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I hereby recommend that the thesis prepared under my supervision by Henry W. Steinmann

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Approved by:

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A STUDY OF CYCLOBUTADIBENZENE AND CYCLOPENTINDENE

A Dissertation Submitted to the

Graduate School of Arts and Sciences

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requirements for the degree of

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by

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B. S. Drexel Institute of Technology 1940

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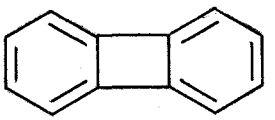
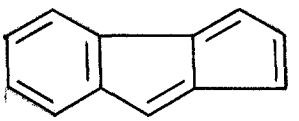
I. INTRODUCTION

The compound, cyclobutadibenzene, I-1, also called



I-1

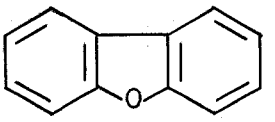
biphenylene, has a rather interesting history inasmuch as its preparation was a matter of dispute among several investigators for a considerable time. The many failures to synthesize this compound were attributed to the strained ring system. Indeed, even when it seemed fairly reasonable that biphenylene was finally prepared by Lothrop (1) in 1941, the question of strain was paramount and its existence was doubted by Baker (2). Instead, he interpreted Lothrop's experiments as leading to a new conjugated ring system, namely, that of cyclopentindene, I-2.



I-2

Although various physical measurements have justified Lothrop's claim for the synthesis of I-1 no definite conclusion can be drawn concerning Baker's counter-claim until I-2 is synthesized. The problem of accomplishing this synthesis and comparing some of the properties of cyclopentindene and biphenylene is the ultimate goal of the research work represented by this thesis.

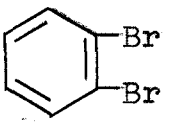
The first mention of biphenylene, I-1, in the literature occurred in 1871 when Hoffmeister (3) attempted its preparation from dibenzofuran, I-3,



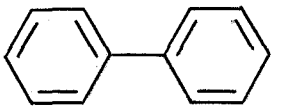
I-3

by distilling the latter with zinc dust in an effort to remove the oxygen atom. Dibenzofuran distilled over unchanged, thus, the action of zinc dust failed to produce biphenylene.

In 1893, Hosaeus (4) treated o-dibromobenzene, I-4,



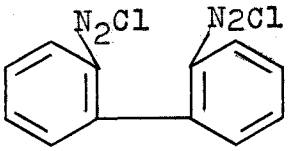
I-4



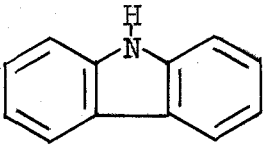
I-5

with sodium in an attempted Wurtz reaction but obtained some biphenyl, I-5, and a mixture of complex products presumably due to the linking up of a number of benzene nuclei.

The work of Niementowski (5) followed in 1901, and consisted of the action of copper powder on the diazonium salt of 2,2'-diaminobiphenyl, I-6.



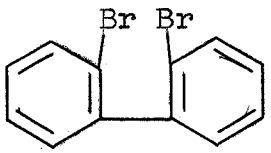
I-6



I-7

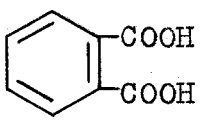
It was expected that an internal Ullmann reaction would lead to the desired compound, I-1, but instead Niementowski obtained carbazole, I-7.

The first claim on biphenylene was made by Dobbie, Fox and Gauge (6) in 1911 when they reported a 100% yield of this hydrocarbon from 2,2'-dibromobiphenyl, I-8,



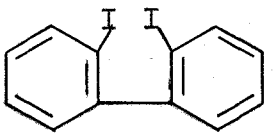
I-8

by the intramolecular Wurtz reaction using freshly cut sodium. The reaction was run in ether under reflux and proceeded very slowly with sodium bromide separating out from the solution. After decanting the solution from the sodium bromide, removal of the ether, and crystallization from light petroleum followed by recrystallization from alcohol, they obtained straw-colored crystals in the form of prisms that melted at 74.5-75°C. The analysis conformed to biphenylene. Molecular weight determination also agreed with that of this compound. These investigators based their proof on having obtained biphenylene by their method of synthesis and also, because oxidation of their compound gave some phthalic acid, I-9.



I-9

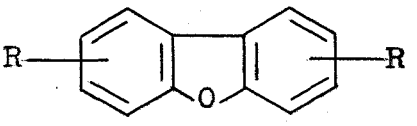
In a later paper (7), Dobbie et al. described several reactions of their new compound which indicated a strained central ring since bromine opened it to give the starting material, I-8, while dilute nitric acid formed dibenzofuran, I-3, among other products. It is interesting to note that this last paper included an attempted synthesis of biphenylene from 2,2'-diiodobiphenyl, I-10,



I-10

by the action of sodium in ether under reflux which gave only resins instead of the desired compound.

In the same year (1911) that Dobbie et al. published their first paper on biphenylene, a rather surprising article concerning this work appeared in the literature. Nierenstein (8) was working with purpurotannin which may be formulated as I-11.



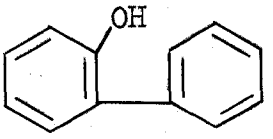
I-11

He distilled this compound with zinc and claimed that the main product was a compound identical with that of Dobbie's et al. This would seem strange since Hoffmeister (see page 2) had found that dibenzofuran itself did not yield biphenylene

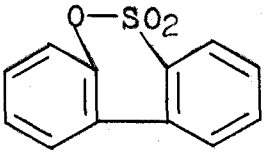
on such treatment.

The work on biphenylene remained idle for a number of years until Schwechten (9) in 1932 resumed investigation of 2,2'-dibromobiphenyl. He was unable to reproduce Dobbie's et al. (6) results. Likewise, in 1933 Mascarelli and Gatti (10) could not obtain biphenylene from 2,2'-dibromobiphenyl by the action of sodium as Dobbie et al. (6) had claimed. Again, in 1941 Rapson (11) attempted this reaction, not only in ether but also in benzene solution, and failed to produce biphenylene.

In the meantime, Cullinane, Morgan and Plummer (12) were attempting to synthesize biphenylene along a somewhat different route. They investigated the effect of dehydrating agents on 2-hydroxybiphenyl, I-12.



I-12

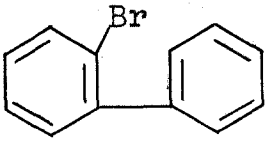


I-13

Phosphorous pentoxide, 50% and concentrated sulfuric acid all were without effect; 70% sulfuric acid gave the sulfone of 2-hydroxybiphenyl-2'-sulfonic acid, I-13.

The claim of Dobbie et al. (6) as having prepared biphenylene now seemed doubtful. Still not certain, however, Lothrop (13) in 1941 began thorough research on 2,2'-dibromobiphenyl. He found that the action of hydrogen, lithium, sodium and potassium all were successful in eliminating the

bromine atoms but the product in each case was biphenyl, I-5, obtained generally in very poor yield and contaminated with a bromine containing oil which was taken to be 2-bromobiphenyl, I-14.

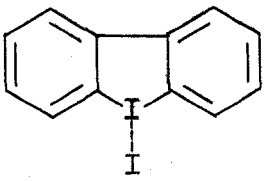


I-14

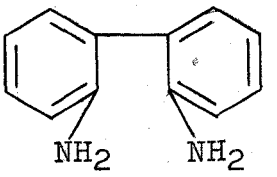
These experiments were conducted with or without solvent and the results were the same. Lothrop found that calcium and zinc were without effect and magnesium reacted only with difficulty with the bromine in the 2-position and could not be forced to replace the second bromine at 2' even under the most drastic conditions.

Lothrop continued his experiments on 2,2'-dibromobiphenyl and found that pyrolysis of this compound with pure copper powder led again to biphenyl and 2-bromobiphenyl. In one of his experiments, however, he used some old copper powder that presumably had been exposed to the air with formation of some cuprous oxide and obtained a new hydrocarbon. This was readily volatile with steam and crystallized from alcohol in long straw-colored prisms melting at 109-110°C. The compound also formed a scarlet picrate melting at 121-122°C. Subsequent experiments showed that it was the cuprous oxide alone that was the active reagent in forming the new hydrocarbon. Pure copper and cupric oxide had no effect.

In the above method some unchanged dibromide was always present in the crude product and could be removed only by a tedious process. This necessitated isolation of the hydrocarbon as the picrate. To avoid this difficulty, Lothrop pyrolyzed biphenylene iodonium iodide, I-15,



I-15



I-16

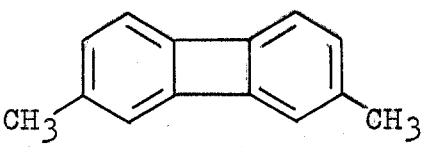
with cuprous oxide. Compound I-15 was prepared from 2,2'-diaminobiphenyl, I-16, by treatment of the latter with sodium nitrite and potassium iodide according to the procedure of Searle and Adams (14). Biphenylene was produced in slightly better yield by this method although the yield was still quite low, about 5%.

It is interesting to note at this point that some of the properties of Lothrop's compound were similar to those of Dobbie's et al. Both crystallized in straw-colored prisms and possessed an odor similar to that of biphenyl. Also, both compounds were volatile with steam. On the other hand, the melting points differed considerably—Dobbie's et al. melted at 74.5-75°C whereas Lothrop's melted at 109-110°C.

There remained, then, the proof of structure of Lothrop's compound. His compound and also the picrate anal-

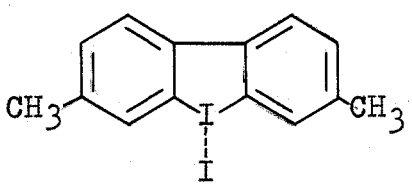
yzed for $C_{12}H_8$. Oxidation with chromic anhydride took place readily to yield phthalic acid, I-9. Hydrogenation over red hot copper gave biphenyl, I-5. All of these experiments would lend support to the fact that Lothrop had prepared biphenylene.

Still more convincing evidence was furnished by Lothrop when he prepared derivatives of biphenylene using similar experimental methods. Thus, he prepared 2,7-dimethylbiphenylene, I-17,

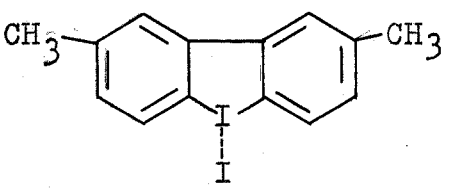


I-17

by two different routes, one by the pyrolysis of 2,7-dimethylbiphenylene iodonium iodide, I-18,

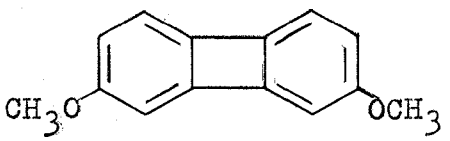


I-18

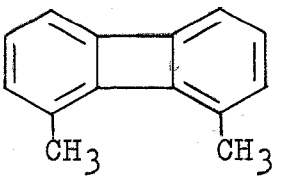


I-19

with cuprous oxide and the other by the pyrolysis of 3,6-dimethylbiphenylene, I-19, with the same reagent. Also, in a later paper (15) published in 1942, Lothrop prepared 2,7-dimethoxybiphenylene, I-20, and 1,8-dimethylbiphenylene, I-21, by pyrolysis of the corresponding iodonium iodide with cuprous oxide. These derivatives (diagrammed on page 9)



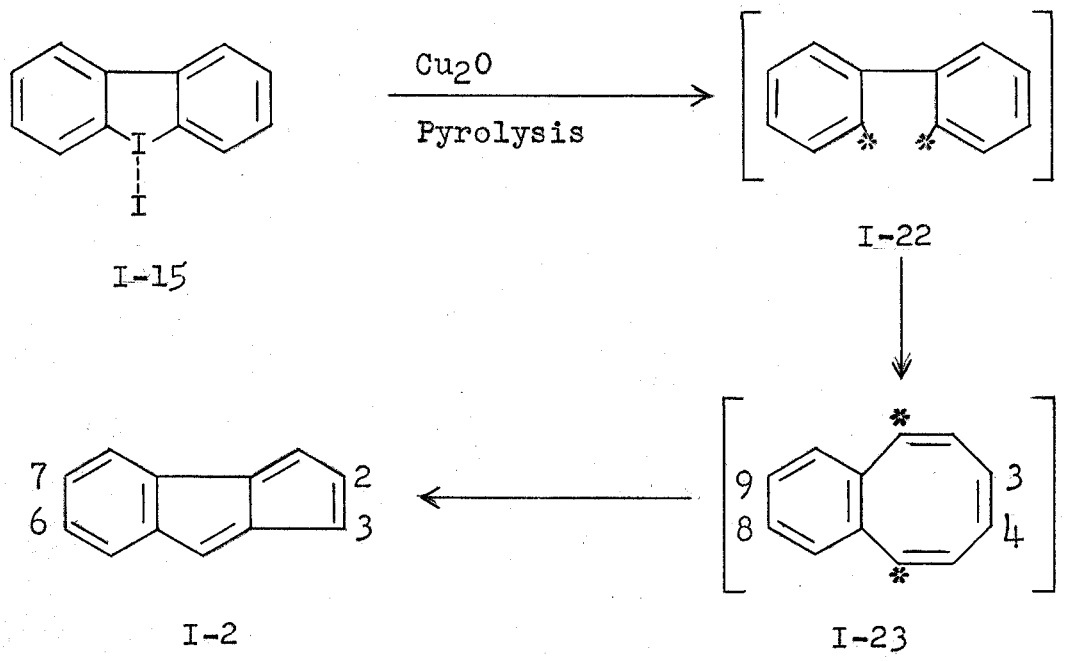
I-20



I-21

certainly lend considerable support in favor of his claim for the synthesis of biphenylene.

Such evidence, however, was not convincing to Baker (16) who published a paper in 1942 that described an entirely different interpretation of Lothrop's experiments. Baker considered it unlikely that under the severe conditions employed by Lothrop a compound so strained and unstable as biphenylene should result, even in small yield. He interpreted the reaction as leading to cyclopentindene, I-2, and suggested the following mechanism:



I-15 I-22 I-23 I-2

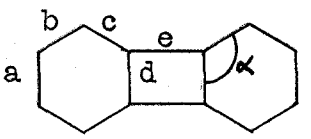
Baker assumed that removal of the iodine from I-15 (or of the two bromine atoms from 2,2'-dibromobiphenyl) with cuprous oxide led to a biphenyl with free valences in positions 2 and 2' as indicated by the asterisks in formula I-22. He further assumed that these valences can only unite with the simultaneous rupture of the potential cyclobutadiene ring to result in a diradical of benzo-cyclo-octatetraene, I-23, in which the carbon atoms 1 and 6 are trivalent (marked by asterisks). This rearranges immediately into cyclopent-indene, I-2, the least strained structure.

Baker claimed that this view for the structure of biphenylene is in harmony with the identity of the other derivatives of biphenylene prepared by Lothrop. Thus, the two isomeric dimethyldiphenyliodonium iodides, I-18 and I-19, must yield the same intermediate, the 4,8-(3,9)-dimethyl derivative of I-23, and therefore, the same final product, which may be either the 2,7- or the 3,6-dimethyl derivative of I-2.

In the same year, Coulson (17) supported Baker's theory by consideration of resonance and strain energies. The numbers of single and double bonds in both I-1 and I-2 are the same and both molecules are planar, so that their energy difference lies chiefly in the strain energies of the 6-bonds. Coulson calculated resonance energies for I-1 and I-2 to be 4.506β and 4.304β respectively, where β is a constant

having a magnitude of about 20 Kcal. These were measured relative to a carbon framework of six double and eight single bonds. These figures indicated that the mobile electrons of I-1 are more stable than those of I-2 by 0.202β, that is, about 4 Kcal. However, strain energies calculated by Coulson according to the method of Penney (19) showed that the strain energy of I-2 is only a few Kcal., but in I-1 it is very large, possibly as great as 100 Kcal. Thus, Coulson concluded that I-2 is much more stable than I-1 since the increased resonance in I-1 is more than compensated by the strain involved in the 6-type bonds.

More recently three pieces of evidence have become available which give strong support to the biphenylene structure. Waser and Schomaker (20) in 1943 made an electron diffraction investigation of Lothrop's compound and determined the following data for biphenylene, I-1:



I-1

$a = b = c = d = 1.41 \pm 0.02$ Å

$e = 1.46 \pm 0.05$ Å

C-H = 1.10 Å (assumed)

$\alpha = 121 \pm 3^\circ$

$\alpha = 121 \pm 3^\circ$

These authors stated that the cyclopentindene structure, I-2, is definitely excluded because there are no C-C distances of 2.30 Å corresponding to the calculated diagonals of two regular pentagons.

Later, in 1944, Waser and Chia-Si Lu (21) studied the crystal structure of biphenylene. Their results coincided with those found in the electron diffraction studies, that is, Lothrop's compound has the structure indicated by biphenylene, I-1, and not that of Baker's cyclopentindene, I-2. Waser and Chia-Si Lu's findings show that the crystal structure of biphenylene is based on a monoclinic unit cell containing six molecules and having the following dimensions:

$a_o = 19.60 \pm 0.03$ Å $\qquad c_o = 5.84 \pm 0.02$ Å

$b_o = 10.50 \pm 0.02$ Å $\qquad \beta = 91^\circ\ 20' \pm 20'$

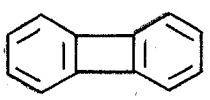
The report also indicated a closely knit packing of the biphenylene crystal.

