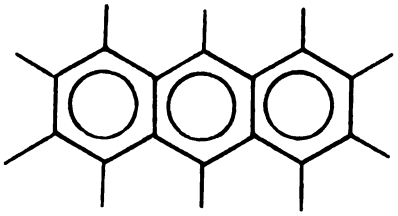
PART II

MISCELLANEOUS

By

Jack Bau-Chien Jiang

The purpose of the first part of this thesis was to synthesize highly methylated anthracenes, with decamethylanthracene (4) as the ultimate target compound. This synthesis presented the problem of constructing an aromatic system and, at the same time, keeping to a minimum the effects of peri interactions and annelation.



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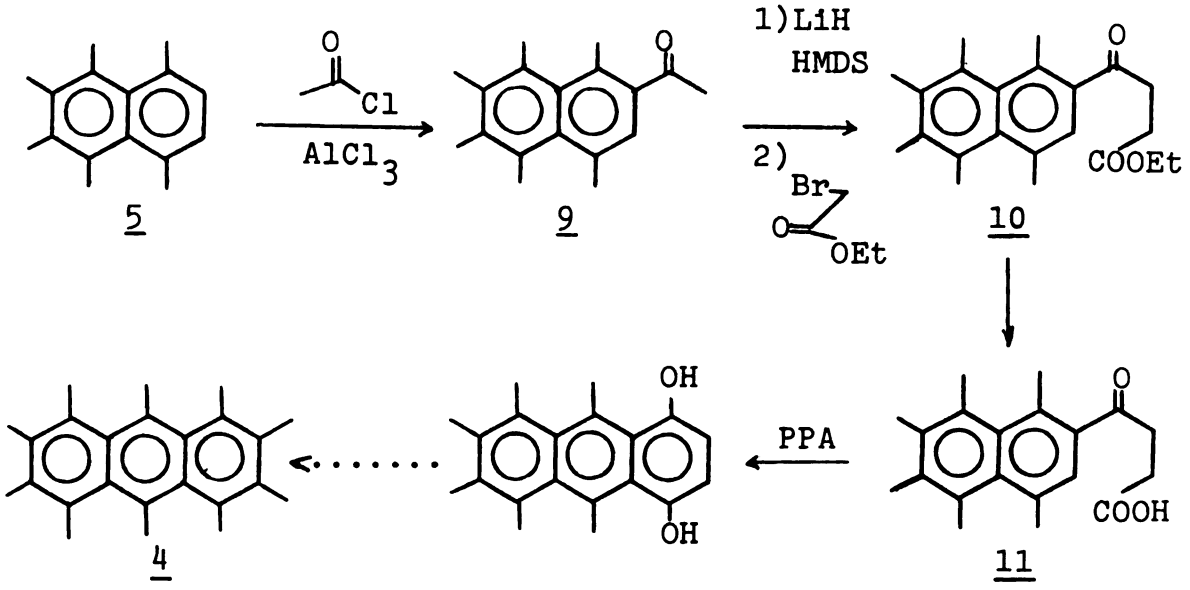
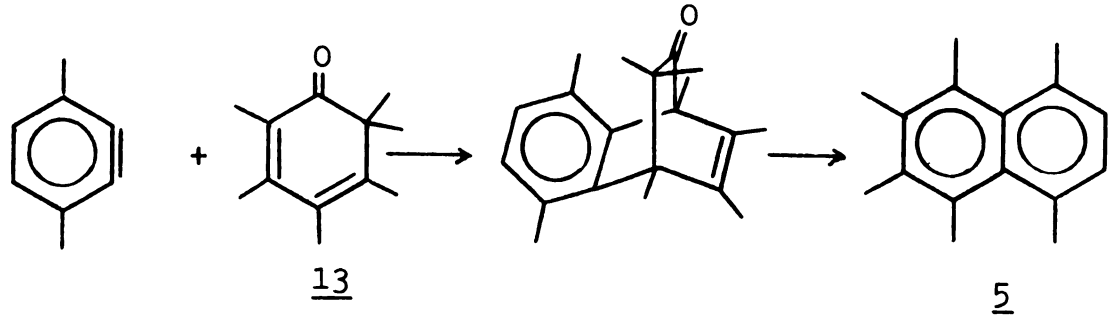
The first route began with hexamethylnaphthalene (5), which was converted to its acetyl derivative (9). Generation of the enolate anion of 9 followed by treatment with ethyl bromoacetate produced the keto ester 10, which in turn was hydrolyzed to 11. Ring closure of 11 was achieved but only in low yield; the further transformation of 11 to 4 was therefore abandoned.

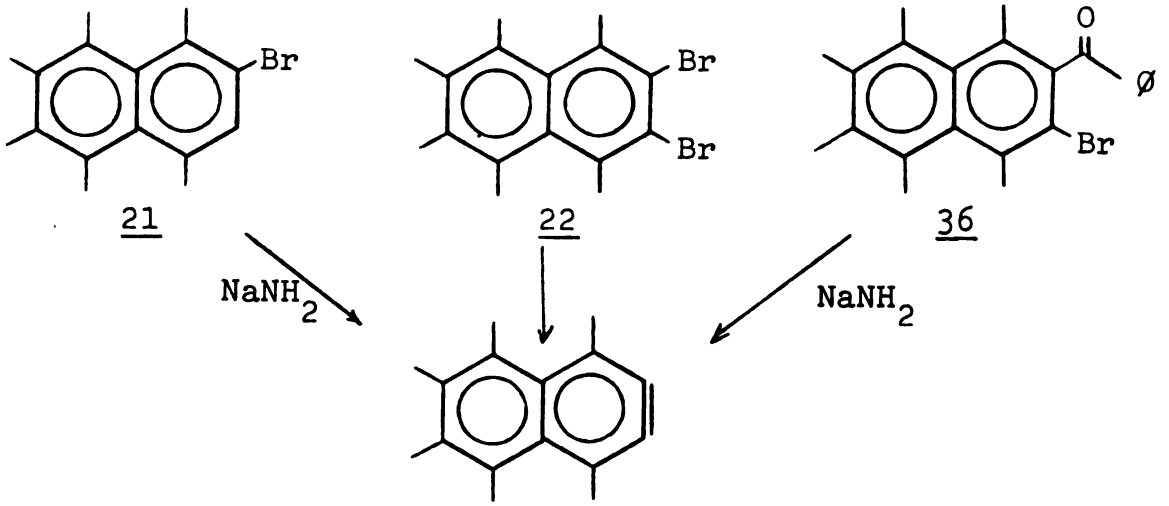


The second route was an imitation of the synthesis of 5, which was prepared from dimethylbenzyne and hexamethyldienone 13.

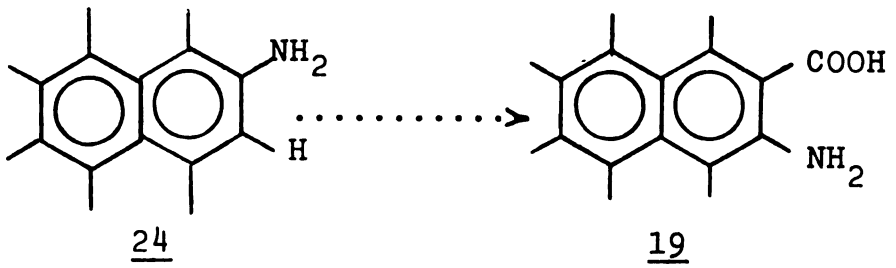


Hence, preparation of the 2,3-naphthyne turned out to be

the primary target in this synthesis. Compounds 21, 22, and 36 were synthesized as possible precursors of the desired 2,3-naphthyne; unfortunately none of them served this purpose successfully. Preparation of 19, the analogue of the

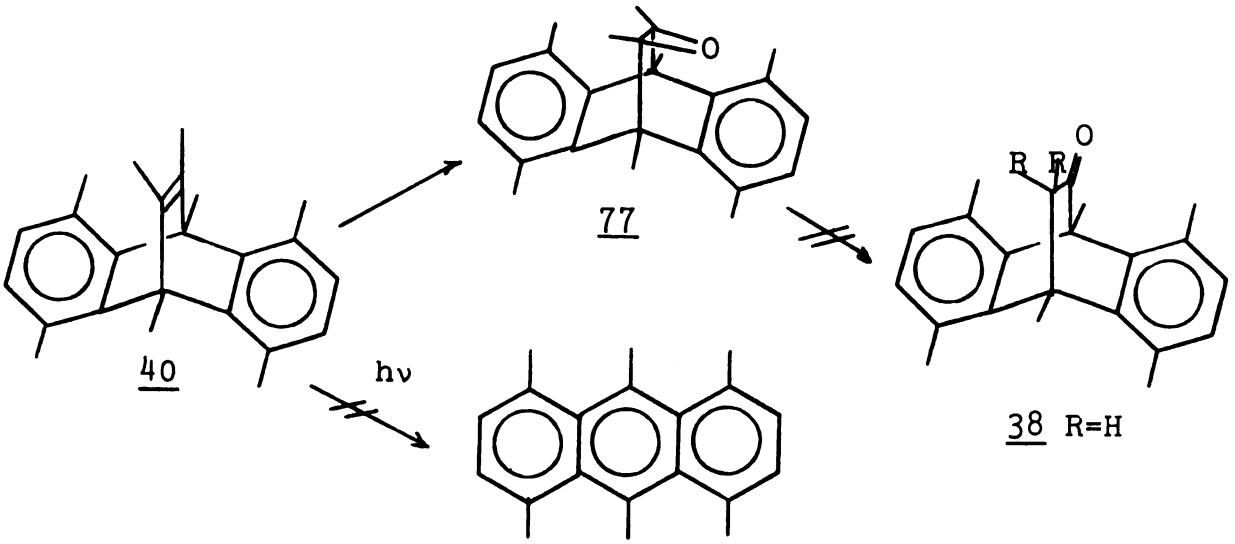


well-known naphthyne precursor 3-amino-2-naphthoic acid, was also tried. The instability and lack of a high-yield synthesis of 24 were obstacles to the preparation of compound 19.

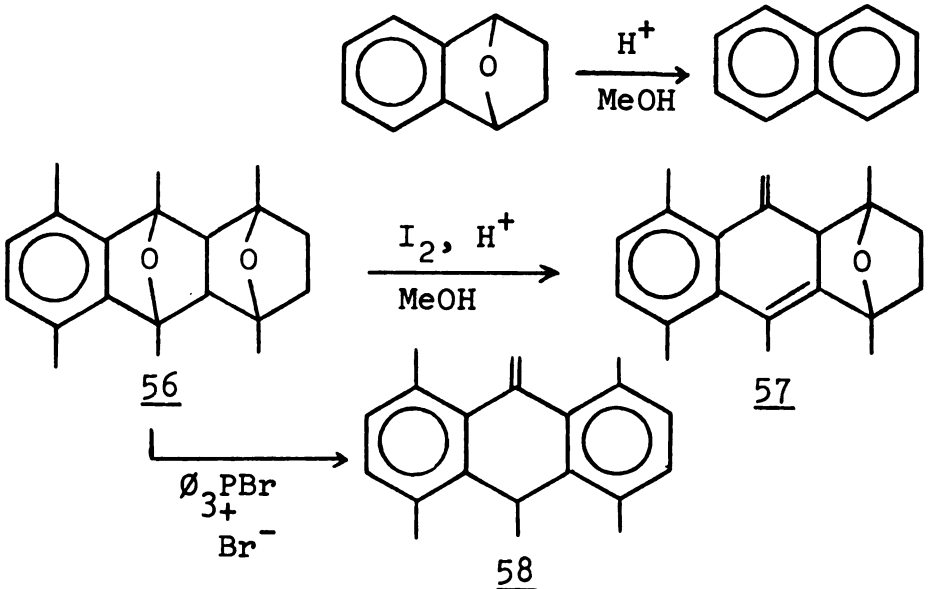


A bridged ketone 38, which would be expected to yield a peri-substituted anthracene on photolysis, was the key synthetic intermediate of the third route. The epoxide 77, obtained from the Diels-Alder adduct of 5 with dimethylbenzyne, did not afford the hoped-for gem-dimethyl analogue of 38 by a rearrangement reaction, and photolysis of 40 did not

eliminate 2-butyne but gave rearranged products.

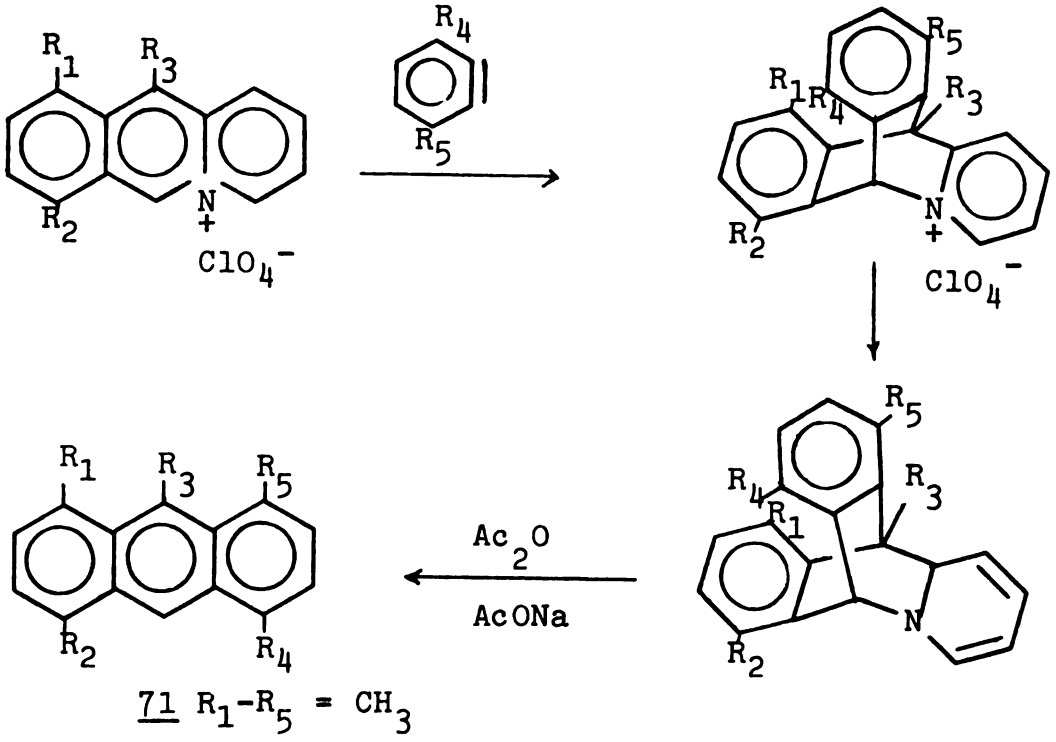


The fourth approach involved the extrusion of oxygens from the endoxide 56. The common procedures which work successfully with systems like tetrahydro-1,4-epoxynaphthalene, failed with 56. Iodine-catalyzed dehydration in acidic media only expelled one oxygen atom, to give 57. A special reagent, bromotriphenylphosphonium bromide, proved effective in extruding both oxygens, but gave 58 an isomer of 4.



The last synthetic route was the only satisfactory method which resulted in anthracenes with substituents at peri

positions. This method consisted of (1) chemical reduction of the appropriate benzyne adducts of acridizinium perchlorates followed by (2) thermolysis of the reduced adducts.



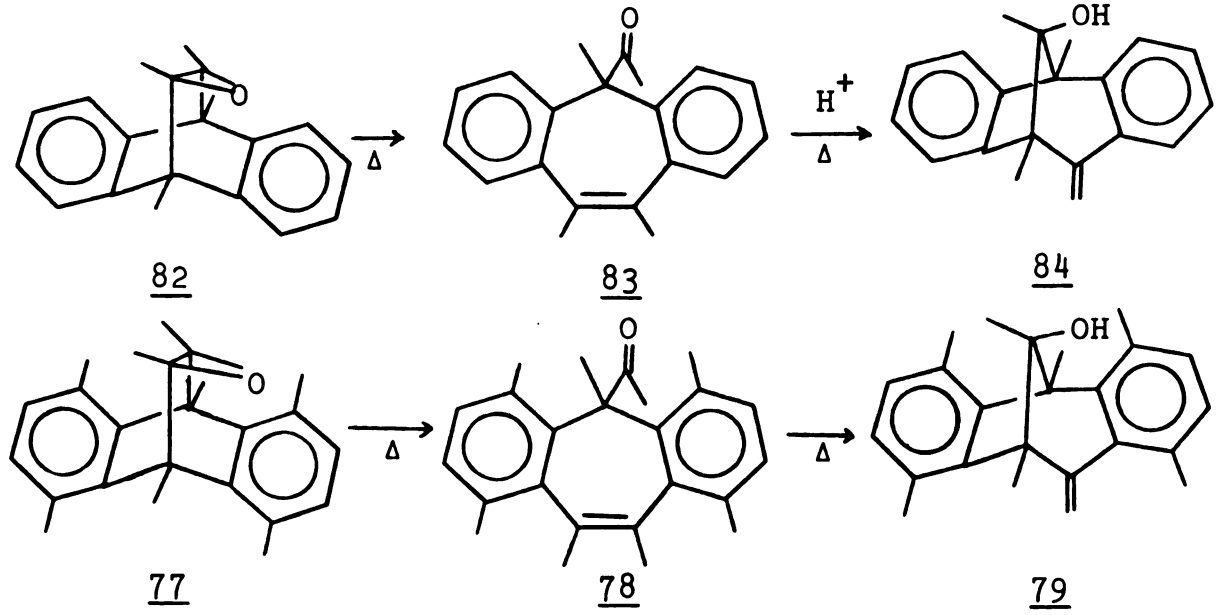
71 R_1-R_5 = CH_3

One of several anthracenes made by this method was pentamethylanthracene (71). A preliminary study of this compound revealed several consequences of strong peri interactions among the C_1-, C_8-, and C_9-methyls (R_1, R_3, R_4).

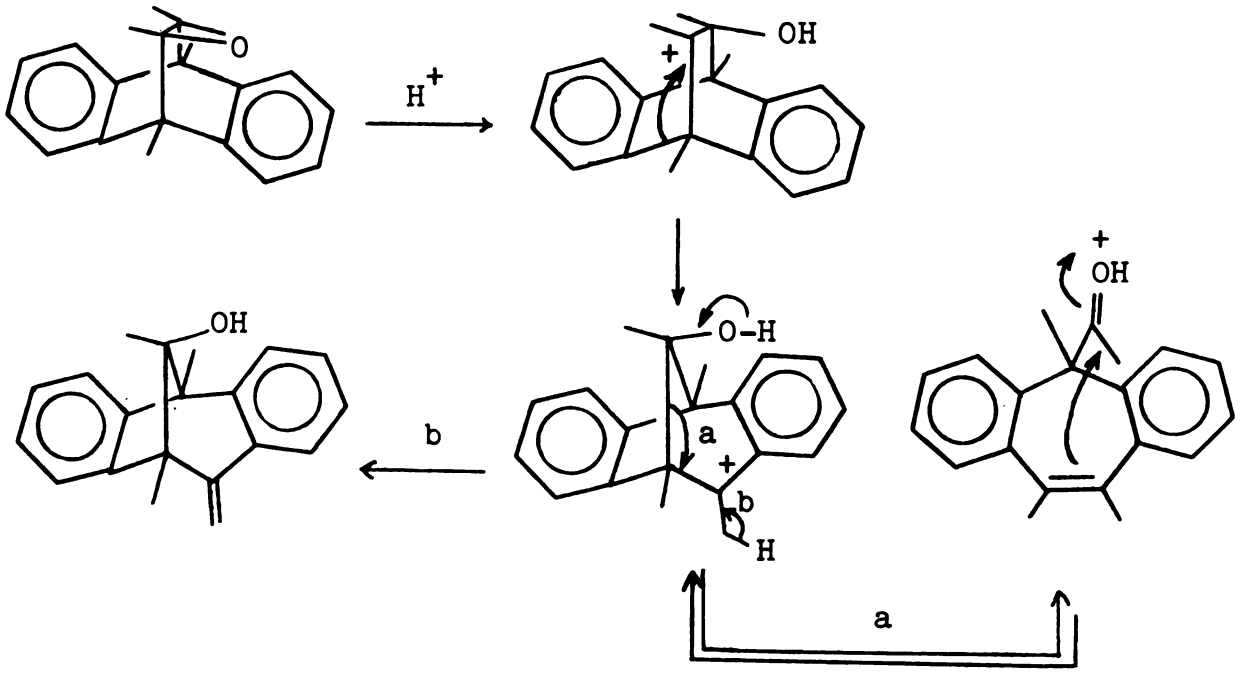
Miscellaneous results that constitute the second part of this thesis include (a) Wagner-Meerwein rearrangement in the dibenzobicyclooctadiene system, (b) non-conventional bromination of octamethylnaphthalene 2, and (c) Birch reduction of 2.

The epoxide 82 and its tetramethyl analogue 77 rearranged, in chloroform solution at room temperature, to 83 and 78 respectively. Compound 77 rearranged much faster than

82. Further rearrangement of 78 to 79 in refluxing chloroform was observed, whereas that of 83 to 84 was achieved only by adding traces of acid.

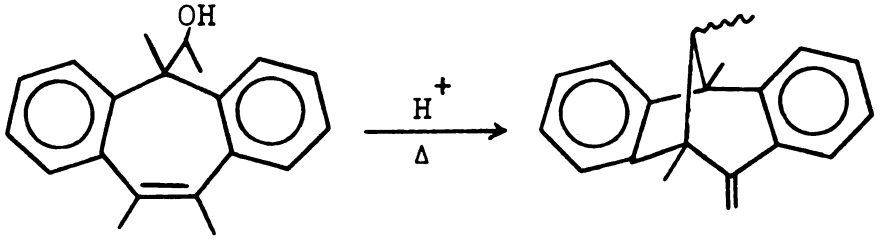


A mechanism for this reaction was proposed as:



The reaction was initiated by traces of acid contained in

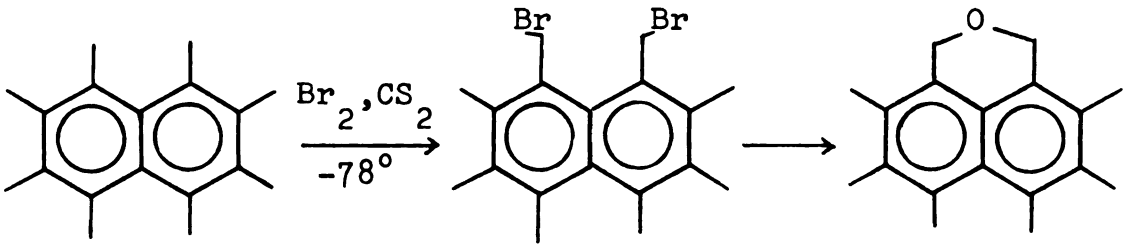
the solvent, because when the solvent was changed from chloroform to pyridine, the above rearrangement was not observed. Double bond participation was supported by the related transformation of 85 to 89 on heating with acid.



85 89

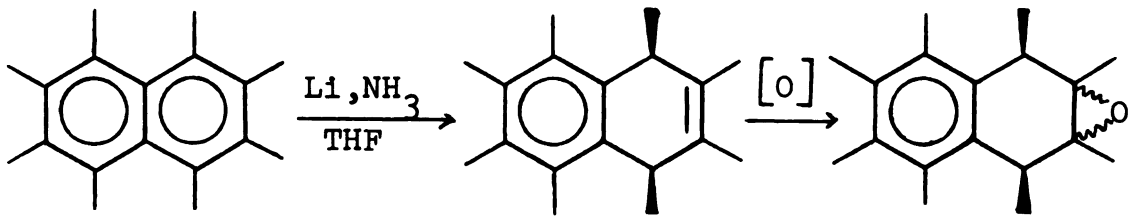
Compound 78 was severely overcrowded. It was not possible to construct a space-filling model of 78, and its nmr spectrum did not show the symmetry expected for free rotation of the acetyl group. Compound 83, however, gave a beautiful symmetrical nmr spectrum at room temperature due to the free rotation of the acetyl group. But as the temperature was lowered to 10°, rotation became hindered and the nmr spectrum of 83 became consistent with that of 78. At much lower temperatures there were signs that rotation of the quaternary methyl substituent was hindered.

Bromination of 2 in CS_2 at -78° in the dark gave 90 which was readily hydrolyzed and dehydrated to give 91.



2 90 91

Birch reduction of 2 with lithium and ethanol in THF and liquid ammonia produced 1,4-dihydrooctamethylnaphthalene (97) in high yield. The cis-geometry at C_1 and C_4 in 93 was demonstrated by epoxidation, which afforded an epoxide with a symmetrical nmr spectrum.



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PART I

THE SYNTHESIS OF HIGHLY SUBSTITUTED PERI-METHYLATED ANTHRACENES

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MISCELLANEOUS

By

Jack Bau-Chien Jiang

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The heavens declare the glory of God;
and the firmament sheweth his handywork.
Day unto day uttereth speech,
and night unto night sheweth knowledge.

Psalm 19: 1,2

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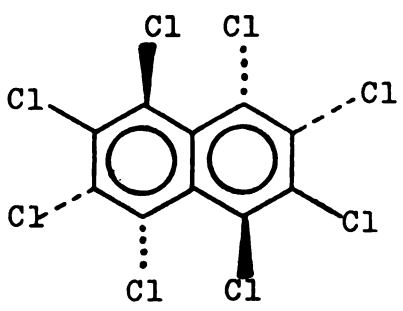
PART I

THE SYNTHESIS OF HIGHLY SUBSTITUTED PERI-METHYLATED ANTHRACENES

INTRODUCTION

A three-dimensional X-ray analysis of octachloronaphthalene was reported by Gafner and Herbstein in 1963.[1] They found that the molecule is severely deformed due to multiple displacements of the substituents and the nuclear carbon atoms. The α-chlorine atoms are displaced out of plane by 0.54-0.79 Å and the β-chlorine atoms are displaced by about 0.37-0.47 Å. The out-of-plane displacement of each carbon atom is about one-third as much and in the same direction as its halogen substituent. Furthermore, adjacent α and β chlorines are displaced in the same sense, so that the molecule takes on a propeller-like conformation (1). These results are contrary to the earlier findings of Donaldson and Robertson[2] regarding the molecular structure of octamethylnaphthalene. The latter workers suggested, on the basis of a two-dimensional X-ray analysis, that adjoining methyl groups are displaced in opposite directions so that they are alternately above and below the general plane of the molecule (2).



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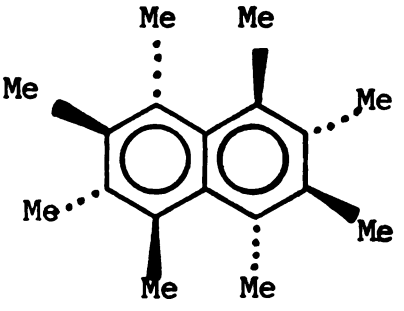


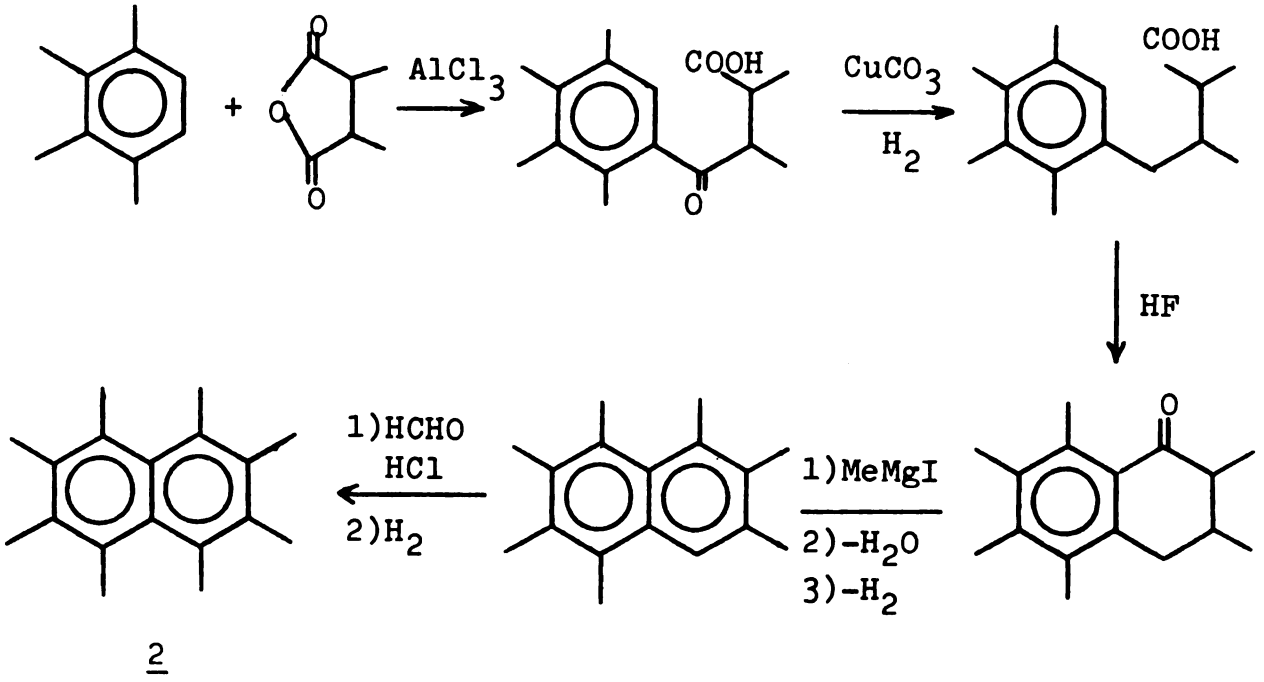
2

Gafner and Herbstein discussed steric strain and its relief in octachloro- and octamethylnaphthalene. If the substituents alternate above and below the molecular plane (i.e. 2), causing similar displacements of the ring carbons, the substituent interaction energy will be minimized but the skeletal strain will be considerable. In a propeller-like conformation (i.e. 1) there is more substituent interaction energy but less skeletal strain. The above authors believe that the former conformation will be energetically preferable only when the bonding is tetrahedral, as in cyclohexane; in overcrowded aromatic systems of the type discussed here, a propeller-like conformation is considered more likely.

In addition to the X-ray analysis, the peculiar molecular spectra of these fully substituted naphthalenes also reflect the fact that the molecule is distorted.[3] For example, 1,4,5,8-tetramethylnaphthalene has an ultraviolet absorption maximum at 296 nm whereas the all β-substituted 2,3,6,7 isomer has its absorption maximum at 270 nm. This bathochromic shift was believed to be the result of peri interactions between adjoining α-methyl groups. An even longer red shift which supported this view was observed in the uv spectrum of octamethylnaphthalene (308 nm). As for nmr spectra,[4] a significant deshielding (about 12 Hz) which appears to result from peri effects has been observed. For instance, the chemical shift (relative to water as external reference) of the methyl groups in 2,7-dimethylnaphthalene and its 1,8 isomer were reported to be 94.8 and 78.7 Hz respectively.[5] There has been no

clear-cut explanation as to how the peri interaction affects infrared spectra.

Compared to the original multi-step synthesis[6] of octamethylnaphthalene (Scheme 1), a simpler, higher-yield synthesis introduced by Hart and Oku in 1967 (Scheme 2)[7] serves as a more attractive starting point for further investigation of highly methylated aromatic systems.