Surprisingly enough, the third piece of evidence in favor of the biphenylene structure for Lothrop's compound came from Baker, himself, in a later paper (22) published in 1945. Actually, this paper was a Tilden Lecture and included some of Baker's unpublished experiments. One of them was concerned with the hydrogenation of biphenylene. In his first paper (17), Baker had included the result of the catalytic hydrogenation of biphenylene in acetic acid at room temperature in the presence of a palladium — charcoal catalyst which showed that 3 moles of hydrogen were absorbed. This fact had reinforced his theory as to the structure of Lothrop's compound being cyclopentindene, I-2, since he reasoned that a

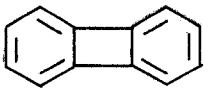
molecule possessing the biphenylene structure, I-1, should undergo ready catalytic reduction with rupture of the strained four-membered ring to give biphenyl (absorption of only 1 mole of hydrogen). Now, however, in the Tilden Lecture mentioned above, Baker included the results of some further experimentation. He found that the course of reduction was quite different when hydrogenation was affected in alcoholic solution in the presence of Raney nickel. In this case, the uptake of hydrogen was rapid and ceased after little more than one molecule of hydrogen was absorbed and an 85% yield of pure biphenyl was isolated. This represents strong chemical evidence in favor of the biphenylene structure since it is not conceivable that cyclopentindene on reduction would involve the breaking of two C-C links with the formation of a new C-C link to give the result. Waser and Schomaker (21) suggested that Baker's first catalytic reduction experiment, which indicated absorption of three moles of hydrogen, could be explained on the assumption that one of the six-membered rings became completely saturated without damage to the four-membered ring.

In view of the evidence that has mounted in favor of the biphenylene structure, it would seem apparent that Lothrop's claim was fully justified. Biphenylene may be regarded as a unique type of molecule in which the cyclobutadiene ring is stabilized by fusion with two benzene nuclei. Furthermore, four possible resonating forms may exist for

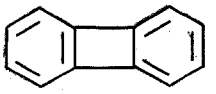
this compound as indicated by I-1A, I-1B, I-1C and I-1D.



I-1A



I-1B

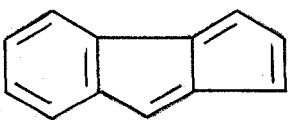


I-1C

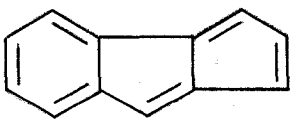
I-1D

This resonance would compensate for the expected instability due to strain. An interesting feature would be the study of the Mills-Nixon effect on biphenylene which may lend information as to the contribution of each of the resonating forms.

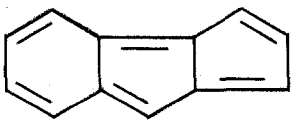
Even though the argument concerning biphenylene and cyclopentindene now seems one-sided, the fact that the latter has never been synthesized is highly significant since only this accomplishment can conclusively settle the controversy. Like biphenylene, cyclopentindene should exist as a planar molecule for which three structures can be written, two benzenoid structures, I-2A and I-2B, and one ortho-quinonoid structure, I-2C.



I-2A



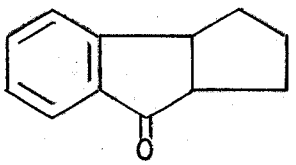
I-2B



I-2C

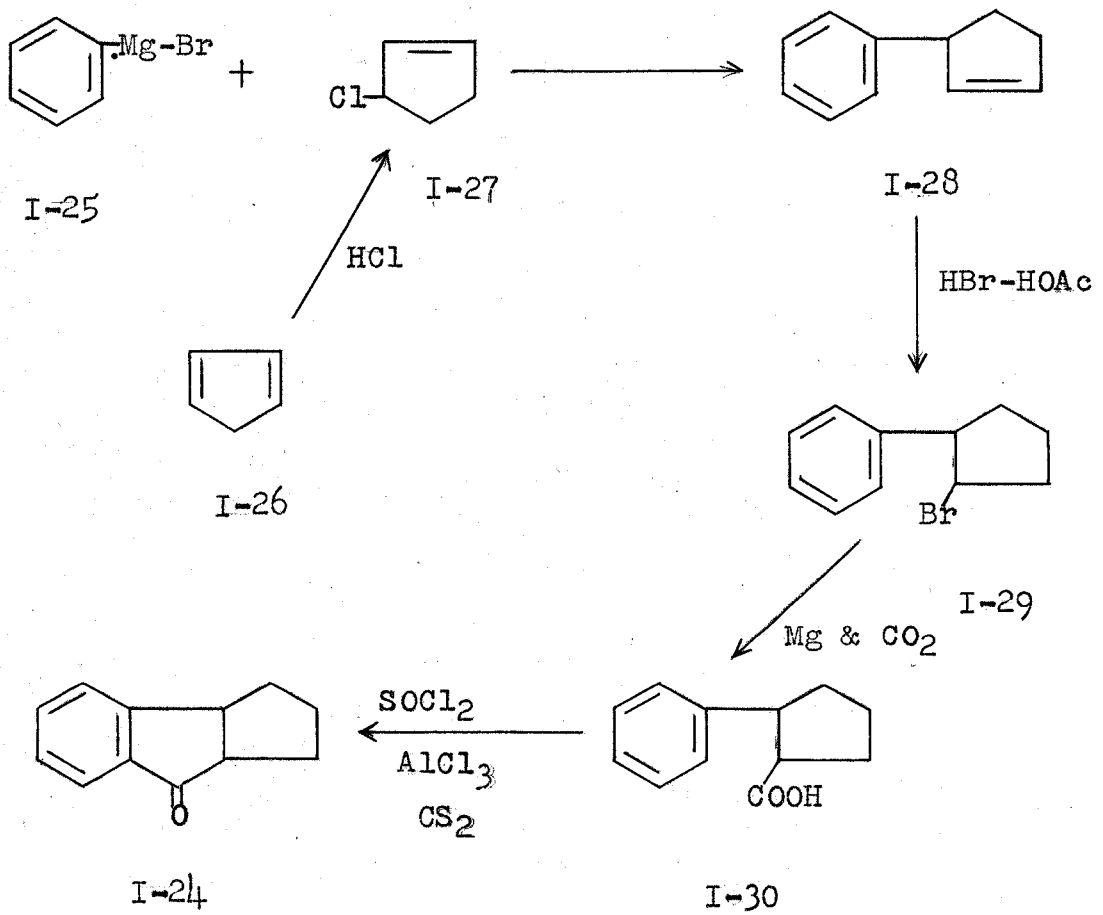
The decreased resonance in cyclopentindene as compared to biphenylene is, however, more than compensated by less bond strain. The preparation of this compound should be feasible.

Not many attempts have been made to prepare cyclopentindene, as a matter of fact, not many compounds having this ring skeleton are known. In 1927, Braun and Kuhn (23) reported the synthesis of 4-keto-1,2,3,4,9,10-hexahydrocyclopentindene, I-24,



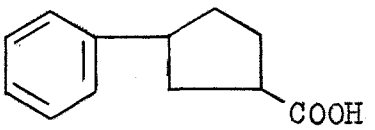
I-24

according to the following scheme:



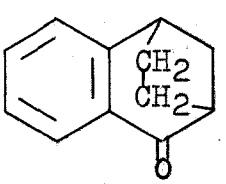
These authors claimed that the reaction of 1-phenylcyclopent-2-ene, I-28, with hydrogen bromide in acetic acid at 100°C. yielded 2-phenyl-1-bromocyclopentane, I-29, as shown in the diagram. The conversion of I-29 to 2-phenylcyclopentane-1-carboxylic acid, I-30, however, was only 25%, the main product being bis-(phenylcyclopentyl). The acid, I-30, was isolated as an oil. Ring closure was very difficult giving only a 30% yield of the ketone, I-24.

In 1948, Baker and Leeds (24) criticized this work. They found that Braun and Kuhn had actually prepared 3-phenylcyclopentane-1-carboxylic acid, I-31,

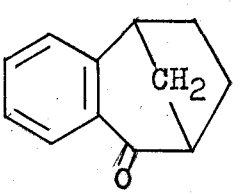


I-31

for the most part and that ring closure gave 4-keto-1,3-endoethylene-1,2,3,4-tetrahydronaphthalene, I-32A,



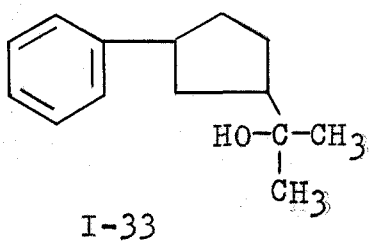
I-32A



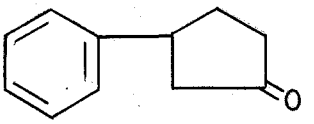
I-32B

the latter of which may be regarded as the bridged benzendomethylenecycloheptenone, I-32B. Their basis for proof was a Barbier-Wieland degradation of the acid, I-31, which gave via its methyl ester and 3-phenylcyclopentyldimethylcarbinol,

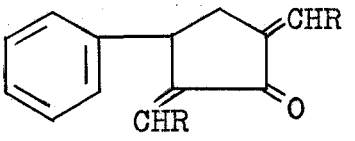
I-33,



I-33

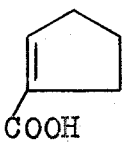


I-34



I-35

the ketone, 3-phenylcyclopentanone, I-34. The position of the ketone group, and hence, the original carboxyl group, was established by the preparation of a dibenzylidene derivative (I-35; R=Ph.) and a dipiperonylidene derivative (I-35; R=3,4-methylenedioxyphenyl). Also, the preparation of the acid, I-31, by another route (Friedel-Crafts reaction of benzene and cyclopent-1-ene carboxylic acid, I-36,

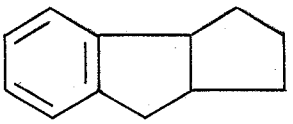


I-36

using aluminum chloride) and the characterization of the ring closure compound, I-32A or B, as semicarbazones were additional evidence as to the identity of the acid, I-31. Later, it was found by Baker (24) that the acid, I-30, is a solid having a melting point of 87-88°C whereas the acid, I-31, is an oil and melts at 17-18.5°C. Since Braun and Kuhn obtained an oil that failed to crystalize it is further evidence (although not too good) that they had actually prepared I-31 and not I-30.

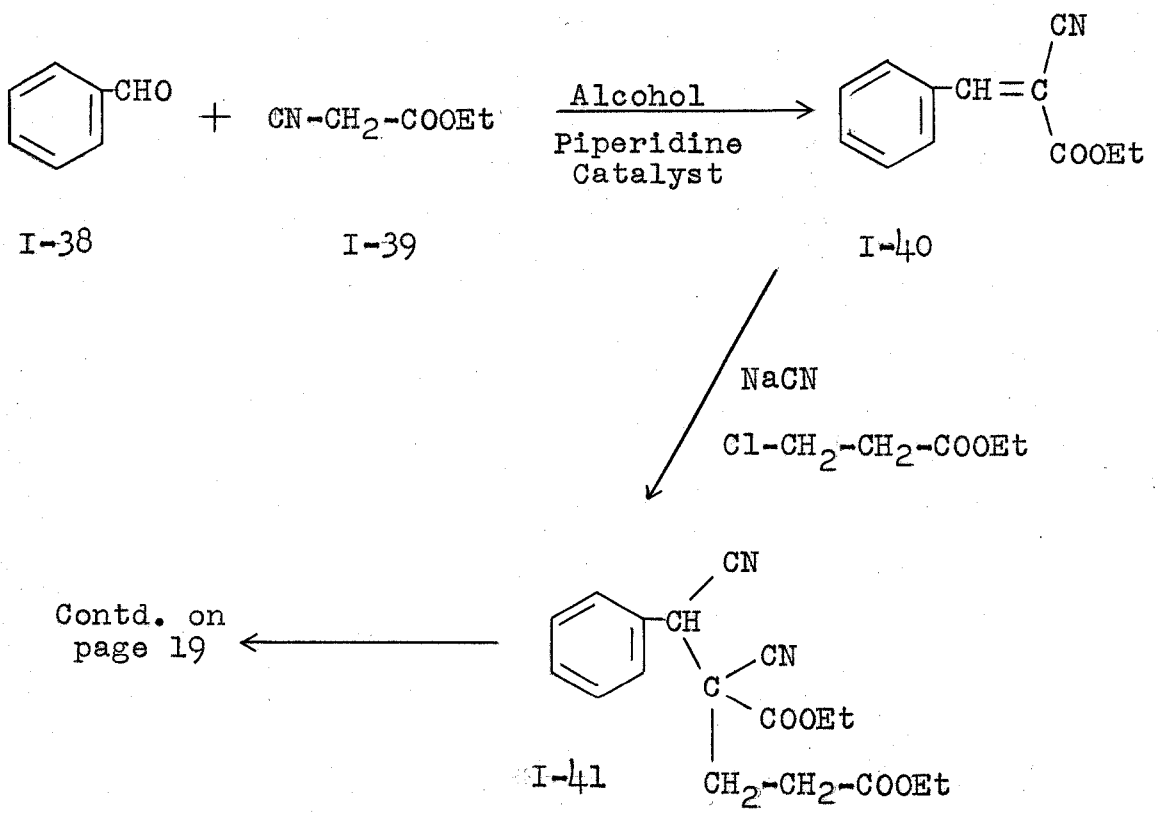
The work of Chatterjee (25) in 1938 was the most

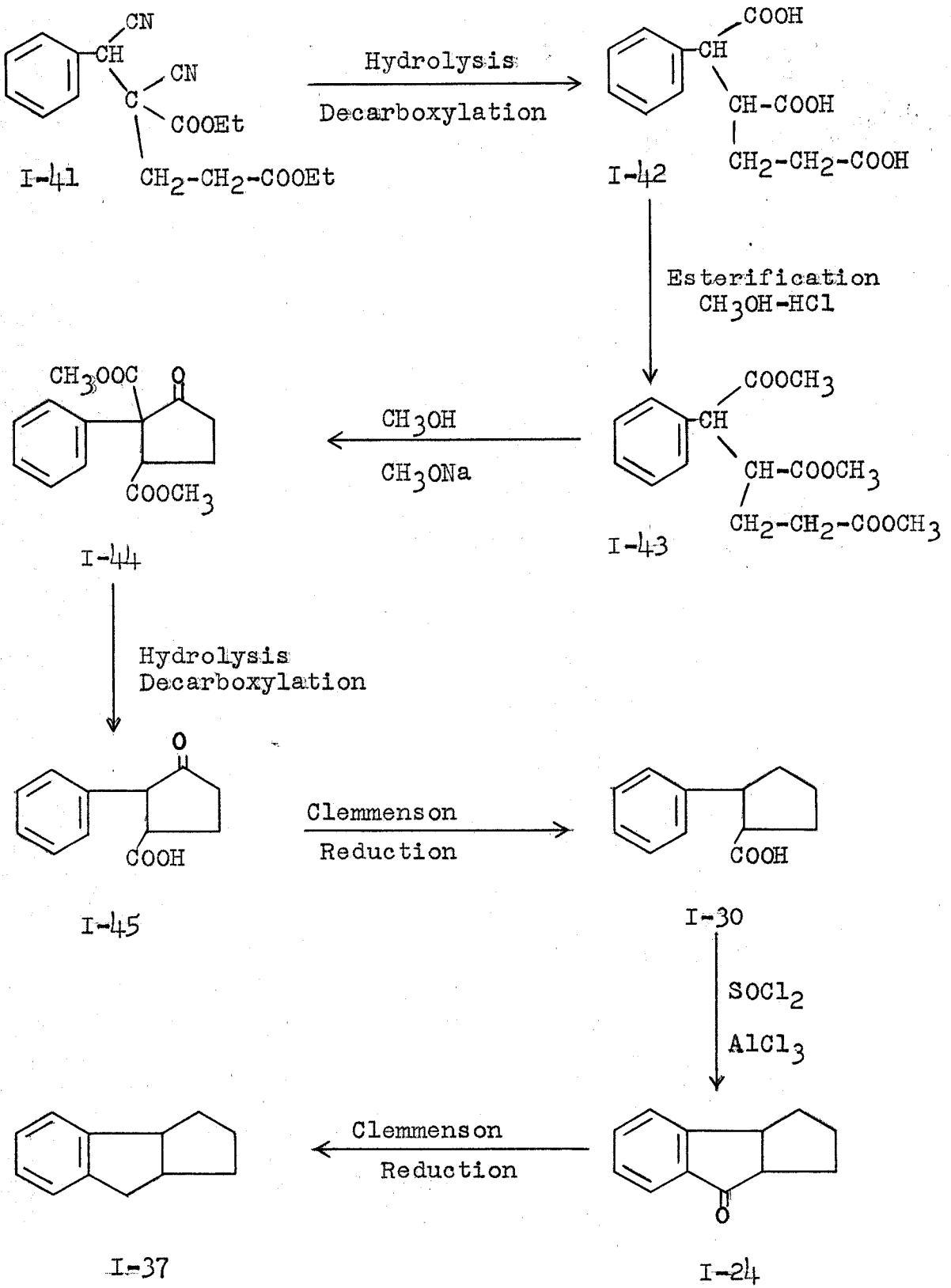
significant concerning the synthesis of the 6-5-5-ring system. His aim was to prepare the saturated compound of cyclopentindene, namely, 1,2,3,4,9,10-hexahydrocyclopentindene, I-37,



I-37

which he accomplished. His reactions may be outlined as follows:



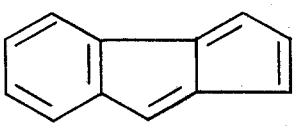


This synthesis was modified by Baker and Leeds (24) who eliminated the isolation of some of the intermediates, namely, ethyl benzylidenecyanoacetate, I-40, and ethyl α,β-dicyano-β-phenylpropionate, I-41. Also, Baker and Leeds used a phosphoric anhydride-phosphoric acid mixture for the ring closure step (conversion of I-30 to I-24) instead of the formation of the acid chloride and Friedel-Crafts reaction as used by Chatterjee. It is interesting to note that Baker's aim was to prepare cyclopentindene but this paper (24) indicated experiments only as far as Chatterjee's ketone, I-24.

Our problem, as previously mentioned, is concerned with the synthesis of cyclopentindene, I-2, and the comparison of some of the properties of this compound with its isomer, biphenylene, I-1.

II. PROCEDURE AND DISCUSSION

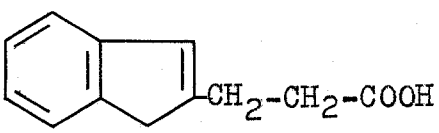
There are three general methods of approach to the preparation of cyclopentindene, II-1,



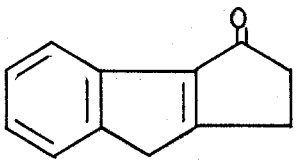
II-1

which may be classified as follows:

1. Formation of the outer five-membered ring by ring closure of an indene derivative such as indene-2-propanoic acid, II-2,



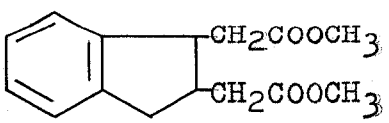
II-2



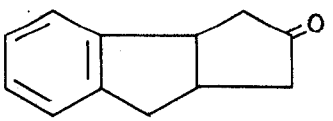
II-3

to give 1-keto-2,3,4-trihydrocyclopentindene, II-3.

2. Formation of the outer five-membered ring by condensation reactions such as a Dieckmann performed on an indan derivative, methyl 1,2-indandiacetate, II-4.



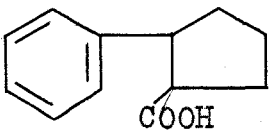
II-4



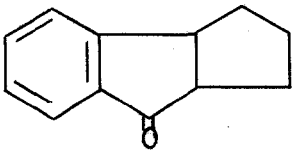
II-5

After hydrolysis and decarboxylation there should result 2-keto-1,3,4,9,10-pentahydrocyclopentindene, II-5.

3. Formation of the inner five-membered ring by ring closure of a phenylcyclopentane derivative such as 2-phenylcyclopentane-1-carboxylic acid, II-6.



II-6



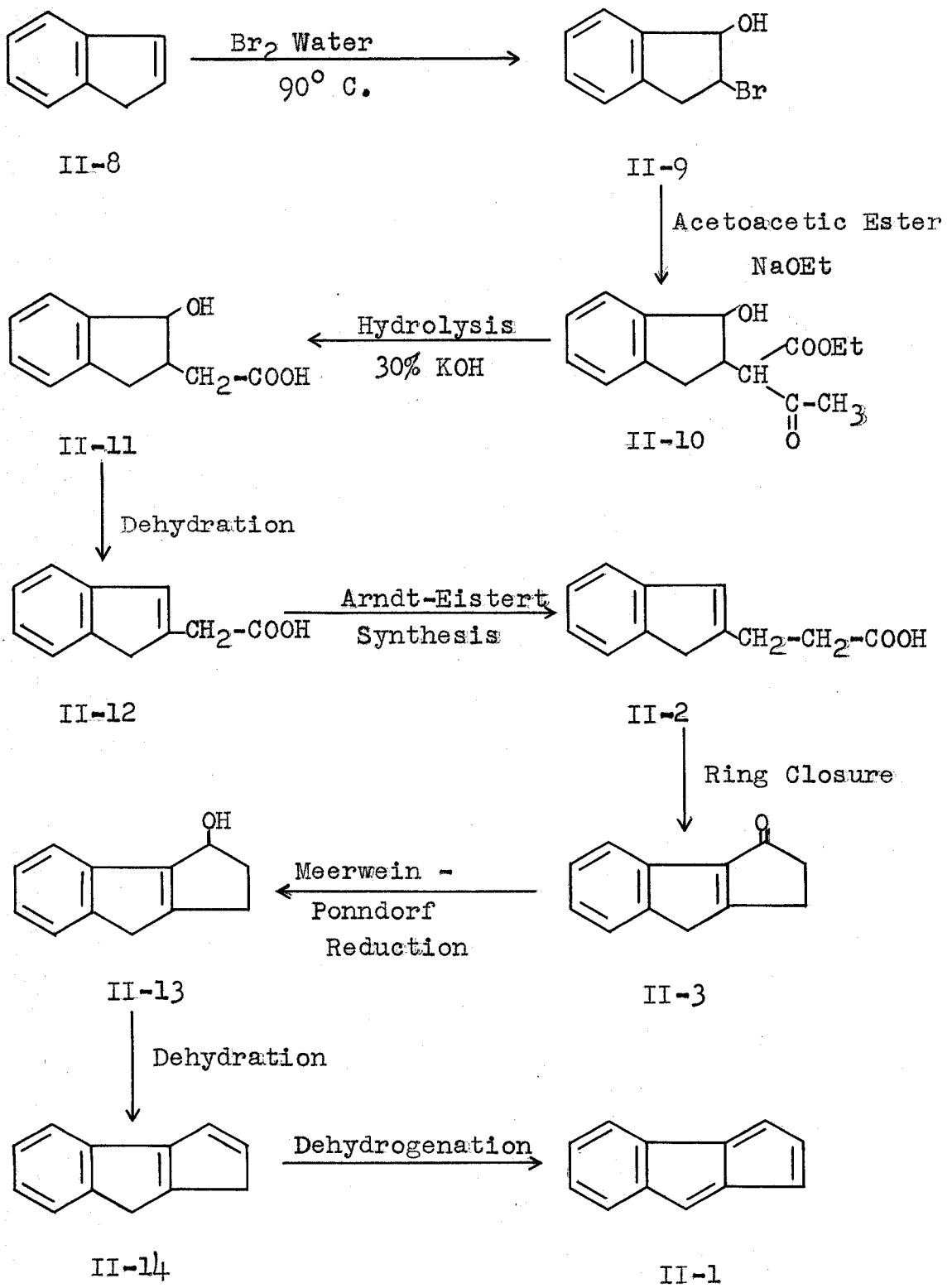
II-7

This should yield 4-keto-1,2,3,9,10-pentahydrocyclopentindene, II-7.

These three methods are applicable to other derivatives and one can determine the best synthesis by investigation of several promising compounds. Once the ring skeleton has been formed it is necessary to perform the appropriate operations that will result in the final compound, II-1.

It was decided that indene derivatives be investigated first in an effort to obtain a successful synthesis of cyclopentindene. Compounds having a side chain on the 2-position of indene (as in formula I-2) were thought to be the most promising for method #1 since ring closure in either direction would give the same carbon framework. Two routes employing this method were investigated.

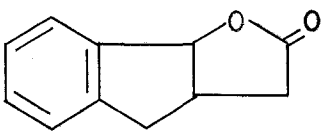
Method 1A



The synthesis of II-12 from II-8 was found in the literature, Pope and Read (26) being credited for the conversion of II-8 to II-9 and Peacock and Menon (27) for the conversion of II-9 to II-12. The compound, II-10, was not isolated in pure form since it underwent hydrolysis (30% KOH) readily to give trans-1-hydroxyhydrindene-2-acetic acid, II-11.

When indene, II-8, was emulsified with water at 90°C and treated with a 5% potassium bromide solution saturated with bromine there resulted 2-bromo-1-hydroxyhydrindene, II-9. An alcoholic solution of this solid was added to a solution of ethyl sodium acetoacetate in alcohol whereupon sodium bromide separated out rapidly to yield the derivative, II-10. This was hydrolyzed to yield the acid, II-11.

The difficulty arose in the conversion of II-11 to II-12. Peacock and Menon (27) claimed that treatment of the acid, II-11, with hydrogen bromide solution at 100°C gave a mixture of the lactone, II-15,

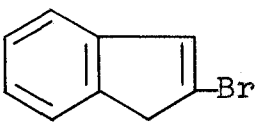


II-15

and indene-2-acetic acid, II-12. No yield of the acid was mentioned in this paper (27). Several attempts were made to duplicate this work but in all cases we were unable to obtain the acid, II-12. Only the lactone, II-15, and unreacted acid, II-11, could be isolated.

Other dehydrating agents were employed in an effort to obtain indene-2-acetic acid. The action of phosphoric anhydride in benzene solution gave the lactone exclusively. The action of barium oxide (basic dehydrating agent to prevent lactone formation) on the barium salt of the acid, II-11, at 200°C was apparently without effect since the original acid was recovered on acidification of the reaction mixture. The ethyl ester of II-11 also gave the lactone when treated with phosphoric anhydride in benzene solution. This emphasizes clearly the stability of this lactone since acidification of the saponified ester regenerated it. Apparently, then, the cis-configuration of the hydroxyl and hydrogen groups and the easy conversion of the acid to the lactone were responsible for the failure of the conversion to II-12.

A last effort was made to prepare indene-2-acetic acid by an acetoacetic ester condensation on 2-bromoindene, II-16.

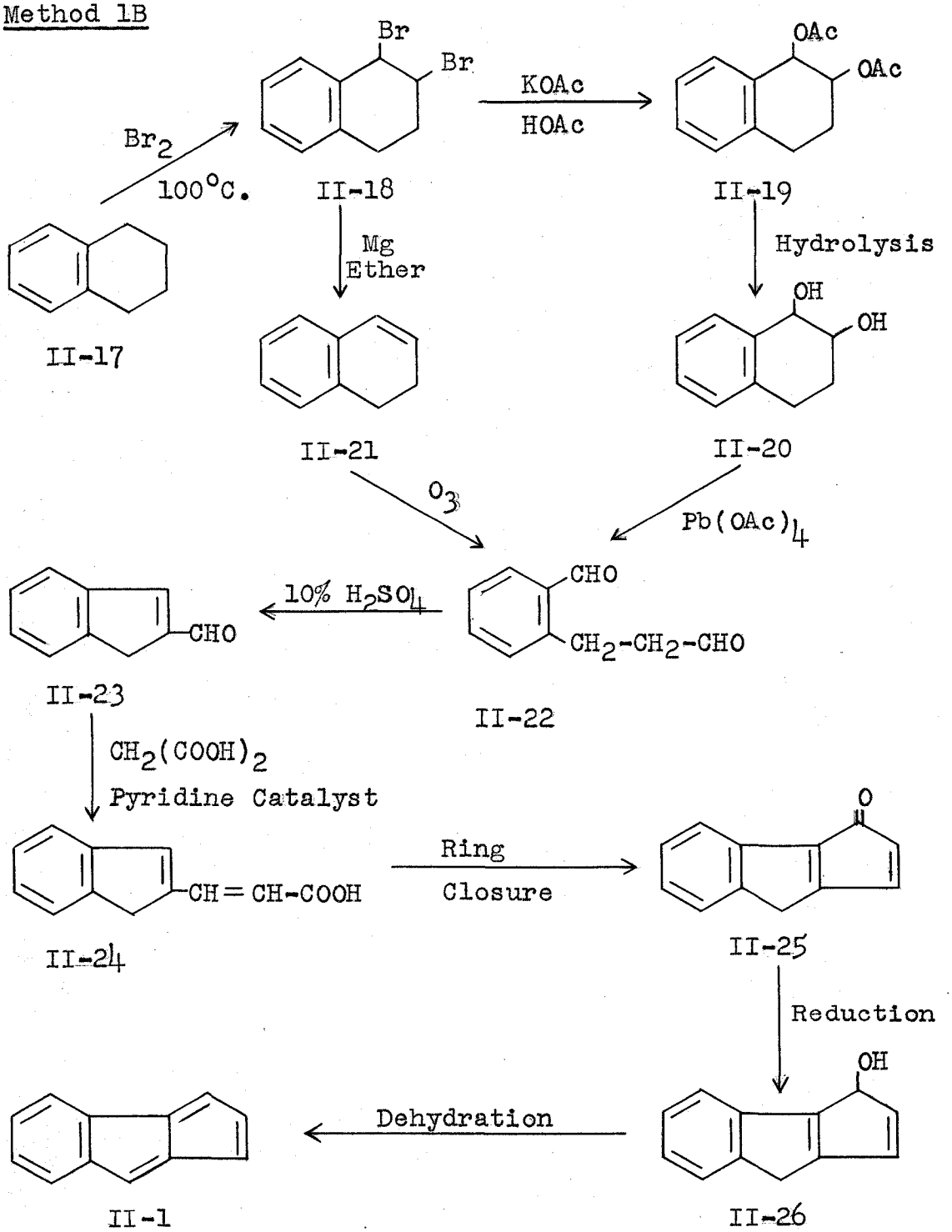


II-16

This was expected to be a somewhat unsatisfactory reaction because of the inactive position of the bromine atom. The reaction mixture in an alcoholic solution turned jet black in color. Neither the acid, II-12, nor the original bromo-compound could be isolated on working up the reaction mixture.

The inability to obtain indene-2-acetic acid caused us to alter the synthesis as described on page 23. The new route investigated may be outlined as follows:

Method 1B



The synthesis of indene-2-aldehyde, II-23, from tetralin, II-17, was reported by Braun and Zobel (28). Their method consisted of the bromination of tetralin to give the dibromide, II-18, which reacted readily with magnesium in ether to yield 1,2-dihydronaphthalene, II-21. The latter compound when ozonized gave the dialdehyde, II-22, which underwent easy ring closure to yield indene-2-aldehyde, II-23. The ozonization procedure was a long, tedious operation and gave only a 35% yield of the dialdehyde, II-22. A better method for obtaining this compound was the formation of the diacetate, II-19, hydrolysis of the latter to dihydronaphthalene-1,2-diol, II-20, and then cleavage of the -diol with lead tetracetate. The last step gave a quantitative yield of β-(o-formylphenyl) propaldehyde, II-22. The route via II-19 and II-20 was reported by Blount (29).

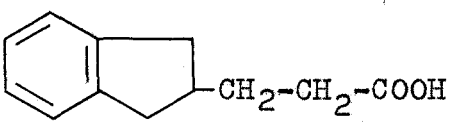
Research work was begun on indene-2-aldehyde, II-23. A Perkin reaction utilizing acetic anhydride and potassium acetate was not successful because the high temperature (175°C) of the reaction gave mostly tars. However, a Doebner reaction utilizing malonic acid and a small amount of pyridine was successful and gave indene-2-propenoic acid, II-24, in 51% yield.

The shortcomings of this synthesis lay in the next step, namely, ring closure of the side-chain acid, II-24. The action of anhydrous hydrofluoric acid gave a polymeric material. The red-brown polymer, however, partially

dissolved in hot sodium bicarbonate solution to yield some unreacted acid on acidification. From this it appears that the reaction took place to some extent but with the formation of considerable polymeric material.

The acid chloride formed readily when the acid, II-24, was treated with thionyl chloride. An intramolecular Friedel-Crafts reaction of the acid chloride in nitrobenzene solution containing anhydrous aluminum chloride appeared to take place readily as evidenced by the steady evolution of hydrogen chloride. The product isolated was a brown-colored polymer mixed with some unreacted acid. It is interesting to note that the reaction did not take place at all in carbon disulfide solvent.

Apparently, two factors were responsible for our failure to obtain the ketone, II-25. First the extreme reactivity of the conjugated double bond system of indene-2-propenic acid gave rise to polymerization and secondly, the possibility that the trans-form of the isomeric acid was in predominate amount and resisted ring closure. No effort was made to reduce the acid in order to eliminate these factors since the product of such a reduction would probably be indan-2-propionic acid, II-27,

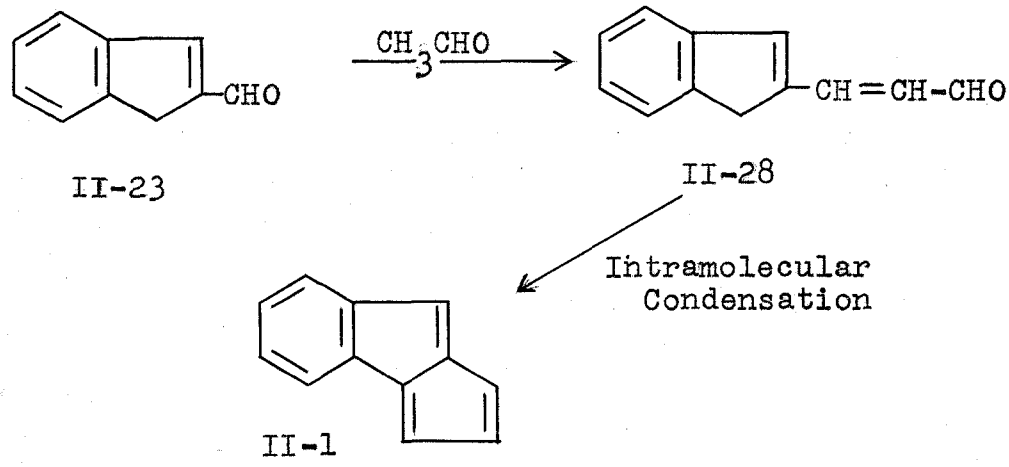


II-27

which is not likely to undergo ring closure due to the absence of a double bond in the five-membered ring.

Since indene-2-propenoic acid did not yield the desired 6-5-5 carbon skeleton, our attention was drawn to the highly reactive indene-2-aldehyde, II-23, which we thought would serve a purpose in a different manner. It introduces the next method of approach, namely, possible condensation reactions that may lead to the desired carbon ring system. The following two-step synthesis (from indene-2-aldehyde) was considered:

Method 2A



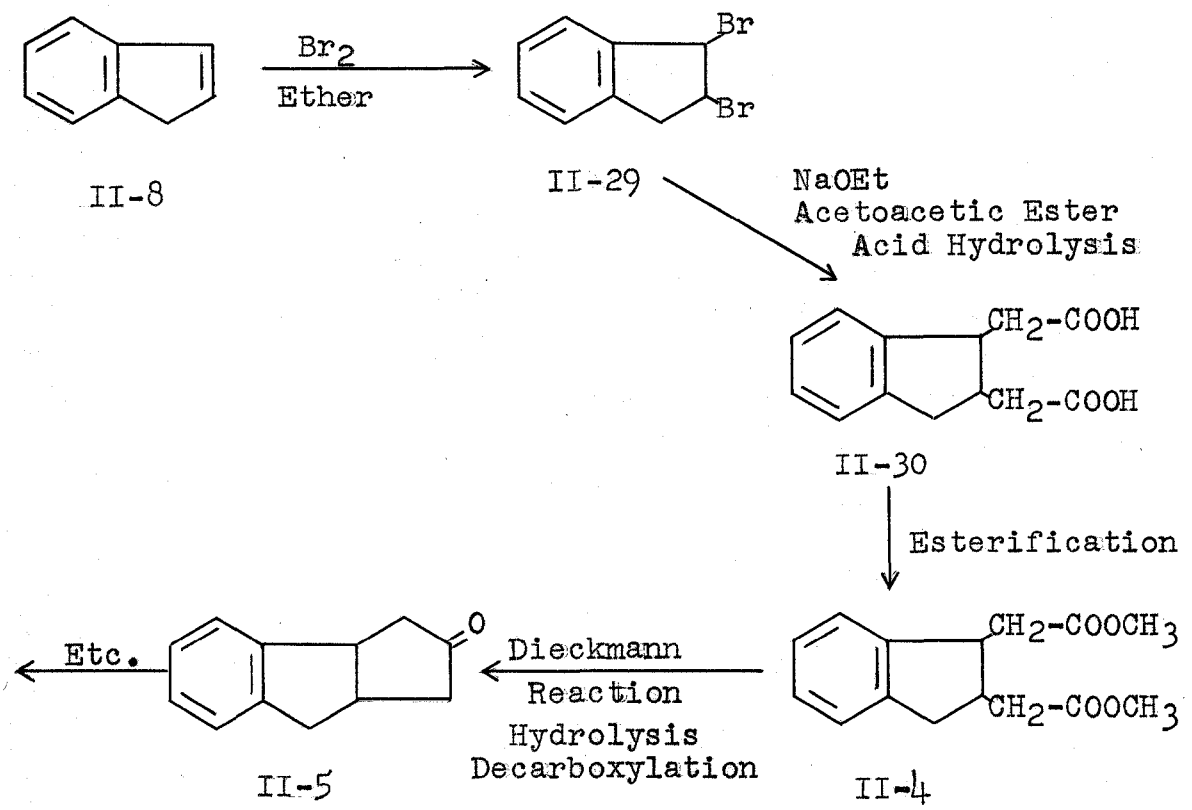
The compound, II-23, is a white solid when freshly prepared but turns yellow after only one hour and sets to a resinous mass on standing a few days. This extreme activity is attributed to the aldehyde and methylene groups. The compound is extremely sensitive to alkali readily giving polymers with this reagent. Hence, it was thought best to

perform the aldol condensation under acid conditions. The most promising agent for this type of reaction was freshly fused zinc chloride. The reaction was performed in a pressure bottle containing a mixture of glacial acetic acid and acetic anhydride as the solvent. The results of the experiment carried out at 120°C indicated excessive polymerization. Some original indene-2-aldehyde was recovered from the polymeric mixture by steam distillation.