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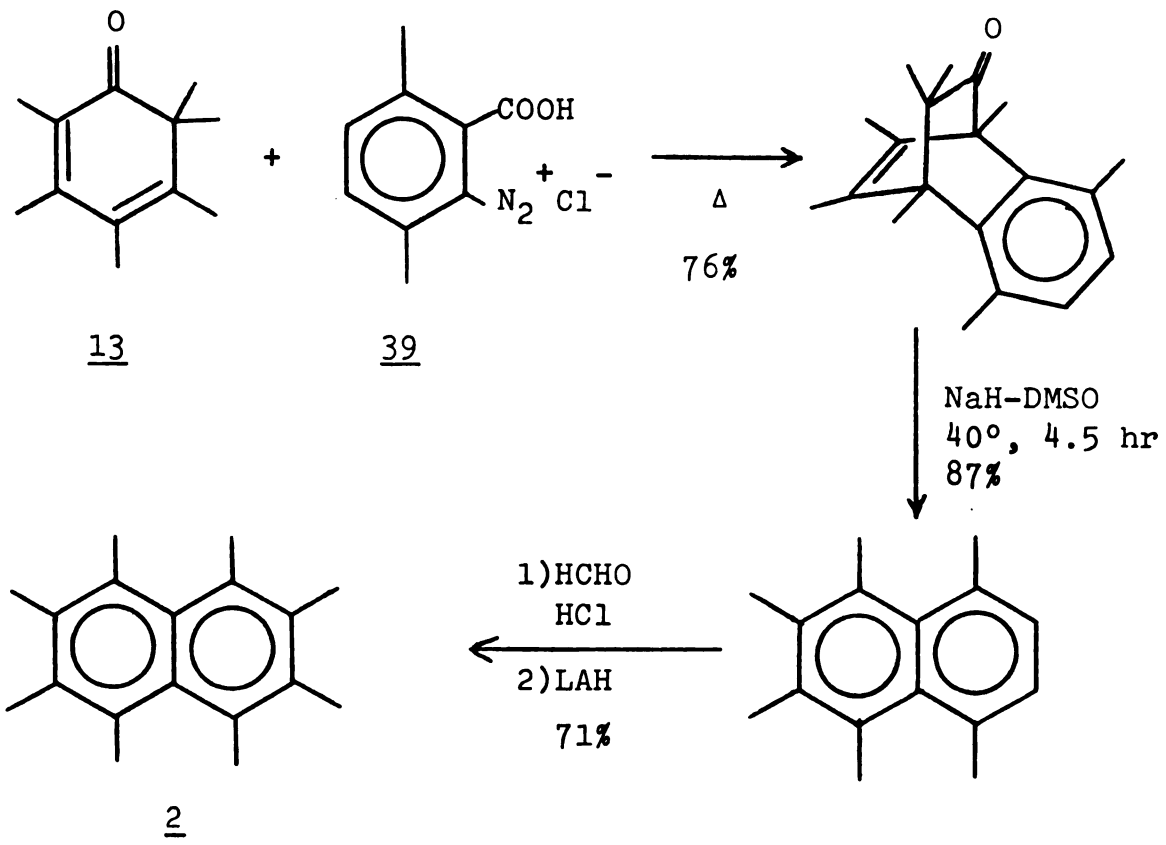
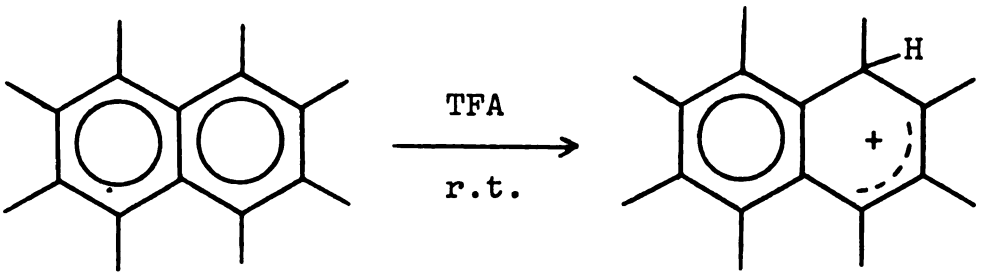
Scheme 1



Scheme 2

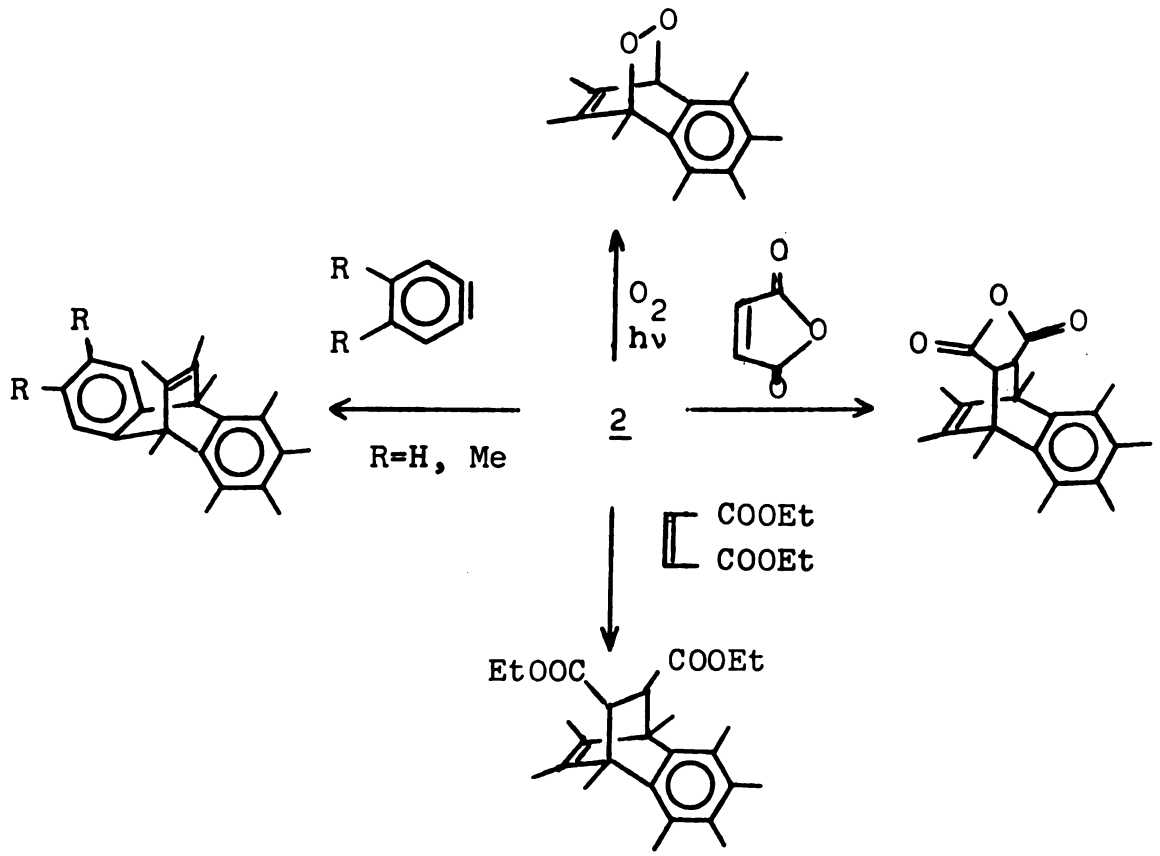
A reexamination of the three-dimensional X-ray structure of 2 indicated that it does have a propeller-like geometry analogous to that of 1.[8] It was expected that twisting of the molecule should alter the π-overlap in 2 and consequently affect its reactivity. An extensive study of its chemistry revealed the unusual reactivity of 2 toward electrophiles and dienophiles.[9] For example, 2 is fully protonated at an α-position in trifluoroacetic acid at room temperature, thus relieving in part the severe peri interactions.



2

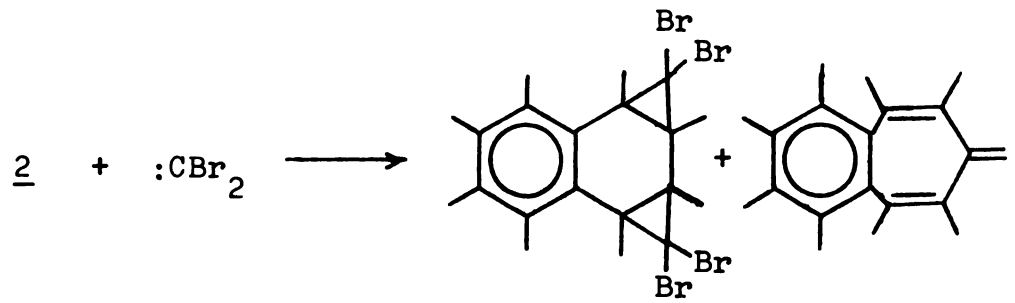
Facile electrophilic attack by bromine on 2 was observed, further details of which are included in the second part of this thesis.

Examples of cycloaddition reactions of 2 with dienophiles are shown in Scheme 3.

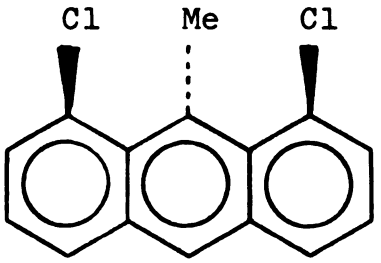


Scheme 3

While these reactions proceed in high yield, naphthalene itself reacts with maleic anhydride to form an adduct in very low yield.[10] There is no report of endoperoxide formation from naphthalene, and no adduct has been obtained from naphthalene and benzyne.[11] With dibromocarbene, 2 gave a homoannular bis adduct and a benzomethylene cycloheptatriene.[9] There were related reactions of naphthalene and certain carbenes, but the yields were hardly noticeable.[11]

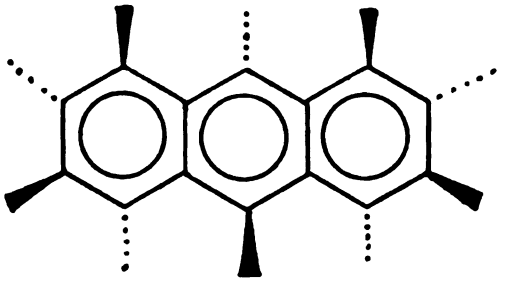


Although a number of anthracene derivatives with peri substituents have been synthesized,[11] only one crystal structure of an anthracene derivative with substituents at the 1, 8, and 9 peri positions has been determined.[12] Dellaca and coworkers found that overcrowding of the peri-substituents in 1,8-dichloro-9-methylanthracene (3) is relieved by a combination of in-plane and out-of-plane deformations. The chlorine atoms are 0.33 Å from the mean molecular plane whereas C_9 and the methyl carbon attached to it are on the opposite side of this plane, 0.19 and 0.80 Å respectively from it.



3

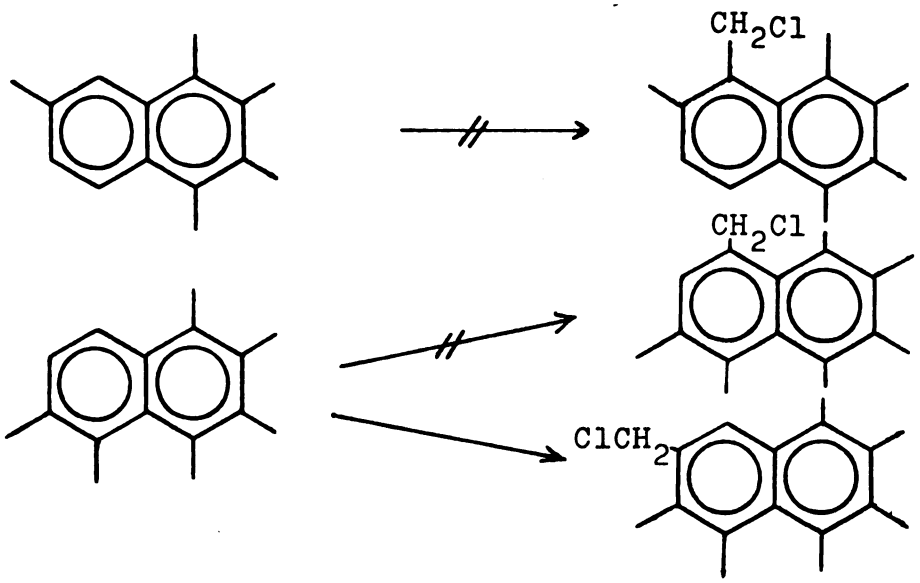
In light of above results, it was of interest to synthesize and study the chemistry of decamethylanthracene (4), which would have four peri interactions instead of two as in the octamethylnaphthalene system. This was the ultimate goal of this research.



4

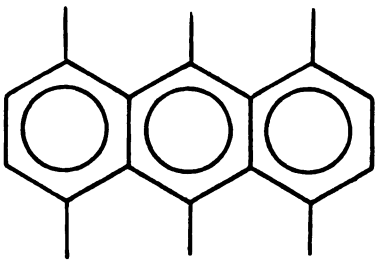
It was reported in the paper on the original synthesis of 2 (Scheme 1),[6] that the steric influence of the methyl group at position 4 caused the failure of 1,2,3,4,6-pentamethylnaphthalene to undergo chloromethylation at position 5. And contrary to the usual α-electrophilic substitution in naphthalenes, chloromethylation took place at the β-position

of 1,2,3,4,5,6-hexamethylnaphthalene.



Although the final stage of this synthesis involved a successful chloromethylation at the hindered α-position, the yield was extremely low (2%).

In view of the above facts, the best strategy for synthesis of a fully methylated anthracene would involve prior introduction of all the peri methyls; and the primary target compound would become either 6 or 7. Subsequent methylation at the β-positions would complete the synthetic process and give the final product 4. The results of different synthetic approaches to these highly substituted anthracenes are the subject of the first part of this thesis.



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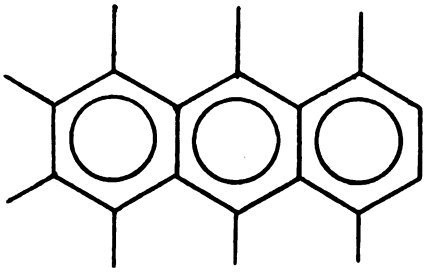
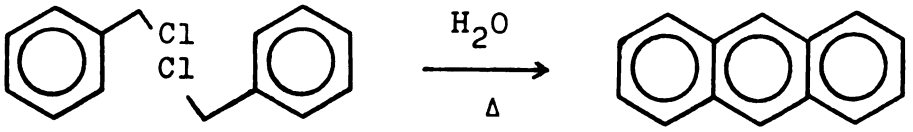


7

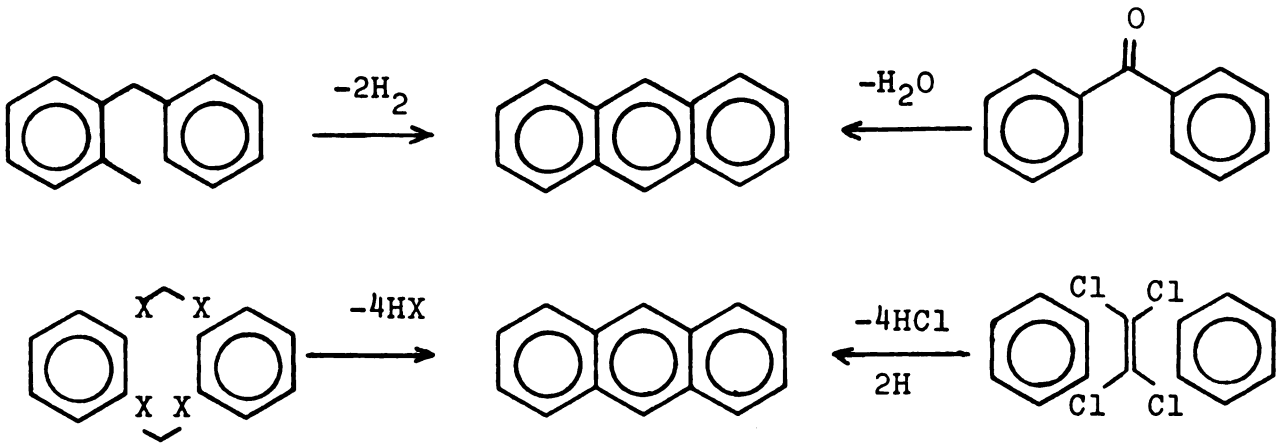
RESULTS AND DISCUSSION

A. Route I: via 1,4-Anthraquinone

The first synthesis of anthracene was achieved in 1866 by Limpricht, who obtained it by heating benzyl chloride with water.[11]



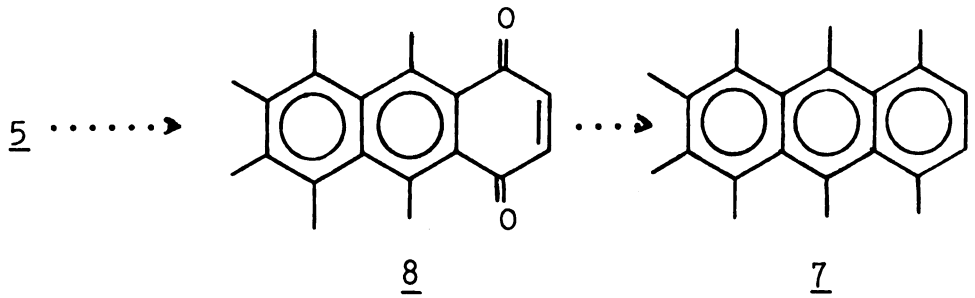
Since then, a large number of anthracene syntheses have been developed (for example, Scheme 4). Most of these processes are based on a single idea; that is, to construct the middle ring (ring B) from synthons having two well-established benzene rings (ring A and ring C).



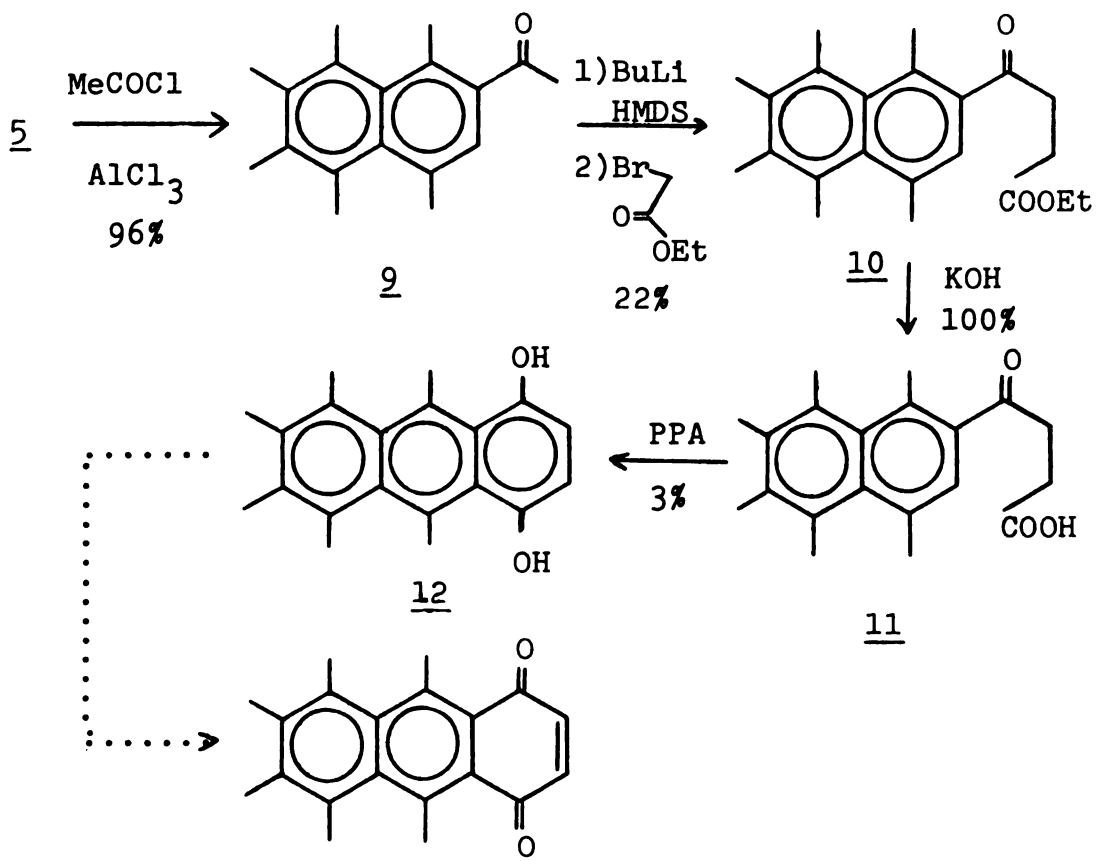
Scheme 4

However, this route seemed to be energetically unfavorable for our target system because of strong interactions between methyls at pre-peri positions. Moreover, the annelation effect of anthracene would produce less aromaticity in the middle ring, so that the driving force for the formation of the anthracene skeleton would probably not be strong enough to conquer the severe peri interactions. A better approach, therefore, might be to construct ring C after rings A and B have been set up with suitably located substituents.

Since a high-yield synthesis of 5 is available (Scheme 2), it seemed reasonable to try to synthesize the target compound 7 by building up the third ring on 5. A primary synthetic intermediate might be the quinone 8, with a benzoquinone moiety fused to the unsubstituted sites of 5. Methylation at both carbonyl groups followed by aromatization should give the all peri-methylated anthracene 7.

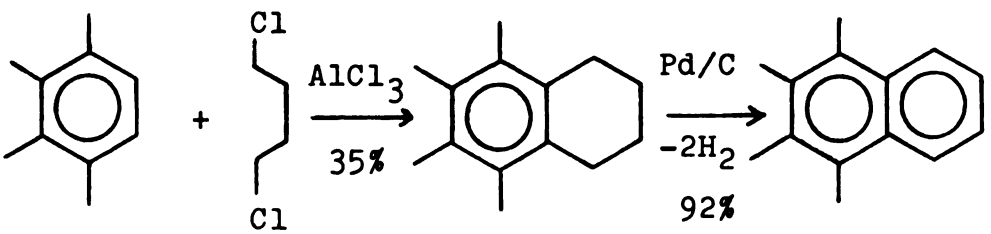


However reaction of 5 with either succinic anhydride or maleic anhydride in the presence of aluminum chloride did not give the desired 8 or its dihydro-derivative. Modest success was achieved in building the third ring by the sequence shown below.

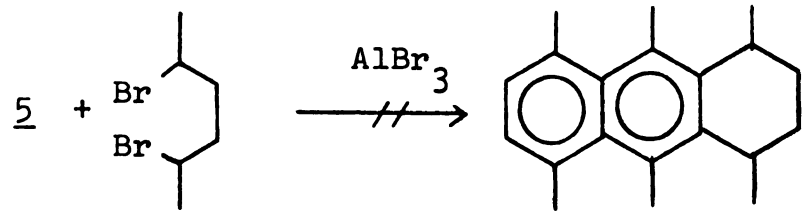


Friedel-Crafts acylation of 5 with acetyl chloride, using aluminum chloride as catalyst, gave a 96% yield of 9, which had a carbonyl absorption at 1690 cm^{-1}. On treatment with strong base (butyllithium in hexamethyldisilazane), the enolate anion of 9 was generated. Nucleophilic substitution on ethyl α-bromoacetate produced the keto ester 10, but in only 22% yield. Saponification[13] of 10 with KOH and cyclization of the resulting 11 with polyphosphoric acid afforded 12 (3%). The infrared spectrum of 12 showed no carbonyl absorption but a medium O-H stretching band at 3450 cm^{-1}. The nmr spectrum gave three singlets in the aromatic methyl region and one singlet in the aromatic proton region with relative intensities 3:3:3:1, consistent with the symmetric structure of 12. Although this product is only one step away from the desired quinone intermediate, the overall yield (0.63%) was low enough to discourage us from continuing this approach.

In 1971[14], Havsigk synthesized 1,2,3,4-tetramethylnaphthalene in good yield from prehnitene and 1,4-dichlorobutane.

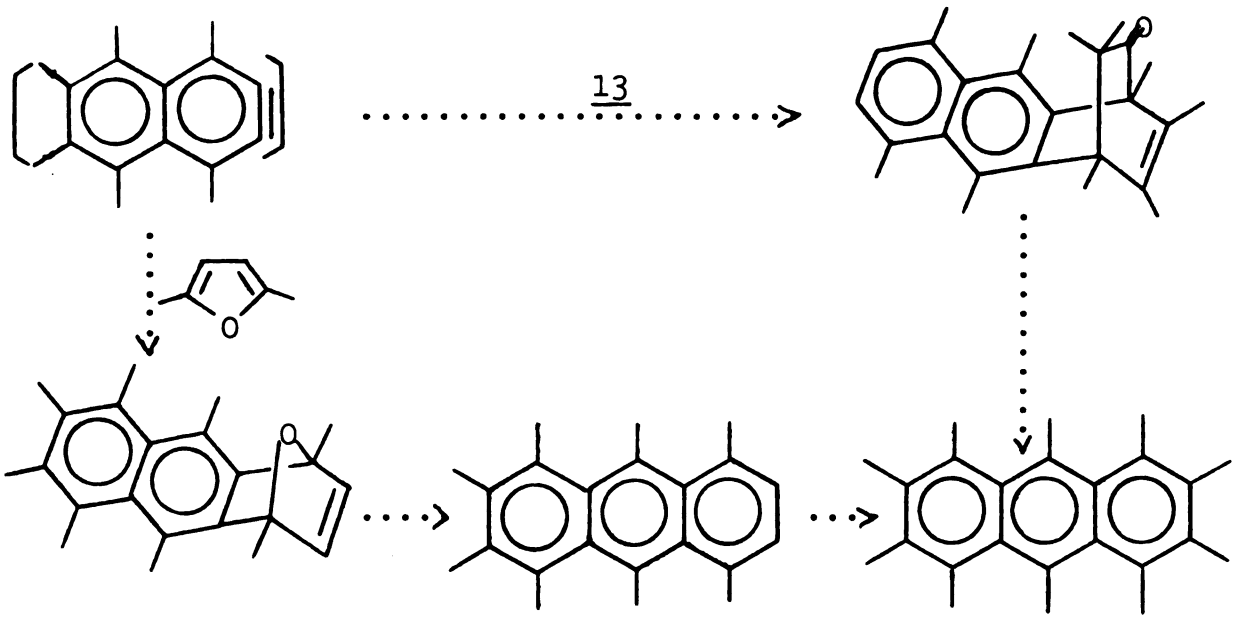


Attempts to prepare anthracene precursor based on a similar approach were tried under various conditions, but none of these ended up as expected.

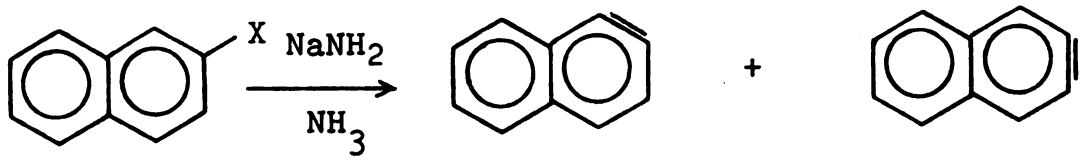


B. Route II: via Hexamethyl-2,3-naphthyne

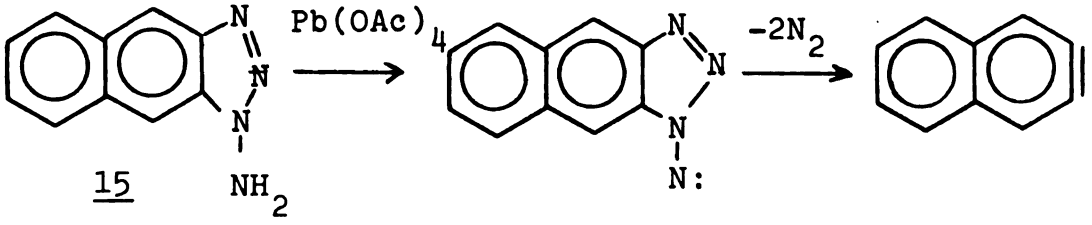
The second approach to our target compound was based on the synthesis of 5, which was formed by elimination of dimethylketene from the Diels-Alder adduct of 2,5-dimethylbenzyne and dienone 13 (Scheme 2). Thus, if a naphthyne could be formed at C_2 and C_3 of 5, it should undergo Diels-Alder addition with 13 or with dimethylfuran, and the adduct should be fairly easily aromatized.



For the purpose of obtaining our desired 2,3-naphthyne intermediate, a brief review of benzyne preparations seems to be essential. Many syntheses of benzyne involve removal of two adjacent substituents from an aromatic nucleus.[15] Among those well known benzyne precursors, only a few have been applied to the 2,3-naphthyne system. For instance,[16] naphthyne has been generated from a halonaphthalene (14) on treatment with strong base (e.g. $NaNH_2$); from aminonaphthotriazole (15) on oxidation by $Pb(OAc)_4$ followed by elimination of nitrogen; or from the commonly used 3-amino-2-naphthoic acid (16) on diazotization and thermal decomposition.



14



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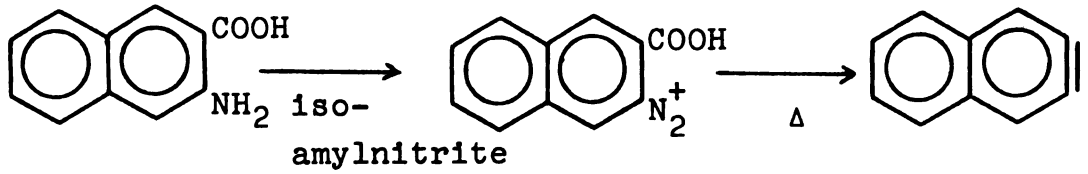
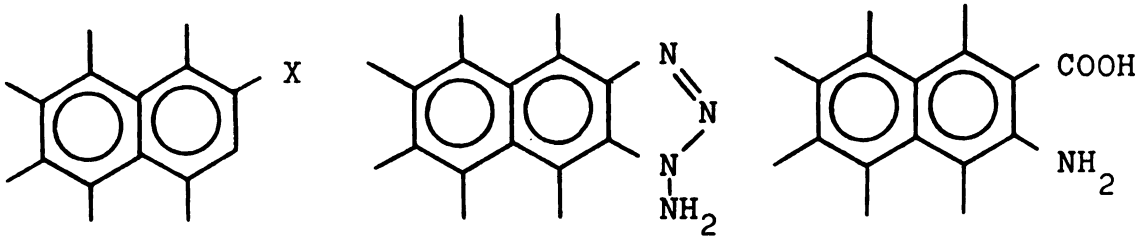


16

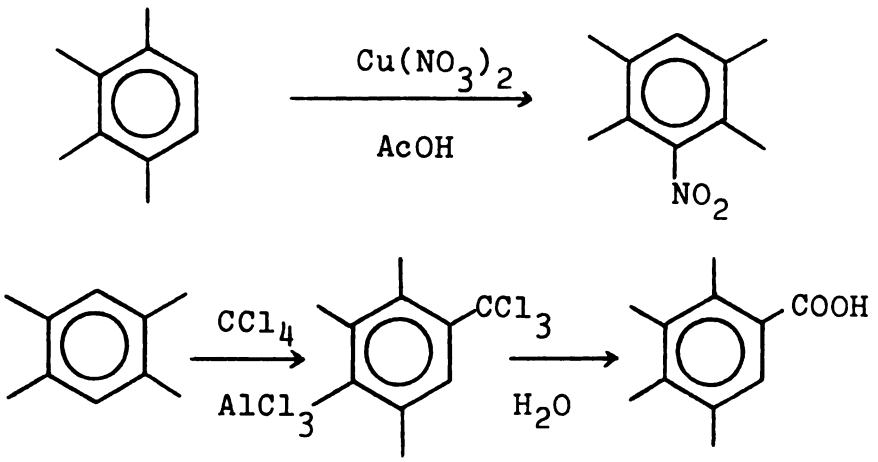
Consequently, the corresponding synthetic intermediates, 17, 18, and 19 were considered as promising candidates for our naphthyne precursors.



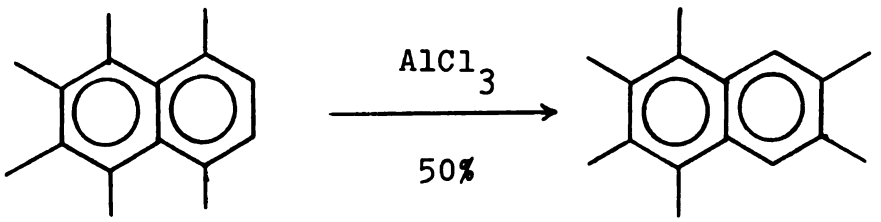
17 18 19

However, difficulties were experienced in introducing functional groups at the unsubstituted β-positions of 5. For example, being sensitive to strong acid, 5 was not readily nitrated. An unpublished result[17] by Hart and Oku illustrated

that an attempt to prepare nitroprehnitene resulted in producing nitrodurene instead; and carboxylation of durene with a Lewis acid (e.g. $AlCl_3$) in carbontetrachloride gave 2,3,4,5-tetramethylbenzoic acid after hydrolysis.

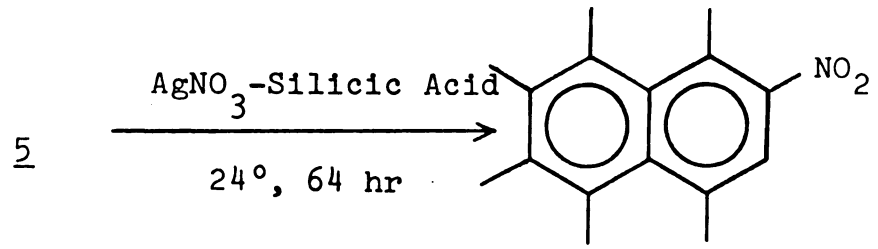


This type of methyl migration in acidic media was also observed by us, upon heating 5 with $AlCl_3$ at 40° for 4 hr.



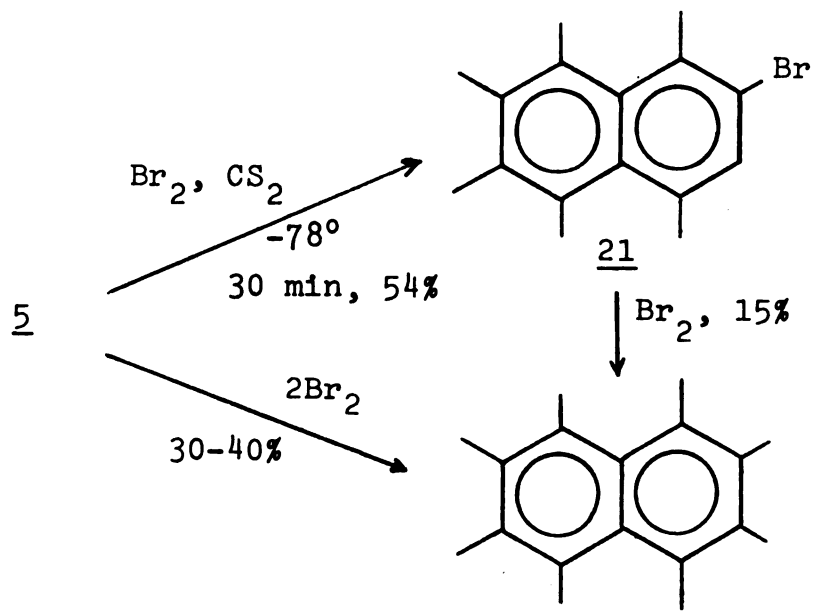
5

Nevertheless, 5 could be converted to 20 under the mild conditions of Gordon's method,[18] which was previously employed to nitrate benzene and anisole. However, a 2% yield of 20 inhibited any further exploration in this route.



20

A surprising achievement was obtained in the low-temperature bromination of 5. The reaction was carried out in darkness at dry-ice temperature (-78 °) and gave a 54% yield of 21 within 30 min. The mass spectrum (M^+ = 290) of 7 showed only one bromine (p + 2 = 98% of p), and the nmr spectrum revealed only one aromatic proton, at δ 7.15.

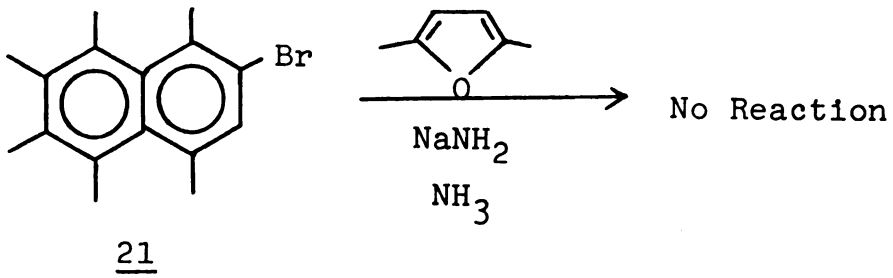


21

22

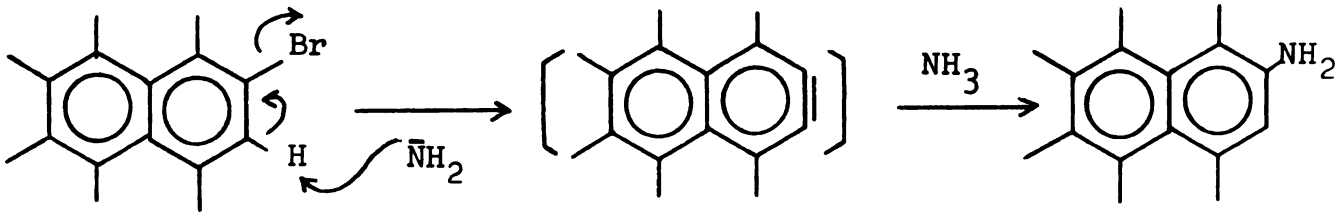
Dibromohexamethylnaphthalene (22) was also prepared under the same condition from either 5 or 21, with 30-40% and 15% yields respectively. The nmr spectrum of 22 showed no peaks in the aromatic region, and the mass spectrum gave p + 4, p + 2, and p peaks with relative intensities 1 : 2 : 1. These data indicated the presence of two bromine atoms on the aromatic ring.