Bomb experiments utilizing alkaline conditions were also carried out in spite of the tendency of indene-2-aldehyde to polymerize under these conditions. An aldol condensation employing 0.1% sodium hydroxide solution gave rise to a sticky polymer in only ten minutes at room temperature. In another experiment an alcoholic potassium hydroxide solution containing the two aldehydes was heated at 120°C in a bomb. There was isolated an orange-brown amorphous solid from this experiment. It melted at 135°C with decomposition into a black resin. The compound could not be crystallized from the usual solvents because it polymerized readily to a sticky resin, a property typical of fulvenes.

These experiments indicated that indene derivatives are too susceptible to polymerization to be of much value in obtaining the cyclopentindene ring system. Therefore, attention was focused upon indanone and indan derivatives. The following route was investigated:

Method 2B



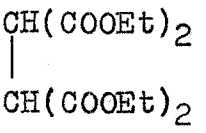
The advantage of this synthesis is the relatively few steps needed to secure the desired ring system. Unfortunately, the second reaction (conversion of II-29 to II-30) took a widely different course from the one indicated and gave some rather surprising results.

Indene (freshly distilled) was brominated according to the procedure of Kraemer and Spilker (30) who utilized a low temperature (0°C) and ether as the solvent. There resulted white crystals of indene dibromide, II-29, which melted at 31-33°C. These were obtained in only a 25% yield. This low yield may be accounted for by the difficulty experienced in recrystallization

of the crude product. Only 80% indene (Barrett Company) could be obtained for the bromination experiment and the impurities that were still present after the bromination were not easily removed without a large loss of the indene dibromide. In our experiments both the purified and the crude indene dibromide gave identical results in the condensation reactions. (It should be noted that Kraemer and Spilker (30) observed a melting point of 43-45°C for indene dibromide whereas Spilker and Dombrowsky (31) later reported a melting point of 31.5-32.5°C for this compound).

For the attempted conversion of II-29 to II-30, both acetoacetic ester and malonic ester were used; both of these esters gave similar results. The reaction of indene dibromide with either of these esters in alcoholic solution appeared to proceed smoothly as evidenced by a precipitation of sodium bromide ranging from 80% to 100% of the theoretical amount. (It is interesting to note that the reaction did not take place at all in ether solution). The puzzling thing about the reaction was noticed after the hydrolysis of the ester. After acidification, decolorizing and filtering the solution, crystals failed to appear on cooling the filtrate in an ice bath. However, by reducing the volume of the solution, crystals were obtained which, when purified, were found to be succinic acid. Furthermore, in the malonic ester experiments, the oil isolated from the condensation reaction partially crystallized and the purified crystals were found

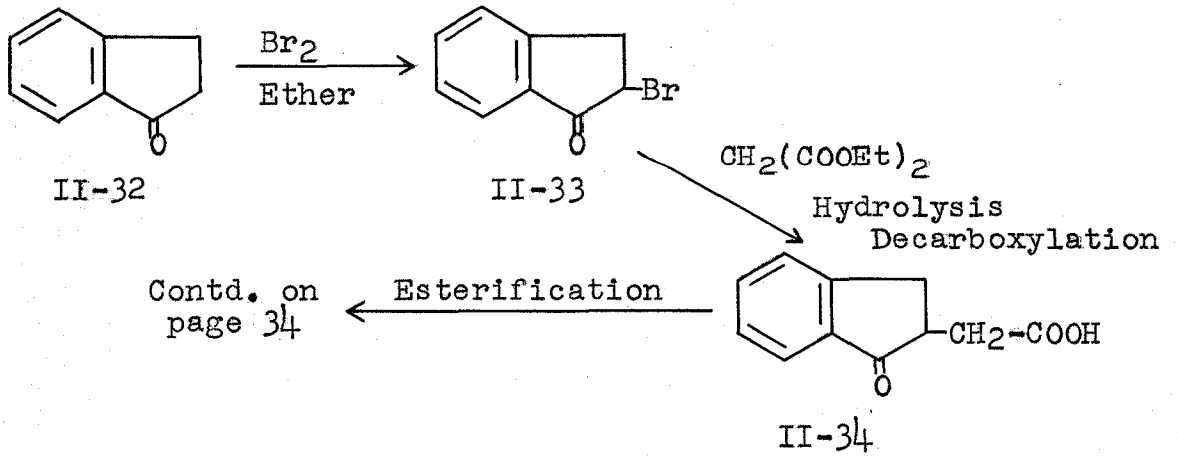
to be ethyl sym-ethanetetracarboxylate, II-31.

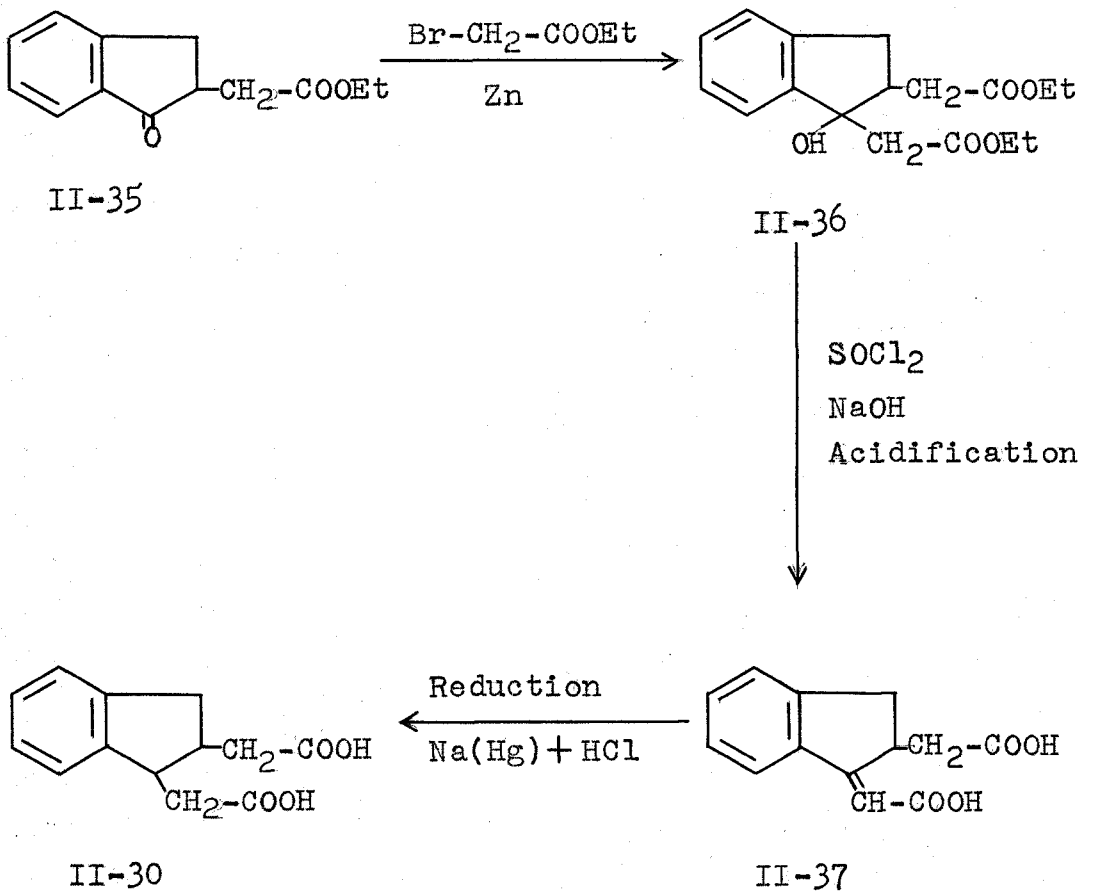


II-31

The explanation for these unexpected products lies in the instability of indene dibromide. The latter compound exercised an effective brominating action on ethyl sodium acetoacetate or ethyl sodium malonate. The net result was analogous to the action of a halogen on these compounds, namely, a coupling of two ester residues with the simultaneous loss of sodium bromide. The fate of the indene dibromide was the production of indene, part of which was recovered with the alcohol when the latter was distilled from the hydrolysis mixture and the remainder extracted from the alkaline solution with benzene.

The synthesis of II-30 was considered along a different angle but involving a greater number of reactions. They may be summarized as follows:



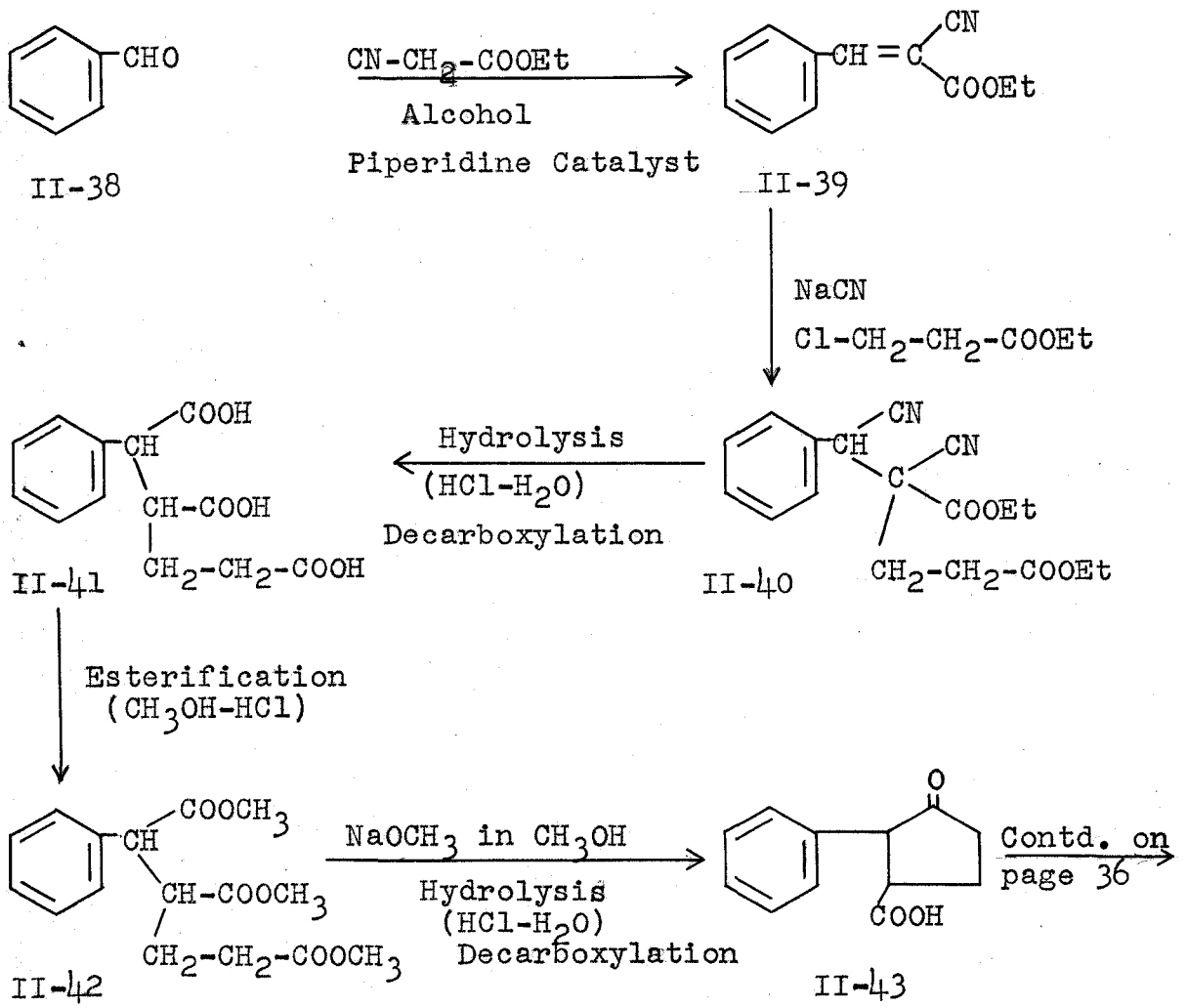


Indanone-1 was brominated in good yield according to the procedure of Johnson and Shelberg (32). The yield on the next step, however, was very low; 1-keto-hydrindene-2-acetic acid, II-34, was isolated in only 5% yield. Most of the product obtained in this reaction was of polymeric nature. The polymer was soluble in hot, dilute sodium bicarbonate solution but the action of charcoal failed to decolorize the solution. Addition of mineral acid reprecipitated the polymer. The structure of this polymer was not investigated although we surmised that it

had a low molecular weight and contained several carboxyl groups..

It was considered unwise to continue this elaborate synthesis in view of the small yield obtained in the second step. Instead, it was decided that method #3 be employed especially since the ground work for this method had already been established by Chatterjee (25). The sequence of reactions may be described as follows:

Method 3A



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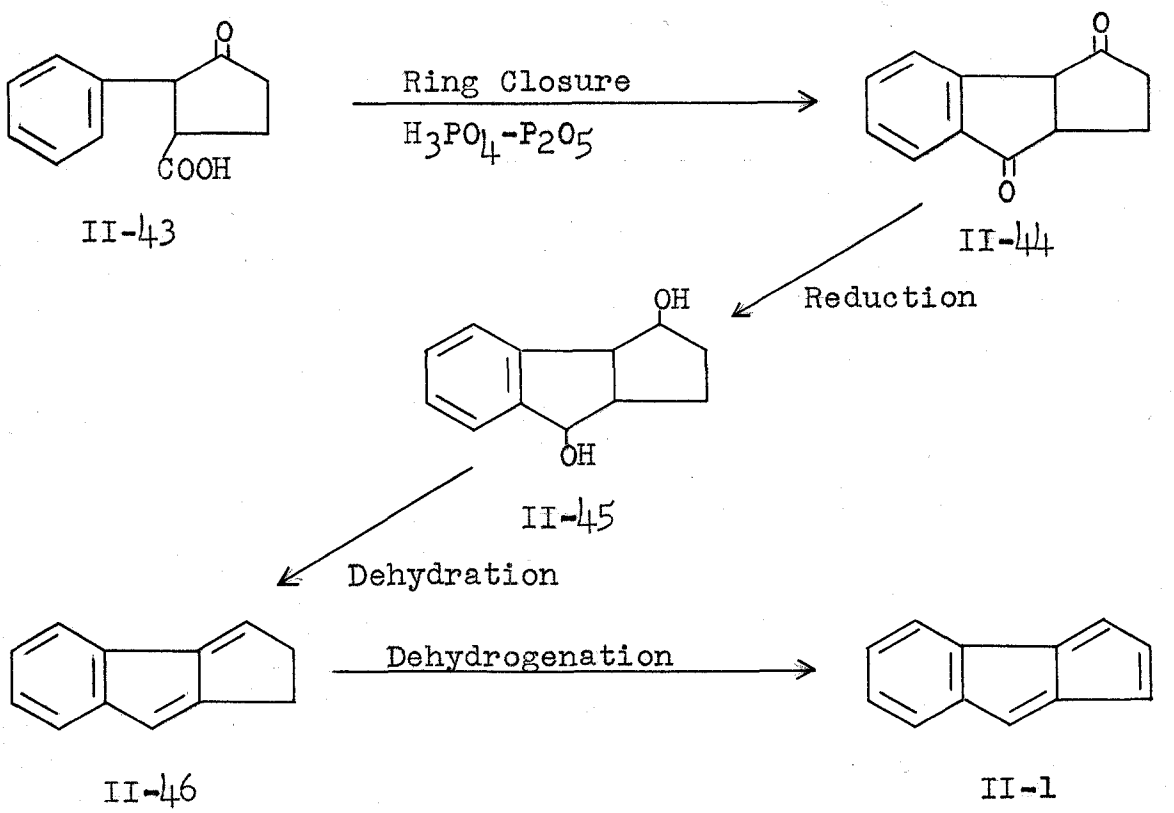


II-43 II-44 II-45 II-46 II-1

The conversion of II-38 to II-43 was accomplished according to the procedure of Baker and Leeds (24) which is a modification of the work of Chatterjee (25). Compounds II-39 and II-40 were not isolated pure in this procedure but were transformed to the tribasic acid, II-41, by hydrolysis and decarboxylation.