Unfortunately, attempts to make naphthyne from 21 failed. Treatment of 21 with sodamide in liquid amonia and 2,5-dimethylfuran resulted in recovery of 21.



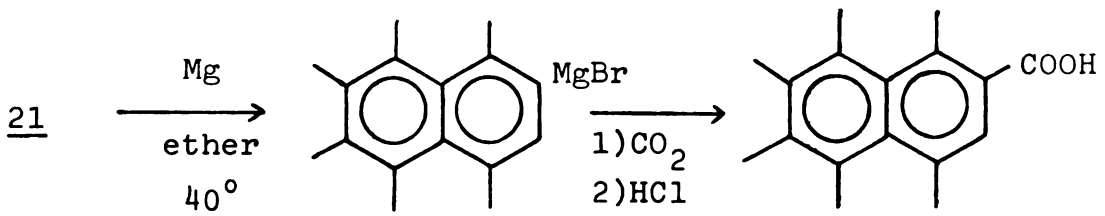
21

The 100% recovery implied that naphthyne was not formed; otherwise an amino derivative should have been observed. This may be due to the electron releasing inductive effect of the six methyls, which makes the proton too weakly acidic to be attacked even by as strong a base as NH_2^-.



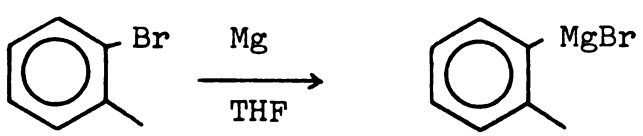
An alternative means of generating benzyne, designed by Wittig and by Huisgen, is the reaction of o-dihaloaromatic compounds with magnesium.[19] But treatment of 22 with magnesium in ether gave only negative results.

Following common procedures, the Grignard reagent of 21 was prepared and treated with carbon dioxide to produce a 50% yield of 23.

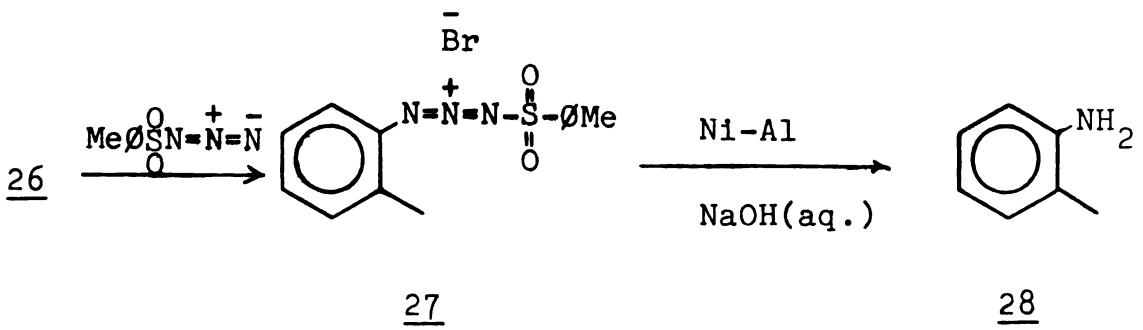


23

Since the Grignard reagent could be formed successfully, it might provide an entry to the synthesis of 24 inasmuch as a synthetic method for converting aryl halides into aryl amines via Grignard reagents had been devised in 1969.[20] It was reported that the Grignard reagent derived from o-bromotoluene reacted with solution of p-toluenesulfonyl azide[21] in THF to give a dark red solution was presumed to contain the species 27. This, on reduction by Raney nickel-aluminum alloy in aqueous NaOH, led to an overall 82% yield of amine 28.

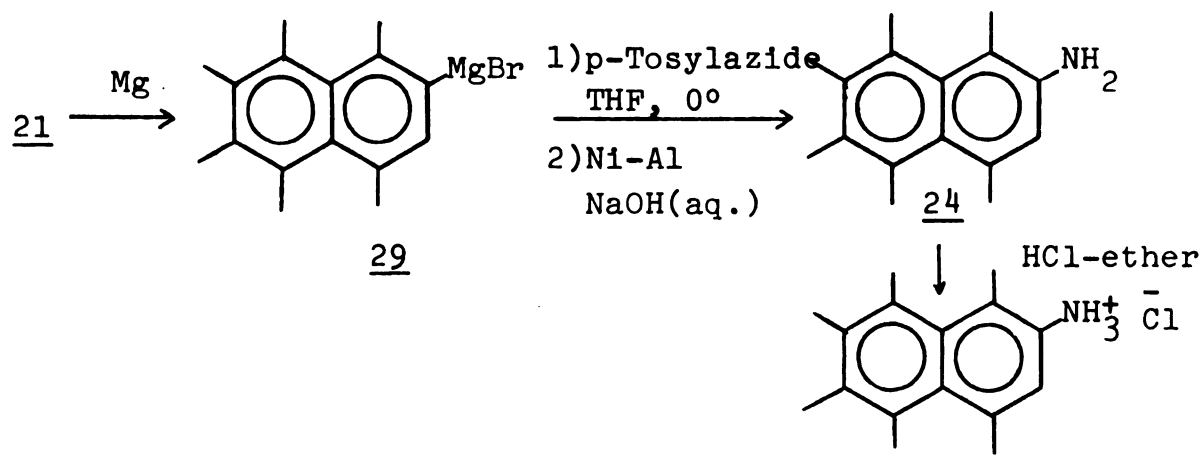


25 26



26 27 28

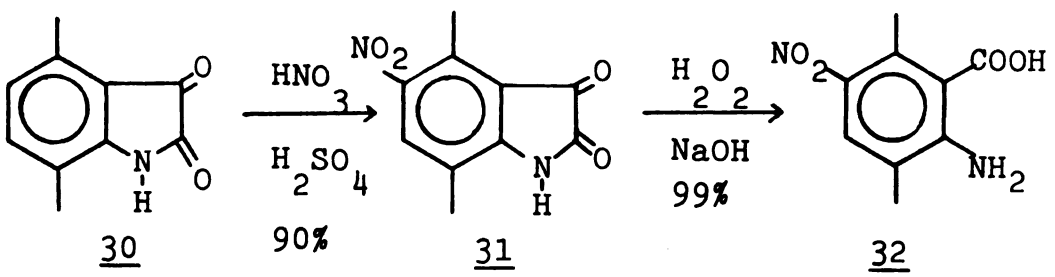
This method was applied to the present problem. On treatment with p-tosyl azide at 0° in THF for 1 hr followed by reduction with Raney nickel-aluminum alloy in NaOH aqueous solution, the hexamethylnaphthalene Grignard reagent (29) yielded 40% of 24, which was isolated as the ammonium chloride salt. A parent peak at m/e 227 in the mass spectrum (70eV) of 24 was also the base peak. The infrared spectrum showed N-H stretching absorption at 3400 cm^{-1} and N-H bending at 1600 cm^{-1}; the nmr spectrum showed six methyls between δ2.20-2.55, two amino protons at δ3.40 and one aromatic proton at δ6.30.



21 29 24

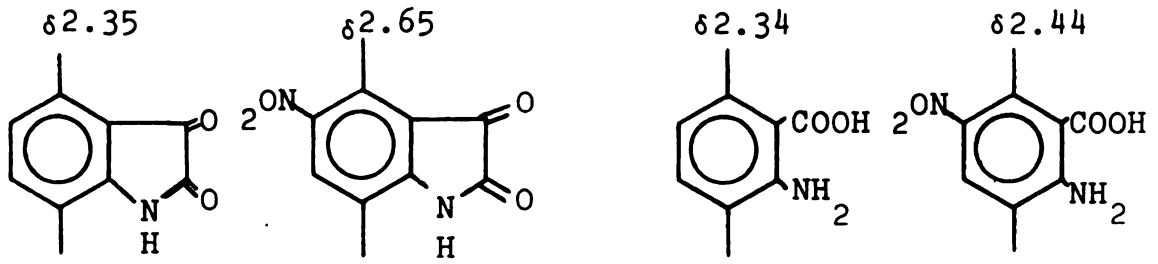
Owing to the inconvenience of the amination of 5, introduction of the amino group at an earlier stage in the synthesis would be a better alternative for the preparation of 24.

In 1925, 5-nitroisatin was prepared by the nitration of isatin with sulfuric acid and fuming nitric acid.[22] By following the same procedure, 31 was prepared in a 90% yield from commercially available 3,6-dimethylisatin. The subsequent ring opening with 3% hydrogen peroxide in 10% sodium hydroxide resulted in 32 (99%).



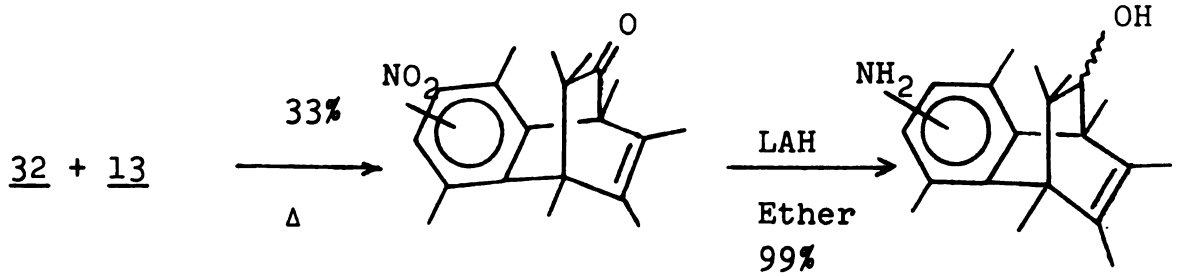
30 31 32

The nmr spectrum (CD_3CN) of 31 showed a singlet for the C_3-methyl at δ2.65, which was 10 Hz lower than the corresponding methyl signal in 30, due to the adjacent nitro group. Compound 32 gave a correct elemental analysis, and its nmr spectrum consisted of two three-proton singlets, one at δ2.10 and the other at δ2.44. Compared with the nmr (CD_3CN) of 3,6-dimethylanthranilic acid, these data are consistent with the structure which has the nitro group at C_4.



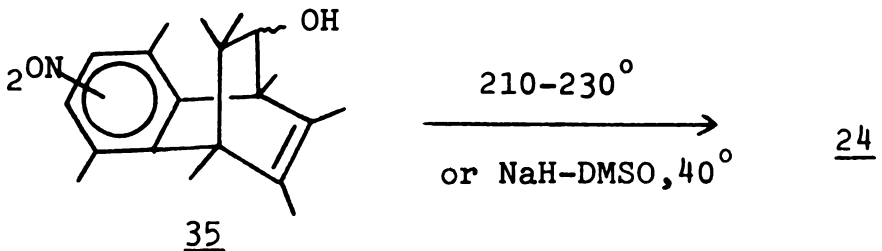
31 32

Diazotization of 32 followed by cyclo-addition with 13 afforded a 33% yield of adduct 34. Reduction of 34 with LAH in absolute ether at reflux temperature produced 35 (99%). The infrared spectrum of 35 showed that both the carbonyl and nitro groups were reduced (3500 cm^{-1}).



34 35

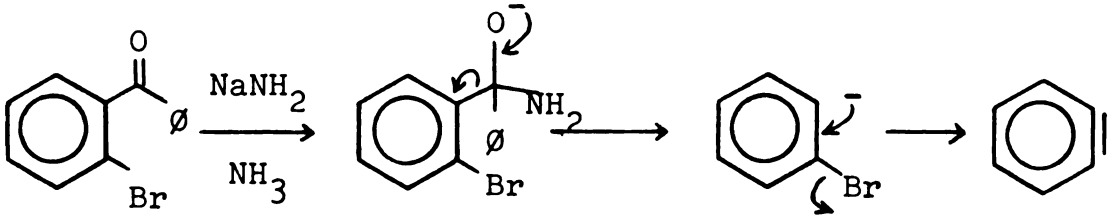
The transformation of 35 to 24 was achieved both by pyrolysis of 35 in benzene at 210-230°under nitrogen (22%) and by the reaction with dimslsodium[23] at 40° (10%).



35 24

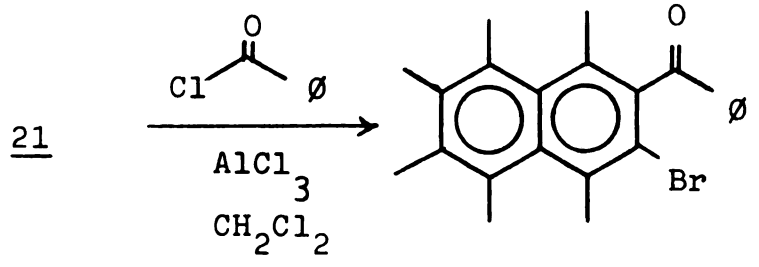
The instability of 24 (it decomposed into a dark oil at room temperature) and the lack of a high-yield synthetic pathway made this approach unattractive for 2,3-naphthyne synthesis.

Another possible route to the desired 2,3-naphthyne was based on a reaction of o-halo-aryl ketones that has been shown[15] to yield benzyne, probably via o-halogenophenyl anions (Scheme 5).



Scheme 5

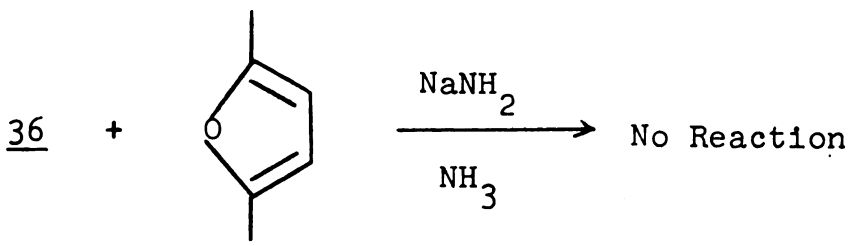
Since 21, the bromohexamethylnaphthalene, had been prepared in adequate yield, benzoylation of 21 would provide a convenient route to 36, the potential precursor of 2,3-naphthyne. In fact the benzoylation of 21 was easily accomplished by a



36

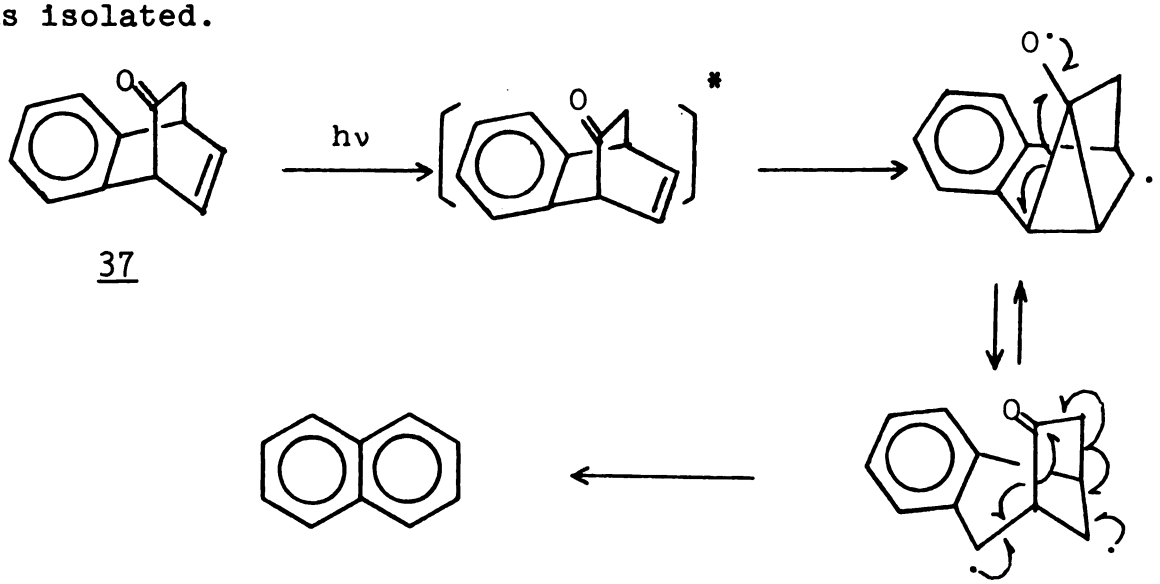
Friedel-Crafts type of reaction at -5∿5° in methylene chloride

with aluminum chloride as the catalyst (38% yield). The mass spectrum (70eV) of 36 showed one bromine (p + 2 = p) in the molecule; the infrared spectrum showed carbonyl absorption at 1680 cm^{-1}. Unfortunately, reaction of 36 with sodium amide in liquid ammonia in the presence of excess dimethylfuran as the diene, gave only a 100% recovery of the starting material.



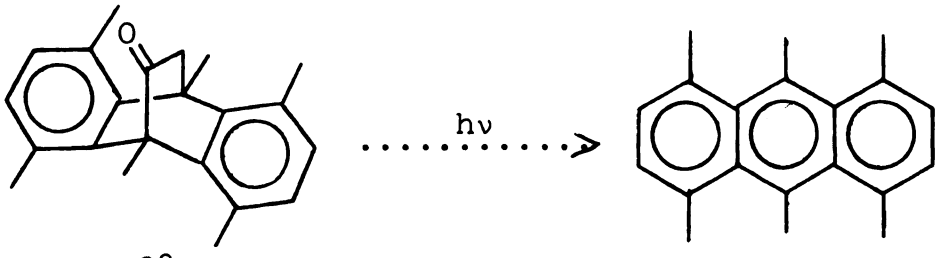
C. Route III: via Photolysis

Givens and Oettle[24] irradiated benzobicyclo [2.2.2] octadienone (37) in acetone. Among other products, naphthalene was isolated.



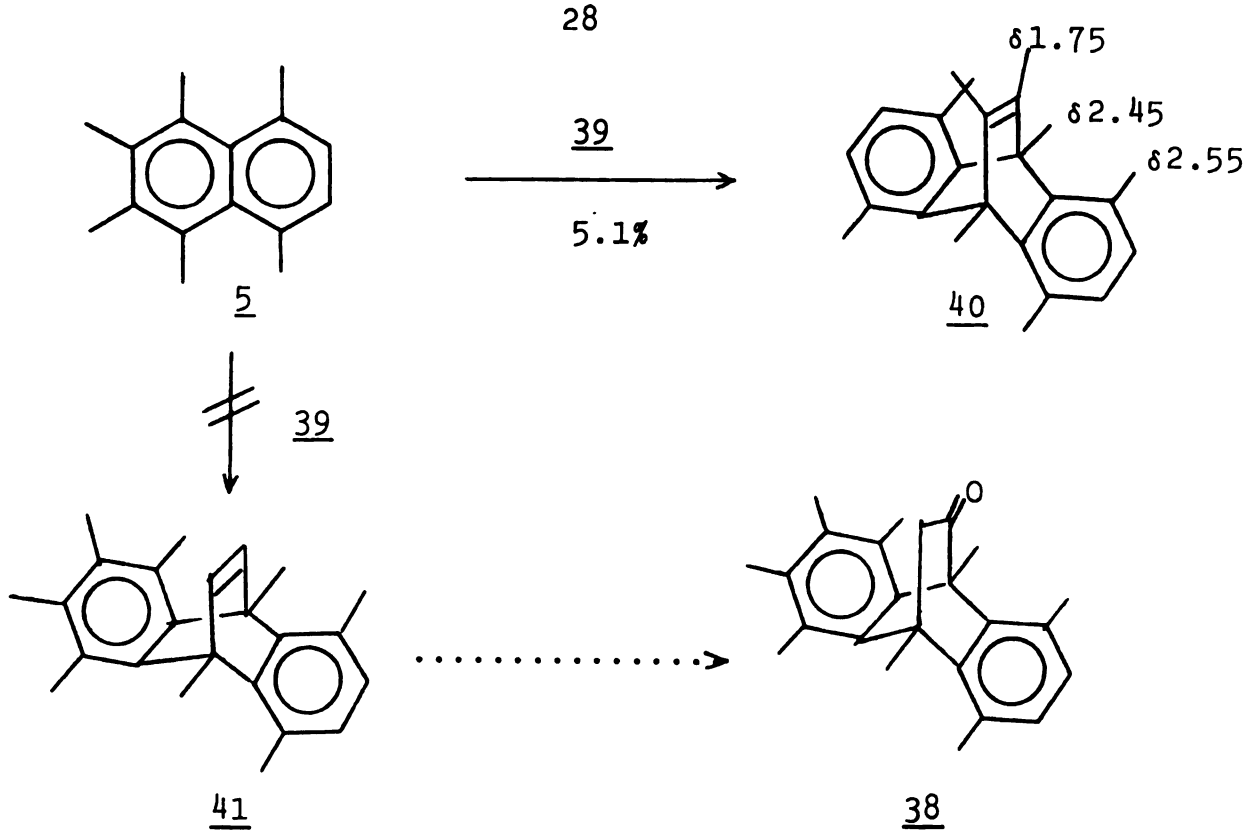
37

This approach suggested another possible route to the anthracene system. If we could make the corresponding dibenzobicyclo[2.2.2]octadienone (38) with three methyls aligned at all the peri positions, the target compound 6 should be easily obtained through photolysis.

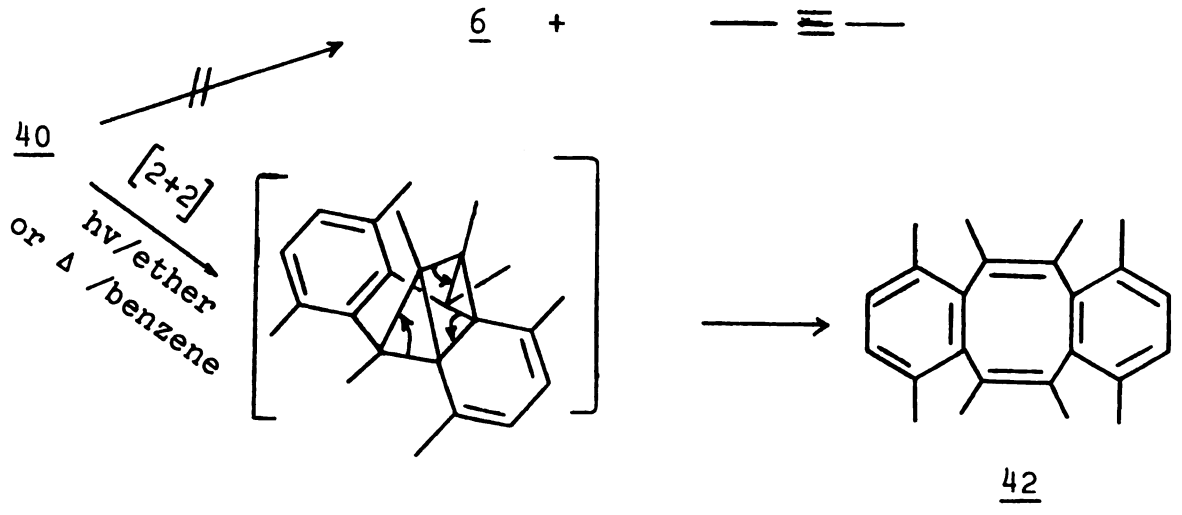


38 6

Cycloaddition of 5 to 39 gave 40 in 5.1% yield. Its nmr spectrum had a sharp singlet for the four aromatic protons at δ6.40 and other peaks as expected from the formula. Addition occurred exclusively on the ring with four methyl substituents. None of adduct (41) was obtained. The two-carbon alkene bridge in 40 could not be converted to a carbonyl-containing bridge, although epoxidation of 40 and subsequent rearrangement of the epoxdie did provide us with interesting results which are described in the second part of this thesis.

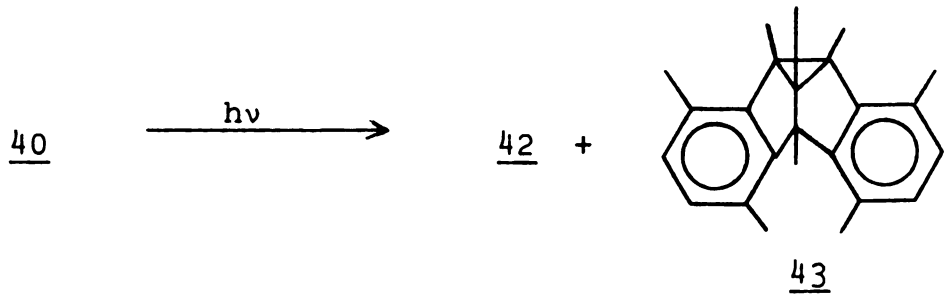


Pyrolysis (600°) or photolysis (Vycor) of 40 showed no elimination of 2-butyne but only the rearrangement product 42 (50-60%). Its nmr spectrum had three sharp singlets, one with four hydrogens at δ6.59 and two with four methyls each, at δ2.08 and 1.91.

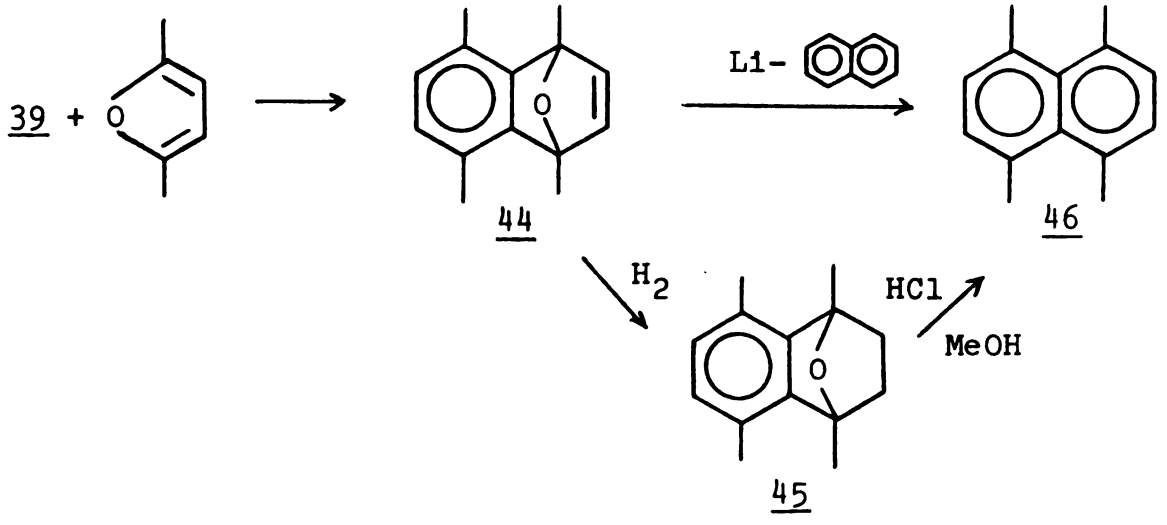


In addition to 42 (40%), irradiation of 40 in acetone using a Vycor filter gave 43 (50%) which was from a di-π-methane

rearrangement. This result is consistent with the irradiation of dibenzobarrelene in acetone,[25] which produced the dibenzo analogue of semibullvalene, except that dibenzosemibullvalene was formed exclusively (85%) and no product corresponding to 42 was reported.

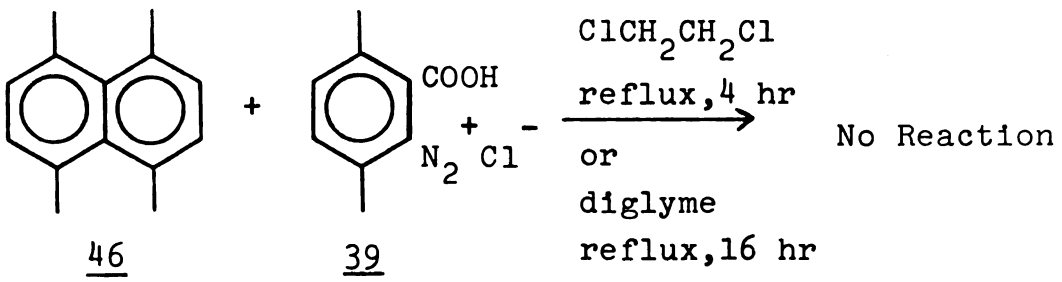


In order to avoid the problem presented by the two vinyl methyls in 40, compound 46 was synthesized (by two different routes). The endoxide 44, which was prepared from 39 and 2,5-dimethylfuran, was treated with lighium naphthalenide.[26] A 100% yield of 46 was obtained. This is the most efficient synthesis of compound 46 yet reported.[11,27] Compound 46 melts at 131-2° (lit. 132-3°).



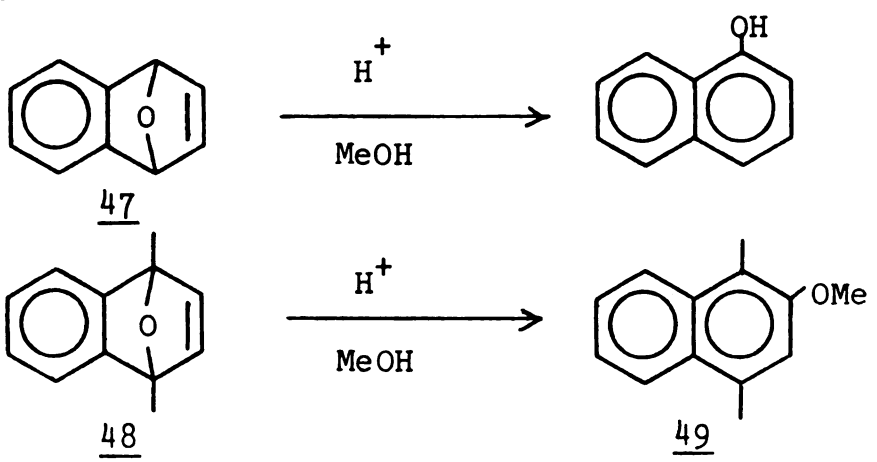
Another route to 46 involved the reduction of 44 followed by acid-catalyzed dehydration of the resulting 45 (see page 34). The yield of 46 by the latter route was no more than 60%.

The reaction of 46 and 39 was then carried out under the usual conditions. No expected adduct was obtained, and 46 was recovered unchanged. Higher temperatures and longer reaction times did not improve the inertness of 46 toward benzyne.

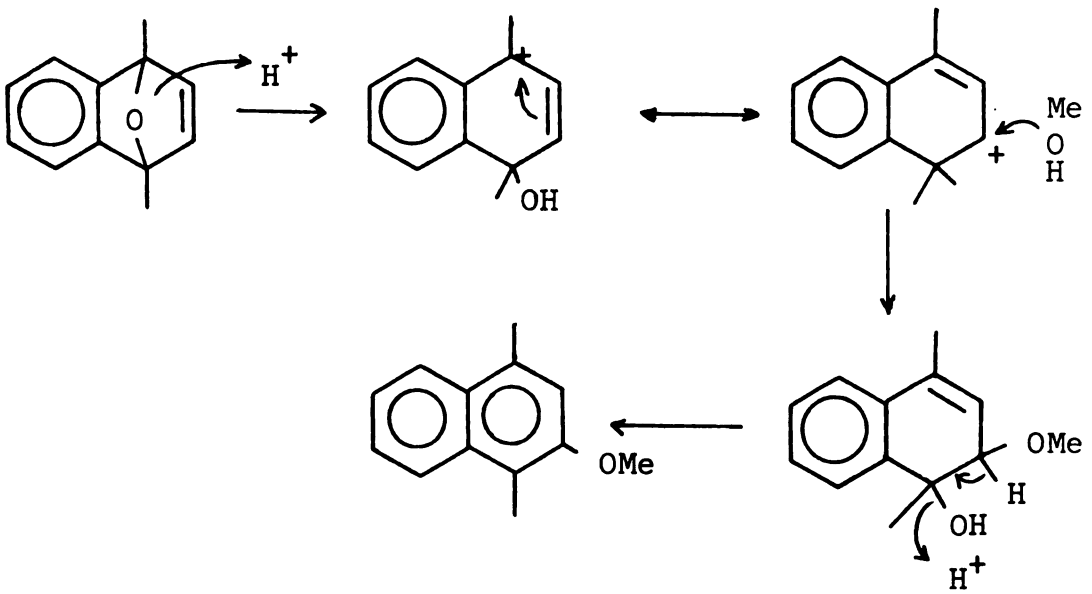


46 39

The above unsatisfactory results prompted us to modify the preparation of 38. Endoxide 47[28] was found[29, 30] to undergo rearrangement in methanol with a trace of acid to give α-naphthol. A 1965 paper reported the related transformation 48 → 49.[31]

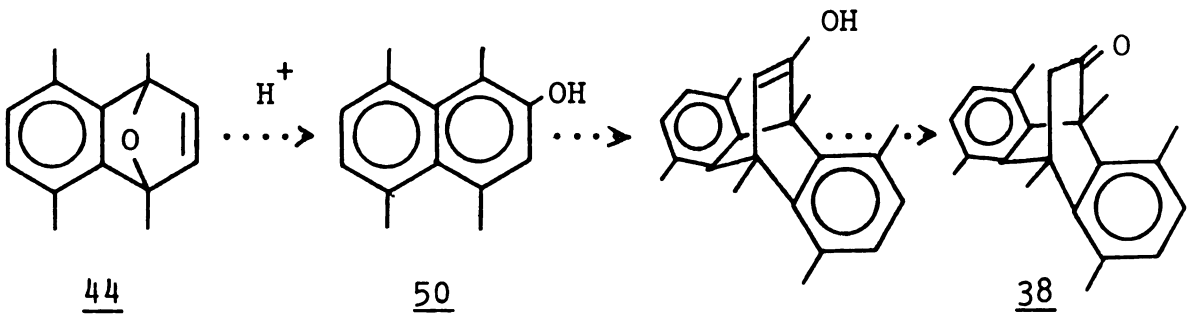


The presence of two methyl groups in 48 apparently affected the orientation of the methoxyl group. A mechanism for this reaction was proposed and is shown in Scheme 6.



Scheme 6

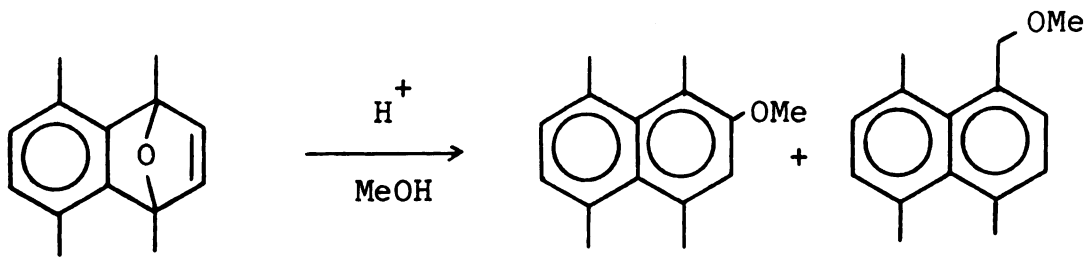
In light of the above results, endoxide 44 was expected to give the intermediate 50 which might undergo cycloaddition with 39 to furnish 38.



44 50 38

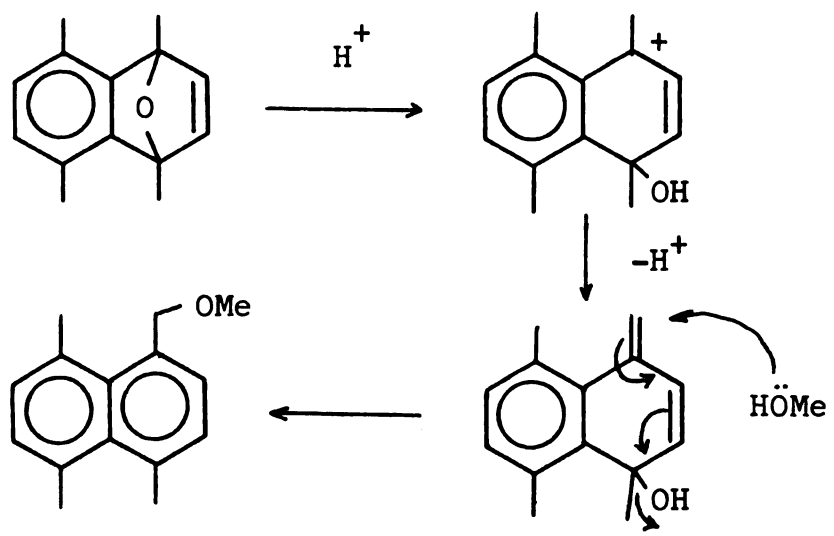
On treatment with acid in methanol, 44 did rearrange, to 51 and 52. Unfortunately, the desired product 51 was formed in only 2.3% yield, whereas 52 was the major product (64.4%).

The nmr spectrum of 51 revealed two singlets for two distinct aromatic methyls at δ2.80 and 2.55, and one singlet for the remaining two aromatic methyls at δ2.75. Compound 52 only gave one singlet for three aromatic methyl groups at δ2.75, and another singlet for two methylene protons at δ4.60.



44 51 52

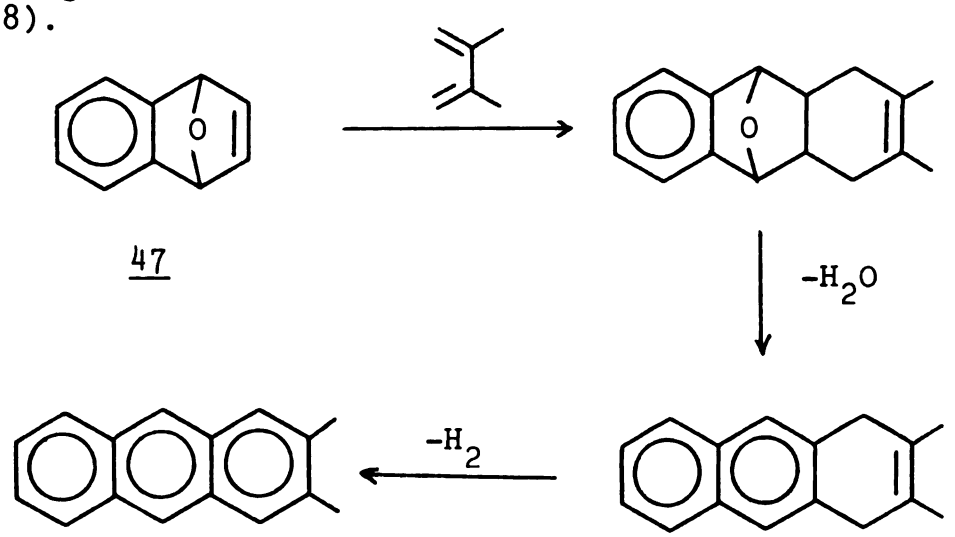
The formation of 52 probably can be rationalized as in Scheme 7.



Scheme 7

D. Route IV: via 1,4,5,8-Tetramethylnaphthalene-1,4-endoxide

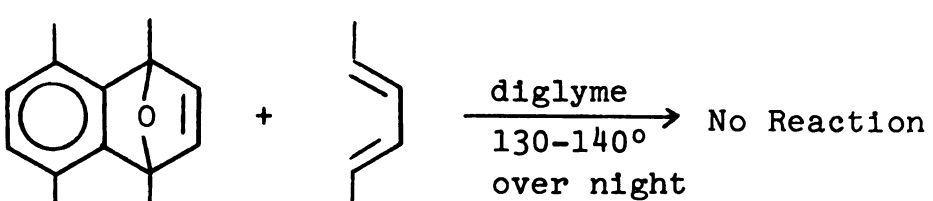
It has been reported that 47 is a good dienophile, and it has been used successfully in an anthracene synthesis (Scheme 8).[32]



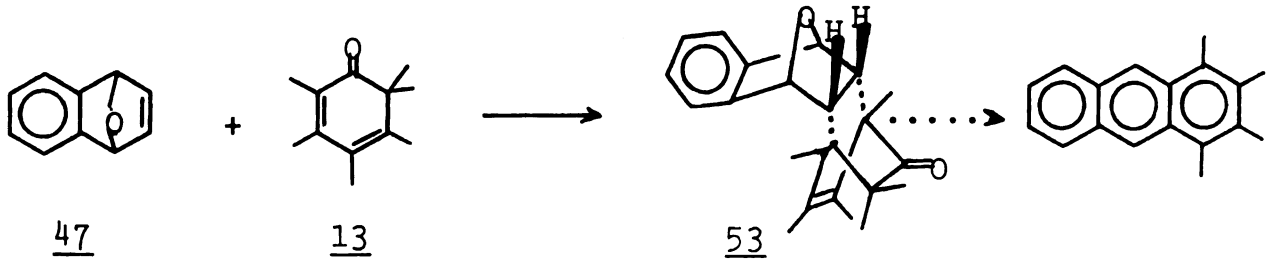
47

Scheme 8

In contrast, our investigation of the similar reaction between 44 and 2,4-hexadiene resulted in no reaction. Of course 2,4-hexadiene is not nearly as successful a diene as 2,3-dimethylbutadiene in Diels-Alder reactions. On the other hand, 1,4-dihydronaphthalene-1,4-endoxide 47 (prepared by Fieser's method[28]) underwent a beautiful reaction with 13, affording 50% of 53 which might be a potential anthracene precursor.



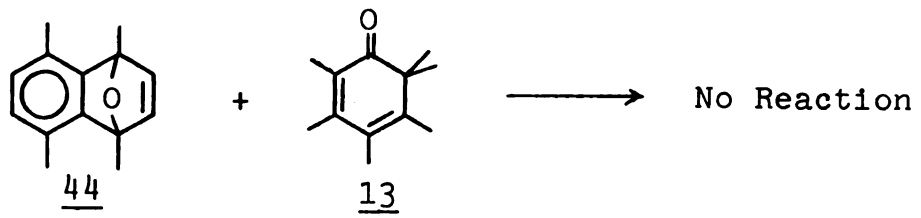
44



47 + 13 → 53

In 53, the coupling constant between the proton at the endoxide bridgehead and the proton at C_7 was 5 Hz. This indicated that the dihedral angle was about 40°, which is consistent with a structure in which the hydrogens at C_7 and C_8 are exo. The low chemical shift (δ1.7-1.8) of the vinyl methyls, presumably due to deshielding by the benzene ring, as well as the larger europium shift numbers for the exo hydrogens compared with the vinyl methyls supported the configuration shown.

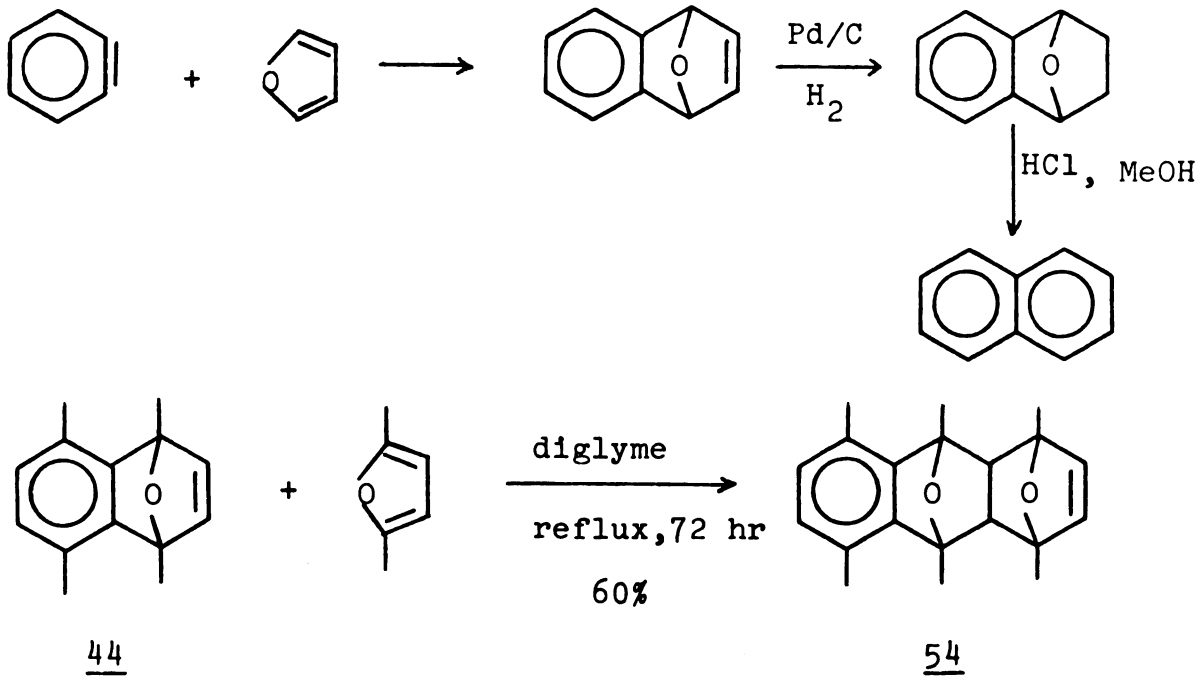
However, the failure of the addition of 44 to 13 made us give up any further investigation on the chemistry of 53 and its related systems.



44 + 13 → No Reaction

Another synthetic example, using the same endoxide system, was given by Wittig and Pohmen in 1956.[30] This inspired us to investigate compound 54, which was prepared from 44 and

2,5-dimethylfuran in diglyme at reflux temperature for 72 hr (60% yield). The nmr spectrum of compound 54 was comprised of three sharp singlets (δ2.32, 1.73, and 1.60) for the six

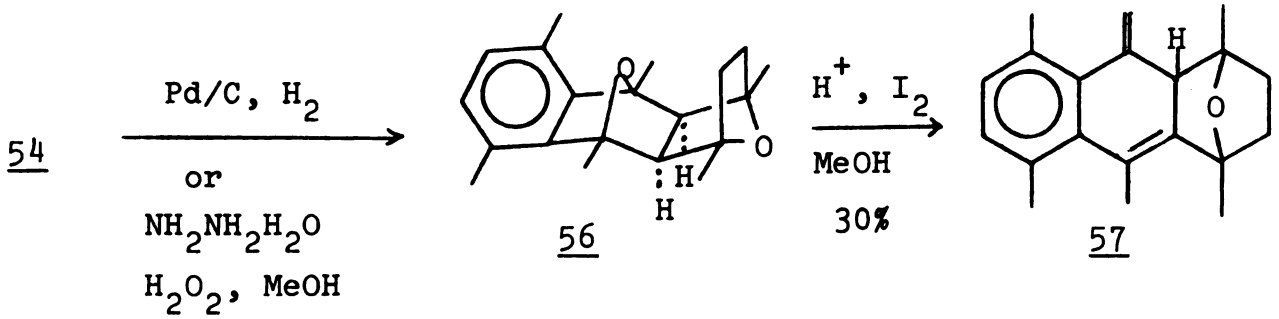


44 54

methyl groups at the peri positions, one singlet for two vinyl protons (δ6.45), and another singlet for two aromatic protons (δ6.85). Protons at C_{4a} and C_{9a} appeared as a singlet at δ2.40. The configuration of 54 was determined by an X-ray analysis of its reduced derivative, 56, which was obtained from a reaction of 54 with diimide in 70.9% yield. This reduction can likewise be achieved under hydrogen atmosphere at room temperature with Pd/C as the catalyst.

Extrusion of the endoxide oxygens in 56 unfortunately could not be accomplished by refluxing the substrate in methanol

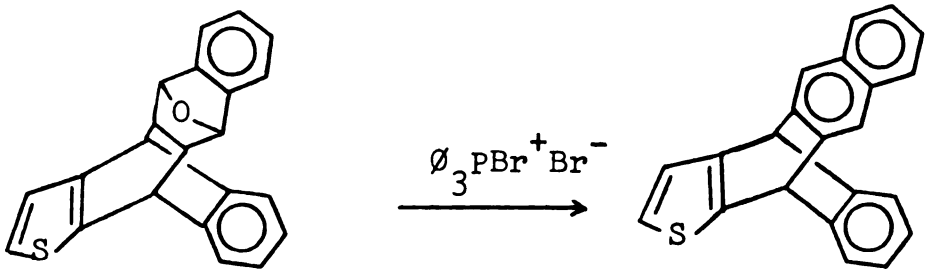
with a catalytic amount of HCl. Since iodine is often used[33] to dehydrate alcohols, a few crystals of iodine were added to the mixture to facilitate extrusion of the oxygens. The result was that only the oxygen in the middle ring was removed. Furthermore, even under such mild acidic conditions, the product 57 was found to have an exocyclic double bond rather than an aromatic central ring.



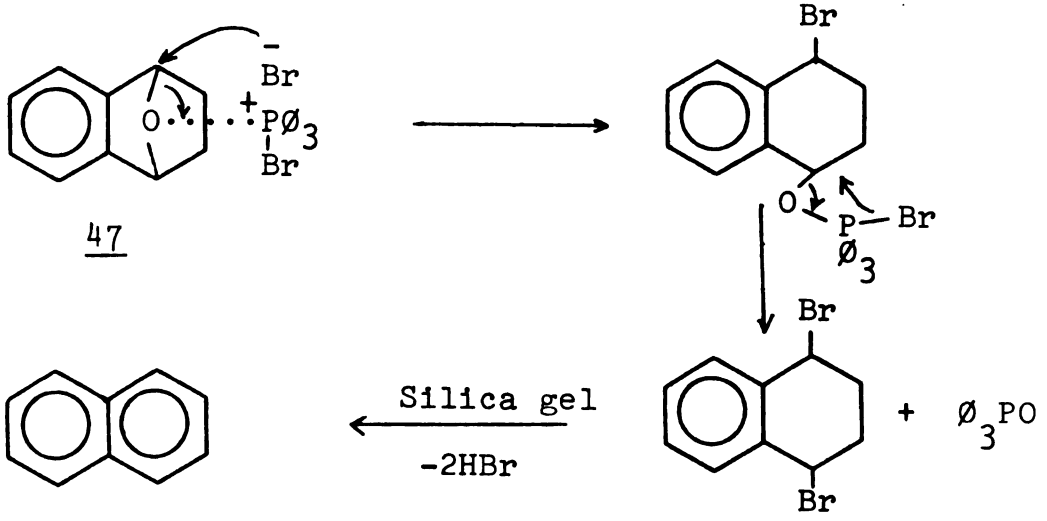
The infrared spectrum of 57 showed C-O-C absorption at 1180 cm^{-1} and a strong terminal methylene absorption at 960 cm^{-1}; the nmr spectrum had two vinyl protons with different chemical shifts (δ5.50 and 4.95), and one vinyl methyl at δ1.69.

It is obvious that extrusion of two endoxide oxygens is more difficult than that of one, so that a search for a more powerful reagent became essential to complete the investigation of this approach.

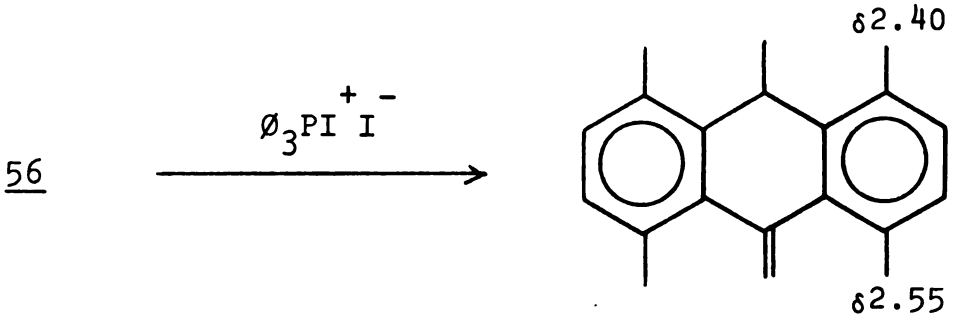
Recently DeWit and Wynberg published their results on the application of an effective deoxygenation reagent, triphenylbromophosphonium bromide, in the system shown.[34]



As a model compound, the saturated derivative of 47, 1,2,3,4-tetrahydronaphthalene-1,4-endoxide, was chosen for a mechanistic study of this deoxygenation reaction.[34] The proposed mechanism involved an initial weak complex formation between the oxygen and the phosphorus, which facilitates S_N1 cleavage of the oxygen-carbon bond. Then reaction with bromide ion followed by abstraction of triphynylphosphine oxide leads to the dibromide. The final stage is a dehalogenation reaction, which was reported to occur on a silica gel column.



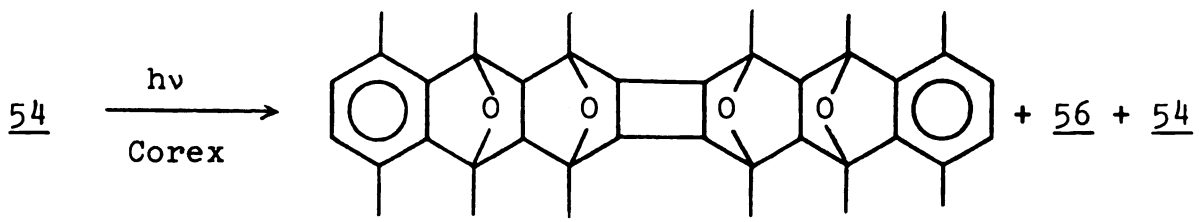
It is known that iodide ion is both a good nucleophile and leaving group. Hence, an iodide derivative of the phosphonium salt should be even more effective for the purpose of deoxygenation. The iodide reagent was made by treatment of triphenylphosphine with an equimolar amount of iodine in DMF at low temperature (-5~0°). The reaction of 56 and triphenyliodophosphonium iodide was carried out at 70° for 2 hr and 135-140° for 4.5 hr. After work-up, 20% of 58 was obtained. Its uv spectrum had an intense maximum at 252 nm ($\varepsilon 1.3 \times 10^4$) and a shoulder at 289 nm (8×10^2); the nmr spectrum showed one singlet for two vinyl protons at δ5.62, one quartet for the C_9-proton at δ4.40 (J = 6 Hz), and a doublet for the C_9-methyl at δ1.30 (J = 6 Hz). The chemical shifts of the aromatic methyls are shown in the formula. Compound 58 is a tautomer of 6 in which the strain due to four peri interactions is avoided by not having an aromatic central ring.



58

An attempt to remove the oxygens photochemically was also tried by irradiating 54 in anhydrous ether with a Corex filter for 8 hr. An ether-insoluble crystalline solid was obtained in 5-6% yield. The mass spectrum gave m/e 592 as

the parent peak and the ir spectrum revealed C-O-C absorption at 1170 and 1160 cm^{-1}. A correct analysis was obtained for $C_{40}H_{48}O_4$, which indicated the formation of the dimer of 54 (i.e. 55). Two more compounds were isolated from the ethereal solution by chromatography on alumina with 50% ether in petroleum ether as the eluent. The first fraction was 56 (17.5%) which was formed presumably by hydrogen abstraction from ether. The second fraction was unreacted 54 (10%).

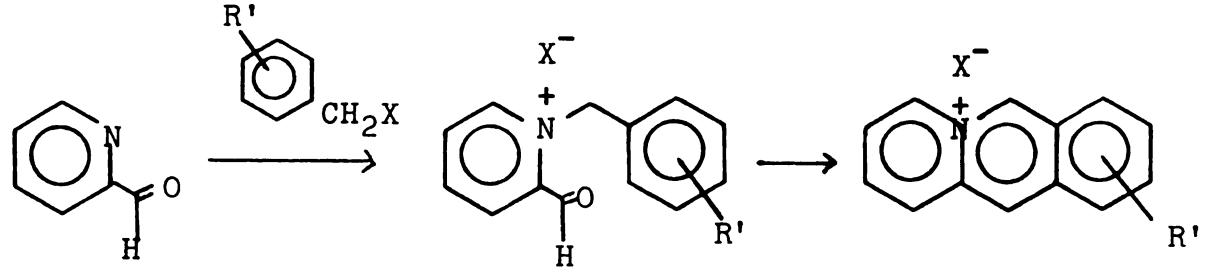


55

The above result suggested one way in which the strain energy in an all peri-methylated anthracene system might be dissipated under the conditions used to form the system. Because of the annellation[35] effect in the anthracene series, the peri-methylated anthracene would prefer a structure with minimum peri interactions to one with a fully conjugated aromatic skeleton. A new synthetic method which would furnish non-acidic media at the key step, the step where peri interactions and aromaticity are introduced, would be more suitable for decamethylanthracene synthesis.

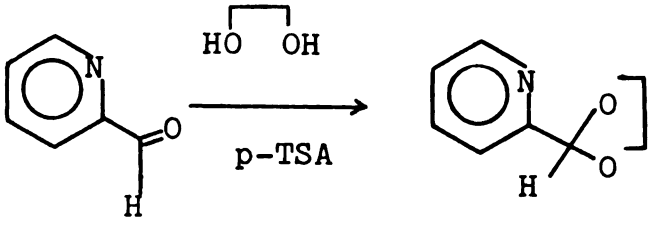
E. Route V: via Acridizinium Compounds

Acridizinium salts (60) were first reported by Bradsher and Beavers in 1954.[36] The salts were prepared by cyclization of the quaternary salts (59) formed when picolinic aldehyde reacted with an appropriate benzyl halide.



59 60

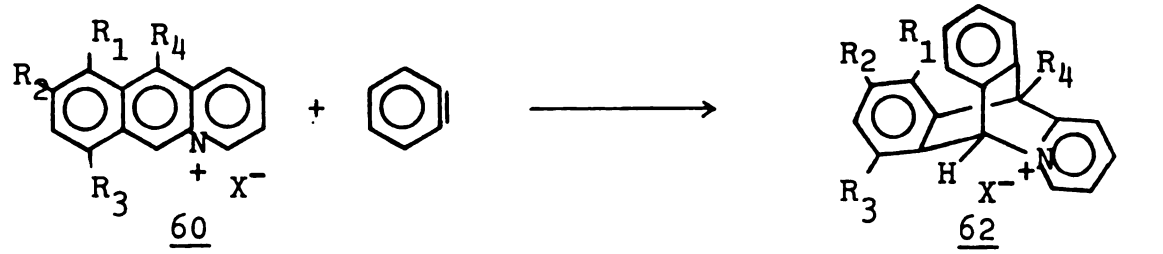
Oxime derivatives of picolinic aldehyde were found to be more desirable[37] than picolinic aldehyde itself for the purpose of a high-yield synthesis of 60. But the most effective synthesis was achieved[38] by using the dioxolan ketal derivatives (61) which were prepared by refluxing a mixture of the picolinic aldehyde, ethylene glycol and p-toluenesulfonic acid in benzene for 64 hr.



61

An extensive study of the application of the acridizinium salts in synthesis was made by Fields.[39, 40] Several substituted anthracenes (63a - 63g) were prepared by a simple and

convenient synthesis consisting of catalytic or chemical reduction and thermolysis of the appropriate benzyne adducts of 4a-azoniaanthracene perchlorates (62a - 62g), (Scheme 9).[39]



60 62

a. $R_1 \sim R_4 = H$

b. $R_1 = Me$, $R_2 \sim R_4 = H$

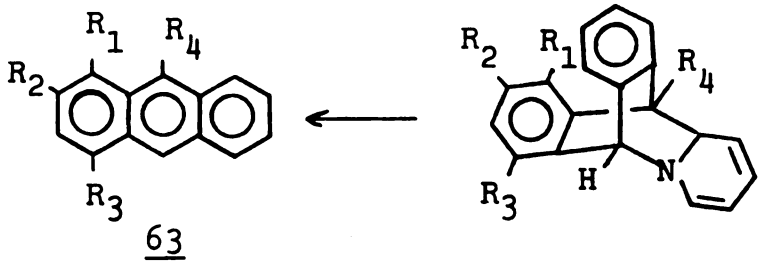
c. $R_1 = R_3 = R_4 = H$, $R_2 = Me$

d. $R_1 = NO_2$, $R_2 \sim R_4 = H$

e. $R_1 = AcO$, $R_2 = R_4 = H$, $R_3 = t\text{-}Bu$

f. $R_1 = R_2 = AcO$, $R_3 = Ph$, $R_4 = H$

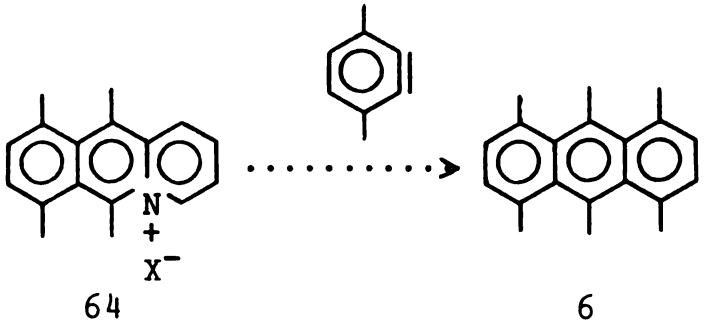
g. $R_1 \sim R_3 = H$, $R_4 = Ph$



63

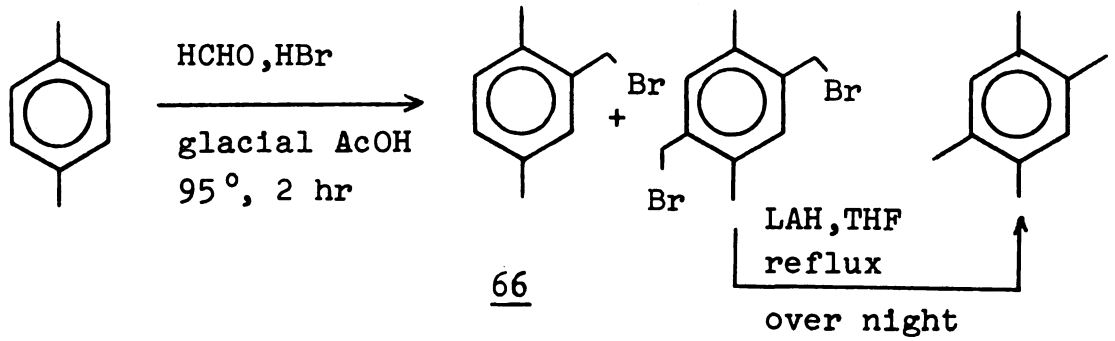
Considering the previous unfavorable results, this route appeared to be worth trying.

Before investing much effort on the synthesis of the synthetic intermediate 64 which would lead to the product 6 according to Field's method, a simpler system was investigated first.



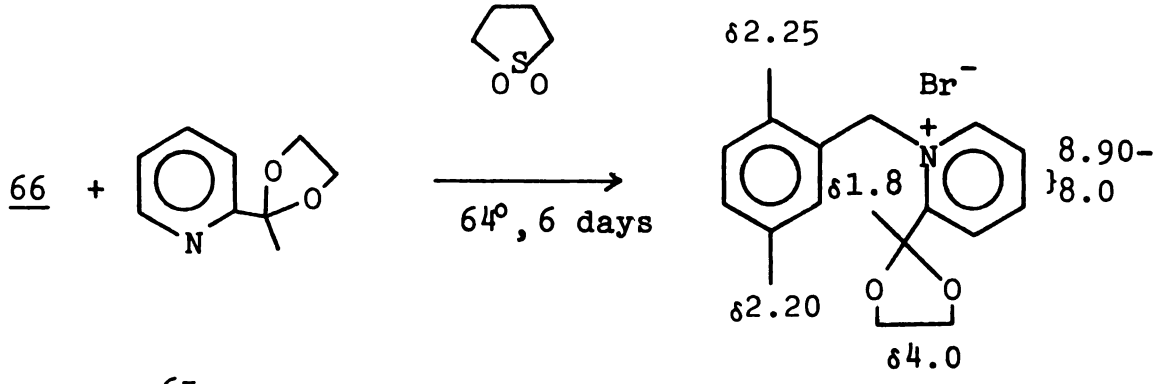
64 6

The dioxolan ketal of 2-acetyl pyridine (65) was prepared by following the literature procedure.[38] Bromomethyl-p-xylene (66) was synthesized in 40% yield by bromomethylation of p-xylene under the conditions shown. A by-product in this reaction was 2,5-dibromomethyl-p-xylene, the structure being proved by reduction to durene.



66

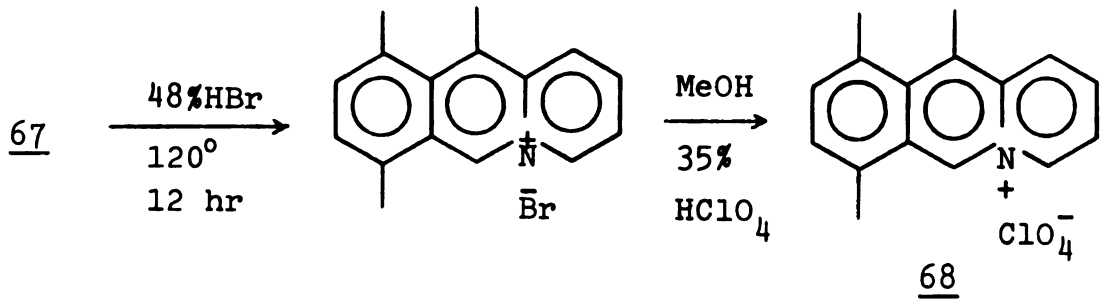
Quaternization of 65 by reaction with 66 in the presence of tetramethylene sulfone was carried out at 64° in a sealed flask for six days. Compound 67 was obtained in 76.5% yield.



65 67

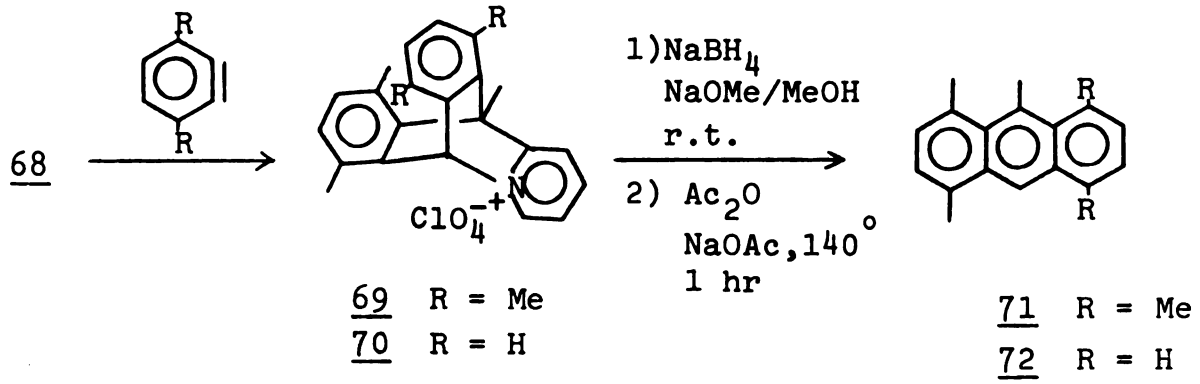
Compound 67 was soluble in chloroform, and its nmr ($CDCl_3$) absorptions are shown in the formula. Cyclization of 67 was achieved by heating in HBr (48%) at 120° for 12 hr. The resulting oil was dissolved in methanol, and 68 was obtained (100%) upon addition of 35% perchloric acid. Since 67 was

insoluble in most organic solvents and undetectable in the



mass spectrometer, it was characterized by a correct elemental analysis and further conversions.

Diels-Alder reaction of 68 with dimethylbenzyne (or benzyne) produced the ether-insoluble adduct 69 (or 70), which was then reduced using sodium borohydride in methanol containing sodium methoxide. The resulting oily material was not purified, and the subsequent thermolysis step was satisfactorily accomplished at reflux temperature in acetic anhydride with added sodium acetate. 1,4,5,8,9-Pentamethylanthracene (71) was obtained in 27% yield (1,4,9-trimethylanthracene 72 was obtained in comparable yield, mp. 80-81°, lit. 81°[11]).

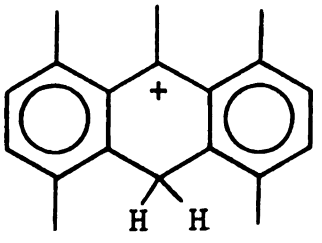


69 R = Me
70 R = H

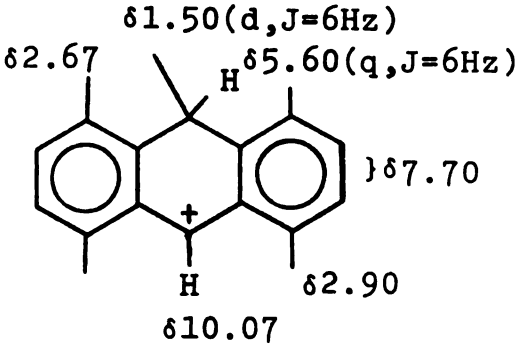
71 R = Me
72 R = H

Pentamethylanthracene (71) is a yellow crystalline solid and its solutions in organic solvents fluoresce. In addition to an intensive maximum at 267 nm ($\varepsilon 6.2 \times 10^4$), its uv spectrum had bands at the borderline near the uv and visible regions of the spectrum: 407 nm (3.6×10^3), 386 (4.2×10^3), and 368 (3.5×10^3). The absorption bands of anthracene itself occur at shorter wavelengths: λ_{max} 375 (9×10^3) and 256 (18×10^4). The nmr spectrum of 71 showed two singlets for aromatic protons (one for the C_{10}-hydrogen at δ8.25, the other for the C_2-, C_3-, C_6-, and C_7-hydrogens at δ7.02); one sharp singlet for the C_9-methyl at δ3.02; and two singlets with two aromatic methyls each, at δ2.80 and 2.70.