The acid, II-43, when treated with a mixture of phosphoric anhydride and phosphoric acid (90%) did not yield the expected diketone, II-44. Instead, analysis of the compound obtained from the reaction showed that it conformed to the formula, $C_{11}H_{10}O$; this falls short of the diketone by one atom each of carbon and oxygen. It was reasoned, then, that one molecule of carbon monoxide was liberated in addition to one

molecule of water splitting out in the reaction.

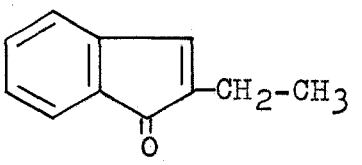
The structure of the compound, $C_{11}H_{10}O$, obtained from this reaction has not been completely elucidated although some properties have been studied which give a few clues as to its identity. The compound is a white solid, melting point 76-77°C, and possessing a ketone group as shown by analysis of the oxime. It has an olefinic linkage and we surmise on the evidence given below that the position of the double bond is 1,4 with respect to the ketone linkage. This was indicated to a certain extent by reduction of the compound with lithium aluminum hydride and aluminum isopropoxide respectively. In the case of the first reagent, two products were obtained, namely, a white solid of melting point 72-73°C in 20% yield and a colorless oil in 80% yield. A Meerwein-Ponndorf reduction, however, gave an 80% yield of the solid melting at 72-73°C. A mixed melting point of the solids obtained from the two different reactions showed no depression. Since the Meerwein-Ponndorf reduction leads exclusively to the alcohol, it is safe to conclude that the solid has the hydroxyl and olefinic groupings. Analysis of this compound showed it to have the formula, $C_{11}H_{12}O$, which is in line with the previously mentioned ketone, $C_{11}H_{10}O$. Further evidence of the alcohol grouping was furnished by characterization with benzoyl chloride to result in the ester melting at 86-88°C. The unsaturated alcohol is rather unstable and sets to a resinous mass on standing; this also indicates an

unstable olefinic compound.

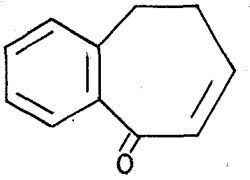
It was expected that the oil resulting from the reduction of the ketone, $C_{11}H_{10}O$, with lithium aluminum hydride would be a saturated ketone formed by a 1,4-addition. The oil responded negatively to the olefin test thus indicating saturation. However, we failed to obtain a crystalline oxime although this test alone is not conclusive. Further reduction of the oil with lithium aluminum hydride led to another oil which did not form a crystalline compound with benzoyl chloride.

Obviously, the investigation of the oil resulting from the reduction of the ketone, $C_{11}H_{10}O$, with lithium aluminum hydride is rather incomplete and no conclusions concerning it should be drawn here. Suffice it to say, however, that since the oil was not formed in the Meerwein-Ponndorf reduction of the above ketone (only the solid, melting point 72-73°C, was formed) we may assume that the reaction of the compound, $C_{11}H_{10}O$, with lithium aluminum hydride is a competing 1,2 and 1,4 addition to the conjugated system with the 1,4 mode of addition predominating.

Oxidation studies on the ketone, $C_{11}H_{10}O$, gave some interesting results. It was thought that phthalic acid would be obtained on vigorous oxidation because we thought that the compound had an indenone or benzocycloheptenone type structure as indicated by formulas II-47 and II-48 respectively.

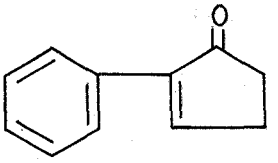


II-47



II-48

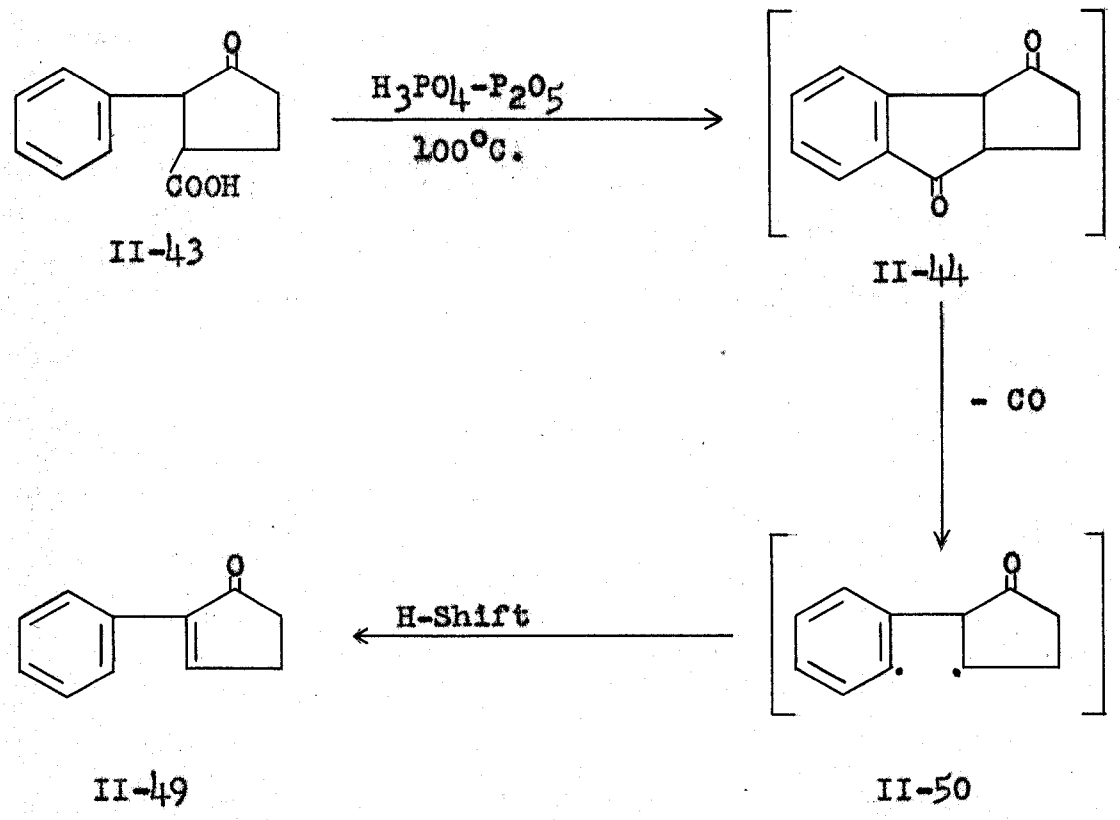
On the contrary, the action of a boiling sodium dichromate-sulfuric acid mixture on the compound, $C_{11}H_{10}O$, gave benzoic acid as shown by melting point and more conclusively, by a mixed melting point of the product and a sample of pure benzoic acid which showed no depression. This evidence would favor a phenylcyclopentenone structure such as II-49.



II-49

The latter compound has not been reported in the literature.

Although no further work has been done on the elucidation of the structure of the compound, $C_{11}H_{10}O$, we are inclined to favor the structure, II-49, and postulate a probable mechanism of the reaction as follows:



II-43 II-44 II-50 II-49

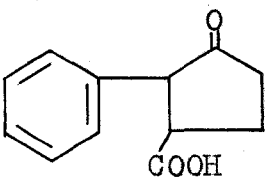
The ring closed to give the diketone, II-44, but under the existing conditions it was unstable and readily lost carbon monoxide to give the diradical, II-50. The hydrogen atom, α to the keto group and phenyl group, then migrated to the phenyl ring to result in the compound, II-49.

Of course, only a rigorous proof of structure of the compound, $C_{11}H_{10}O$, will give definite conclusions as to its identity.

It should be noted that other methods were attempted in an effort to convert the acid, II-43, to the diketone, II-44. The use of anhydrous hydrofluoric acid was without effect, most of the acid II-43 being recovered unchanged. When II-43 was treated with thionyl chloride so as to obtain

the acid chloride for a Friedel-Crafts type ring closure, a red tar was obtained. This reaction took place vigorously with ready evolution of hydrogen chloride, but apparently the resulting acid chloride condensed with the ∝-hydrogen to the keto group of another molecule; this process being repeated to yield a polymeric material.

The advantage of obtaining the diketone, II-44, is quite apparent in that this compound can be reduced to the dialcohol and afford subsequent unsaturation in the outer five-membered ring thereby facilitating complete dehydrogenation in the ring. However, since we were unable to obtain the diketone there remained two alternative routes leading from the acid, II-43.

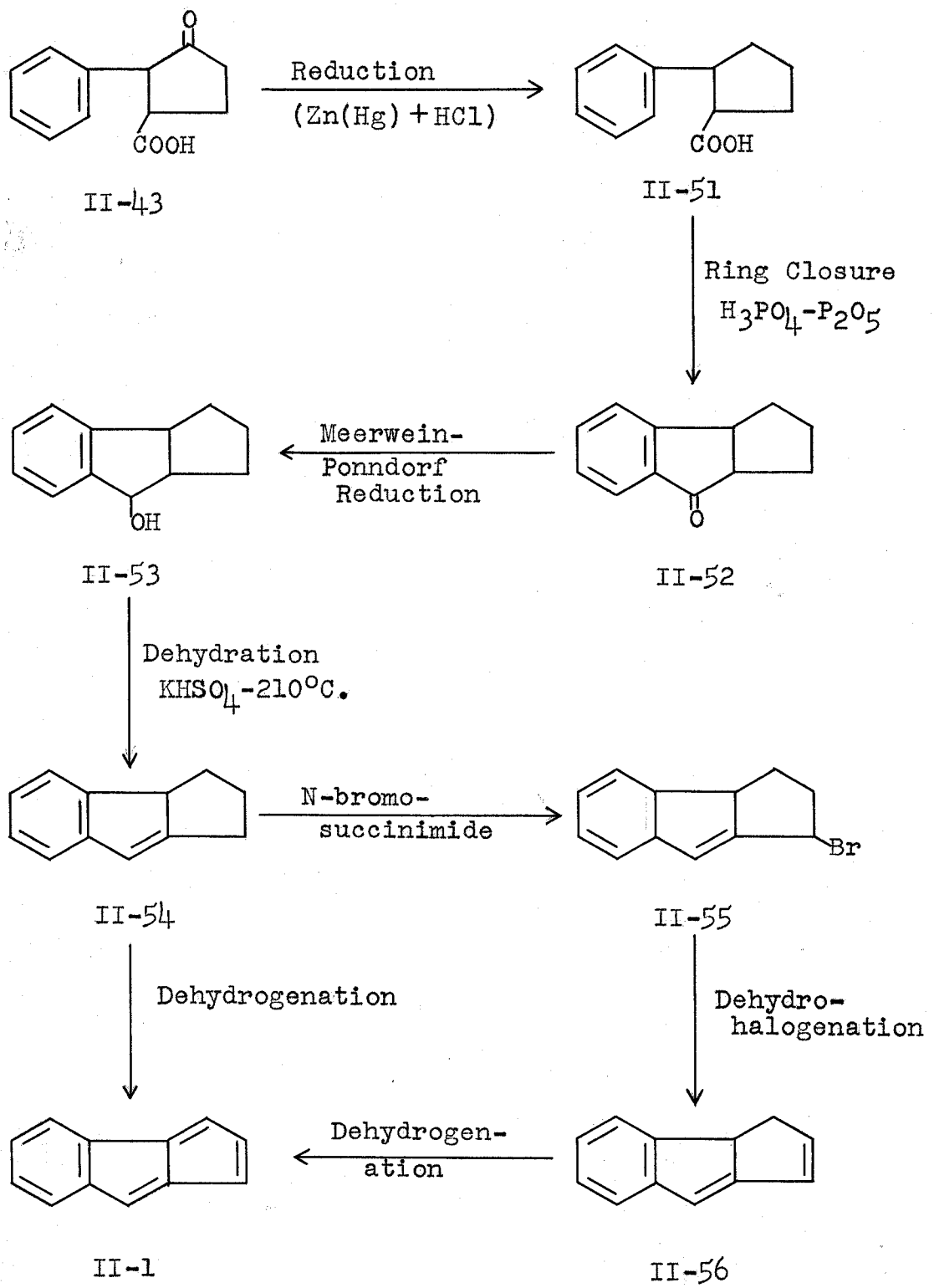


II-43

One of the routes involved reduction of the ketone group to the hydrocarbon (Clemmenson reduction) followed by ring closure. The other route consisted of esterification of the acid, reduction of the carbonyl group to the alcohol, methylating the alcohol group and then ring closure. Time permitted only the full investigation of the first route and only a partial investigation of the latter route. The first route will now be discussed but the second route will be discussed in a later portion of this thesis (under suggestions

for further research).

Method 3B



II-43 II-51 II-53 II-52 II-54 II-55 II-1 II-56

As mentioned in the introduction (page 19), the ketone, II-52, was prepared by Chatterjee (25). The procedure we used for the preparation of this compound was the modified one according to Baker and Leeds (24).

Research work was begun on the ketone, II-52. It underwent slow reduction with aluminum ispropoxide to give the hydroxy compound, II-53, in 82% yield. Dehydration of II-53 with potassium acid sulfate at 210°C afforded the olefin, II-54, in 42% yield.

The olefin resisted the action of N-bromosuccinimide, with or without peroxide catalyst. Refluxing in carbon tetrachloride solution overnight had no effect as evidenced by the lack of formation of succinimide and the recovery, in part, of the olefin. Some polymerization was noticed when the catalyst (benzoyl peroxide) was used. It should be noted here that the olefin is rather unstable and polymerizes readily at room temperature in the presence of air.

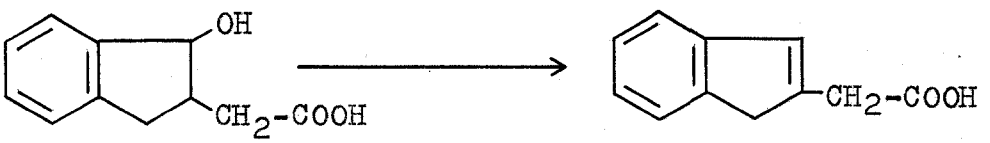
Some dehydrogenation experiments were attempted on the olefin in an effort to obtain the final compound, cyclopentindene. The method of Arnold and Collins (33) which employs chloranil in boiling xylene, produced a viscous dark-colored oil which failed to crystallize on cooling. The oil was not steam-distillable. Two dehydrogenation experiments that employed sulfur were carried out. In one experiment, the olefin, II-52, was heated with two equivalents of sulfur at 245°C for twenty minutes. Hydrogen sulfide was evolved

readily thus indicating progress of the reaction. However, on cooling the reaction mixture a black, brittle solid polymer was obtained. This polymer was extracted several times with boiling ligroin (90-120°C). Filtration of the hot solution followed by evaporation of the filtrate gave a black, tarry residue.

The dehydrogenation experiment with sulfur was repeated with the plan of heating at 245°C for only five minutes followed by a rapid vacuum distillation to remove the unpolymerized product. This procedure was unsuccessful because when a reduced pressure (25 mm. Hg) was applied after five minutes the reaction mixture swelled in the flask but failed to distill. On cooling the reaction mixture, extracting it with boiling ligroin (90-120°C) and filtering there was obtained a red-colored filtrate. Evaporation of the ligroin left a red-colored oil which failed to crystallize on cooling. The oil in alcoholic solution did not form a picrate.

III EXPERIMENTAL

1. Attempted dehydration of trans-1-hydroxyhydrindene-2-acetic acid, II-11.



II-11 II-12

Compound, II-11, was prepared according to the procedure of Peacock and Menon (27).

(a) Use of hydrobromic acid (Method of Peacock and Menon (27)).

A saturated solution of hydrobromic acid at 0°C was prepared by bubbling hydrogen bromide into 25 ml. of water until no more gas was absorbed. The hydrogen bromide was prepared by dropping bromine onto naphthalene and then purified by passing the gas through a wash bottle containing carbon tetrachloride. The wash bottle was packed in ice to prevent excessive volatilization of the carbon tetrachloride. This washing operation was efficient in removing bromine from the hydrogen bromide gas.

Six grams of II-11 were placed in a pressure bottle and the cold saturated solution of hydrobromic acid added. The bottle was sealed and heated on a boiling water bath for six hours. An oil settled out in the early part of the heating.

While the solution was still hot, the lighter aqueous layer was separated from the oil by decantation. Addition of some acetic acid to the aqueous layer and cooling caused a precipitation of a white solid which when filtered and dried melted at 131°C. This melting point was identical with that of the starting material, II-11. Mixed melting points showed no depression.

The yellow oil, when cooled in an ice bath, became rubber-like but crystallized on continual stirring. It was filtered and recrystallized from low boiling ligroin in the form of white, fluffy bunches. Melting point — 73°C. The crystals were insoluble in sodium bicarbonate solution.

(b) Use of phosphoric anhydride in benzene solution.

In a 3-necked flask (300 ml.) equipped with a mercury-sealed stirrer and reflux condenser, there were added 3 grams of II-11 and 50 ml. of benzene. The solution was refluxed until most of the acid dissolved. It was then cooled slightly and 3 grams of phosphoric anhydride added all at once. The vigorously stirred solution was again refluxed for two hours.

The solution was cooled and the clear, yellow filtrate decanted from the gummy phosphoric acid. The benzene was removed under reduced pressure and there remained a yellow oil which crystallized on cooling and stirring in an ice bath. The crude crystals were treated with 40 ml. of a saturated solution of sodium bicarbonate but very little, if any, dissolved. The solution was filtered and the filtrate acidified with conc.

hydrochloric acid. It became slightly milky but crystals failed to appear when the solution was cooled in an ice bath.

The residue was washed with water and dried overnight. The dried solid was recrystallized from low boiling ligroin. The melting point of the white, fluffy solid was 70-71°C. Another crystallization from ligroin brought the melting point to 73°C. The yield on the solid melting at 70-71°C was 74%. This solid conformed to the lactone.

(c) Formation of the barium salt of II-11 followed by attempted dehydration with barium oxide.

Three grams of II-11 were dissolved in hot water and clear barium hydroxide added to neutralize the solution. An excess of barium hydroxide was then added and the solution evaporated to dryness. The resulting white solid was mixed with 5 grams of barium oxide and pulverized in a mortar. The mixture was transferred to a large test tube having a side arm and heated in an oil bath at 200°C under a reduced pressure of 25 mm. Hg for two hours. A small amount of glass wool was introduced in the tube to prevent loss of powder when the vacuum was applied.