It was of great interest to investigate the orientation of the protonation in the middle ring of 71 (it was reported[41] that anthracene itself was protonated at meso-positions in sulfuric acid). Instead of generating the tertiary carbonium ion 73 (9-methylanthracene was protonated on C_{10} in HF + BF_3[42]), 71 was fully protonated on the methyl-bearing carbon (C_9) at room temperature in trifluoroacetic acid. The nmr data are shown in the formula 74. The relief of strong peri interactions



73

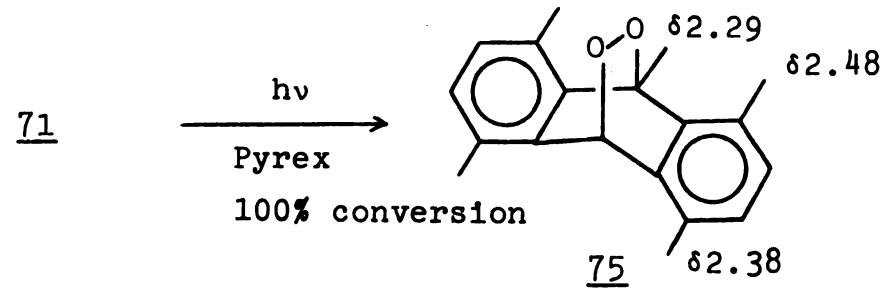


74

must provide the driving force for protonation. This is similar to exclusive α-protonation of octamethylnaphthalene[9] (see Introduction).

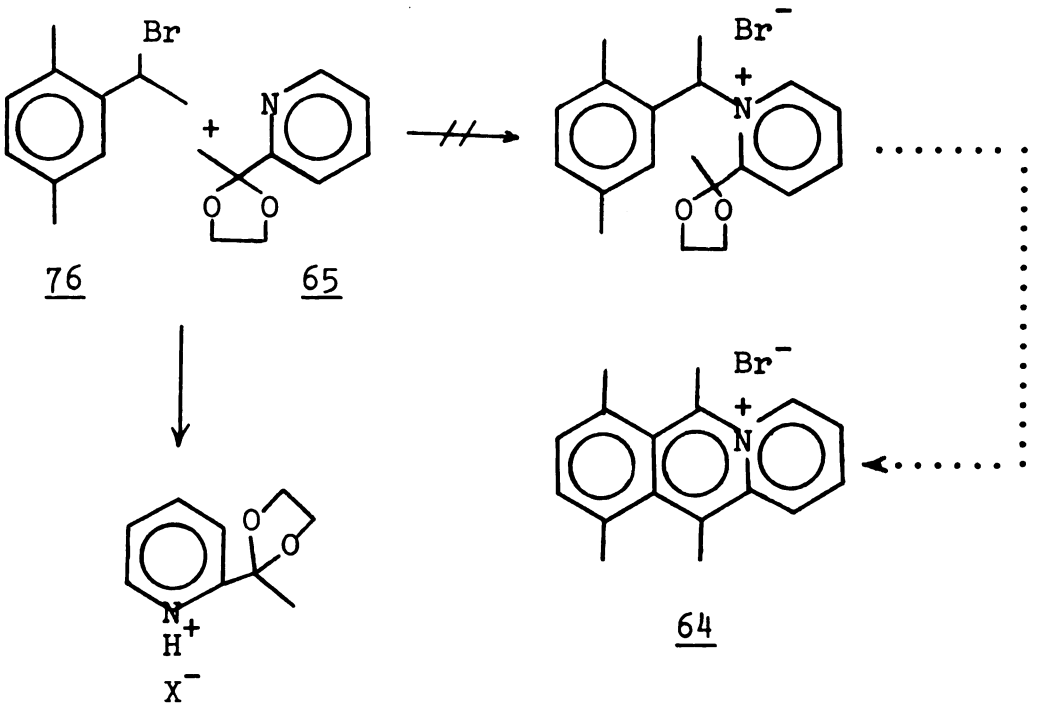
Irradiation of an undegassed solution of 71 in cyclohexane with a Pyrex filter for 3 hr, gave 100% conversion to 75. This endoperoxide 75 was first obtained simply by allowing a cyclohexane solution of 71 to stand at room temperature for about a week, exposed to the flourescent lamps of the laboratory.

Compound 75 gave one singlet at δ6.75 for the four aromatic protons and one singlet at δ6.25 for C_{10}-proton. The nmr data for the methyl groups are shown in the formula.

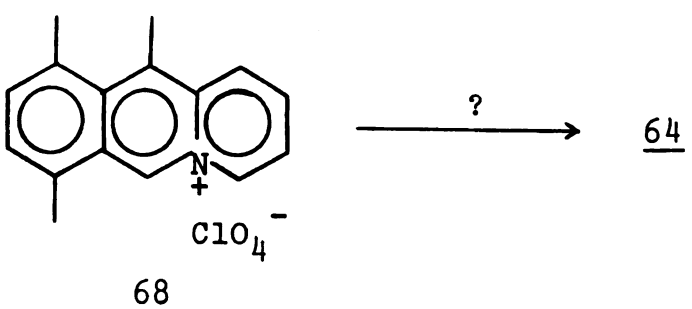


The above preliminary results revealed the consequences of strong peri interactions among the C_1-, C_8-, and C_9-methyls in compound 71; and the ultimate target compound, decamethylanthracene (4), becomes more attractive to us.

However, attempts to synthesize compound 64 (see page 41) were made using 76 as the starting halide. No quaternization product was isolated; instead a salt of 65 was obtained. This probably is due to elimination from 76 brought about by the base 65.



Compound 68 could be alternatively used as the substrate for introducing the C_{10}-methyl group. We leave this problem for further research.



EXPERIMENTAL

General Procedures

All nmr spectra were measured in the organic solvents noted, with tetramethylsilane as an internal standard. The 60 MHz spectra were recorded on a Varian T-60 or A56/60 spectrometer. Ultraviolet spectra were recorded on a Unicam SP-800 spectrophotometer in the solvent noted. Infrared spectra were recorded on a Unicam SP-200 spectrophotometer, and major peaks are reported in units of cm^{-1}. Mass Spectra were obtained using a Hitachi-Perkin Elmer RMU-6 at 70eV, operated by Mrs. Ralph Guile. Elemental analyses were performed by Spang Microanalytical Laboratories, Ann Arbor, Michigan and Clark Microanalytical Laboratories, Urbana, Illinois.

2-Acetyl-1,4,5,6,7,8-hexamethylnaphthalene (9)

Hexamethylnaphthalene[7] (5, 500 mg, 2 mmol) in CH_2Cl_2 (10 ml) was added slowly to a suspension of $AlCl_3$ (550 mg, 4 mmol) and acetyl chloride (320 mg, 4 mmol) in methylene chloride (5 ml). The mixture was stirred for 2 hr at 0 - 5° . The greenish brown solution was then poured into 10% HCl solution. The aqueous layer was washed successively with dilute HCl,

5% NaOH solution (X 2) and water, and was dried ($MgSO_4$). Chromatography on silica gel with $CHCl_3$/hexane (2/1.5) gave a 96% yield of the title compound, mp 78-9°. Ir (CCl_4) 2990 (s), 1689(s); mass spectrum (70eV) 254 (M^+, 100), 239 (94), 211 (34), 196 (24), 181 (27), 165 (25); nmr (CCl_4) δ7.21 (1H, s, aromatic proton), 2.70 (3H, s, aromatic methyl at C_1), 2.62 (3H, s, aromatic methyl), 2.59 (6H, s, two aromatic methyls), 2.56 (3H, s, aromatic methyls), 2.36 (6H, s, one aromatic methyl and one acetyl methyl).

Anal. Calcd for $C_{18}H_{22}O$: C, 84.99; H, 8.72. Found: C, 85.02; H, 8.71.

Ethyl β-(1,4,5,6,7,8-hexamethyl-2-naphthyl)propionate (10)

A three-necked flask which was flushed with nitrogen several times, was immersed in an ice-water bath. All chemicals were injected through a septum in the following order: 0.5 ml (1 mmol) of 2.1 M butyllithium in ether, 0.15 ml (1 mmol) of hexamethyldisilazane, 4 ml of dry THF, and 300 mg (1 mmol) of 9 in 2 ml of dry THF. The mixture was stirred for 15 min at 0° and 0.16 ml (1.5 mmol) of ethyl β-bromoacetate was introduced by injection all at once. The flask was allowed to warm to room temperature and the contents were stirred overnight. A white solid (LiBr) precipitated. The reaction mixture was then diluted with water, extracted with ether and dried ($MgSO_4$). Chromatography on silica gel with benzene gave 78 mg (22%) of 10 as an oil (the 4th fraction; the previous three fractions

were unidentified). Ir (neat) 3000 (s), 1735 (s), 1690 (s), 1310 (s); nmr (CCl_4) δ7.25 (1H, s, aromatic proton), 4.15 (2H, q, J = 7 Hz, methylene on the ethoxy group of the ester), 3.15 (2H, t, J = 6 Hz, α-methylene), 2.70 (3H, s, aromatic methyl at C$_1$), 2.65 (5H, multiplet, one aromatic methyl and β-methylene), 2.50 (6H, s, two aromatic methyls), 2.36 (6H, s, two aromatic methyls), 1.30 (3H, t, J = 7 Hz, methyl on the ethoxy group).

Saponification[28] and Cyclization of 10

Ester 10 (78 mg) in 5% alcoholic KOH (1.5 ml) was stirred at room temperature. After 4 hr, 10% HCl (1 ml) was added. A brown oil separated after the acidic solution was diluted with water. The organic layer was dried ($CaCl_2$). Evaporation of the solvent gave a brownish oil which solidified on standing in the refrigerator overnight.

Anal. Calcd for $C_{20}H_{24}O_3$: C, 76.89; H, 7.74. Found: C, 76.70; H, 7.78.

This solid was then added to 1 g of polyphosphoric acid which was previously heated to 100°. The mixture was stirred vigorously while the temperature was raised to 150°. After 15 min, 20 ml of water was added, and the mixture was extracted with ether. The ethereal solution was washed with water three times and then with 5% NaOH solution. The organic layer was separated and dried over $MgSO_4$. The solvent was removed under vacuo. Thick-layer chromatography on silica gel with $CHCl_3$/

benzene (1/1) gave a brown oil (1st fraction) which solidified (12) after removing the solvent and chromatography on silica gel with hexane as the eluent. The yield (for the two steps) of 12 was 3%. Ir (KBr) 3450 (m), 2950 (s); nmr (CCl_4) δ7.6 (2H, s, aromatic protons), 2.52 (6H, s, two methyls at C_9 and C_{10}), 2.40 (6H, s, two methyls at C_5 and C_8), 2.35 (6H, s, two methyls at C_6 and C_7).

1,4,5,6,7,8-Hexamethyl-2-nitronaphthalene (20)[18]

(A) Preparation of silver nitrate impregnated silicic acid: Chromatographic silicic acid (1.8 g) was slurried with absolute methanol (5 ml) and added to a solution of silver nitrate (0.47 g) in 50% aqueous methanol (3 ml). The resulting slurry was then evaporated to dryness. The solid was dried overnight in an oven at 150°.

(B) Nitration of Hexamethylnaphthalene: To the freshly-dried silver nitrate-silicic acid sample was added a solution of CCl_4 and hexane (1/1, 10 ml). After 15 min, hexamethylnaphthalene (5) (0.5 g, 2 mmol) in the same CCl_4/hexane solvent (6 ml) was added. The mixture was agitated and allowed to stand for 64 hr at 24°, then was transferred to a small silica gel column with ether as the eluent. A brown oil was obtained. Chromatography on silica gel with hexane/chloroform (2/1) gave the yellow crystalline 20 (2%, the second fraction; the first fraction was unidentified), mp 100-1°. Mass spectrum (70eV) 257 (M^+), 225 (15), 206 (67), 181 (49), 165 (100),

152 (48), 141 (37), 128 (37), 115 (50); nmr(CCl_4) δ7.45 (1H, s, aromatic proton), 2.73 (3H, s, methyl at C_1), 2.68 (3H, s, aromatic methyl), 2.58 and 2.40 (6H each, s, four aromatic methyls).

1,4,5,6,7,8-Hexamethyl-2-bromonaphthalene (21)

A solution of 212 mg (1 mmol) of 5 in 5 ml of CS_2 was cooled to -78° in a flask which was wrapped with aluminum foil. Bromine (0.06 ml, 1 mmol) in 5 ml of CS_2 was added very slowly. After the mixture was stirred at -78° in the dark for 30 min, 100 mg of sodium bisulfite was added (exothermic). Water was added, and the organic layer was washed with $NaHCO_3$ solution twice and then with water twice. The organic layer was dried ($MgSO_4$) and chromatographed on alumina with pentane as the eluent. Evaporation of the solvent gave a colorless oil which, after recrystalization from petroleum ether (bp 30-60°), afforded 21 (155 mg, 54%), mp 68-9°. Ir (CCl_4) 3080 (w), 3050 (m), 2950 (s), 1580 (m), 1500 (w), 1470 (s), 1450 (s), 1400(m), 1320 (w), 1260 (m), 1210 (w), 883 (s); mass spectrum (70eV) 292 (98), 290 (M^+, 100), 227 (32), 275 (33), 211 (24), 196 (23), 181 (23), 165 (27); nmr (CCl_4) δ7.15 (1H, s, aromatic proton at C_3), 2.75 (3H, s, aromatic methyl at C_1), 2.65, 2.52, and 2.45 (3H each, s, three aromatic methyls), 2.30 (6H, s, two aromatic methyls).

Anal. Calcd for $C_{16}H_{19}Br$: C, 66.21; H, 6.55; Br, 27.24. Found: C, 66.27; H, 6.39; Br, 27.21.

1,4,5,6,7,8-Hexamethyl-2,3-dibromonaphthalene (22)

(A) From hexamethylnaphthalene: A solution of 212 mg (1 mmol) of hexamethylnaphthalene in 5 ml of CS_2 was cooled to -78° in a dark flask. Bromine (0.12 ml, 2 mmol) in CS_2 (5 ml) was added slowly. After 30 min, the mixture was warmed to room temperature, and an aqueous solution of sodium bisulfite was then added. The organic layer was separated and washed with $NaHCO_3$ and with water several times. After being dried over $MgSO_4$, the solution was evaporated to give an oil which was eluted through an alumina column by 10% ether in pentane. The first fraction gave 22 (30-40%), mp 174-5°. Mass spectrum (70eV) 372 (50), 370 (100), 368 (M^+), 357 (12), 355 (19), 353 (11), 292 (30), 290 (32); nmr ($CDCl_3$) δ 2.70 (6H, s, two aromatic methyls at C_1 and C_4), 2.45 (6H, s, two methyls at C_5 and C_8), 2.30 (6H, s, two methyls at C_6 and C_7).

(B) From 2-bromo-hexamethylnaphthalene: The same procedure was followed except that only 1 mmol of bromine was used. The yield of 22 was 15%.

Anal. Calcd for $C_{16}H_{18}Br_2$: C, 52.17; H, 4.89. Found: C, 52.29; H, 4.83.

Reaction of 21 with Sodium Amide in Ammonia

To the solution of 21 and 2,5-dimethylfuran in liquid ammonia was added sodium metal in small pieces. The mixture was then stirred at dry-ice temperature for six hr and at room temperature for another six hr. After work-up, only compound 21 was recovered (100%).

1,4,5,6,7,8-Hexamethyl-2-naphthoic acid (23)

In a dry three-necked flask was placed 85 mg (3.5 matom) of magnesium turnings and 10 ml of dry ether. A solution of 290 mg (1 mmol) of 21 and 218 mg of ethyl bromide in 10 ml of dry ether was placed in a funnel. Stirring was commenced and about ¼ of the halide solution in the funnel was added; the solution was then heated to 40°. The rest of the halide solution was added during the course of 1 hr to the vigorously refluxing mixture. After completion of the addition, reflux was maintained by heating for another hour. The reaction mixture was then cooled, and a large excess of solid carbon dioxide was added slowly in small pieces with rapid stirring. The resulting gummy addition product was decomposed by adding with stirring a solution of 1 ml of concentrated HCl in 2 ml of water dropwise. After most of the solid had dissolved, the mixture was transferred to a separatory funnel with the addition of ordinary ether. The ethereal layer was washed three times with cold water and dried ($MgSO_4$). Evaporation of the solvent gave a gummy yellow solid which was recrystalized as a pale yellow solid in ethanol (125 mg, 50%), mp 192-3°. Ir (CCl_4) 3000 (s), 2950 (s), 2900 (s), 1680 (s), 1595 (w), 1450 (m), 1430 (m), 1390 (m), 1350 (m), 1270 (s), 1190 (w), 1130 (m), 923 (s); mass spectrum (70eV) 256 (M^+), 220 (22), 212 (100), 197 (59), 165 (27), 142 (40); nmr ($CDCl_3$) δ7.70 (1 H, s, aromatic proton at C_3), 2.90 (3H, s, methyl at C_1), 2.72, 2.60, and 2.55 (3H each, s, three aromatic methyls), 2.40 (6H, s, two aromatic methyls).

Anal. Calcd for $C_{17}H_{20}O_2$: C, 79.65; H, 7.86. Found: C, 79.50; H, 7.91.

1,4,5,6,7,8-Hexamethyl-2-aminonaphthalene (24)

(A) Preparation of p-tosyl azide:[21] p-Toluenesulfonyl azide was prepared by adding with swirling 700 mg of sodium azide in 2 ml of water to 1.7 g of freshly-distilled p-toluenesulfonyl chloride[43] in 10 ml of 95% ethanol. After separation, the oily sulfonyl azide was washed three times with water and dried (Na_2SO_4).

(B) Naphthylamine: Grignard reagent was prepared as in the synthesis of 23 from 2.5 g of 21, 0.5 g of ethyl bromide and 0.9 g of magnesium turnings in 20 ml of dry THF under nitrogen. The solution turned into light brown indicating that the reaction had occured. After the mixture was stirred for 3 hr at 40°, it was cooled in an ice bath and 1.4 g of dry p-tosyl azide in 5 ml of dry THF was added dropwise with stirring under nitrogen. The resulting greenish solution was stirred for four additional hours at 35°. In another flask, was placed 20 ml of 50% NaOH and a few pieces of ice. To this basic solution, a small portion of a total of 7 g of Raney nickel-aluminum alloy was added. After hydrogen started evolving, the azide solution was added dropwise. The rest of the alloy was added after the addition of azide, in five portions at 15 min intervals. This mixture was then extracted with ether. The ethereal solution was washed with water and

dried over NaOH. Evaporation of the solvent gave a brownish oil which was diluted with dry ether. An equal volume of dry ether was saturated with dry HCl. Then this acidic ether was dropped into the brownish-red ethereal solution slowly. A pale yellow solid precipitated (0.9g, 40%), which was the ammonium chloride salt of compound 24. Ir (neat) 4450 (w), 3400 (m), 3000 (s), 1680 (m), 1640 (m), 1600 (s); mass spectrum (70eV) 227 (M^+, 100), 212 (75); nmr (CS_2) δ6.3 (1H, s, aromatic proton at C_3), 3.40 (2H, s, amino protons), 2.55 (3H, s, methyl at C_1), 2.50 and 2.35 (3H each, s, two aromatic methyls), 2.25 (6H, s, two aromatic methyls), 2.20 (3H, s, aromatic methyl).

Alternative preparation of 24 from 34 via 35

To an ice-cold suspension of lithium aluminum hydride (150 mg) in absolute ether (10 ml) was added with stirring over 30 min an ether solution (10 ml) of 34 (327 mg). After the mixture was refluxed for 2 hr, it was poured into ice-water and extracted with ether. The ethereal solution was dried (NaOH) and evaporated to give a reddish oil (35) (99%). The infrared spectrum of this product 35 indicated that both the carbonyl and the nitro group were reduced: 3500 (s), 1630 (m), 1603 (m). This product was added into the dimslsodium solution which was prepared from sodium hydride (50% dispersion in mineral oil, 300 mg) in DMSO (10 ml).[23] After 16 hr at 40°, the dark brownish-red solution was poured on an ice-water mixture. After work-up, a reddish oil was obtained in 10%

yield; it gave identical spectral data as 24. The same result was obtained (22%) from the pyrolysis of 35 with benzene as the solvent at 210-230° under nitrogen. The pyrolysis was carried out by dropping a benzene solution of 35 from the top of a Pyrex hot tube (25 inches) packed with glass beads and collecting the product with a flask connected with the tube.

1,4,5,6,7,8-Hexamethyl-2-bromo-3-benzoylnaphthalene (36)

A solution of 21 (290 mg) in dichloromethane (3 ml) was added slowly to a suspension of aluminum chloride (0.3 g) and benzoyl chloride (0.3 g) in dichloromethane (3 ml) at $-5 \sim 5^{\circ}$. After one hour at this temperature, the excess aluminum chloride was decomposed by adding the reaction mixture to 10% HCl solution. The aqueous layer was extracted with chloroform and the combined organic layers were then washed successively with dilute HCl solution, Na_2CO_3 solution and water, and dried ($MgSO_4$). Elution through alumina with 20% ether in petroleum ether gave starting material (1st fraction, 50 mg) and 36 (2nd fraction, 150 mg), mp 189-190° from $CHCl_3$ and MeOH. Ir (KBr) 3000 (s), 1680 (s), 1600 (m), 1460 (s), 1400 (m), 1260 (s), 1205 (m); mass spectrum (70eV) 396 (100), 394 (M^+, 100), 314 (71), 300 (76), 299 (62); nmr ($CDCl_3$) δ7.8-7.2 (5H, m, aromatic protons on benzoyl group), 2.6 (3H, s, aromatic methyl), 2.47 (6H, s, two aromatic methyls), 2.38, 2.34, and 2.30 (3H each, s, three aromatic methyls).

Anal. Calcd for $C_{23}H_{23}OBr$: C, 70.11; H, 5.88. Found: C, 69.90; H, 5.75.

Reaction of 36 with Sodium in Liquid Ammonia

Sodium (150 mg) was dissolved in liquid ammonia. The blue color first formed and then disappeared after 10 min. Liquid ammonia was added while adding sodium to keep the volume to 50 ml. After the blue color completely disappeared, a solution of 36 and 2,5-dimethylfuran (excess) in THF was added dropwise. The reaction mixture was warmed to room temperature for 7 hr, and then was quenched by adding ammonium chloride (300 mg). After ordinary work-up procedures, only a 100% recovery of 36 (400 mg) was obtained.

3,6-Dimethyl-4-nitroisatin (31)

A solution of 8.75 g (50 mol) of 3,6-dimethylisatin 30 in 20 ml of concentrated sulfuric acid was cooled to 0°, and to this solution was added slowly 3.1 g of fuming nitric acid. After 30 min, the mixture was poured over 200 g of cracked ice. Compound 31 was obtained as a dark yellow solid (9.9 g, 90%), mp 249-250°. Nmr (DMSO-d_6)δ8.12 (1H, s, aromatic proton), 2.65 (3H, s, methyl at C_3), 2.24 (3H, methyl at C_6). Compound 31 was used in the next step, to prepare 32, without further purification.

3,6-Dimethyl-4-nitroanthranilic acid (32)

To the solution of 9.9 g of 31 in 150 ml of 10% NaOH was added 150 ml of 3% H_2O_2 (exothermic). After the H_2O_2 was

added, the mixture was heated to 40° for 6 hr. A light yellow solid was sparingly precipitated when the mixture was acidified with concentrated HCl (foaming). The solid was filtered and washed with water, giving a 99% yield of 32, mp 155 (sublimed) from 80% acetic acid. Mass spectrum (70eV) 210 (M^+), 175 (100), 164 (48), 118 (70); nmr (CD_3CN) δ7.65 (1H, s, aromatic proton), 5.30 (2H, s, amino protons), 2.44 (3H, s, aromatic methyl at C_1), 2.1 (3H, s, aromatic methyl at C_6).

Anal. Calcd for $C_9H_{10}O_4N_2$: C, 51.42; H, 4.80. Found: C, 51.49; H, 4.82.

1,3,3,4,7,8-Hexamethyl-5,6-(3,6-dimethyl-4-nitrobenzo)bicyclo-[2.2.2]octa-5,7-dien-2-one (34)

(A) Diazotization of 3,6-dimethyl-4-nitroanthranilic acid: To a solution of 32 (2.3 g) and HCl (10 ml) in absolute ethanol (30 ml) was added isoamyl nitrite (3 ml) at 4°. The mixture was then stirred at 0° for 2 hr. Absolute ether (40 ml) was added and the resulting mixture was stirred at 0° for another hour. A pale yellow solid (3,6-dimethyl-4-nitrobenzenediazonium-2-carboxylate hydrochloride, 33) was obtained (54%), mp 98° (exploded).

(B) Preparation of the title compound: The mixture of 33 (1.285 g), 13 (0.89 g) and propylene oxide (2 ml, added last) in 15 ml of $ClCH_2CH_2Cl$ was heated at 80° for 2 hr. Ether was then added (20 ml). The ethereal solution was washed three times with dilute sodium hydroxide solution and three

times with water, and was dried ($MgSO_4$). The solvent was then evaporated under vacuo. The resulting brownish red oil crystallized upon dilution with a small portion of absolute methanol to give 0.54 g (33%) of 34, mp 169-171°. Mass spectrum (70eV) 327 (M^+), 257 (72), 240 (58), 225 (84), 210 (100); nmr ($CDCl_3$) δ7.24 (1H, s, aromatic proton), 2.65 (3H, s, aromatic methyl adjacent to nitro group), 2.50 (3H, s, aromatic methyl), 1.99 (6H, s, two vinyl methyls), 1.97-1.85 (6H, multiple, two methyls at bridgeheads), 1.12 and 0.85 (3H each, s, two methyls at C_3).

Anal. Calcd for $C_{20}H_{25}O_3N$: C, 73.36; H, 7.70. Found: C, 73.44; H, 7.63.

1,4,7,8-Tetramethyl-2,3-5,6-di(3,6-dimethylbenzo)bicyclo-[2.2.2]octa-2,5,7-triene (40)

A mixture of 3,6-dimethylbenzenediazonium-2-carboxylate hydrochloride (39)(1.06 g, 5 mmol), 5 (0.53 g, 2.5 mmol) and propylene oxide (2 ml) in $ClCH_2CH_2Cl$ (15 ml) was refluxed at 80 - 90° for 1.5 hr. Evaporation of the solvent gave a dark brown oil which was redissolved in ether and washed with dilute NaOH solution, with water, and dried ($MgSO_4$). Evaporation of the solvent gave an oil which was diluted with a small portion of ether and cooled in ice. The solid which formed was filtered and recrystallized from chloroform and ether proved to be the dimer of dimethylbenzyne. The filtrate was subjected to column chromatography on silica gel with cyclohexane

as the eluent. The first fraction was recovered 5 (400 mg). The second fraction was an unidentified material with low yield. The third fraction was a white solid which gave, after recrystallization from chloroform and petroleum ether, 40 mg (5.1%) of 40, mp 160° (sublimed). Mass spectrum (70eV) 316 (M^+), 301 (100), 286 (82), 271 (61); uv (CH_3CN) λ_{max} (ε) 232 nm (14.2×10^3), 288 (shoulder, 4.2×10^3), 215 (shoulder, 11.5×10^3); nmr ($CDCl_3$) δ6.4 (4H, s, aromatic protons), 2.55 (12H, s, four aromatic methyls), 2.45 (6H, s, two methyls at bridgeheads), 1.75 (6H, s, two vinyl methyls).

Anal. Calcd for $C_{24}H_{28}$: C, 91.08; H, 8.92. Found: C, 90.33; H, 8.93. This analytical data was bad due to the contamination of 40 by 5.

1,2,5,6-Tetramethyl-3,4-7,8-di(3,6-dimethylbenzo)cycloocta-tetraene(42)

(A) via Pyrolysis: A solution of 50 mg of 40 in 5 ml of benzene was flashed under nitrogen through a hot quartz tube at 600°. A dark brown oil was obtained in the receiver. Column chromatography on silica gel with cyclohexane as the eluent gave a pale orange colored product 42 (50-60%), mp 174-6° from absolute methanol. Mass spectrum (70eV) 316(M^+), 301 (100), 286 (75), 271 (73), 256 (36); nmr ($CDCl_3$) δ6.59 (4H, s, aromatic protons), 2.08 (12H, s, four aromatic methyls), 1.91 (12H, s, four vinyl methyls).

Anal. Calcd for $C_{24}H_{28}$: C, 91.08; H, 8.92. Found: C, 90.89; H, 8.71.

(B) via Photolysis: A solution of 50 mg of 40 in 25 ml of ether was purged with nitrogen in a 2 cm X 15 cm Quartz test tube, which was then sealed and irradiated using a 450° watt Hanovia lamp with a Vycor filter for 45 min. The major product was separated by preparative vpc (5' X ¼" 20% SE-30 on DMCS at 210°) and identified as 42. Two more products which had longer retention time and were formed in low yields were unseparable by vpc and were not identified.

1,2,5,8-Tetramethyl-3,4-6,7-di(3,6-dimethylbenzo)tricyclo-[3.2.1.$0^{2,8}$]octa-3,6-diene (43)

A solution of 50 mg of 40 was dissolved in 20 ml of acetone. The acetone solution was degassed with nitrogen and irradiated using a 450 watt Hanovia lamp with a Vycor filter for 1 hr. Two major products were separated by vpc (5' X ½" 10% SE-30 on DMCS at 200°). The chromatogram revealed a 100% conversion of the starting material to compounds 42 (40%) and 43 (50%) at retention times of 20 min and 30 min respectively. Compound 43 was recrystalized from methanol. Mass spectrum (70eV) 316 (M^+), 301 (100), 286 (59), 271 (45); nmr ($CDCl_3$) δ6.45 (4H, s, aromatic protons), 2.45 and 2.20 (6H each, s, four aromatic methyls), 1.95(3H, s, methyl at C_3), 1.52 (6H, s, two methyls at C_1 and C_2), 1.19 (3H, s, methyl at C_8).

1,4,5,8-Tetramethyl-1,4-dihydronaphthalene-1,4-endoxide (44)

To 100 ml of $ClCH_2CH_2Cl$ was added 23.2 g (0.14 mol) of 39, 34 ml of propylene oxide and 59.7 ml (0.56 mol) of 2,5-dimethylfuran. The mixture was refluxed at 83° for 2.5 hr. Evaporation of the solvent gave a red brown oil which was then redissolved in ether. The ethereal solution was washed with dilute NaOH and with water. The product 44 (15.5 g, 55% based on 39) was distilled at 93° (0.6 torr). Ir (neat) 3000 (s), 1500 (s), 1460 (s), 1400 (s), 1305 (s), 1150 (s); mass spectrum (70eV) 200 (M^+), 174 (21), 157 (100), 142 (52); nmr (CCl_4) δ6.65 (2H, s, aromatic protons), 6.50 (2H, s, two vinyl protons), 2.25 (6H, s, two aromatic methyls), 1.87 (6H, s, two methyls at C_1 and C_4).

Anal. Calcd for $C_{14}H_{16}O$: C, 83.96; H, 8.05. Found: C, 83.77; H, 8.17.

1,4,5,8-Tetramethyl-2-methoxynaphthalene (51), and 1-Methoxymethyl-4,5,8-trimethylnaphthalene(52)

A solution of 200 mg (1 mmol) of 44 in 5 ml of absolute MeOH with 1 drop of concentrated HCl was heated at 60-65° for 2 hr. After work-up, 130 mg of crude product was obtained. Column chromatography with 1% ether in petroleum ether (30-60°) on alumina gave two products. The first fraction was 51 (5 mg, 2.3%), mp 54-56°. Ir (KBr) 2950 (s), 1600 (s), 1110 (s); mass spectrum (70eV) 214 (M^+, 100), 199 (32), 171 (44), 156 (32); nmr ($CDCl_3$) δ6.80 (3H, s, aromatic protons), 3.80

(3H, s, methoxy methyl), 2.80 (3H, s, methyl at C_1), 2.75 (6H, s, two aromatic methyls), 2.55 (3H, s, aromatic methyl).

Anal. Calcd for $C_{15}H_{18}O$: C, 84.07; H, 8.47. Found: C, 84.09; H, 8.44.

The 2nd fraction was 52 (140 mg, 64.4%), mp 48-50°. Ir(KBr) 3000 (s), 1870 (w), 1600 (s), 1105 (s); mass spectrum (70eV) 214 (M^+), 182 (65), 167 (100), 152 (30); nmr (CCl_4) δ6.8-7.0 (4H, multiplet, aromatic protons), 4.60 (2H, s, methylene protons at C_1), 3.20 (3H, s, methoxy methyl), 2.75 (9H, s, three aromatic methyls).

1,4,5,8-Tetramethylnaphthalene (46)

(A) From 44 and Lithium Naphthalenide: The stock solution of lithium naphthalene radical anion was prepared in 1,2-dimethoxyethane (DME). Small strips of lithium wire (100 mg, 14 mmol) were added to a solution of naphthalene (1.8 g, 14 mmol) in 30 ml of dry solvent under an argon atmosphere. The blue-green color of the radical anion appeared within 2 hr. The solution was stirred (glass-covered stirring bar) overnight. To this solution, 44 (100 mg, 0.5 mmol) in DME (10 ml) was injected from a syringe. The mixture was stirred at ambient temperature for 2 hr. The dark green solution was decomposed with an iodine crystal, and the resulting colorless cloudy suspension was evaporated in vacuo. The residue was suspended in ether and washed with 1 N sodium thiosulfate solution and water. The solution was then dried

($MgSO_4$) and evaporated to give 100% of 46, mp 131-2°(lit.[27] 132-2°). Mass spectrum (70eV) 184 (M^+, 100), 169 (96); nmr ($CDCl_3$) δ6.90 (4H, s, four aromatic protons), 2.79 (12H, s, four aromatic methyls).

(B) From 44 via 45: To a solution of 200 mg of 44 in 10 ml of methanol was added 100 mg of hydrazine hydrate and a trace of cupric sulfate. Hydrogen peroxide (30%, 500 mg) was then added dropwise at room temperature. The reaction was worked up after 1 hr to give 202 mg of 45. Nmr ($CDCl_3$) δ6.60 (2H, s, two aromatic protons), 2.30 (6H, s, two aromatic methyls), 1.40-1.80 (4H, multiplet, four protons at C_2 and C_3).