The powder turned to a brown color indicating some carbonization. It was treated with dilute hydrochloric acid in order to precipitate the product and also dissolve the barium oxide. A precipitate remained which appeared white but contaminated with some tar. The solution was filtered and the residue dissolved in sodium bicarbonate solution. Decolorization with a pinch of charcoal followed by acidification with hydrochloric

acid gave white crystals melting at 131°C. This checked with the starting material, II-11.

(d) Formation of ethyl ester of II-11 followed by dehydration with phosphoric anhydride.

Five grams of II-11, 20 ml. of absolute ethanol and 4 drops of concentrated sulfuric acid were refluxed for two hours. The solution turned to a pale-red color.

The ethanol was removed by distillation leaving a clear, red liquid. Twenty ml. of benzene were added and the resulting solution washed with two portions of 20 ml. each of saturated sodium bicarbonate solution followed by two portions of 20 ml. each of distilled water. The benzene solution was dried over calcium sulfate.

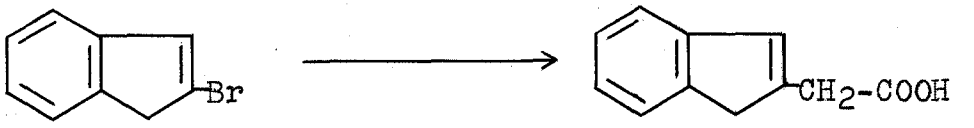
The dry benzene solution of the ester was transferred to a 3-necked flask equipped with mercury-sealed stirrer and condenser. Two grams of phosphoric pentoxide were added and the mixture vigorously stirred and refluxed for one hour.

The solution was filtered and the benzene removed from the filtrate by distillation. There remained a pale, red oily residue which did not crystallize on cooling and stirring in an ice bath.

The red oil was saponified with sodium hydroxide solution (2.5 g. NaOH per 10 ml. water) by refluxing with the latter until all the oil dissolved. The alkaline solution was diluted with a little water and then acidified with HCl (1:1). An orange-colored oil separated out which solidified on stirring

and cooling. The crystals did not dissolve in sodium bicarbonate solution. They were recrystallized from low boiling ligroin and melted at 71-72°C. This product conforms to the lactone.

2. Attempted formation of indene-2-acetic acid, II-12, from 2-bromoindene, II-16.



II-16 II-12

Compound, II-16, was prepared according to the procedure of Porter and Suter (34).

Into a 300 ml., 3-necked flask equipped with mercury-sealed stirrer and condenser, there were introduced 20 ml. of absolute alcohol. Forty-one thousandths of a mole (0.94gram) of sodium (freshly cut under ligroin) was dissolved in the alcohol. While the solution was still hot, 5.32 grams (0.041 mole) of acetoacetic ester were added through a dropping funnel. After five minutes had elapsed a solution of eight grams (0.041 mole) of 2-bromoindene, II-16, in 20 ml. absolute alcohol was added dropwise to the warm, well-stirred ethyl sodium acetoacetate solution. Immediately the reaction mixture began to darken and appeared green-black in only a few minutes. The solution was refluxed for three hours. During this time it became jet-black in color and no sodium bromide was seen on the bottom of the reaction flask when the stirrer was stopped at intervals.

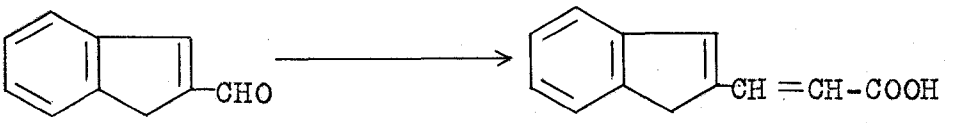
The black-colored solution was cooled and filtered. The black filtrate was distilled under reduced pressure to remove the alcohol. There remained a black, thick oil which had

a strong, tarry odor. The oil was added dropwise to a rapidly stirred solution of 8 grams of KOH dissolved in 10 ml. of water. After the addition of the oil the reaction mixture was heated on a boiling water bath for two hours. At the end of this heating time there still remained a black, oily layer on top of the alkaline layer although it appeared that some of the oil had dissolved.

The solution was cooled, diluted with a little water, and the black, tarry layer that had failed to dissolve was extracted with benzene. The alkaline layer (which was also dark in color) was acidified with HCl (1:1). More tar resulted. The solution was boiled with 2 grams of charcoal and filtered hot. The slightly colored filtrate was cooled in an ice bath but no crystals appeared on stirring a sufficient time.

The benzene solution of the black oil that remained after the alkaline treatment was not investigated.

3. Conversion of indene-2-aldehyde, II-23, to indene-2-propenoic acid, II-24.



II-23 II-24

The compound, II-23, was first prepared according to the procedures of Braun and Zobel (28). Later, the modified procedures of Blount (29) were used. The outlines for both procedures are shown on page 26.

(a) Attempted conversion using an acetic anhydride-potassium acetate mixture (Perkin reaction).

In a small R.B. flask, 3.77 grams of II-23 were dissolved in 15 ml. of acetic anhydride to give a colorless solution. Two and two-tenths grams of freshly fused potassium acetate were added, a condenser attached and the solution refluxed for two hours. Some interesting color changes took place even before the reflux temperature (175°C) was reached. Immediately on the addition of the potassium acetate the solution became yellow. As it was heated the color changed to orange, red, dark red, and finally black at the reflux temperature.

The hot reaction mixture was poured into 100 ml. of warm water and the contents steam-distilled to remove any unreacted II-23. The two-layer residual liquid (black, tarry oil on top) was boiled and most of the tar removed mechanically.

Then 2 grams of charcoal were added, the solution boiled for 5-10 minutes and filtered through a sintered-glass filter (previously heated at 120°C) while still hot. The clear filtrate was heated to boiling, 2 ml. of conc. HCl added, and the hot solution cooled rapidly with stirring. Crystals failed to appear.

(b) Conversion using malonic acid and pyridine (Doebner reaction).

An intimate mixture of 8.25 grams of II-23 and 7.26 grams of malonic acid was placed in a 125 ml. R.B. flask. Three ml. of pyridine (dried over KOH sticks) were added, the condenser quickly attached and the reaction mixture heated on a boiling water bath for 1 hour. During this time the mixture was shaken occassionally. Carbon dioxide came off readily and the reaction mixture began to cake and swell during the latter part of the heating.

The brown cake was cooled and treated with dilute HCl (87 ml. H_2O and 17 ml. conc. HCl) to dissolve the pyridine. The cake dispersed nicely and the suspension was filtered and washed with small amounts of water.

The brown precipitate was dissolved in hot ammonium hydroxide (1 liter of water and 100 ml. conc. NH_4OH). The dissolving was very slow and took a considerable length of time. The brown, cloudy solution was boiled an additional ten minutes with 3 grams of charcoal and filtered hot. The filtrate, which was clear but light-brown in color, was acidified with

conc. HCl. The crude product precipitated out as a white solid but when collected and dried in air overnight was tan-colored.

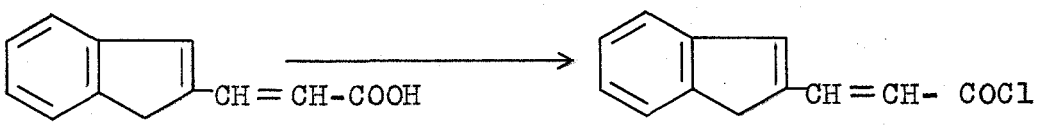
The tan, crude product was recrystallized from benzene (in which it was found to be only sparingly soluble). Seven hundred ml. of dry benzene were used, the solution being refluxed for considerable time to dissolve all the acid. On cooling, beautiful needle-like crystals came out. When filtered and freed from solvent in a vacuum dessicator, there resulted 5.45 grams (51% of theoretical yield) of indene-2-propenoic acid, pale yellow in color and melting at 237-239°C.

Analysis:

Calc'd. for $C_{12}H_{10}O_2$:	C=77.30	H=5.38
Found:	C=77.28	H=5.57

A second crop of crystals weighing 0.8 gram were obtained by evaporating down the mother liquor to about 100 ml. and cooling. However, these crystals were brown in color.

4. Formation of the acid chloride of indene-2-propenoic acid, II-24A.



II-24 II-24A

Twenty ml. of thionyl chloride (purified according to the procedure of Fieser (35)) were added to 1.58 grams of II-24 in a small R.B. flask equipped with a condenser. The ingredients were warmed on a water bath maintained between 45 and 50°C for two hours. Hydrogen chloride came off readily. During this time, the acid continued to dissolve in the thionyl chloride and was completely dissolved at the end of the first hour.

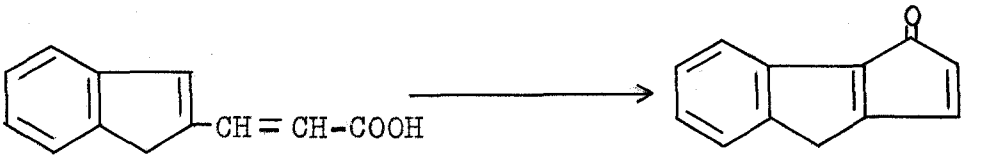
The excess thionyl chloride was removed under reduced pressure with the temperature of the water bath never exceeding 50°C. The vacuum was gradually increased so long as serious bumping did not occur. Finally, the full vacuum of the water aspirator was applied to remove all of the thionyl chloride.

The yellow solid was broken up into a powder and dissolved in hot benzene. On cooling the solution, rhombic crystals of the acid chloride precipitated out. They were yellow in color and melted at 136-138°C.

Analysis: Calc'd. for $C_{12}H_9OCl$: Cl = 17.36%

Found: Cl = 18.22%

5. Attempted ring closure of indene-2-propenoic acid, II-24, to give 1-keto-4-hydrocyclopentindene, II-25.



II-24 II-25

(a) Use of anhydrous hydrofluoric acid.

The reaction was carried out in a platinum crucible. The anhydrous hydrofluoric acid was obtained by cooling the gas from a cylinder (Harshaw Chemical Company) by means of a cooling coil immersed in a methanol-dry ice mixture. The reaction was run in a good hood.

A weight of 1.5 grams of II-24 was used. Enough hydrofluoric acid was added to nearly fill the crucible. The contents were stirred at intervals with a copper stirring rod as the hydrofluoric acid evaporated from the crucible. It took twenty minutes before most of the reagent had volatilized. During this time, the color of the solution was dark-red. The crucible was permitted to remain in the hood an additional hour.

There remained a red-brown residue which was broken up with a stirring rod and washed with cold water. The residue was insoluble in benzene, absolute alcohol and ether. In acetone it was partially soluble giving a yellow solution. This was filtered and the filtrate evaporated. Impure crystals of the starting material, II-24, were obtained. They melted

at 234-238°C.

The residue partially dissolved in a sodium bicarbonate solution. The mixture was filtered and the alkaline filtrate boiled with a pinch of charcoal. It was filtered hot, cooled and acidified. A white precipitate came out which when collected and dried melted at 236-238°C. Again, this checks the starting material, II-24.

The polymeric material that did not dissolve in the sodium bicarbonate solution was also insoluble in a number of organic solvents including benzene and ether. No effort was made to steam-distill the polymeric material.

(b) Attempted ring closure of the acid chloride in carbon disulfide with anhydrous aluminum chloride as catalyst.

The acid chloride was prepared according to the directions of page 54 except that two grams of II-24 were used and also, the acid chloride was used without recrystallizing it from benzene. Some carbon disulfide was added to the solid to dissolve it and then the solvent removed under reduced pressure. More carbon disulfide was added to redissolve the acid chloride and again the solvent removed under reduced pressure. In the last operation, the solid was evacuated with a vacuum pump to remove all traces of thionyl chloride.

The acid chloride was redissolved in about 30 ml. of carbon disulfide and the resulting solution transferred to a small, three-necked flask equipped with mercury-sealed stirrer and condenser having a drying tube attached. A weight of 1.64

grams of anhydrous aluminum chloride was added to the solution with vigorous stirring. The aluminum chloride turned red in color and tended to accumulate in a mass as the mixture was refluxed for three hours. The solution was allowed to stand overnight.

The carbon disulfide was removed under reduced pressure and the residue treated with ice cold dil. HCl (50 ml. H_2O and 5 ml. conc. HCl). The precipitate was extracted with ether, washed twice with small portions of 5% $NaHCO_3$ solution (shaken at long intervals in order to dissolve any unreacted acid), and finally dried over anhydrous sodium sulfate. The ether was removed by distillation and there remained a small amount of a yellow oil which quickly solidified to a sludge on cooling. It was recrystallized from benzene and found to melt at 136-138°C, identical with that of the acid chloride. (This was surprising since it was reasoned that any unreacted acid chloride would have been hydrolyzed to the acid on the above treatment.)

The aqueous sodium bicarbonate solution was acidified with a few drops of conc. HCl and gave an immediate precipitate. This was collected and dried. It melted at 235-239°C, indicating the acid, II-24.

The yellow crystals that melted at 136-138°C were boiled with water in order to determine if they were either the acid chloride or the expected product of the reaction. After boiling the solution for about an hour, it was cooled slightly

and sodium bicarbonate (solid) added. The yellow precipitate dissolved to give a cloudy solution which was decolorized with charcoal, filtered hot and the cooled filtrate acidified with a few drops of conc. HCl. A white precipitate came out immediately. This was filtered and dried. It melted at 237-240°C, again indicating the original acid, II-24.

(c) Attempted ring closure of the acid chloride in nitrobenzene using anhydrous aluminum chloride as the catalyst.

The acid chloride was prepared according to the directions on page 55 except that 1.58 grams of II-24 were used and also, the acid chloride was not recrystallized from benzene.

All traces of thionyl chloride were removed from the acid chloride by evacuating the solid with a vacuum pump. (Temperature was maintained at 45°C.)

A weight of 2.33 grams of anhydrous aluminum chloride was dissolved in 20 ml. of nitrobenzene (freshly distilled) to give a red solution. This solution was cooled in an ice bath. Ten ml. of nitrobenzene were added to the acid chloride and dissolved by warming the latter to result in a yellow-orange colored solution. This solution likewise was cooled in an ice bath. The two ice cold solutions were mixed and an immediate blood-red coloration formed. Fumes of hydrogen chloride were seen issuing from the mouth of the flask. The solution was continually shaken in an ice

bath for about 15 minutes. The flask containing the mixture was then loosely corked and placed in a refrigerator over the week-end.

On addition of ice cold dil. HCl (90 ml. of water and 10 ml. conc. HCl) to the blood-red solution, there resulted a brown paste of the reaction product with nitrobenzene. The latter was steam-distilled leaving a brown solid residue.

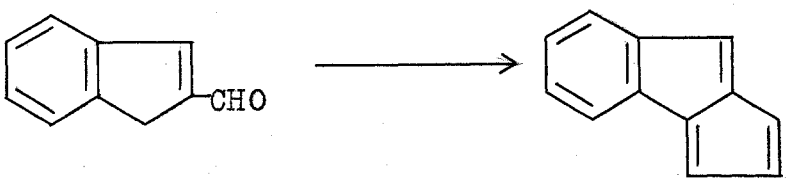
The residue was first extracted with benzene but on seeing that it was rather insoluble ether was employed. However, ether did not seem to dissolve much of the residue either. The yellow benzene-ether solution was distilled until most of the ether was removed. The benzene residual solution was treated with 0.5 gram of charcoal, boiled for a few minutes and filtered through a hot sintered-glass filter. The filtrate was pale yellow in color. When it was distilled crystallization occurred in the residual liquid. The crystals were filtered off and placed in a vacuum dessicator. The pale yellow crystals melted at 235-238°C. They dissolved in sodium bicarbonate solution thus indicating the original acid, II-24.

The brown residue left after the benzene-ether treatment was digested with hot dilute ammonium hydroxide to remove the rest of the unreacted acid. The solution was filtered and the brown residue digested with glacial acetic acid. The acetic acid solution turned yellow in color and it

seemed that part of the residue was dissolving. The solution was filtered while still hot and then distilled under reduced pressure in order to remove the acetic acid. There remained a yellow, sticky solid having a wide melting point (210-230°C).

The remainder of the brown solid was extracted with boiling acetone and filtered. The acetone was evaporated off leaving a yellowish-red colored, sticky residue which could not be crystallized and had the appearance of a polymer.

6. Attempted conversion of indene-2-aldehyde, II-23, to cyclopentindene, II-1.



II-23 II-1

(a) Under acid conditions.

A weight of 9.5 grams of indene-2-aldehyde was dissolved in 10 ml. of glacial acetic acid by warming the solution. In another test tube, 1.17 grams of freshly fused zinc chloride were dissolved in a mixture of 5 ml. glacial acetic acid and 10 ml. of acetic anhydride. Both solutions were poured into a pressure bottle, cooled in an ice bath and 4 grams of acetaldehyde added. The bottle was quickly sealed. A white precipitate settled out but this was found to be indene-2-aldehyde in a later run; cooling in the ice bath caused its precipitation.

The bomb was heated at 120°C for 2½ hours. The solution turned dark green in color and finally black at the end of the heating period.

The solution was cooled and the contents transferred to another flask and steam-distilled. Some unreacted II-23 distilled over as evidenced by its melting point of 51-52°C as well as its characteristic odor. The residue from the steam distillation was dark-maroon in color and existing in

beautiful pearly plates. It was thought that the product was crystalline. However, when a melting point was attempted on the crystals the temperature of the bath was raised as high as 340°C but the material did not melt. Also, an attempt was made to sublime the material but it only fused to a tarry mass. The material did dissolve in benzene to give a red solution but on evaporation of the benzene a red polymer resulted.

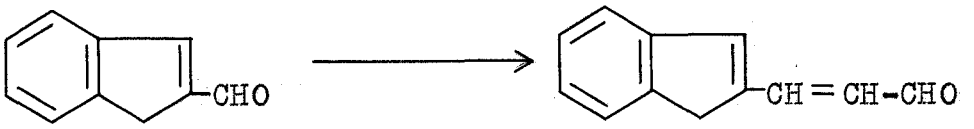
(b) Under basic conditions.

To a cold solution of 9.5 grams of indene-2-aldehyde in 20 ml. absolute alcohol in a pressure bottle, there were added 4 grams of acetaldehyde. A solution of 0.5 gram of KOH in 30 ml. of absolute alcohol was added and the bottle quickly sealed. A vigorous reaction took place with the formation of a red-colored solution. The solution was allowed to stand overnight.

The bomb was then heated at 120°C for 2½ hours. It was cooled and the contents poured into water. A brilliant orange, amorphous precipitate flocculated. It was filtered and dried in air. The color of the dry solid was orange-brown. It was soluble in the various organic solvents with the exception of low and high boiling ligroin. When the solid was dissolved in hot benzene followed by cooling crystals failed to appear. Evaporation of the solvent left a red-colored, sticky polymer. Either the solid was already a polymer before attempting its crystallization

or it polymerized afterwards. In all probability, it was already present as a polymer before the crystallization experiment.

7. Attempted conversion of indene-2-aldehyde, II-23, to indene-2-propenaldehyde, II-28.



II-23 II-28

A mixture of 8 grams of II-23 and 15 grams of acetaldehyde was shaken in a bomb until most of the indene-2-aldehyde dissolved. A solution of 0.1 gram of sodium hydroxide in 100 ml. of water was added and the mixture shaken at room temperature. The solution warmed and had to be cooled at intervals. Within ten minutes a viscous, yellow oil separated out. The bomb was opened immediately and the contents poured into dilute hydrochloric acid in order to stop the reaction. (In previous experiments it was found that if the reaction mixture remained alkaline too long the yellow oil polymerized to a sticky solid.) The aqueous layer was decanted off and the oil cooled in an ice bath. It failed to crystallize. Instead, it became very viscous and elastic. Apparently, the compound, II-23, polymerized even in so short a time as ten minutes.

8. Bromination of indene

II-8 II-29

A modification of the procedure of Kraemer and Spilker (30).

The indene was obtained from the Barrett Company as commercial indene, 70% pure. When freshly distilled it still had approximately the same assay value as indicated by the amount of bromine absorbed.

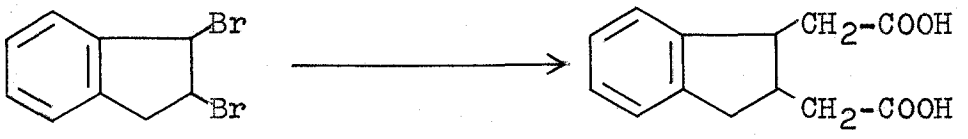
One hundred and sixteen grams of the freshly-distilled commercial indene were dissolved in about 500 ml. of anhydrous ether in a 1-liter, 3 necked flask equipped with stirrer, dropping funnel and thermometer so that the latter was immersed in the solution. The solution was cooled in an ice-salt mixture until the temperature was 0°C. One hundred and thirty grams of bromine were added slowly over a period of two hours with constant stirring and never allowing the temperature to exceed 5°C. (Considerable heat was evolved in the reaction which necessitated a slow addition of the bromine.)

The cold solution was transferred to a distilling flask and the ether removed under reduced pressure with the temperature of the water bath never exceeding 20°C. There

remained a pale-yellow oil.

The oil was brought to room temperature and ligroin (40-60°C) added until it was completely dissolved. The solution was cooled in a methanol-dry ice bath with vigorous stirring. There separated out a yellow viscous oil which crystallized after prolonged stirring. The mixture was filtered while still very cold and the yellow crystals washed twice with 75 ml. portions of absolute alcohol. This was done most efficiently by transferring the precipitate from the filter to a beaker so that it could be mixed well with the alcohol. The alcohol mixture was then cooled in the methanol-dry ice mixture and filtered while very cold. The last filtration gave very white crystals. However, as the temperature of the crystals approached room temperature (22°C) they started to melt and a considerable amount of oil filtered through the funnel. There remained pure white crystals which weighed 55 grams (25% of theoretical yield based on 70% indene as the starting material). They melted at 31-33°C. (Spilker and Dombrowsky (31) reported a melting point of 31.5-32.5°C.)

9. Attempted conversion of indene dibromide, II-29, to hydrindene-1,2-diacetic acid, II-30.



II-29 II-30

(a) Acetoacetic ester in ether solution.

Into a 2-liter, 3-necked flask equipped with a mercury-sealed stirrer, condenser with a calcium chloride drying tube attached and dropping funnel, there were introduced 1 liter of anhydrous ether and 94.2 grams (0.724 mole) of acetoacetic ester. A weight of 16.7 grams (0.724 mole) of sodium was sliced thin under ligroin and added portionwise to the ether solution. Cooling was necessary to control the reaction in the beginning. The thick suspension of ethyl sodium acetoacetate impeded the reaction of the remaining sodium. Refluxing and good stirring were necessary for a period of four hours in order to have all the sodium react.

One hundred grams (0.362 mole) of the pure indene dibromide were dissolved in 200 ml. of dry ether and this solution added rapidly to the reaction mixture. No reaction seemed to occur as evidenced by the fact that the thick ethyl sodium acetoacetate suspension remained. The solution was refluxed for four hours but without effect. Refluxing was continued all night and still the reaction

failed to take place.

To prove further that the thick suspension was ethyl acetoacetate and not sodium bromide about 200 ml. of absolute ethanol were added to the suspension; immediately the suspension dissolved to result in a clear solution. Thus, reacting in ether solution for sixteen hours had no effect.

The ether was removed by distillation and simultaneously replaced by alcohol. As the temperature rose sodium bromide began to separate out from the solution. This solution was worked up in a manner that will be described under part (b).

A repeat run was made that employed ethyl sodium malonate in ether solution and similar results were observed. Refluxing the ether solution overnight had no effect — the reaction did not take place.

(b) Acetoacetic ester in alcohol solution.

Barrett's commercial indene (80%) was purified according to the procedure of Naidus and Mueller (36). In this procedure, the commercial indene was refluxed with 40% NaOH to remove benzonitrile and then shaken for 24 hours with 6N-HCl to remove tar bases. The indene was distilled under a reduced pressure of 25 mm. of Hg. (It should be noted that Naidus and Mueller purified it further by fractional recrystallization, however, we simply used the distilled indene after the alkaline and acid treatments.)

Into a 1-liter, 3-necked flask equipped with stirrer, dropping funnel and thermometer, were poured 400 ml. of anhydrous ether. One-half mole (58 grams) of the purified indene was added and the solution cooled to 0°C by means of an ice-salt mixture. Bromine was added dropwise through the funnel over a period of one hour. The temperature of the solution never exceeded 5°C. The theoretical amount of bromine was 80 grams but actually only 70 grams were needed before the solution colorized. Apparently, the indene was still only 88% pure.

The ether was removed under reduced pressure (boiling stones were used instead of capillary). The bath temperature was never permitted to exceed 20°C during this operation. There remained an almost colorless oil. This was used directly in the condensation reaction without further purification.

One mole (23 grams) of sodium was sliced under ligroin and added portionwise to 350 ml. of absolute alcohol contained in a 1-liter, 3-necked flask equipped with mercury-sealed stirrer, condenser holding a drying tube and a dropping funnel. After all of the sodium had dissolved the solution was cooled somewhat from the reflux temperature and 1 mole (130 grams) of acetoacetic ester added over a period of ten minutes. While the solution was still hot, the oily indenedibromide was added rapidly over a period of fifteen minutes. The solution became cloudy and as it was brought

to the reflux temperature a large quantity of sodium bromide separated out from the reaction mixture. The solution was refluxed overnight (14 hours).

The solution was cooled and filtered. The sodium bromide precipitate was washed with small portions of alcohol. (A weight of 72 grams of NaBr was obtained which amounted to 80% of the theoretical amount of NaBr.) The alcohol was removed by distillation under reduced pressure to leave a dark-red colored oil. The weight of the crude oil was 170 grams. This oil was added dropwise to a well-stirred caustic potash solution (170 grams of KOH and 225 ml. of water) contained in a 1-liter, 3-necked flask equipped with stirrer, condenser with thermometer and dropping funnel. The temperature of the solution rose from 26°C to 49°C during the addition of the oil afterwhich the contents were heated on a boiling water bath for 2¼ hours to complete the hydrolysis. The color of the solution at the end of this heating period was purple. A layer of indene had formed on top of the alkaline solution. Four hundred ml. of water were added and the solution distilled to remove the alcohol. Some of the indene also distilled over. Distillation was continued until 250 ml. of distillate were collected. The residual liquid was cooled and transferred to a separatory funnel and extracted with benzene to remove the remainder of the indene and also any tar. The dark-red alkaline solution was acidified with hydrochloric acid (1:1). Only a red tar

came out. Most of this was removed mechanically. The solution was cooled in an ice bath but crystals failed to appear.

The solution was brought to boil, treated with 5 grams of charcoal and filtered hot. The cooled solution failed to produce crystals. However, when it was evaporated down to about 400 ml. and cooled in an ice bath a large crop of crystals appeared. These were filtered and washed with small portions of ether which removed the yellow color to give white crystals. These were dried in an oven at 120°C.

The white crystals consisted of a mixture of succinic acid and potassium chloride. The acid was separated from the potassium chloride by extracting it with four 100 ml. portions of absolute alcohol. The alcohol was evaporated off leaving crude succinic acid crystals (contaminated with potassium chloride). The product was recrystallized from a small amount of water to yield some succinic acid melting at 182-186°C.

(c) Malonic ester in absolute alcohol.

One-half mole of indene was brominated as described in part (b). The resulting oily dibromide was used without further purification.

One mole of sodium was sliced under ligroin and added portionwise to 400 ml. of absolute alcohol contained in a 1-liter, 3-necked flask equipped with a mercury-sealed stirrer, condenser with calcium chloride tube attached

and dropping funnel. After all of the sodium had dissolved, the solution was cooled slightly below the reflux temperature and 160 grams (1 mole) of malonic ester added over a period of 10 minutes. Then the oil was added over a period of 15 minutes. When the solution was brought to the reflux temperature sodium bromide separated out abundantly. The solution was permitted to reflux for ten hours. The color of the solution was lavender after this heating period.

The solution was cooled and filtered. The residue of NaBr was washed several times with small portions of absolute alcohol. (The residue was found to weigh 96 grams or 93% of the theoretical amount.)

The filtrate was distilled under reduced pressure to remove the alcohol. A precipitate occurred in the residual oil thus giving rise to an oily suspension. When this was treated with water the red-colored oil settled to the bottom. This was extracted with ether and the etheral solution washed three times with 50 ml. portions of water and then dried over anhydrous sodium sulfate.

The ether was removed by distillation and the resulting oil distilled under 3 mm. of Hg. pressure using an ordinary Claisen flask. Four cuts were taken in the distillation:

First cut - up to 80°C

Second cut - 80 - 110°C

Third cut - 110 - 135°C

Fourth cut - 135 - 160°C (Mostly 152 -158°C)

The third fraction was composed of very little material and was all in solid form. The fourth fraction was large and was also completely solid.

From the combined third and fourth fractions there were obtained 75 grams of a solid which distilled over at 156-158°C under 3 mm. Hg pressure.

The first and second lighter fractions were redistilled and four cuts taken:

First cut - up to 70°C

Second cut - 70 - 90°C

Third cut - 90 - 120°C

Fourth cut - 120 - 152°C

The fourth cut was all solid and weighed 9.0 grams. This was considered the same as the solid obtained in the third and fourth fractions of the first distillation.

The first cut of this last distillation consisted mostly of indene. It weighed 33 grams. The second and third cuts combined weighted 26 grams and gave a positive Beilstein test.

The solid which distilled over at 156-158° under 3 mm. of mercury was washed repeatedly with small portions of ligroin to result in pure white crystals

melting at 74-76°C. They were obtained in 39% yield based on indene. (This melting point checks with that of ethyl ethane-1,2-tetracarboxylate.)

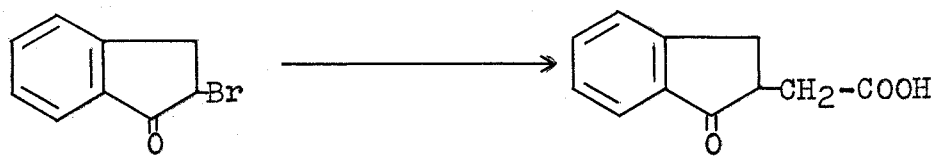
This compound was saponified by the following procedure:

In a small R.B. flask equipped with a condenser there were placed 9.5 grams of the above ester. An alkaline solution (18 grams KOH in 18 grams H_2O) was added. When the solution was warmed a vigorous saponification took place with the sodium salt separating out. The solution was refluxed for 15 minutes.

The cooled solution was treated with cold sulfuric acid (18 ml. conc. H_2SO_4 and 36 ml. H_2O). It was then refluxed for two hours. Evolution of carbon dioxide took place readily.

The solution was cooled and on continued stirring a large crop of crystals resulted. These were filtered, dried and extracted with hot glacial acetic acid. On cooling the combined extracts, crystals of succinic acid were obtained. The crystals melted at 180-186°C.

10. Conversion of 1-keto-2-bromohydrindene, II-33, to 1-keto-hydrindene-2-acetic acid, II-34.



II-33 II-34

The compound, II-33, was prepared according to the procedure of Johnson and Shelberg (32).

In a 300 ml., 3-necked flask equipped with a condenser holding a calcium chloride drying tube, mercury-sealed stirrer and dropping funnel, there were dissolved 2.73 grams of sodium (sliced thin under ligroin) in a mixture of 35 ml. absolute alcohol and 20 ml. of benzene (anhydrous, C.P.). When all of the sodium was dissolved the solution was cooled somewhat from the reflux temperature and 19 grams of malonic ester added within a period of 5 minutes. The compound, II-33, amounting to 15.8 grams, was dissolved in 70 ml. of benzene and this solution added to the ethyl sodium malonate solution during a period of 10 minutes. When the solution was brought to the reflux temperature sodium bromide separated out. The solution turned from colorless to purple. The solution was refluxed for 3½ hours.

The solution was filtered and the residue washed with small portions of benzene. The combined filtrate and washings were subjected to a current of air to evaporate the

benzene. There remained a dark-colored oil.

For the saponification a mixture of 58 ml. of 45% KOH and 58 ml. of methanol was used. This was added to the oil and the resulting mixture heated on a warm water bath for one-half hour. A small amount of water was added and then the mixture heated on a boiling water bath for one hour.

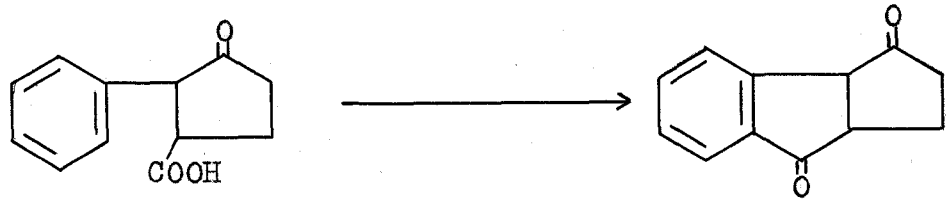
The solution was acidified with dilute H_2SO_4 (1:3), a little more water added and the resulting solution refluxed overnight (15 hours).

The solution was cooled whereupon yellow-colored crystals separated out accompanied by a considerable amount of a polymeric looking material. The crystals were dissolved in sodium bicarbonate solution but the polymer dissolved also. The hot solution was treated with a pinch of charcoal, filtered while still hot, acidified with dilute hydrochloric acid and cooled in an ice bath. White crystals separated out, but again, the polymer accompanied them. The impure crystals were dissolved in hot water; in this treatment the polymeric material did not dissolve. Treatment with charcoal, filtering and cooling the solution gave almost white crystals. On repeating this operation there was obtained 0.7 gram of pure white crystals melting at 148-151°C.

Analysis:

Calcd. for $C_{11}H_9O_3$: C = 69.44 H = 5.30
Found: C = 69.37 H = 5.16

11. Attempted ring closure of 2-phenylcyclopentan-3-one-1-carboxylic acid, II-43, to yield 1,4-diketo-1,2-dihydrocyclopentindene, II-44.



II-43 II-44

The compound, II-43, was prepared according to the procedures of Baker and Leeds (24) which are the modified procedures of Chatterjee (25). The outline for these reactions is shown on page 35.

(a) Use of anhydrous hydrofluoric acid. (The reaction was run in a good hood.)

In a copper flask equipped with a copper stirring rod there were placed 8 grams of the acid, II-43. Anhydrous hydrofluoric acid (in liquid form) was poured into the crucible until 110 grams of the reagent were added. The solution was stirred at intervals while the excess hydrofluoric acid evaporated. It took 3/4 of an hour for the acid to evaporate. It seemed that a red-colored solution existed during the presence of the reagent. The crucible was permitted to remain in the hood an additional hour.

A 10% solution of sodium carbonate (200 ml.) was added to the crucible whereupon most of the solid dissolved to give a green solution.

The alkaline solution was filtered and there remained only a small residue. The filtrate was acidified with dilute HCl (1:1) which caused a precipitation of a yellow, fluffy precipitate. The solution was diluted with some water, boiled to dissolve the precipitate, decolorized with charcoal and filtered while still hot. On cooling the filtrate, a white fluffy precipitate came down.

The precipitate was filtered and dried in air at room temperature. It melted at 115°C. with previous softening, this property being identical to that of the starting material, II-43.

(b) Attempted formation of the acid chloride of II-43 prior to the ring closure experiment.

In a small R.B. flask there were placed 10.2 grams of the acid, II-43. Eleven grams of thionyl chloride (purified according to Fieser (35)) were added and the solution warmed on a water bath maintained at 45°C. The acid dissolved and hydrogen chloride came off freely. However, the solution continued to darken in color and became more viscous. Hydrogen chloride came off readily for three hours. The contents of the flask congealed to a red, sticky polymer. The polymer was discarded.

(c) Use of a phosphoric acid and phosphoric anhydride mixture for the attempted ring closure of II-43.

This procedure is similar to the one used by Baker and Leeds (24) who employed it for the ring closure

of the compound, II-51.

Phosphoric acid (90%) was prepared from 85% phosphoric acid by the addition of 3.6 grams of P_2O_5 per 100 grams of 85% H_3PO_4.