45 was then redissolved in 10 ml of absolute methanol, and to this solution 2 drops of concentrated HCl was added. The solution was refluxed for 12 hr. After work-up, the crude product was chromatographed on alumina with cyclohexane as the eluent to give 110 mg (60%) of 46.

1,3,3,4,5,6-Hexamethyl-7,8-(1,4-epoxy-1,2,3,4-tetrahydronaphtho)bicyclo[2.2.2]-5-ene-2-one (53)

A mixture of 1.44 g of 1,4-dihydronaphthalene 1,4-endo-oxide[28] and 1.78 g of 13 in 20 ml of chlorobenzene was refluxed for 6.5 hr. After evaporation of the solvent, a little ethanol was added and the resulting liquid was kept in the refrigerator. A colorless crystalline solid was obtained which was recrystallized from 50% aqueous MeOH at room

temperature to give a 50% yield of 53, mp 123-7°. Ir (CCl_4) 3003 (s), 1710 (s), 1470 (m), 1400 (m), 1030 (m); mass spectrum (70eV) 322 (M^+), 234 (48), 134 (85), 118 (100); nmr (CCl_4) δ7.1 (4H, s, aromatic protons), 5.10 (2H, d, J = 5 Hz, endoxide bridgehead protons), 2.30-1.60 (8H, multiplet, protons at C_7, C_8 and two vinyl methyls), 1.32 (6H, s, methyls at C_1 and C_4), 0.90 (3H, s, geminal methyl), 0.85 (3H, s, geminal methyl).

Anal. Calcd for $C_{22}H_{26}O_2$: C, 81.95; H, 8.13. Found: C, 82.14; H, 8.18.

1,4,5,8,9,10-Hexamethyl-4a,9a-dihydroanthracene-1,4-9,10-diendoxide (54)

A solution of 2 g (10 mmol) of 44 and 6 ml (50 mmol) of 2,5-dimethylfuran in 10 ml of diglyme was refluxed at 150-160° for 72 hr. After work-up, a crystalline solid was obtained (1.8 g, 60%), mp 100-5° from petroleum ether. Ir (CCl_4) 3050 (s), 1400 (s), 1220 (w), 1200 (w), 1150 (m); mass spectrum (70eV) 296 (M^+), 200 (74), 173 (87), 157 (100), 142 (68), 128 (61), 115 (59), 106 (56), 96 (98); nmr ($CDCl_3$) δ6.85 (2H, s, two aromatic protons), 6.45 (2H, s, vinyl protons), 2.40 (2H, s, protons at C_{4a} and C_{9a}), 2.32 (6H, s, aromatic methyls), 1.73 (6H, s, methyls at C_9 and C_{10}), 1.60 (6H, s, methyls at C_1 and C_4).

Anal. Calcd for $C_{20}H_{24}O_2$: C, 81.04; H, 8.16. Found: C, 81.18; H, 8.04.

Photolysis of 54

A solution of 296 mg of 54 in 10 ml of anhydrous ether was degassed with nitrogen and irradiated with a Corex filter for 8 hr (450 watt lamp). A fine crystalline product (55) which deposited in the form of plates on the test tube was filtered (30-35 mg, 5-6%), mp higher than 350°. Mass spectrum (70eV) 592 (M^+), 175 (18), 174 (100), 173 (12), 159 (7); ir (KBr) 3000 (s), 2960 (s), 1500 (m), 1470 (s), 1400 (s), 1260 (s), 1240 (s), 1170 (m), 1160 (m), 1120 (s), 920 (m), 880 (s), 860 (s), 820 (s), 770 (s). Compound 55 was insoluble in most organic solvents ($CHCl_3$, DMSO, acetone, etc.).

Anal. Calcd for $C_{40}H_{48}O_4$: C, 81.04; H, 8.16. Found: C, 81.10; H, 8.27.

The filtrate was evaporated to dryness and chromatographed on alumina with ether and petroleum ether (1/1). Two fractions were collected. The second fraction proved to be unreacted 54 (10%). The first fraction was crystallized after distillation under vacuo and gave the same spectral data and mp as compound 56 (17.5%).

1,4,5,8,9,10-Hexamethyl-2,3,4a,9a-tetrahydroanthracene-1,4-9,10-diendoxide (56)

To a solution of 54 (700 mg), hydrazine hydrate (1.5 g) and a trace of cupric sulfate in 7 ml of MeOH was added 5.04 g of 30% H_2O_2 in 7 ml of MeOH while the temperature was kept

at 0 - 5°. After being stirred at room temperature for 30 min, the reaction mixture was diluted with water and extracted with ether. The ethereal solution was dried ($MgSO_4$) and evaporated (under vacuo). The remaining oil was kept in the refrigerator overnight, and crystalline 56 was obtained in 70.9% yield, mp 88-89°. Ir (CCl_4) 3020 (s), 1510 (m), 1480 (m), 1400 (s), 1360 (w), 1280 (w), 1260 (m), 1185 (w), 1120 (m); mass spectrum (70eV) 298 (M^+), 154 (69), 152 (90), 139 (68), 137 (100); nmr (CCl_4) δ6.63 (2H, s, aromatic protons), 2.30-2.31 (10H, multiplet, two aromatic methyls and four protons at C_2 and C_3), 2.08 (2H, s, protons at C_{4a} and C_{9a}), 1.85 (6H, s, two methyls at C_9 and C_{10}), 1.40 (6H, s, two methyls at C_1 and C_4).

Anal. Calcd for $C_{20}H_{26}O_2$: C, 80.49; H, 8.78. Found: C, 80.51; H, 8.74.

The same result was obtained by using Pd-C as the catalyst under hydrogen atmosphere at room temperature. The configuration of 56 was determined by X-ray analysis.

1,4,5,8,9-Pentamethyl-10-methylene-2,3,4a-trihydroanthracene-1,4-endoxide (57)

A solution of 500 mg of 56 with five drops of HCl (or HBr) and a trace of iodine in 10 ml of MeOH (absolute) was refluxed at 75° for 126 hr. The mixture was diluted with ether and washed with sodium bicarbonate and with water several times. The organic solution was dried ($MgSO_4$) and evaporated (under vacuo). Column chromatography (Florisil, 5%

ether in hexane) of the residue afforded 150 mg (30%) of 57 (the 1st fraction), mp 110-2° from petroleum ether (30 - 60°). Ir (CCl_4) 3000 (s), 2950 (s), 2900 (s), 1500 (m), 1180 (s), 1130 (s), 960 (s); mass spectrum (70eV) 280 (M^+), 279 (39), 175 (76), 174 (100), 173 (39); nmr (CCl_4) δ6.70 (2H, s, two aromatic protons), 5.50 (1H, broad, vinyl proton), 4.95 (1H, broad, vinyl proton), 2.20 (6H, s, methyl at C_9), 1.60 (6H, s, two methyls at C_1 and C_4).

Anal. Calcd for $C_{20}H_{24}O$: C, 85.66; H, 8.63. Found: C, 85.31; H, 8.35.

1,4,5,8,9-Pentamethyl-10-methylene-9-monohydroanthracene (58)

To a solution of 524 mg (2 mmol) of triphenylphosphine in 3 ml of DMF was added 508 mg (2 mmol) of iodine in 1 ml of DMF slowly under nitrogen at -5 ∿0°. The temperature was raised to 70° and 298 mg (1 mmol) of 56 was added in one portion. After 2 hr at this temperature, 108 mg of NaOMe was added. The reaction was continued for 4.5 more hours at 135 ∿ 140°. The reddish-brown solution was extracted with pentane, and the pentane solution was washed with $NaHCO_3$ solution and then with water. The solution was dried ($MgSO_4$) and eluted through a short column on Florisil using pentane as the eluent. Evaporation of the solvent gave a fine crystalline solid (50mg, 20%) which was recrystallized from ethanol. Uv (pentane) λ_{max} (ε) 289 (sh.) (0.82×10^3), 252 (1.3×10^4); mass spectrum (70eV) 262 (M), 247 (100); nmr ($CDCl_3$) δ7.0 (4H, s, aromatic protons), 5.62 (2H, s, vinyl protons), 4.40 (1H, q, J = 6 Hz,

C_9-proton), 2.55 and 2.40 (6H each, s, four aromatic methyls), 1.30 (3H, d, J = 6 Hz, C_9-methyl).

The Preparation of 2-(2-Methyl[1,3]dioxolan-2-yl)pyridine (65)[38]

A mixture of 7 g (57 mmol) of 2-acetylpyridine, 11 ml (200 mmol) of ethylene glycol and 5 g of p-toluenesulfonic acid in 150 ml of benzene was refluxed for 64 hr in an apparatus provided with a modified Dean-Stark water separator. The reaction mixture was then poured into concentrated Na_2CO_3 solution, and the benzene layer was separated. The aqueous layer was extracted four times with benzene, then the combined organic layers were washed once with water and dried over $MgSO_4$. Benzene was removed under vacuo, and the residue was distilled at 70° (0.5 torr). The yield of 65 was ~70%.

1,4-Dimethyl-2-bromomethylbenzene (66)

Dry HBr was bubbled through a solution of paraformaldehyde (12 g, 4 mol) in glacial acetic acid (150 ml) until the solution turned clear. p-Xylene (10.6 g, 0.1 mol) was added dropwise to the above solution at 95°. The mixture was then stirred at this temperature for 2 hr, and the reaction was stopped by pouring the mixture onto ice-water. The water solution was extracted with ether several times. The combined ethereal solution was washed with $NaHCO_3$ solution twice, with water once, and was dried ($MgSO_4$). Two products were obtained from column chromatography (Florisil, hexane). The

1st fraction gave 66 (7.7 g, 40%), bp 57°(0.1 torr). Mass spectrum (70eV) 200 (7), 198 (M^+), 120 (17), 119 (100), 117 (8), 105 (14), 91 (17), 77 (9); nmr ($CDCl_3$) δ6.94 (2H, multiplet, aromatic protons at C_5 and C_6), 6.90 (1H, s, aromatic proton at C_3), 4.38 (2H, s, methylene protons), 2.30 (3H, s, methyl at C_1), 2.25 (3H, s, methyl at C_4).

The 2nd fraction gave 2,5-bis-bromomethyl-p-xylene which was recrystallized from methanol, mp 145-6°(this compound has lachrymatory vapor). Mass spectrum (70eV) 294 (2), 292 (4), 290 (M^+), 213 (36), 211 (37), 132 (100); nmr ($CDCl_3$) δ7.0 (2H, s, aromatic protons), 4.37 (4H, s, methylene protons), 2.30 (6H, s, two aromatic methyls).

This bis-bromomethyl compound (1 g) was dissolved in THF (20 ml), which was added slowly into a mixture of LAH (500 mg) and THF (10 ml) at room temperature. Then the resulting mixture was refluxed over night. After work-up, the oily residue was chromatographed on alumina with hexane as the eluent. The first fraction was durene (50%); the second fraction was the unreacted bis-bromomethyl compound (50%).

1-(2,5-Dimethylbenzyl)-2-(2-methyl [1,3] dioxolan-2-yl)pyridinium Bromide (67).

The quaternization of 3.30 g of 65 by reaction with 3.96 g of 66 in the presence of 4 ml of dry tetramethylene sulfone was carried out at 64° in a sealed flask. After 6 days, the reaction mixture was cooled to room temperature. The resulting viscous yellow oil was diluted with ethyl acetate. A white

solid formed. This solid was filtered and washed repeatedly with ethyl acetate to give 5.50 g (76.5%) of 67. No parent peak was shown in the mass spectrum. The base peak was at m/e 198 which is the molecular weight of 66. Nmr ($CDCl_3$) δ8.90-8.0 (4H, multiplet, aromatic protons on pyridinium ring), 7.0 (1H, s, proton on p-xylene ring), 6.42 (1H, s, proton adjacent to methylene on p-xylene ring), 6.30 (1H, s, proton on p-xylene), 4.0 (4H, multiplet, four protons on dioxolan), 2.25 (3H, s, aromatic methyl), 2.20 (3H, s, aromatic methyl), 1.80 (3H, s, acetyl methyl on pyridinium ring).

7,10,11-Trimethylacridizinium Perchlorate (68)

A solution of 4.2 g (11 mmol) of 67 in 20 ml of HBr (48%) was stirred at 120° for 12 hr. HBr was removed under vacuo (aspirator). The remaining yellow syrup was then dissolved in methanol and cooled in ice. A yellow solid precipitated upon the addition of 35% of perchloric acid. This yellow solid was filtered and washed with methanol. Recrystallization from acetonitrile and ether gave 3.2 g (100%) of yellow crystalline 68, mp higher than 265° (turned dark).

Anal. Calcd for $C_{16}H_{16}NClO_4$: C, 59.72; H, 5.01. Found: C, 59.69; H, 5.00.

1,4,5,8,9-Pentamethylanthracene (71)

A solution of 2.4 g (7.4 mmol) of recrystallized 68 in 100 ml of refluxing acetonitrile was cooled to room temperature. One third of 1.7 g (8 mmol) of freshly-prepared 3,6-dimethylbenzenediazonium-2-carboxylate hydrochloride (39) was added. The resulting dark solution was stirred at 45° and then the rest of 39 was added portionwise. After the mixture was refluxed for 1 hr, it was cooled to room temperature and diluted with 50 ml of ether-petroleum ether (2/1) mixture. The solid which deposited as the mixture stood in the refrigerator was filtered and washed with ether. This solid was added to a mixture of 700 mg of NaOMe and 400 mg of $NaBH_4$ in 30 ml of methanol at room temperature. After 30 min standing at room temperature, the clear part of the mixture was added to water. The resulting white opaque solution was acidified with concentrated HCl, then neutralized with $NaHCO_3$, and finally extracted with ether several times. The combined ethereal solution was dried ($MgSO_4$) and evaporated to dryness. The oily residue was dissolved in 25 ml of acetic anhydride, and 400 mg of NaOAc (anhydrous) was added. The mixture was then refluxed at 145° for 1 hr. Water was added to the reaction mixture, which was then filtered and redissolved in ether. The ethereal solution was washed with $NaHCO_3$ solution and water, and was dried ($MgSO_4$). Evaporation of the solvent afforded 0.5 g (27%) of 71 which was recrystallized from methanol, mp 158-159°. Uv (CH_3CN) λ_{max} (ε) 224 (1.6×10^4), 267 (6.2×10^4), 368 (3.5×10^3), 386 (4.2×10^3), 407 (3.6×10^3);

ir (KBr) 3000 (s), 1830 (w), 1620 (m), 1470 (s), 1400 (w), 1350 (w), 1050 (w), 880 (s), 840 (s); mass spectrum (70eV) 248 (M^+), 233 (67); nmr ($CDCl_3$) δ8.25 (1H, s, aromatic proton at C_{10}), 7.02 (4H, s, aromatic protons at C_2, C_3, C_6, and C_7), 3.02 (3H, s, methyl at C_9), 2.80 (6H, s, two methyls at C_1 and C_8), 2.70 (6H, s, two methyls at C_4 and C_5).

Anal. Calcd for $C_{19}H_{20}$: C, 91.88; H, 8.12. Found: C, 91.83; H, 8.15.

1,4,9-Trimethylanthracene (72)

The same procedure of the preparation of 71 was followed, using 68 and benzenediazonium-2-carboxylate hydrochloride as starting materials. Compound 72 was obtained in comparable yield to that of 71 and recrystallized from methanol, mp 80-81° (lit. [11] 81°). Nmr ($CDCl_3$) δ8.20 (1H, s, C_{10}-proton), 8.15-7.20 (4H, multiplet, protons at C_5, C_6, C_7, and C_8), 6.97 (2H, s, protons at C_2 and C_3), 3.15 (3H, s, C_9-methyl), 2.85 (3H, s, C_1-methyl), 2.63 (3H, s, C_4-methyl).

1,4,5,8,9-Pentamethylanthracene-9,10-endoperoxide (75)

Compound 71 (50 mg) was dissolved in cyclohexane (16 ml). The solution was then irradiated (Hanovia 450 watt lamp) without being degassed, with a Pyrex filter for 3 hr. After evaporation of the solvent, 75 was obtained in 95% yield (100% conversion), mp 210-212° from methanol. Ir (KBr) 2950 (s),

1503 (s), 1460-1480 (broad), 1390 (s), 1090 (s), 840 (s), 800 (s), 750 (s); mass spectrum (70eV) 280 (M^+), 265 (14), 264 (14), 250 (20), 249 (50), 248 (100), 247 (22), 233 (50); nmr ($CDCl_3$) 6.75 (4H, s, aromatic protons), 6.25 (1H, s, proton at C_{10}), 2.48 (6H, s, two methyls at C_1 and C_8), 2.38 (6H, s, two methyls at C_4 and C_5), 2.29 (3H, s, methyl at C_9).

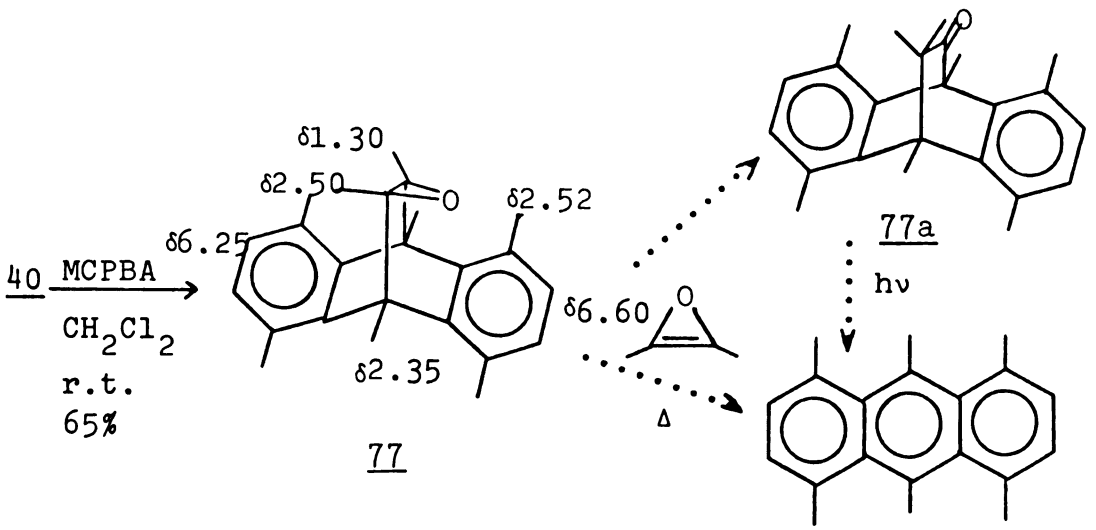
Anal. Calcd for $C_{19}H_{20}O_2$: C, 81.39; H, 7.19. Found: C, 81.64; H, 7.34 (corrected for 2.52% of ash).

PART II

MISCELLANEOUS

A. Wagner-Meerwein Rearrangement in the Dibenzobicyclooctadiene System

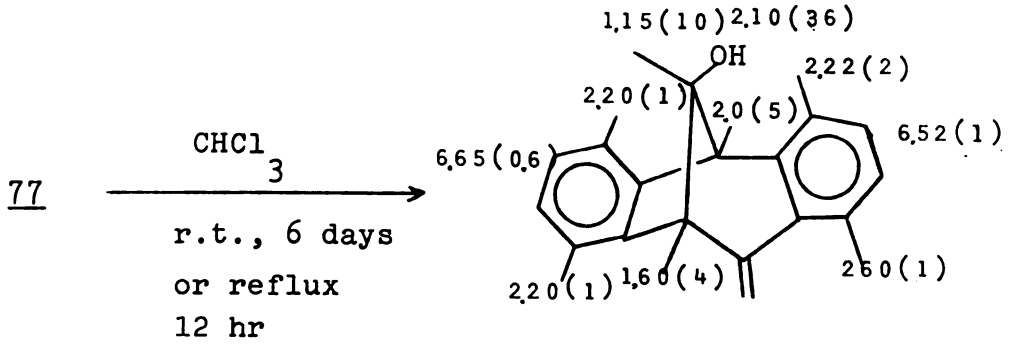
During attempts to synthesize highly methylated anthracenes, dibenzobicyclooctadiene (40) was synthesized (see Part I, Route III). It was hoped that after epoxidation, 77 would rearrange to ketone (77a) which in turn would photochemically eliminate the bridge[24] or thermally eliminate an oxirene to give the highly methylated anthracene.



A facile epoxidation of 40 with metachloroperbenzoic acid (MCPBA, washed with pH 7 buffer solution) in methylene chloride gave a 65% yield of epoxide 77 within seconds. Compound 77 was recrystallized from methylene chloride-hexane.

After standing at room temperature for six days, a solution of 77 in chloroform was found to contain no 77 but a new compound 79 which gave a correct analysis for $C_{24}H_{28}O$ (isomer of 77). The uv spectrum revealed a maximum at

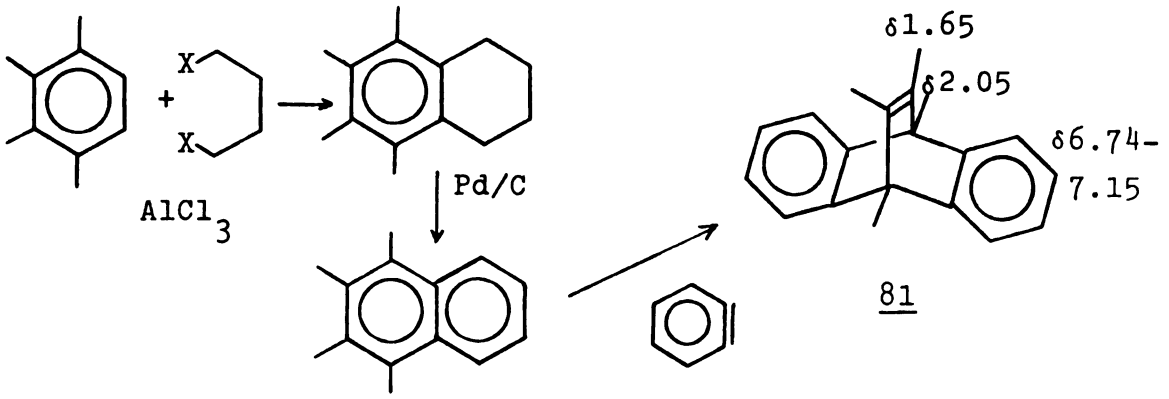
λ_{max} 235 nm (2.28×10^4) with shoulders at 308 (10^3). 283 (3.4×10^3) and 265 (7.1×10^3); the infrared spectrum indicated the presence of a hydroxyl group (3500 cm^{-1}). The nmr spectrum gave two singlets for two vinyl protons at δ 5.45 and 5.20. Other nmr data with europium shift numbers in parenthesis are shown on the proposed structure.



79

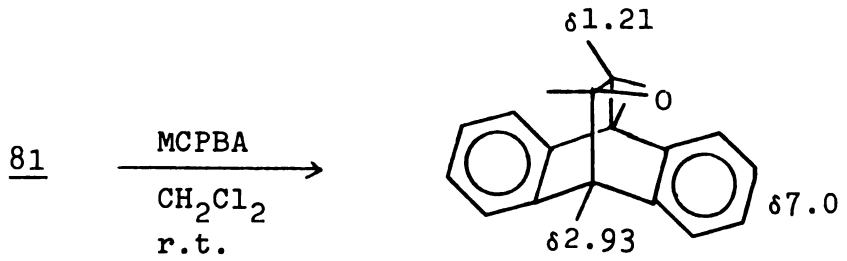
This rearrangement process was also achieved by refluxing a solution of 77 in chloroform for 12 hr or by injection of 77 on a gas chromatograph (15% SE-30, 230°). It was further observed, by following the rearrangement at room temperature with nmr, that after 24 hr a completely new set of peaks appeared different from those of 77 or 79. However, this intermediate could not be isolated; all attempts to isolate and purify it gave the final product 79.

To study the above rearrangement more easily, a simpler system which would give the same reaction sequence but exhibit less complicated nmr spectra was desired. Therefore compound 81 was synthesized from benzyne and 1,2,3,4-tetramethylnaphthalene which was prepared by following Havsigk's procedure.[14]

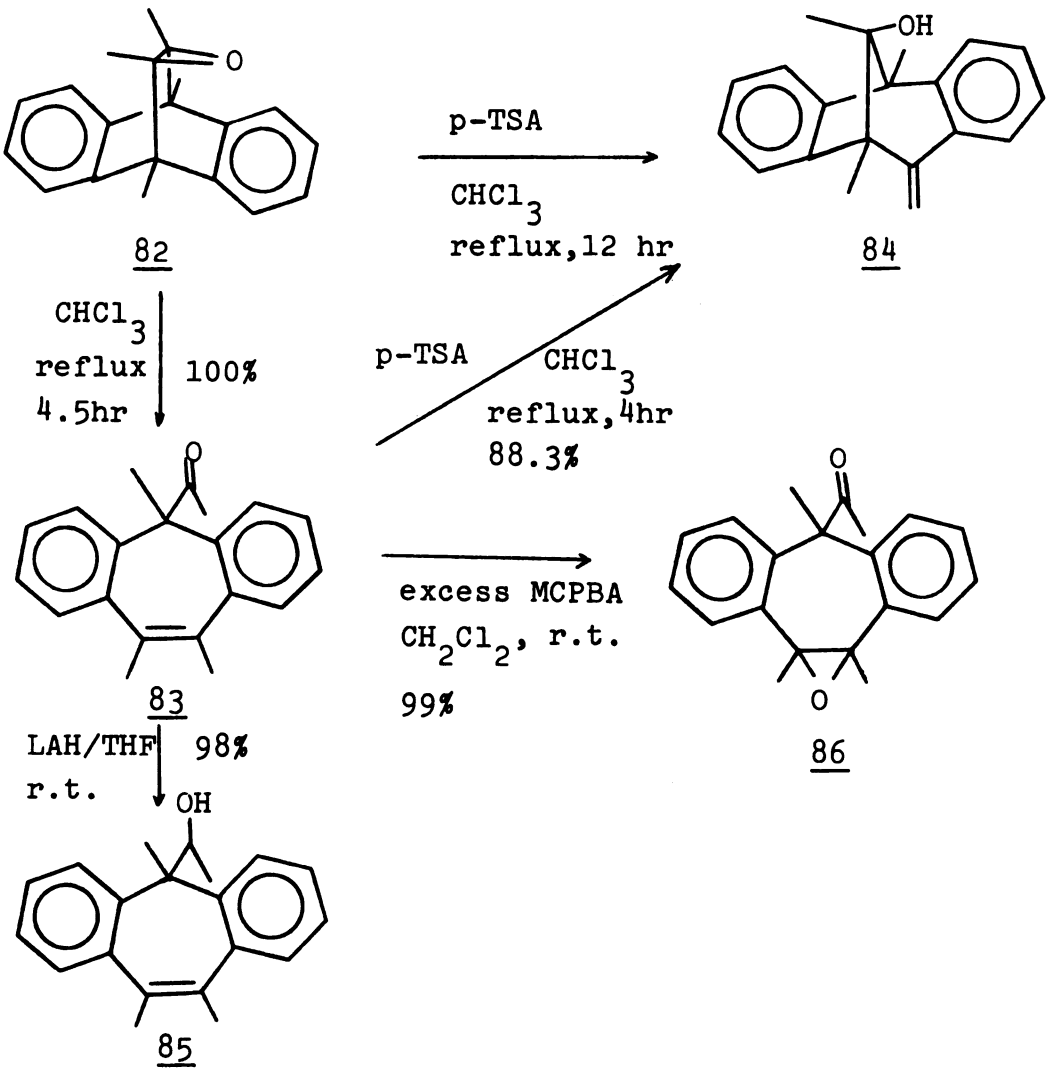


81

Using the same conditions as for the epoxidation of 40, compound 81 was transformed to 82 in 72.4% yield. The nmr data of 81 and 82 are shown in the formulas. At reflux temperature for 4.5 hr, a chloroform solution of 82 afforded a nicely crystalline compound 83 (100%) which had its λ_{max} at 266 nm (9.3×10^3) and 228 (1.54×10^4). The infrared spectrum showed strong absorption at 1703 cm^{-1}, indicating the presence of a carbonyl group; the nmr spectrum consisted of one multiplet between δ7.0-7.4 for the eight aromatic protons, one singlet at δ2.20 for the two vinyl methyls, and two equal singlets at δ1.93 and 1.80 for the C_1- and acetyl methyl groups respectively.



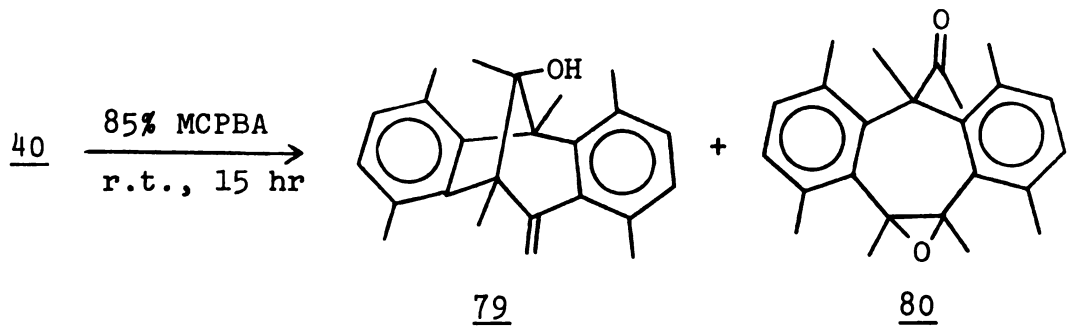
82



The presence of carbonyl and olefin functional groups was supported by the following experiments:

Compound 83 was reduced by LAH in THF at room temperature to give the alcohol 85. Its infrared spectrum showed no carbonyl absorption but a strong band at 3480 cm^{-1}. The nmr spectrum of 85 showed one quartet at δ5.0 (J = 6 Hz) for the carbinyl proton and one doublet at δ0.85 (J = 6 Hz) for

the methyl group adjacent to the carbinol group. When compound 83 was treated with an excess of MCPBA in methylene chloride at room temperature, it yielded the epoxide 86 (99%). The structure of 86 was confirmed by its nmr spectrum (bands due to the vinyl methyls disappeared and a new singlet was shown at δ1.70 for the two methyls attaching to the epoxide ring), the C-O-C absorption at 1180 cm^{-1}, and the parent peak (m/e 292) in its mass spectrum. A tetramethyl analogue 80, was also obtained by the reaction of 40 and 85% MCPBA at room temperature for 15 hr. The products were separated by vpc. Compound 79 was obtained in 70% yield, and 80 in 30% yield (for its nmr spectrum see page 84).

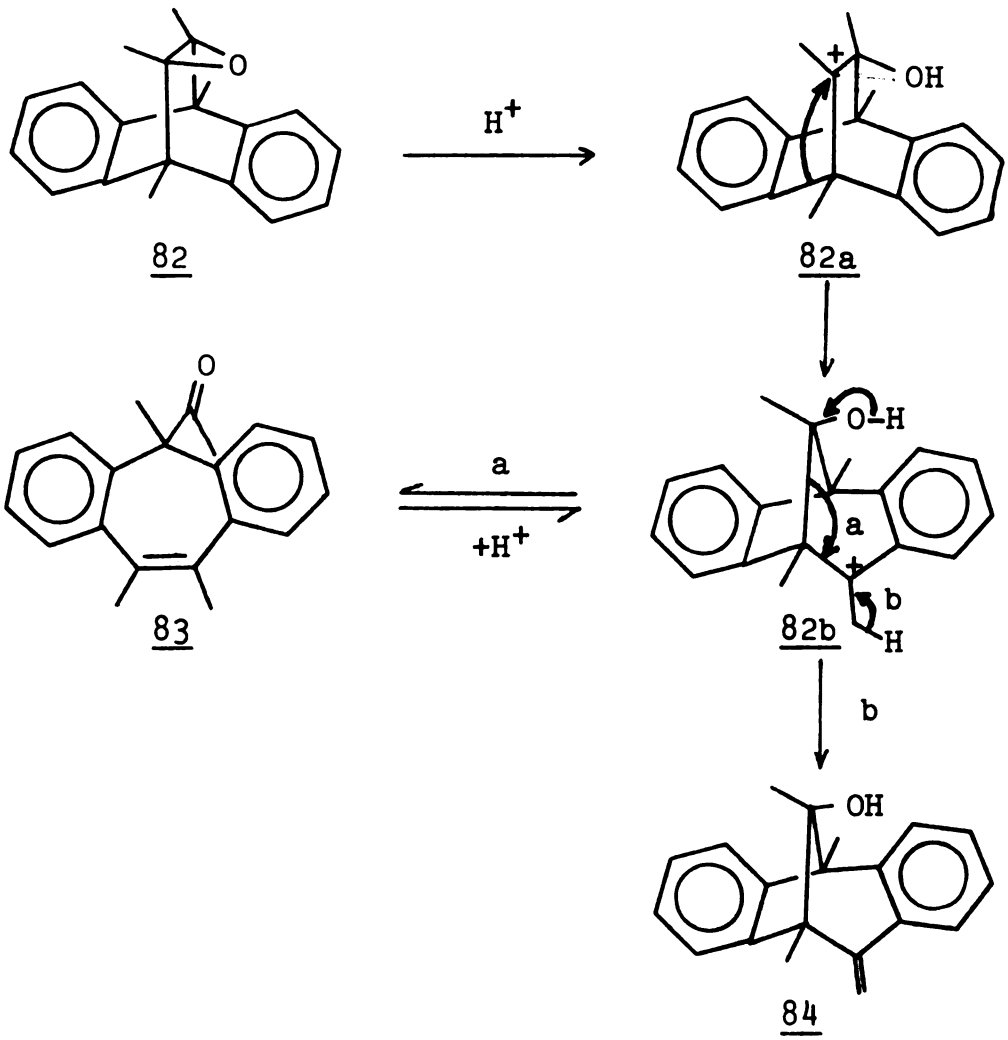


79 80

No further rearrangement of 83 was observed on prolonged reflux of its chloroform solution for 12 more hours. Isomer 84 was obtained only by refluxing a solution of 82 (or 83) in chloroform with a trace of p-toluenesulfonic acid for 12 hr (4 hr for 83). The yield of 84 was 88.3% accompanied with a 10.3% recovery of 83. Compound 84 gave a correct analysis, and its nmr spectrum had multiple peaks between

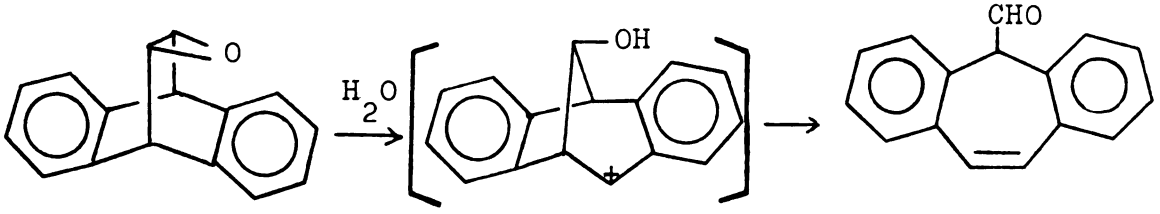
δ7.50-6.95 for the eight aromatic protons, two equal singlets at δ5.55 and 5.15 for the two vinyl protons, and three equal singlets at δ1.70, 1.58 and 1.0 for the C_1, C_5 and C_8 methyls respectively.

On the basis of this information, a proposed mechanistic path rationalizing these skeletal rearrangements is shown in Scheme 10.



Scheme 10

The first three steps (82 → 83) are consistent with the results of previous work by Cristol in 1960,[44] who found that epoxide 87 was converted to aldehyde 88 on heating.

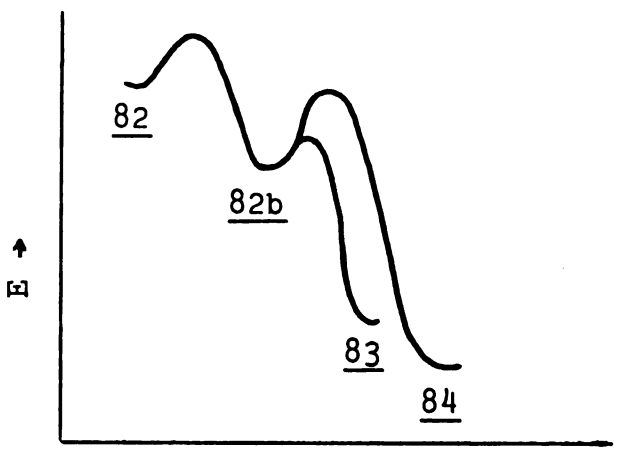


87 87a 88

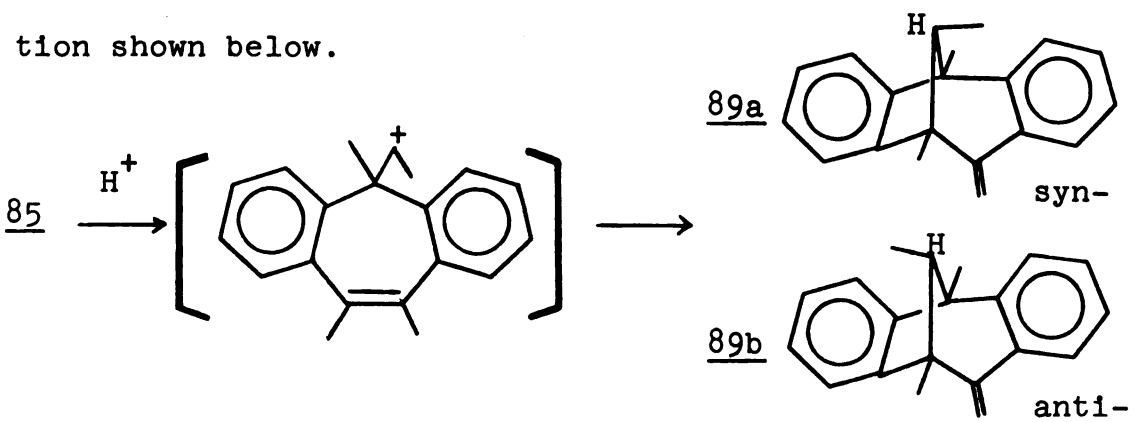
Since then, the same research group has published a series of papers concerned with the rearrangement of the above system. The existence of the intermediate 87a has been confirmed by trapping with halide or acetate anions.[45] According to our results, the phenyl migration step can be supported by the fact that 77 rearranged to 78 much faster than 82 to 83, because the migratory aptitude of the migrating phenyl group was enhanced by methyl substituents. Moreover, a thermal reaction of 82 in pyridine was conducted at 65-75° to give a total recovery of 82, the absence of rearrangement product 83 implies that the rearrangement was induced by traces of acid present in the solvent.

The next steps to 84 are first a double-bond participation to regenerate the carbonium ion 82b and then loss of one proton to form the exocyclic olefin.

An energy diagram can be drawn to help visualize the above rearrangement. The activation energy between 82b and 84 must be higher than that between 82b and 83. The reason why 82b did not rearrange to 84 in the first place can be explained if the conversion of 82b to 83 is kinetically controlled whereas that of 82b to 84 is thermodynamically controlled.

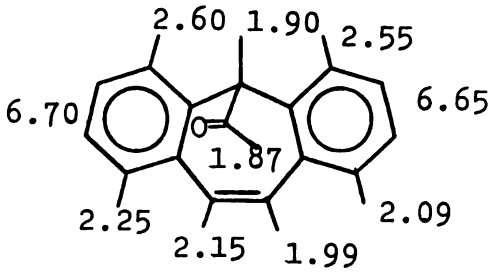


The double bond participation was supported by the reaction shown below.

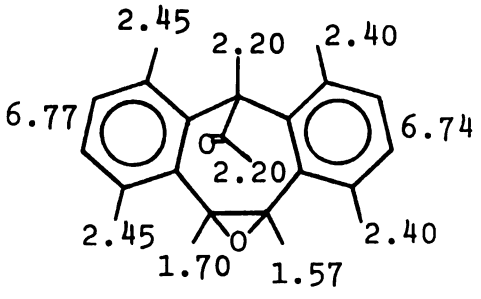


On treatment with p-toluenesulfonic acid, a solution of 85 in benzene turned pink. After 3 hr at reflux temperature, a mixture of two isomeric alkenes was obtained (89a and 89b). They were separated by preparative vpc (5% SE-30 on Chromosorb W at 160°) with 53.33% and 10.66% yields for the first and second fractions respectively. The nmr spectrum of the first isomer had one multiplet at δ6.90-7.60 for the aromatic protons, two equal singlets at δ5.60 and 5.10 for the vinyl protons, another multiplet at δ2.10 for the C_8-proton, two singlets at δ1.70 and 1.56 for C_1- and C_5-methyls respectively, and one doublet (J = 6 Hz) at δ0.76 for C_8-methyl; the nmr spectrum of the 2nd isomer showed one multiplet at δ6.80-7.10 for the aromatic protons, two equal singlets at δ2.0 and 1.86 for the methyls at C_1 and C_5 respectively, another multiplet at δ1.30-1.70 for the proton at C_8, and one doublet (J = 6 Hz) at δ0.82 for the methyl at C_8. No configurational assignment has been made.

The nmr spectrum of 83 is consistent with its symmetrical structure, but that of 78 is not. By using a space-filling model, it can be seen that interference between methyl substituents has extremely distorted the symmetry of the molecule. The nmr spectrum of 80 shows a similar perturbation.

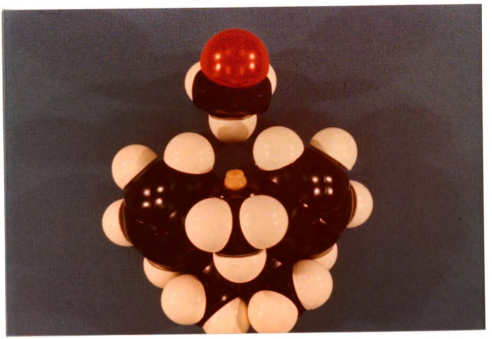


78



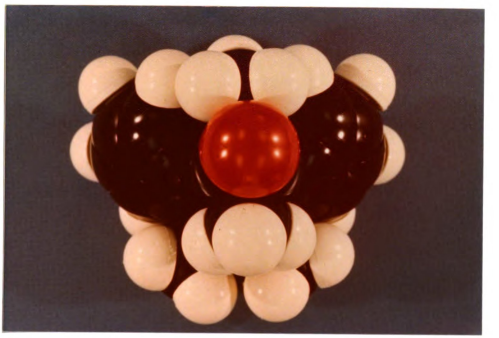
80

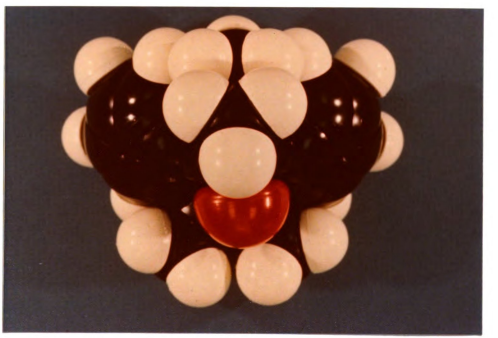
Figure 1. Models of 1-acetyl-2,3-6,7-dibenzo-1,4,5-trimethylcyclohepta-2,4,6-triene (83): A. methyl group axial; acetyl cannot be added to the model in the equatorial position; B. asymmetric conformation with the acetyl group axial; this is the predominent conformation at low temperature; C. two symmetric conformations with the acetyl group axial; each represents a possible transition state for the interconversion of enantiomeric asymmetric conformations.



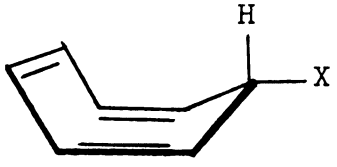
A

B

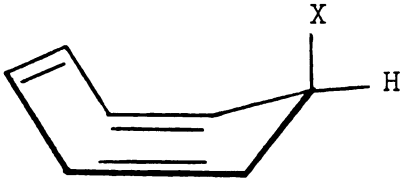




According to a 1975 paper,[46] C_1-substituted cycloheptatrienes have two isomeric structures; that is, the substituent may be in either an equatorial or an axial position. This gives us another possible explanation for the unsymmetrical nmr spectrum of 78, which is the possibility of conformational interconversion.

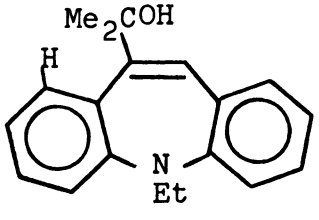


Equatorial

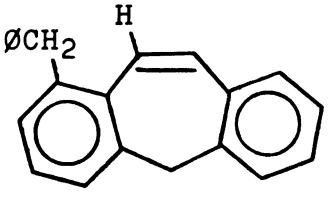


Axial

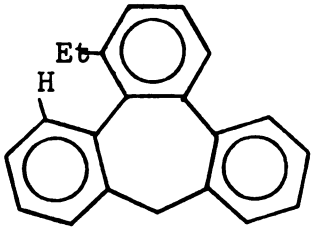
However, this possibility can be ruled out by the following arguments: (1) Ollis[47] and his coworkers reported numerical data for nonbonded interaction energies in their study of the energy barriers to conformational inversion of the system shown below.



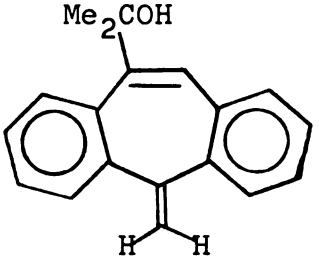
21.7 Kcal/mole



11 Kcal/mole



27 Kcal/mole



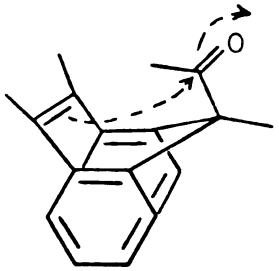
21.2 Kcal/mole

In light of the above result, a higher activation energy was expected for the conformational inversion of our system. (2) A study of the low temperature nmr spectra of 83 showed that at 10°, the sharp singlet due to the two vinyl methyls began to split and eventually two sharp singlets (with a difference of 8 Hz) were observed at -20°. If this split was caused by conformational interconversion (that is, at low temperature, the flipping of the seven-membered ring slowed down so that both conformers were observed), two sets of peaks for the C_1- and acetyl methyls should also have appeared in the spectrum. However, although the first singlet (vinyl methyls) split, the other two singlets (C_1- and acetyl methyls) still remained sharp. This result also revealed that it was not only a plane of symmetry but also the free rotation of the acetyl group, which caused a symmetric nmr spectrum of 83 at room temperature. As the temperature was lowered, the rotation became hindered, and the acetyl group was squeezed out of the plane of symmetry by its crowded surroundings to give an 8 Hz difference between the two vinyl methyls. The acetyl group of 78 which has an even more crowded structure, stopped its rotation at room temperature to give a comparable difference (8 Hz) between the vinyl methyls.

It was also observed that at much lower temperatures (-70∿95°), the peak due to the quaternary methyl of 83 broadened, indicating that its rotation was probably also hindered.

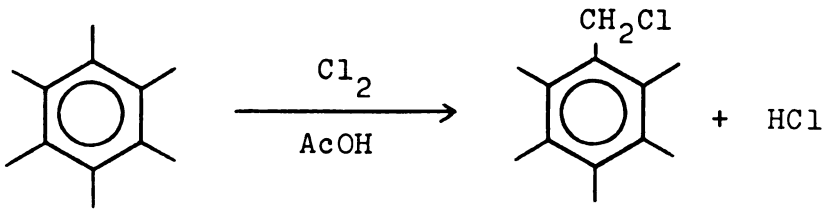
Now, we know that the flipping of the seven-membered ring did not occur and only one of the two conformers of 83 (or 78)

was observed. Since an axial acetyl group is required by the mechanism of its formation (Scheme 10, page 81), the total conversion of 78 (or 83) to 79 (or 84) by double bond participation can prove that the acetyl group is axial.

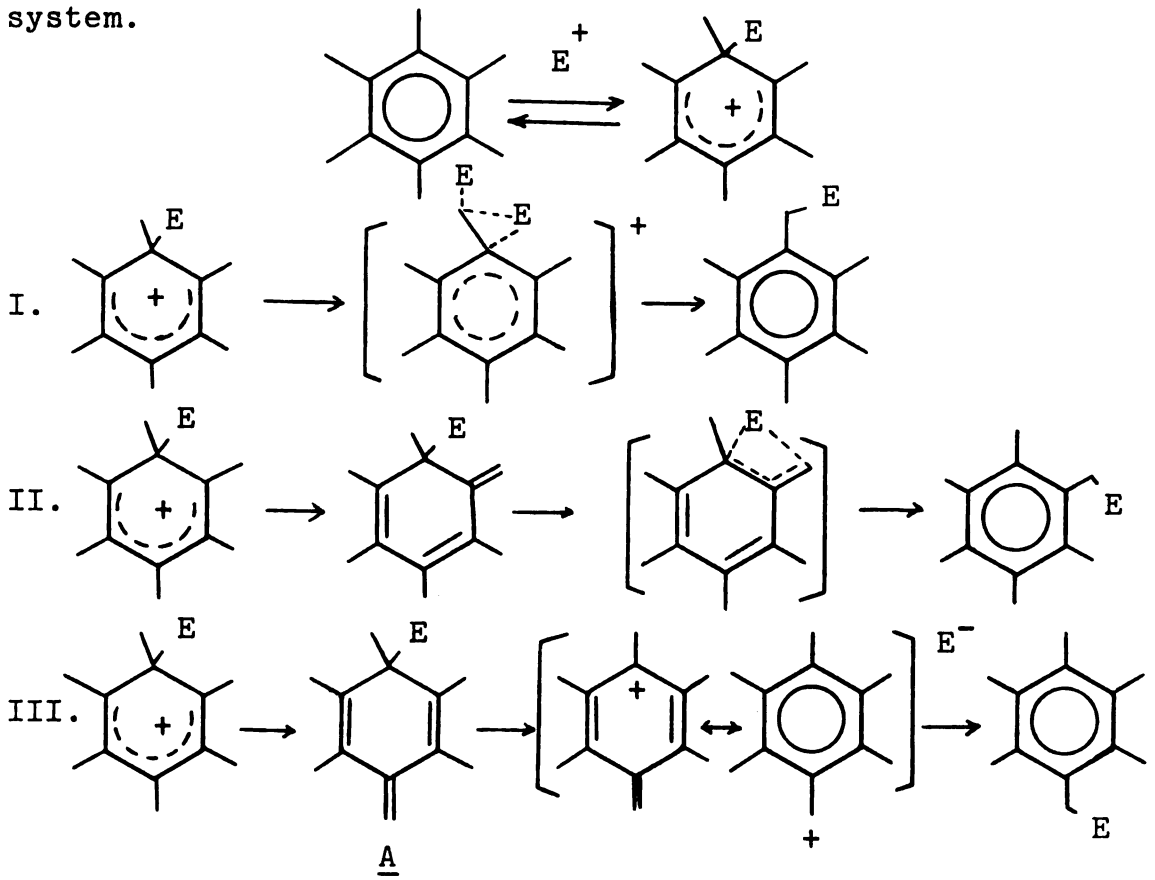


B. Non-Conventional Electrophilic Aromatic Substitutions of Octamethylnaphthalene

A recent review article[48] contained an extensive discussion of non-conventional electrophilic aromatic substitution and related reactions. This type of reaction can be described as an electrophilic reaction of aromatic compounds in which side-chain substitution is involved. For example, hexamethylbenzene and molecular chlorine react in acetic acid, in the absence of light and catalyst, to give mainly chloromethylpentamethylbenzene.[49] The scope of these reactions includes halogenation,[49-53] nitration,[54,55] and isotope exchange.[56]



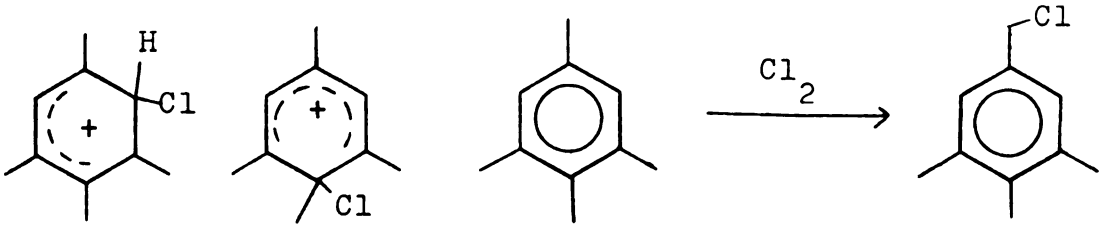
Three mechanisms have been proposed (Scheme 11), which involve a common slow step; that is, the electrophile may initially attack any activated position of the aromatic system.



Scheme 11

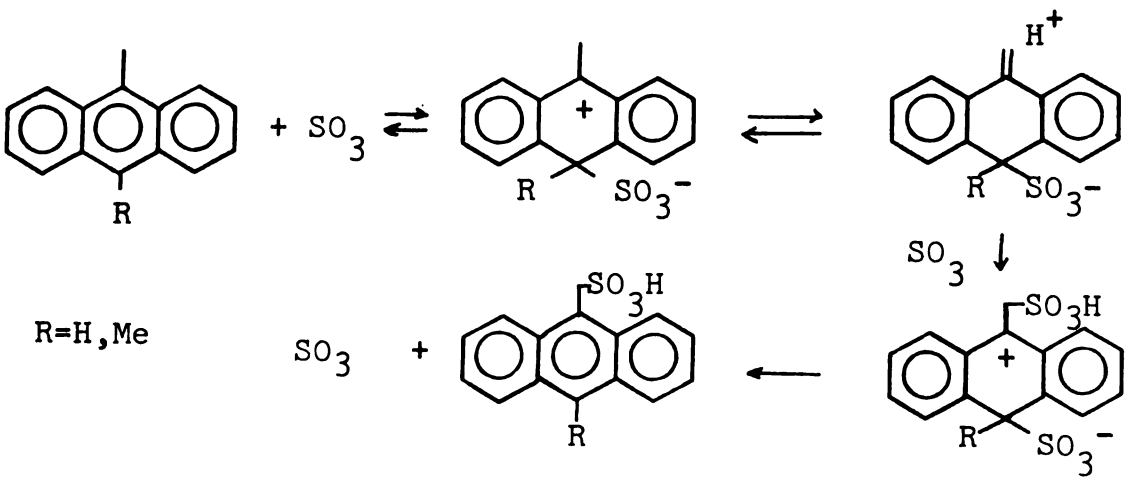
In mechanism I,[50] the electrophile migrates to the methyl group attached to the attacked position. Another mechanism (II) calls for the electrophile to migrate to an ortho double bond.[50] The last mechanism (III) suggests that proton loss from the carbonium ion generated in the slow step can lead to A.[51] Rearrangement may then occur at an ion-pair stage with high retention of halogen, as observed.[48] Mechanism I seems to be eliminated by a study of the chlorination of

isodurene. The carbonium ions possibly involved are B and C, in which the positions attacked are both activated by two ortho-methyl groups and one para-methyl group. Nevertheless, substitution occurs almost exclusively on the C_5-methyl group to give 3,4,5-trimethylchloromethylbenzene.[57]



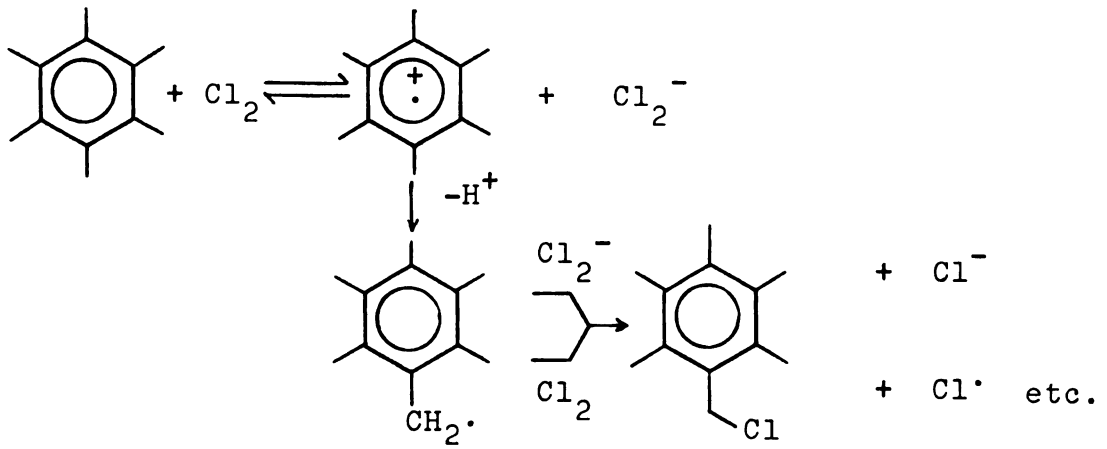
B C

Some support for ionic intermediates (mechanism III) was reported by Illuminati and coworkers.[58] They found that in the chlorination of hexaethyl-benzene, the amount of side-chain substitution (ca. 15%) was significantly larger than the 5% found in the case of hexamethylbenzene. Another result favoring ionic intermediates was reported by Cerfontain on the study of side-chain sulfonation of meso-methylated anthracenes.[59] The mechanism proposed is shown in Scheme 12.



Scheme 12

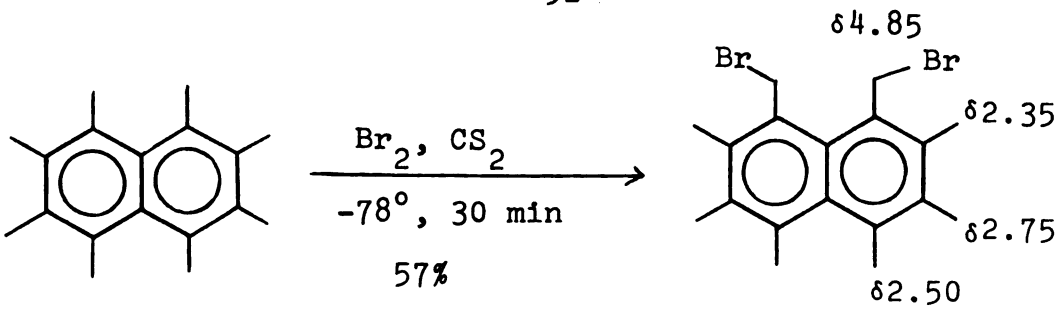
An electron transfer mechanism similar to mechanism III was proposed not long ago by Kochi[60](Scheme 13), who observed a well-resolved esr spectrum of hexamethylbenzene cation-radical during the chlorination reaction which was conducted by mixing acetic acid solutions of chlorine and hexamethylbenzene directly in the cavity of an electron spin resonance spectrometer.



Scheme 13

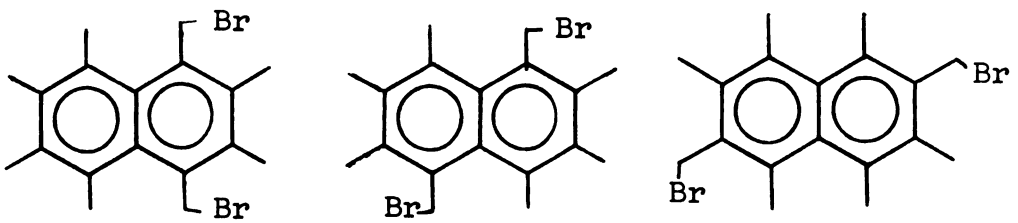
One interesting system that has never been explored in this context is octamethylnaphthalene (2).

Compound 2 was treated with bromine in CS_2 at -78° in the dark. The reaction was worked up after 30 min and the viscous residue was diluted with a small portion of ether. The resulting crystalline solid (57%) analyzed correctly for $C_{18}H_{22}Br_2$ and gave a reasonable nmr spectrum for the bisbromomethyl compound (90).

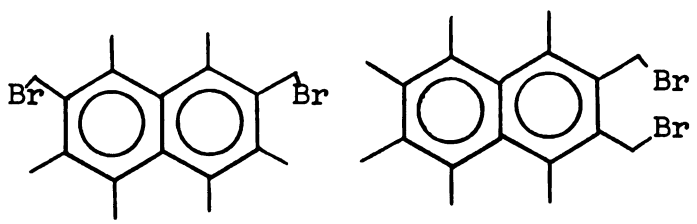


2 90

Other possible structures for this product whose symmetry would also satisfy the observed nmr spectrum are:



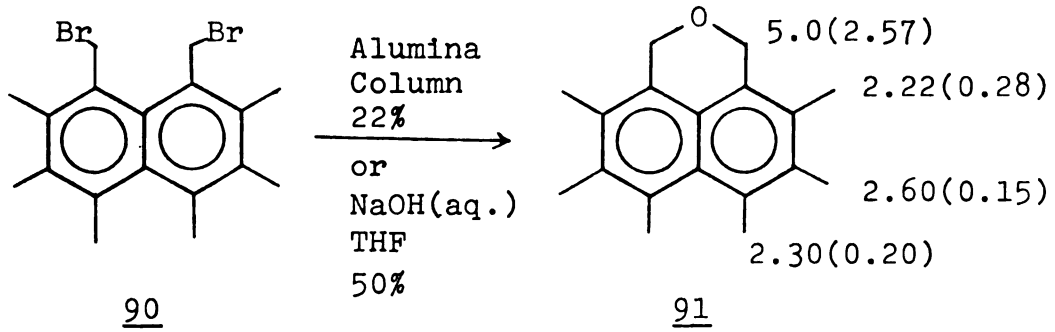
90a 90b 90c



90d 90e

Attempts to purify 90 by column chromatography on alumina with 15% chloroform in carbon tetrachloride as the eluent gave a 22% yield of an ether, assigned structure of 91. This result was also achieved (50% yield) by hydrolysis of 90 in NaOH and THF at 40-70° for 40 min. In addition to its correct analysis for $C_{18}H_{22}O$, compound 91 displayed a consistent nmr spectrum as shown in the formula with europium shift numbers in parenthesis. The infrared spectrum showed strong absorption at

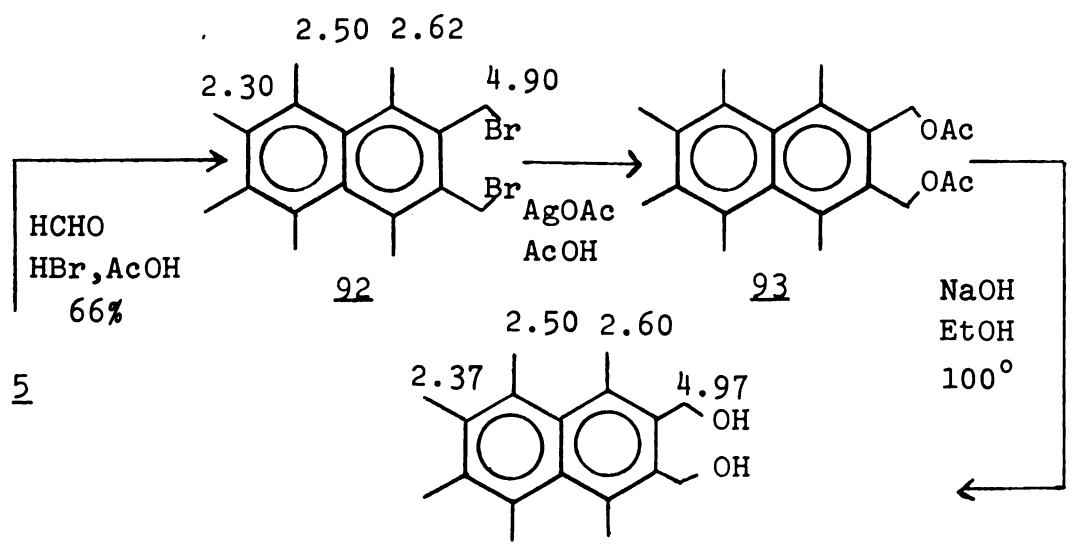
1143 cm^{-1} indicating a C-O-C linkage.



90 91

As a consequence, all those structures which cannot form a cyclic ether linkage can be ruled out; only 90 and 90e remain as possible structures for the dibromo compound. The following series of reactions confirmed that the 1,8-bisbromomethyl isomer (90) was the product obtained.

Hexamethylnaphthalene (5) was bisbromomethylated with paraformaldehyde and hydrogen bromide in glacial acetic acid to produce a 66% yield of 92, which had an nmr spectrum similar to but distinctly different from that of 90 (see structure).

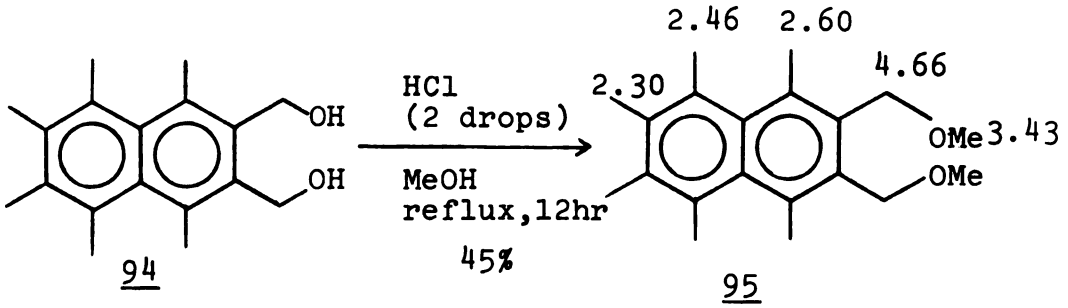


5 92 93 94

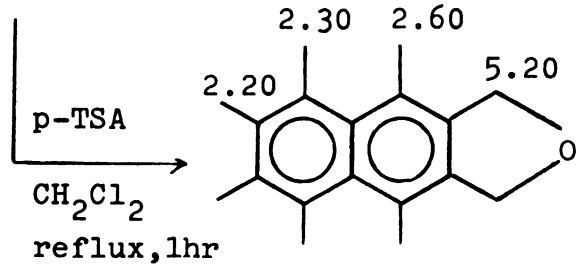
It was not possible to convert 92 to the corresponding alcohol 94 under the common solvolytic conditions. Thus a two-step process involving the acetate as an intermediate was employed.[61] The diester 93 was obtained by treatment of 92 with silver acetate in glacial acetic acid at 100-110° for 7 hr. Its nmr spectrum had one singlet at δ5.40 for the four methylene protons, three singlets at δ 2.60, 2.50 and 2.37 with two methyls each for the six aromatic methyls, and one singlet at δ 2.10 for the two acetyl methyls.

This diester was subsequently hydrolyzed in aqueous sodium hydroxide and ethanol at 100° for 2 hr to give the diol 94 in 82% yield (for the two steps).

An attempt to dehydrate 94 with HCl in methanol only afforded the dimethoxy compound 95. Its nmr spectral data are illustrated in the formula.



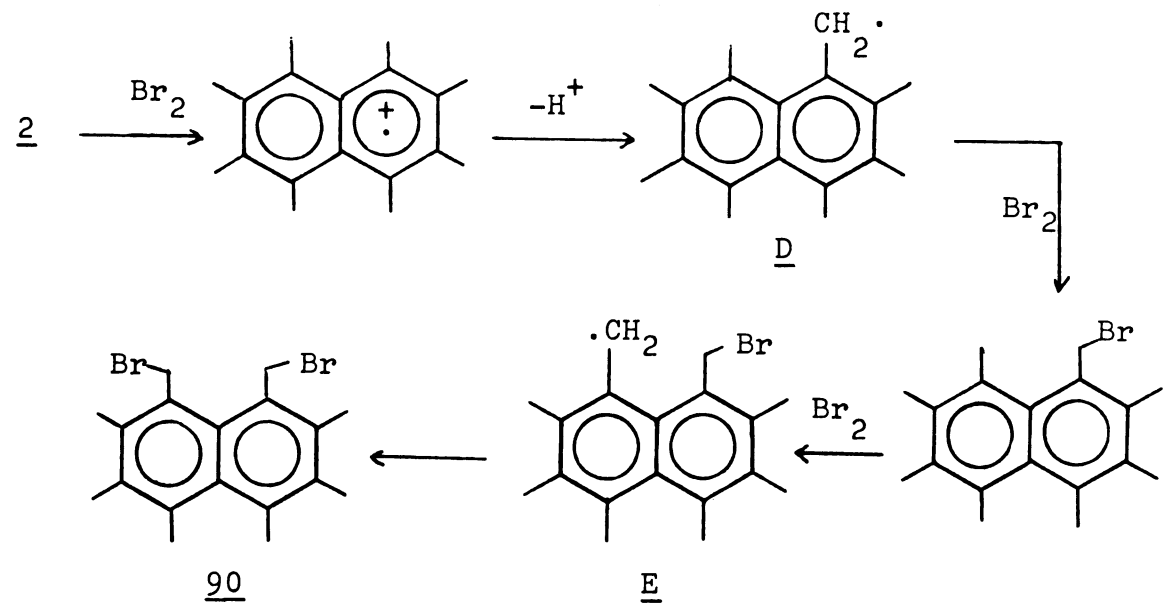
94 95



96

The dehydration of 94 was accomplished by reflux for 1 hr in methylene chloride in the presence of p-toluenesulfonic acid.

In a manner similar to Kochi's mechanism, an electron transfer pathway for the formation of 90 from octamethylnaphthalene is proposed in Scheme 14.

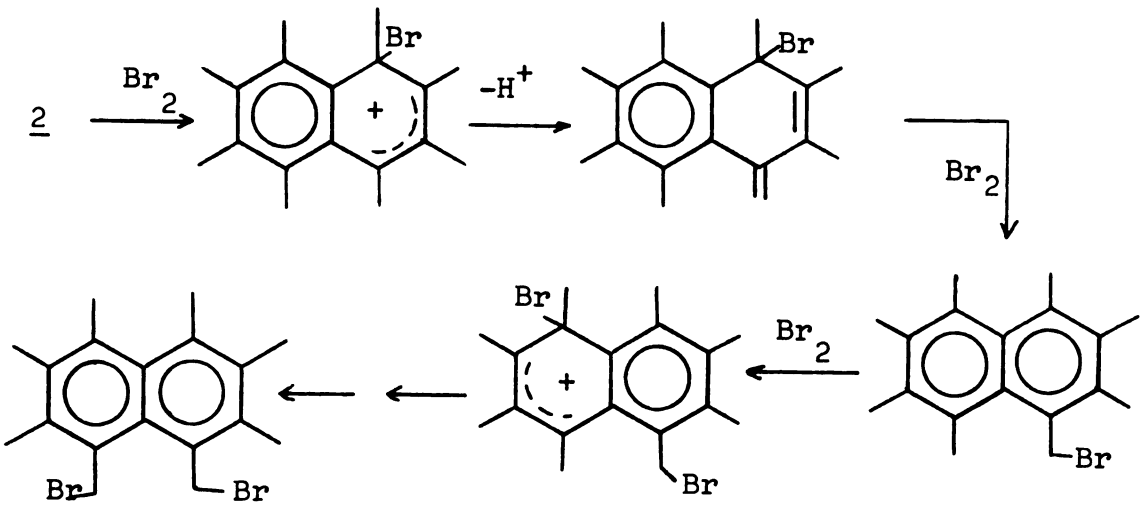


Scheme 14

Possible reasons why bromination occurred at the C_1- and C_8-methyls are (1) the loss of a peri-methyl proton from the cation radical to give intermediate D may minimize the strong peri interaction; (2) the loss of the second proton from C_8-methyl and C_1-bromomethyl groups, which is expected to be greater than that between C_4- and C_5-methyls; and (3) the

radical of intermediate E could be stablized by the adjoining bromine in the manner of neighboring-group participation.

Another reasonable pathway is shown in Scheme 15.



90

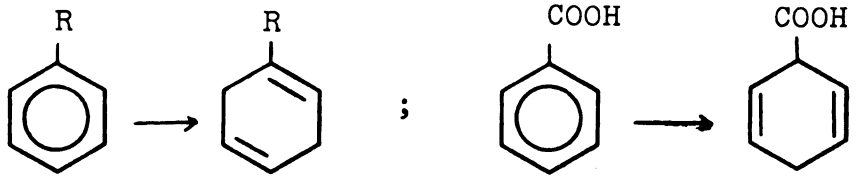
Scheme 15

Since in compound 2 the most reactive position toward electrophiles are α-positions,[9] bromine may initially attack one of the peri-carbons. The second bromine-attack may have occurred at C_5 instead of C_8 because steric hindrance by the bulky bromomethyl group blocked the C_8 position.

Clearly much remains to be learned about the mechanisms of these reactions, but the results described here show that bromination of octamethylnaphthalene gives mainly a simple dibromo product, 90.

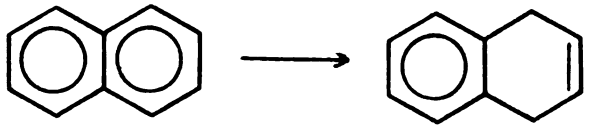
C. The Birch Reduction of Octamethylnaphthalene

When aromatic rings are reduced by sodium (or potassium or lithium) in liquid ammonia, 1,4-addition of hydrogen takes place, and nonconjugated cyclohexadienes are produced. This reaction is known as the Birch reduction.[62] The rule of addition of hydrogen atoms to a benzene ring based on the experimental evidence is as follows: The hydrogen atoms are added in positions para to each other, avoiding carbon atoms carrying electron-repelling groups, and being attracted to carboxyl groups.[63]

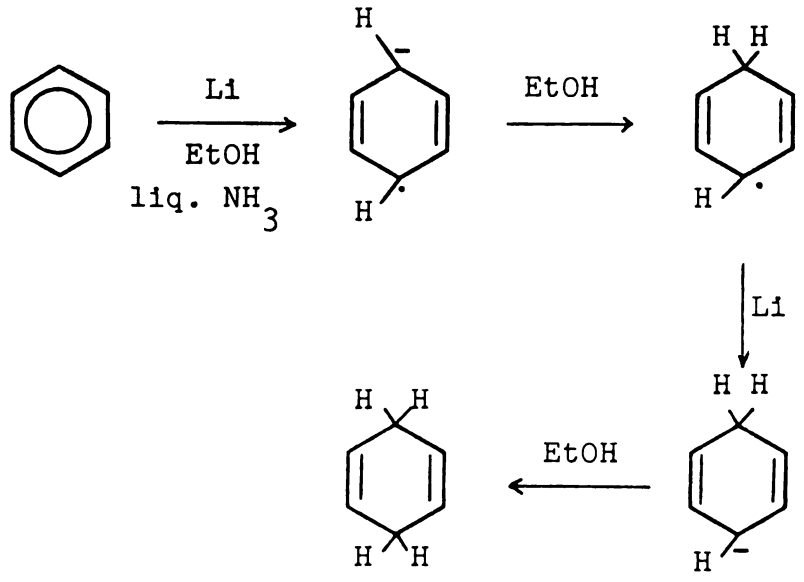


R = MeO, NMe_2, Alkyl

For the naphthalene system without substituents, hydrogen atoms have been found to add at the α-positions.[64]

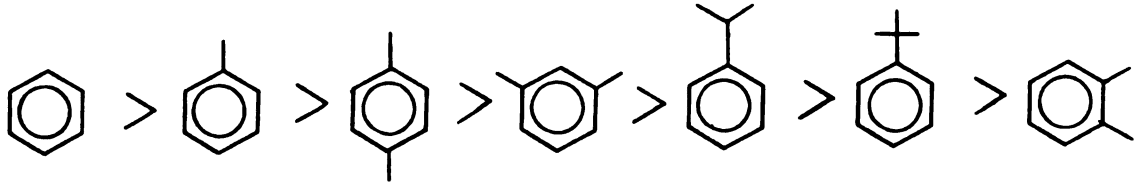


A mechanism was proposed for this type of reaction as shown in Scheme 16.[65]



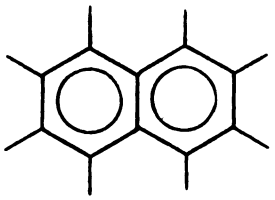
Scheme 16

The lithium transfers an electron to the ring, becoming oxidized to Li^+ and creating an ion-radical. The ion-radical accepts a proton from ethanol to give a radical, which is then reduced to a carbanion by another lithium atom. The relative stabilities of alkylbenzene anion radicals in tetrahydrofuran-1,2-dimethoxyethane mixtures have been measured by Lawler and Tabit.[66]



This implies that the Birch reduction of any aromatic system should be retarded by alkyl substituents. Since compound 2

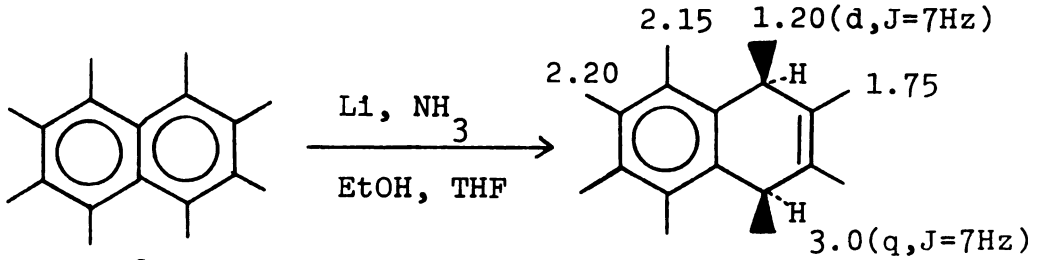
carries methyl groups in all possible locations, it seemed interesting to investigate the orientation of the proton additions and the effect of substituents on the Birch reduction of 2.



Birch Reduction ⟶ ?

2

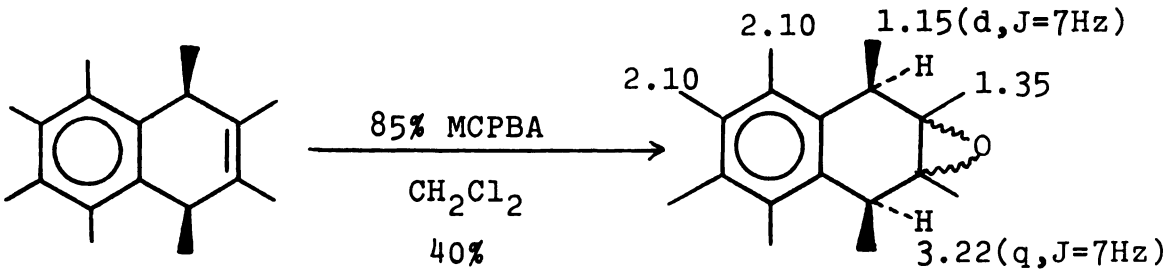
The reaction of 2 was carried out in a solution of liquid ammonia, THF and absolute ethanol, with the slow addition of lithium metal at dry ice temperature. The reaction was continued until the blue color vanished. Evaporation of the ammonia and work-up in the usual way afforded a 39-86.7% yield of product (yield varies with different ratio of 2/Li, and with temperature). The product was isolated by recrystallization from petroleum ether (30-60°), and was identified as the 1,4-dihydro derivative 97. Its nmr spectral data are shown in the formula.



2 97

2/Li:		
1/6	-78°	39% + 2
1/12	-50°	58% + 2
1/24	-50°	86.7% no 2

The stereochemistry of 97 was cis, as shown by the symmetrical nmr spectrum of its epoxide derivative 98.



97 98

The epoxidation was carried out at room temperature over night using 85% MCPBA in methylene chloride to give a 40% yield of 98.

EXPERIMENTAL

1,4,7,8-Tetramethyl-2,3-5,6-di(3,6-dimethylbenzo)bicyclo [2.2.2]octa-2,5,7-triene-7-epoxide (77)

A methylene chloride solution of meta-chloroperbenzoic acid (50 mg, washed with pH 7 buffer solution and dried under vacuo) was added dropwise to a solution of 40 (64 mg) in methylene chloride (5 ml) at room temperature. After 1 min, the reaction mixture was poured into an aqueous solution of sodium sulfite. The aqueous layer was separated and extracted with ether, and the combined organic layer was then washed with $KHCO_3$ solution and water, and was dried over $MgSO_4$. The solvent was removed under vacuo at room temperature. A white solid remained which was recrystallized from methylene chloride/hexane. The yield of 77 was 42.5 mg (65%). Compound 77 was unstable in organic solutions and decomposed when the melting point was measured (125°). Mass spectrum (70eV) 332 (M^+), 317 (43), 289 (100); nmr ($CDCl_3$) δ6.60 (2H, s, two aromatic protons on the benzene ring which is syn to the epoxide), 6.52 (2H, s, two aromatic protons on the benzene ring which is anti to the epoxide), 2.52 (6H, s, two aromatic methyls on the benzene ring which is syn to the epoxide), 2.50 (6H, s, two aromatic methyls on the benzene ring which is anti to the epoxide), 2.35 (6H, s, two methyls at C_1 and C_4),

1.30 (6H, s, two methyls at C_7 and C_8).

The Rearrangement of 77

Compound 77 was dissolved in chloroform in an nmr tube, and allowed to stand at room temperature over night. The reaction was followed by changes in the nmr spectrum. A 100% conversion of 77 to 78 was observed. Nmr ($CDCl_3$) δ 6.70 and 6.65 (2H each, s, aromatic protons), 2.60 and 2.55 (3H each, s, two aromatic methyls at carbons ortho to C_2 and C_7), 2.25 and 2.09 (3H each, s, two aromatic methyls at carbons ortho to C_3 and C_6), 2.15 and 1.99 (3H each, s, vinyl methyls at C_4 and C_5), 1.90 (3H, s, methyl at C_1), 1.87 (3H, s, acetyl methyl). Then the solution in the nmr tube was evaporated to dryness at room temperature under vacuo. The white solid obtained was quickly mixed with dry KBr, and the infrared spectrum of 78 was taken: 3000 (s), 1690 (s), 1470 (s), 1390 (m), 1360 (m), 830 (s), 800 (m).

Further rearrangement was observed on redissolving 78 in chloroform and allowing it to stand for six more days. After evaporation of the chloroform, 79 was obtained in 100% yield. This rearrangement was also accomplished in 100% yield either by refluxing 77 in chloroform for 12 hr or by injecting 77 on the gas chromatograph (5' X ¼" 15% SE-30 on 30/60 Chromosorb W at 230). Recrystallization of 79 from chloroform and absolute methanol gave a 90% yield of pure 79, mp 205-7°. Uv (MeOH) $\lambda_{max}(\varepsilon)$ 308 (sh.) (1 X 10^3), 283 (sh.) (3.4 X 10^3), 265 (sh.) (7.1 X 10^3), 235 (2.28 X 10^4);

ir (KBr) 3500 (s), 3000 (s), 1620 (m), 1470 (s), 1390 (s), 1340 (s), 920 (m), 830 (s); mass spectrum (70eV) 332 (M^+), 317 (43), 289 (100), 274 (49), 259 (63), 244 (30), 235 (30); nmr ($CDCl_3$) δ6.65 (2H, s, aromatic protons), 6.52 (2H, s, aromatic protons), 5.45 and 5.20 (1H each, s, vinyl protons), 2.60 and 2.22 (3H each, s, two aromatic methyls), 2.20 (6H, s, two aromatic methyls), 2.10 (1H, broad, hydroxyl proton), 2.0 (3H, s, methyl at C_1), 1.60 (3H, s, methyl at C_5), 1.15 (3H, s, methyl at C_8).

Anal. Calcd for $C_{24}H_{28}O$: C, 86.70; H, 8.49. Found: C, 86.59; H, 8.46.

1,4,7,8-Tetramethyl-2,3-5,6-dibenzobicyclo[2.2.2]octa-2,5,7-triene (81)

A mixture of 1,2,3,4-tetramethylnaphthalene[14] (1 g, 5.4 mmol), benzenediazonium-2-carboxylate hydrochloride (1.2 g, 5.6 mmol), propylene oxide (15 ml) and 1,2-dichloroethane (50 ml) was gradually heated until gas evolution occurred. After the solution became clear, the reaction was continued at reflux temperature for 2 hr. The volatile solvents were removed under vacuo, and the oily residue was dissolved in ether. The ethereal solution was washed with cold 2% NaOH, with water, and dried over $MgSO_4$. The brown residue which remained after the solvent was evaporated was chromatographed on silica gel with cyclohexane as the eluent. The first fraction proved to be the unreacted starting material; the second fraction, which was recrystallized from methanol, mp 178-180°,

was the title compound with a yield of 32% (448 mg). Mass spectrum (70eV) 260 (M^+), 245 (100), 230 (42), 215 (32), 206 (18); nmr ($CDCl_3$) δ6.74-7.15 (8H, m, aromatic protons), 2.05 (6H, s, two methyls at C_1 and C_4), 1.65 (6H, s, two vinyl methyls).

Anal. Calcd for $C_{20}H_{20}$: C, 92.26; H, 7.74. Found: C, 92.29; H, 7.74.

1,4,7,8-Tetramethyl-2,3-5,6-dibenzobicyclo[2.2.2]octa-2,5,7-triene-7,8-epoxide (82)

The same procedure for the epoxidation of 40 was followed to transform 125 mg (0.48 mmol) of 81 into 96 mg (72.4%) of 82, mp 154-155° (decomposed at 120°). Uv (CH_3CN) λ_{max} (ε) 233 (1.64 X 10^3), 266 (1.28 X 10^3), 274 (1.46 X 10^3); mass spectrum (70eV) 276 (M^+), 233 (100), 218 (26), 203 (22), 202 (25), 191 (23); nmr ($CDCl_3$) δ7.0 (8H, m, aromatic protons), 2.93 (6H, s, two methyls at C_1 and C_4), 1.21 (6H, s, two methyls at C_7 and C_8).

Anal. Calcd for $C_{20}H_{20}O$: C, 86.92; H, 7.29. Found: C, 86.98; H, 7.34.

1-Acetyl-2,3-6,7-dibenzo-1,4,5-trimethylcyclohepta-2,4,6-triene (83)

A solution of 82 (98 mg) in chloroform (5 ml) was refluxed for 4.5 hr. Evaporation of the solvent gave

98 mg (100%) of 83, mp 173-5° from methanol. Uv (CH_3CN) λ_{max} (ε) 266 (9.3×10^3), 228 (1.54×10^4); ir (KBr) 3050 (m), 1703 (s), 1480 (m), 233 (100), 218 (25), 202 (29); nmr ($CDCl_3$) δ7.0-7.4 (8H, m, aromatic protons), 2.20 (6H, s, two vinyl methyls), 1.93 (3H, s, methyl at C_1), 1.80 (3H, s, methyl at carbonyl).

Anal. Calcd for $C_{20}H_{20}O$: C, 86.92; H, 7.29. Found: C, 86.85; H, 7.34.

Thermal Reaction of 82 in a Basic Medium

Compound 82 (20 mg) was dissolved in pyridine (3 ml). The flask was previously rinsed with concentrated ammonium hydroxide and dried in an oven. The reaction mixture was heated at 65-75° for 5 hr and then evaporated to dryness under vacuo. The nmr spectrum showed only recovered starting material, 82.

Reduction of 83 by LAH

A solution of 83 (99 mg) in THF (5 ml) was added slowly at room temperature into a suspension of LAH (70 mg) in THF (5 ml). After the mixture was stirred at room temperature for 1 hr, the excess LAH was decomposed by pouring the mixture over ice. The resulting suspension was then extracted with ether, and the ethereal solution was washed repeatedly with water and dried over $MgSO_4$. After chromatography on

alumina with 50% ether in hexane as the eluent, 95 mg of 85 (98%) was obtained from the second fraction (the 1st fraction was an unidentified solid). The colorless liquid 85 gave no carbonyl absorption in its ir spectrum (neat): 3480 (s), 3010(s), 1485 (s), 1400 (m), 1270 (m), 1050 (s). Mass spectrum (70eV) 278 (M^+), 260 (34), 233 (100), 218 (28), 206 (34), 202 (28); nmr ($CDCl_3$) δ6.80-7.30 (8H, m, aromatic protons), 5.0 (1H, q, J = 6 Hz), 3.26 (1H, s, hydroxyl proton), 2.24 (6H, s, two vinyl methyls), 1.85 (3H, s, methyl at C_1), 0.85 (3H, d, J = 6 Hz).

1,5,8-Trimethyl-4-methylene-2,3-6,7-dibenzo-8-hydroxylbicyclo-[3.2.1]octa-2,6-diene (84)

A solution of 82 (68 mg) in chloroform (5 ml) with a trace amount of p-toluenesulfonic acid was refluxed for 12 hr. The chloroform solution was then washed with $NaHCO_3$ solution and dried over $MgSO_4$. The residue which was obtained after evaporation of the solvent was chromatographed on silica gel with 20% ether in hexane as the eluent. The first fraction was 83 (7 mg, 10.3%), and the second fraction was 84 (60 mg, 88.3%), mp 170-3° from methanol. Mass spectrum (70eV) 276 (M^+), 233 (100); nmr ($CDCl_3$) δ7.50-6.95 (8H, m, aromatic protons), 5.55 and 5.15 (1H each, s, vinyl protons), 1.70 (3H, s, methyl at C_1), 1.58 (3H, s, methyl at C_5), 1.0 (3H, s, methyl at C_8).

Anal. Calcd for $C_{20}H_{20}O$: C, 86.92; H, 7.29. Found: C, 86.93; H, 7.33.

The same result was obtained by refluxing the chloroform solution of 83 in the presence of a small amount of p-toluenesulfonic acid for only four hours.

1-Acetyl-2,3-6,7-dibenzo-1,4,5-trimethylcyclopenta-2,4,6-triene-4-epoxide (86)

A solution of 83 (276 mg, 1 mmol) in methylene chloride (5 ml) was treated with MCPBA (excess, washed with pH 7 buffer solution and dried under vacuo) over night at room temperature. After work-up, 86 was obtained in 99% yield, mp 140-143° from ether and petroleum ether (30-60°). Ir (KBr) 3000 (m), 1710 (s), 1480 (w), 1390 (m), 1180 (m), 1100 (m), 770 (s); mass spectrum (70eV) 292 (M^+), 206 (42), 146 (52), 43 (100); nmr ($CDCl_3$) δ7.50-7.0 (8H, m, aromatic protons), 2.15 (3H, s, methyl at C_1), 1.97 (3H, s, acetyl methyl), 1.70 (6H, s, two methyls at C_4 and C_5).

1-Acetyl-2,3-6,7-di(3,6-dimethylbenzo)-1,4,5-trimethylcyclopenta-2,4,6-triene-4-epoxide (80)

To a solution of 40 (64 mg) in methylene chloride (5 ml) was added 85% MCPBA (50 mg, 25% excess) at room temperature. After 15 hr, the reaction was worked up as usual. A mixture of two products was obtained. They were separated by preparative vpc (5' X ¼" 15% SE-30 on 30/60 Chromosorb W at 225°). The first fraction was 79 in 70% vpc yield, and the next fraction was 80 in 30% vpc yield. Ir (KBr) 3510 (w), 3000 (s),

1620 (m), 1460 (s), 1390 (s), 1340 (s), 1150 (m), 1120 (m), 920 (s), 830 (s); mass spectrum (70eV) 348 (M^+), 330 (44), 287 (64), 272 (28), 257 (20), 174 (100), 173 (88), 159 (38); nmr ($CDCl_3$) δ6.77 and 6.74 (2H each, s, aromatic protons), 2.45 (6H, two s, aromatic methyls at carbons ortho to C_2 and C_7), 2.40 (6H, two s, aromatic methyls at carbons ortho to C_3 and C_6), 2.20 (6H, two s overlaped, methyls at C_1 and carbonyl), 1.70 (3H, s, methyl at C_4), 1.57 (3H, s, methyl at C_5).

Acid Rearrangement of 85

p-Toluenesulfonic acid (20 mg, 0.12 mmol) was added to a solution of 85 (68 mg, 0.24 mmol) in benzene (100 ml). The solution turned pink when the acid started to dissolve. After 1.5 hr at reflux temperature, 20 mg of anhydrous Na_2SO_4 was added. The reaction mixture was refluxed for another 1.5 hr. The solution was passed through a short silica gel column with benzene as the eluent. Evaporation of the solvent followed by chromatography on alumina with hexane as the eluent gave a mixture of two isomers which were separated by vpc (5' X ¼" 5% SE-30 on Chromosorb W at 160°). The 1st fraction, with retention time of 20 min, was completely separated from the 2nd fraction with retention time of 25 min. These two isomers gave exactly the same mass spectrum (70eV) 260 (M^+), 245 (34), 215 (24), 206 (100), but different nmr spectra. Nmr (1st isomer, $CDCl_3$)

δ6.90-7.60 (8H, m, aromatic protons), 5.60 and 5.10 (1H each, s, vinyl protons), 2.10 (1H, m, proton at C_8), 1.70 (3H, s, methyl at C_1), 1.56 (3H, s, methyl at C_5), 0.76 (3H, d, J = 6 Hz, methyl at C_8); nmr (2nd isomer, $CDCl_3$) δ6.80-7.10 (8H, m, aromatic protons), 4.94 and 4.60 (1H each, two d, J = 2 Hz, vinyl protons), 2.0 (3H, s, methyl at C_1), 1.86 (3H, s, methyl at C_5), 1.30-1.70 (1H, m, proton at C_8), 0.82 (3H, d, J = 6 Hz, methyl at C_8). The total yield of the two isomers was 64%. The relative yield from vpc was 5/1 (1st/2nd).

Anal. Calcd for $C_{20}H_{20}$: C, 92.26; H, 7.74. Found: C, 91.91; H, 7.44.

The Bromination of Octamethylnaphthalene

A mixture of carbon disulfide (5 ml) and octamethylnaphthalene (2) (480 mg, 2 mmol) was kept in a flask wrapped with aluminum foil at -78°. To this mixture was added slowly a solution of bromine (0.12 ml, 2 mmol) in CS_2 (3 ml). After 30 min at this temperature, the reaction was stopped by adding sodium bisulfite solution. The organic layer was separated, diluted with chloroform, and washed with sodium bicarbonate solution. Solvent was removed under vacuo after the solution was dried ($MgSO_4$). The viscous residue was then diluted with a small portion of ether. A crystalline solid (90) was obtained in 57% yield (450 mg), mp 165-170°. Mass spectrum (70eV) 398 (10), 396 (M^+), 319 (14), 317 (14), 238 (100), 223 (45), 207 (30), 193 (26); nmr ($CDCl_3$) δ4.85

(4H, s, methylene protons), 2.75 (6H, s, aromatic methyls at C_3 and C_6), 2.50 (6H, s, aromatic methyls at C_4 and C_5), 2.35 (6H, s, aromatic methyls at C_2 and C_7).

Anal. Calcd for $C_{18}H_{22}Br_2$: C, 54.59; H, 5.60. Found: C, 54.47; H, 5.63.

2,6-Dihydro-naphtho[1,8,8a-c,d]pyran (91)

Column chromatography 450 mg of 90 on alumina with 15% chloroform in carbon tetrachloride as the eluent gave three fractions. The first two fractions were insignificant, and attempts to identify them were unsuccessful. The third fraction, after recrystallization from ether, gave 63 mg (22%) of 91, mp 194-8°. Ir (CCl_4) 3050 (s), 2950 (s), 2850 (m), 1470 (m), 1400 (m), 1143 (s), 1060 (m), 980 (m); mass spectrum (70eV) 254 (M^+), 239 (80), 225 (56), 211 (43), 195 (19), 179 (20), 165 (21); nmr ($CDCl_3$) δ5.0 (4H, s, methylene protons), 2.60 (6H, s, aromatic methyls at C_3 and C_6), 2.30 (6H, s, aromatic methyls at C_4 and C_5), 2.22 (6H, s, aromatic methyls at C_2 and C_7).

Anal. Calcd for $C_{18}H_{22}O$: C, 84.99; H, 8.72. Found: C, 85.02; H, 8.69.

Compound 90 (250 mg) was dissolved in THF (10 ml). This solution was then added into an aqueous solution of NaOH, and the resulting mixture was heated at 40-70° for 40 min. After work-up, a 50% yield of 91 was obtained.

Bisbromomethyl-1,4,5,6,7,8-hexamethylnaphthalene (92)

Dry HBr was bubbled through a suspension of paraformaldehyde (300 mg) in glacial acetic acid (5 ml) until the solution turned clear. To this solution was added at 35° a glacial acetic acid (5 ml) solution of 5 (212 mg). The resulting solution was stirred at this temperature for 2 hr, and at 40-45° for another hour. A white solid was precipitated. The mixture was then poured onto ice, and the solid was filtered and washed with water. The solid was redissolved in ether and the ethereal solution was washed with aqueous $NaHCO_3$ and water, and was dried ($MgSO_4$). Evaporation of the solvent and recrystallization from ether and chloroform gave a 66% yield of 92, mp 182-4°. Mass spectrum (70eV) 398 (11), 396 (M^+), 319 (43), 317 (43), 238 (100), 223 (43), 208 (30), 193 (30); nmr ($CDCl_3$) δ4.90 (4H, s, methylene protons), 2.62 (6H, s, methyls at C_1 and C_4), 2.50 (6H, s, methyls at C_5 and C_8), 2.30 (6H, s, methyls at C_6 and C_7).

Anal. Calcd for $C_{18}H_{22}Br_2$: C, 54.59; H, 5.60. Found: C, 54.58; H, 5.67.

1,4,5,6,7,8-Hexamethyl-2,3-dihydroxymethylnaphthalene (94)[58]

Silver acetate was precipitated by adding excess aqueous KOAc to $AgNO_3$ (1 g) in water. The solid was filtered and washed three times with glacial acetic acid, and was then diluted with glacial acetic acid and dried with acetic

anhydride. The dibromo compound 92 (800 mg) was then added to this solution, and the mixture was held at 100-110° for 7 hr. The white solid (AgBr) was filtered after the reaction was stopped. The filtrate was concentrated under reduced pressure and purified with elution on alumina with 50% ether in hexane as the eluent. The diester 93, nmr in $CDCl_3$ δ5.40 (4H, s, methylene protons), 2.60 (6H, s, methyls at C_1 and C_4), 2.50 (6H, s, methyls at C_5 and C_8), 2.37 (6H, s, methyls at C_6 and C_7), 2.10 (6H, s, two acetyl methyls) obtained was redissolved in 10% of aqueous NaOH (30 ml) and absolute ethanol (30 ml). The solution was stirred at 100° for 2 hr, and gave 450 mg (82%) of diol 94, after work-up, mp 178-180° from chloroform and petroleum ether (30-60°). Ir (KBr) 3350 (s), 2950 (s), 1580 (w), a series of bands between 1490-1100, 1000 (s); mass spectrum (70eV) 272 (M^+), 254 (100), 239 (43), 225 (45), 211 (31), 195 (20), 179 (22), 165 (23); nmr ($CDCl_3$) δ4.97 (4H, s, methylene protons), 2.60 (6H, s, methyls at C_1 and C_4), 2.50 (6H, s, methyls at C_5 and C_8), 2.37 (6H, s, methyls at C_6 and C_7).

Treatment of 94 with Acid

The diol 94 (100 mg) was dissolved in absolute methanol (10 ml), and 2 drops of concentrated HCl was added. The mixture was refluxed for 12 hr, and was worked up and dried ($MgSO_4$). Chromatography on alumina with 50% ether in petroleum ether (30-60°) as the eluent gave 50 mg (45%) of 95,

mp 96-97°. Mass spectrum (70eV) 300 (M^+, 100), 268 (86), 253 (94), 238 (40), 225 (25), 223 (25), 207 (27); nmr ($CDCl_3$) δ4.66 (4H, s, methylene protons), 3.43 (6H, s, methoxy methyls), 2.60 (6H, s, methyls at C_6 and C_7).

Anal. Calcd for $C_{20}H_{28}O_2$: C, 79.95; H, 9.39. Found: C, 79.87; H, 9.39.

Dihydro-iso-1,4,5,6,7,8-hexamethylnaphthofuran (96)

To a 1,2-dichloroethane solution of diol 95 (100 mg), was added a saturated solution of p-toluenesulfonic acid in 1,2-dichloroethane. The mixture was heated at 40-50° for 1 hr and then worked up. Chromatography on alumina with 30% ether in petroleum ether (30-60) as the eluent gave a crystalline solid of 92 (30%), mp 180° (decomposed). Nmr ($CDCl_3$) δ5.20 (4H, s, methylene protons), 2.60 (6H, s, methyls at C_1 and C_4), 2.30 (6H, s, methyls at C_5 and C_8), 2.20 (6H, s, methyls at C_6 and C_7).

1,4-Dihydrooctamethylnaphthalene (97)[67]

A three-necked flask equipped with a dry-ice condenser, a mechanical stirrer, and an inlet tube, was charged with 240 mg of octamethylnaphthalene (2). The stirrer was started, and to the rapidly stirred flask contents was added 50 ml of ammonia as rapidly as possible. A portion (ca. 5 ml) of THF was then added to dissolve the insoluble organic material. The liquid ammonia was passed through a sodium hydroxide tube

before being condensed into the flask. When all the octamethylnaphthalene had gone into solution, 3 ml of absolute ethanol was added. To this mixture was then added 168 mg of lithium metal in small pieces and at such a rate as to prevent the ammonia from refluxing too violently. After the addition of the lithium had been completed (ca. 45 min), the solution was stirred for a while until the blue color disappeared. Evaporation of the ammonia and decomposition of the residue with cold water were followed by extraction with ether. Evaporation of ether under vacuo gave 210 mg (86.7%) of the product 97. Recrystallization was successful with proper amount of petroleum ether (30-60°), mp 70-73°. Mass spectrum (70eV) 242 (M^+), 227 (80), 212 (100), 198 (23), 162 (25), 147 (56); nmr ($CDCl_3$)δ3.0 (2H, q, J = 7 Hz, protons at C_1 and C_4), 2.20 (6H, s, methyls at C_6 and C_7), 2.15 (6H, s, methyls at C_5 and C_8), 1.75 (6H, s, methyls at C_2 and C_3), 1.20 (6H, d, J = 7 Hz, methyls at C_1 and C_4).

Anal. Calcd for $C_{18}H_{26}$: C, 89.19; H, 10.81. Found: C, 89.63; H, 10.87.

1,4-Dihydro-2,3-epoxy-octamethylnaphthalene (98)

The epoxidation of 97 was carried out by adding MCPBA (85%, 150 mg) to a solution of 97 (100 mg) in 5 ml of methylene chloride. The reaction mixture was stirred at room temperature for 15 hr. The organic solution was washed with Na_2CO_3 solution and dried ($MgSO_4$). Chromatography on silica gel with

10% ether in cyclohexane as the eluent gave 50 mg (40%) of 98, mp 128-9° from petroleum ether (30-60°). Ir(KBr) 2950 (s), 1480 (s), 1400 (s), 1120 (s), 1080 (s), 1020 (m), 890 (s); mass spectrum (70eV) 258 (M^+), 241 (70), 229 (73), 225 (100), 215 (71), 201 (70), 185 (62); nmr (CCl_4) δ3.22 (2H, q, J = 7 Hz, protons at C_1 and C_4), 2.10 (12H, s, four aromatic methyls), 1.35 (6H, s, methyls at C_2 and C_3), 1.15 (6H, d, J = 7 Hz, methyls at C_1 and C_4).

Anal. Calcd for $C_{18}H_{26}O$: C, 83.66; H, 10.14. Found: C, 83.78; H, 10.20.

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