Three grams of II-43 were added to a cooled mixture of 25 ml. of 90% H_3PO_4 and 25 grams of P_2O_5 contained in a 500 ml., 3-necked flask equipped with a mercury-sealed stirrer and a condenser with drying tube attached. The mixture was heated on a boiling water bath for three hours. Good stirring was necessary. As the heating was continued the mixture became thicker and had the appearance of thick pea-soup. Furthermore, it appeared to swell in the flask indicating the evolution of a gas.

One-hundred ml. of distilled water were added to the cooled solution. A light-brown colored oil settled on top of the aqueous layer. Thirty ml. of ether were added and the solution stirred. The two layers were transferred to a separatory funnel and the aqueous layer drawn off and extracted twice with small portions of ether. The extracts and original ether layer were combined.

Eleven such experiments were carried out and a composite made of the ether solutions. This ether solution was washed twice with 10% sodium hydroxide solution; first with a 100 ml. portion and then with a 50 ml. portion. This was followed by two washings with 75 ml. of distilled water. The ethereal solution was dried over anhydrous sodium sulfate.

The ether was distilled off and the residual oil distilled under reduced pressure. It came over at 108-110°C under 3 mm. Hg. as a colorless oil which tended to solidify in the receiving flask.

The crystals had some oil attached. They were recrystallized from 300 ml. of low boiling ligroin, filtered and placed in a vacuum dessicator to be freed of the ligroin. The melting point of the product was 76-77°C. The weight of dry, ligroin-free crystals was 12.9 grams or 43% of the theoretical amount based on obtaining the diketone, II-44.

Analysis of the compound, however, showed it to have the empirical formula, $C_{11}H_{10}O$. Molecular weight determination gave 134 as compared to the calculated 158. This indicates the presence of a monomer.

Calc'd. value based on $C_{11}H_{10}O$: C = 83.55 H = 6.39

Found: C = 83.45 H = 6.41

The yield based on the formula $C_{11}H_{10}O$ becomes 51%.

12. Experiments performed on the compound, $C_{11}H_{10}O$.

(a) Formation of the oxime

Procedure similar to that of Fieser (37).

One gram of the compound, $C_{11}H_{10}O$, was dissolved in 10 ml. of absolute alcohol. A mixture of 6 ml. of 5M hydroxylamine hydrochloride and 6 ml. of 5M sodium acetate was added. The solution was refluxed for 2½ hours. While the solution was still refluxing white crystals separated out.

The solution was cooled in an ice bath to bring about the crystallization of the remainder of the product. The crystals were filtered and washed with distilled water. They were recrystallized from 50% alcohol and dried in a vacuum dessicator. The crystals melted at 155-156°C.

Analysis:

Calcd. for $C_{11}H_{10}NO$: N = 8.09

Found: N = 8.03

(b) Reduction with lithium aluminum hydride

A weight of 2.64 grams of lithium aluminum hydride was dissolved in about 150 ml. of anhydrous ether contained in a 500 ml., 3-necked flask equipped with a mercury-sealed stirrer, dropping funnel and condenser with a calcium chloride drying tube attached. The solution was stirred vigorously for an hour but there still remained some suspended material.

A solution of 12.93 grams of $C_{11}H_{10}O$ in 100 ml. of ether was added dropwise to the ether solution of lithium aluminum hydride so as to maintain a steady, gentle reflux. This took a period of 50 minutes. The solution was then refluxed for one hour.

The solution was cooled in an ice bath and 10 ml. of water added cautiously through the dropping funnel. The reaction was vigorous at first but subsided considerably in a short time. The reaction mixture was poured into ice water and 100 ml. of 10% sulfuric acid added to dissolve the hydroxide. The layers were separated and the aqueous layer extracted twice with small portions of ether. The combined ether layer was washed once with 100 ml. of 5% sodium bicarbonate solution and then dried over anhydrous sodium sulfate.

The ether was distilled over leaving an almost colorless oil. Enough ligroin (40-60°C) was added to give miscibility with the oil and then the solution cooled in an ice bath. Innoculation with a crystal from a previous run brought about immediate crystallization in the form of a fluffy, white precipitate. The precipitate was filtered and washed with small portions of cold ligroin (40-60°C) and placed in a vacuum dessicator overnight.

The crystals turned yellow in the dessicator and some oil penetrated them. They were redissolved in ligroin, recrystallized, filtered, washed with cold ligroin

and allowed to stand in the air at room temperature (to evaporate off the ligroin). White feathery needles resulted which melted at 72-73°C. The weight of the product was 2.58 grams. A mixed melting point with the ketone, $C_{11}H_{10}O$, was run and melted at 44-46°C.

Analysis:

Calcd. for $C_{11}H_{12}O$: C = 82.50 H = 7.55

Found: C = 82.27 H = 7.50

Evaporation of the mother liquor from the last recrystallization to a smaller volume gave a second crop of crystals weighing 0.27 gram. However, these were yellow in color.

The mother liquor resulting from the first crystallization of the above compound was evaporated down to yield a pale yellow oil. This was cooled in an ice bath and innoculated with a crystal obtained previously but the oil failed to crystallize. It was distilled under vacuum and came over at 103°C under 4 mm. of Hg pressure as a colorless oil. It weighed 8 grams. Innoculation of the distilled oil and cooling still failed to bring about crystallization.

Characterization of the alcohol, $C_{11}H_{12}O$

A weight of 0.3 gram of the alcohol, $C_{11}H_{12}O$, was dissolved in benzene and mixed with a solution of 30 drops of benzoyl chloride in benzene. Two ml. of pyridine were added. A precipitate occurred immediately on

the addition of pyridine accompanied by a warming of the solution.

The solution was refluxed for 1/2 hour, cooled and water added. The precipitate dissolved in the water layer. Ether was added, the layers agitated well and the aqueous layer drawn off. The ether layer was washed with dilute hydrochloric acid (1:5), 5% sodium hydroxide and finally water. It was dried over anhydrous sodium sulfate. The ether was evaporated off leaving an oil which quickly solidified on cooling. This was dissolved in absolute alcohol, boiled a few minutes with a pinch of charcoal and filtered hot. The colorless filtrate was evaporated on a watch glass and white needles of the product came out. These were collected and recrystallized from a small amount of alcohol. The product was filtered and placed in a vacuum dessicator. The melting point of these crystals was 86-88°C.

(c) Reduction of $C_{11}H_{10}O$ with aluminum isopropoxide.

In a small R.B. flask there was placed a mixture of 3.0 grams of the compound, $C_{11}H_{10}O$, and 3.8 grams of aluminum isopropoxide (prepared and purified according to the directions of Wilds (38)). Fifteen milliliters of isopropyl alcohol (distilled from CaO) were added. A condenser with the water-jacket empty acted as the fractionating column. This was connected to a condenser turned downward for distillation. The solution was slowly distilled

(5-10 drops per minute) until the acetone test was negative. This required four hours.

The excess isopropyl alcohol was removed under reduced pressure leaving a thick, viscous residual liquid. This was hydrolyzed with cold dilute hydrochloric acid (7 ml. of conc. HCl and 38 ml. water). A colorless oil resulted which was extracted with ether. The aqueous portion was extracted twice with small portions of ether. The combined ether solution was washed with 100 ml. of 5% sodium bicarbonate solution and then dried over anhydrous sodium sulfate.

The ether was distilled off leaving a colorless oil. Low boiling ligroin was added to give complete miscibility with the oil and the resulting solution cooled in an ice bath. Innoculation brought about an immediate crystallization. The crystals were filtered and washed with small portions of cold ligroin. The ligroin-free, white, feathery needles weighed 2.4 grams or 80% of the theoretical amount based on the formula, $C_{11}H_{10}O$.

A mixed melting point of these crystals and those obtained from the lithium aluminum hydride reduction showed no melting point depression.

(d) Test for olefin grouping in the ketone, $C_{11}H_{10}O$.

A few crystals of the compound were dissolved in carbon tetrachloride and the solution cooled in an ice bath. Bromine was added dropwise from a pipette and became

immediately decolorized when contacting the solution.

Also, a solution of the ketone, $C_{11}H_{10}O$, in acetone decolorized a sulfuric acid solution of potassium permanganate when the latter was added dropwise.

(e) Vigorous oxidation of the ketone, $C_{11}H_{10}O$.

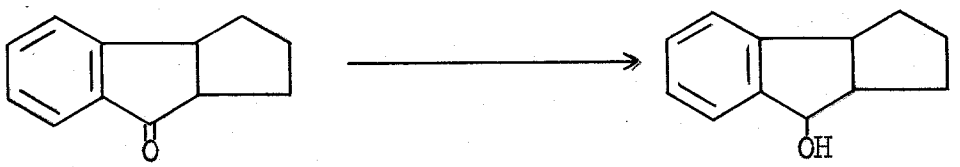
In a small R.B. flask there were placed 3 grams of $C_{11}H_{10}O$ and 9 grams of sodium dichromate. The solids were mixed intimately. Twenty ml. of water were added, the condenser attached and 15 ml. of conc. sulfuric acid cautiously added portionwise through the top of the condenser. A vigorous reaction took place with the solution heating almost to the reflux temperature. After the addition of all of the acid, the solution was refluxed for 3 hours.

The cooled solution was poured into 100 ml. of water and there separated out crystals contaminated with tar. The solution was filtered and the crystals dissolved in sodium bicarbonate solution. Most of the tar was removed mechanically. The alkaline solution was boiled with charcoal, filtered and acidified with dilute hydrochloric acid (1:1). The crystals were filtered and dried but were pale yellow in color. They were redissolved in sodium bicarbonate solution, the latter boiled with charcoal again, filtered and acidified. Crystals came out white in color. They were collected and dried over concentrated sulfuric acid in a vacuum dessicator. The crystals melted at 122-123°C.

A mixed melting point of these and pure

benzoic acid showed no depression. Also, the odor of the crystals obtained in this experiment was the same as benzoic acid.

13. Reduction of 4-keto-1,2,3,9,10-pentahydrocyclopentindene, II-52.



II-52 II-53

The compound, II-52, was prepared according to the procedures of Baker and Leeds (24). The outline of reactions for synthesizing this compound is shown on page 42.

In a 300 ml. R.B. flask, there were dissolved 10.46 grams (0.0523 mole) of purified aluminum isopropoxide in 100 ml. of isopropyl alcohol (distilled from calcium oxide). Nine grams (0.0523 mole) of the ketone, II-52, were added. A condenser with the water-jacket empty was attached so as to supply the fractionating column. The solution was distilled slowly (5-10 drops per minute) until the acetone test was negative. This required 5 1/2 hours. During this time 70 ml. of distillate were collected.

The remaining alcohol was removed under reduced pressure to leave a viscous residue. This was hydrolyzed with cold dilute hydrochloric acid (17 ml. conc. HCl and 87 ml. water). The oil that separated out was extracted with ether. The aqueous portion was extracted two times with small portions of ether. The combined ether solutions were washed with 100 ml. of 5% sodium bicarbonate solution

followed by 50 ml. of water. It was dried over anhydrous sodium sulfate.

The ether was distilled off through a small fractionating column. There remained a pale yellow oil which was distilled under reduced pressure. It distilled over at 110°C under 3 mm. of Hg pressure as a colorless oil. The weight of oil was 7.5 grams or 82% of the theoretical amount.

Analysis:

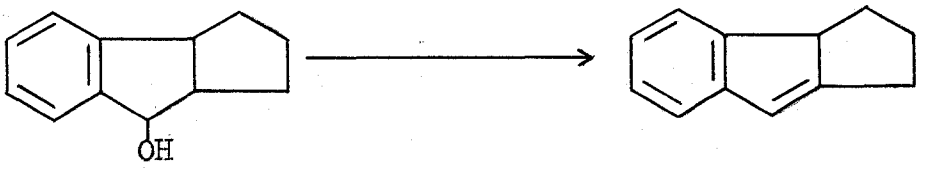
Calcd. for $C_{12}H_{14}O$: C = 82.71 H = 8.10

Found: C = 83.34 H = 8.04

$d_4^{25} = 1.287$

$n_D^{20} = 1.5680$ (corrected to benzene)

14. Conversion of 4-hydroxy-1,2,3,9,10-pentahydrocyclopentindene, II-53, to 1,2,3,9-tetrahydrocyclopentindene, II-54.



II-53 II-54

Ten grams of freshly fused, powdered potassium acid sulfate were placed in a small Claisen flask and 7.3 grams of II-53 added. The mixture was heated by means of an oil bath to a temperature of 210-215°C. As the heating proceeded droplets of water could be seen collecting on the upper walls of the flask. When the temperature range was reached a reduced pressure of 50-60 mm. of Hg was applied so that a very slow distillation took place. Water vapor and the olefin distilled over. Near the end of the distillation the full reduced pressure of the water aspirator was applied (25 mm. of Hg). There remained in the flask a considerable amount of polymerized material.

Ether was added to the distillate and the resulting solution dried over anhydrous sodium sulfate. The ether was distilled off leaving an almost colorless oil. This distilled over at 78°C under 3 mm. of Hg pressure as a colorless oil. The weight obtained was 2.8 grams or 42% of the theoretical amount.

n_D^{20} = 1.5878 (corrected to benzene)

Analysis:

Calcd. for $C_{12}H_{12}$: C = 92.31 H = 7.69

Found: C = 90.92 H = 7.75

Tests on the olefin:

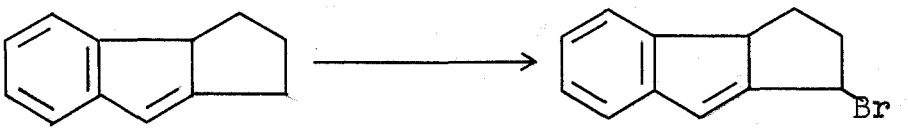
(a) When the olefin was dissolved in carbon tetrachloride and the solution cooled it decolorized bromine instantly.

(b) The olefin dissolved in acetone decolorized a sulfuric acid solution of potassium permanganete immediately.

Note:

The poor analysis for carbon could have been due to the tendency of the olefin to polymerize thus rendering the sample impure before the analysis. However, we feel that the more logical cause was the presence of some of the alcohol, II-53, which we found difficult to remove from the olefin by fractionation because of the tendency of the olefin to polymerize.

15. Attempted bromination of 1,2,3,9-tetrahydrocyclopentindene, II-54, with N-bromosuccinimide.



II-54 II-55

In a small 3-necked flask equipped with a mercury-sealed stirrer and a condenser with drying tube attached, there were introduced 3.36 grams of the olefin, II-54. Twenty ml. of carbon tetrachloride were added to dissolve the olefin. Then 3.84 grams of N-bromosuccinimide were added and the solution stirred while it was heated to the reflux temperature. Within the first hour no reaction seemed to take place as evidenced by the complete settling of the solid suspension to the bottom of the flask when the stirrer was stopped. The solution was refluxed for four hours and similarly, at the end of this time, the reaction had failed to take place.

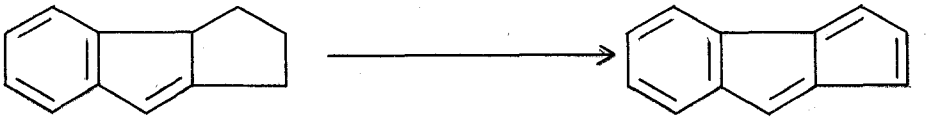
A particle of benzoyl peroxide was added and the solution refluxed overnight (15 hours).

When the stirrer was stopped some of the suspended material floated on top of the solution (indicative of succinimide). The solution was cooled and filtered. The residue (brown in color) was washed several times with small portions of carbon tetrachloride. This left a light

tan-colored residue. The amber-colored filtrate was transferred to a distilling flask and the carbon tetrachloride removed under vacuum using a nitrogen capillary. There remained a reddish-colored oil of rather fluid consistency. The oil failed to crystallize on cooling in an ice bath. Addition of 95% alcohol and cooling also failed to bring about crystallization. The oil was taken up in ether and dried over anhydrous sodium sulfate. The ether and alcohol were distilled over and then the oil distilled under reduced pressure. It distilled over between 80° and 123°C under 3 mm. of Hg. Along with the yellow oil some crystalline material also came over. The oil and crystals were treated with water whereby the crystals dissolved in the water layer indicating succinimide. The wet oil was extracted with ether and the ether layer washed with water to remove the remainder of the succinimide. Then it was dried over anhydrous sodium sulfate. The ether was distilled over and the oil redistilled. It came over between 80° and 125°C under 3 mm. of Hg as a yellow oil and possessing an odor similar to that of the starting compound, II-54.

A small portion of the oil was put in a test tube and some 95% alcohol added. The solution clouded somewhat. Then some aqueous 0.1N silver nitrate solution was added. The solution became cloudy but was due only to a precipitation of the oil itself (which collected as a globule on the bottom of the test tube). Silver bromide did not form.

16. Attempted dehydrogenation of 1,2,3,9-tetrahydrocyclopentindene, II-54.



II-54 II-1

(a) Use of chloranil in xylene. Procedure similar to that of Arnold and Collins (33).

A solution of 2.13 grams (0.01365 mole) of the olefin, II-54, and 6.72 grams (0.0273 mole) of chloranil in 15 ml. of xylene was refluxed for 19 hours. The color of the solution was blood-red at first but after refluxing this length of time the color was red-brown. A residue had precipitated out.

The solution was cooled and filtered. The residue consisted of a heterogeneous mixture of an amorphous looking tan-colored solid and a black, brittle solid. The xylene solution (filtrate) was diluted with ether and the resulting solution extracted with 4% potassium hydroxide. The aqueous layer was a deep dark-red color and the ether layer light-red in color. The latter was dried over anhydrous sodium sulfate. When the ether and xylene were removed under reduced pressure, there remained a red-brown, thick viscous oil. The oil failed to crystallize alone or from a ligroin (90°-120°C) solution.

An attempt was made to steam-distill the oil but it failed to distill. It was thought that the oil resulted from the polymerization of the olefin, II-54.

The amorphous looking residue mixture was not investigated.

(b) Use of sulfur at 245°C.

In a small Claisen flask there were introduced 1.7 grams (0.0109 mole) of II-54 and 0.7 gram (0.0218 mole) of sulfur. The mixture was heated by means of a wax bath to 245°C at which temperature hydrogen sulfide was evolved. It was noticed that this gas was not released at lower temperatures such as 225°C.

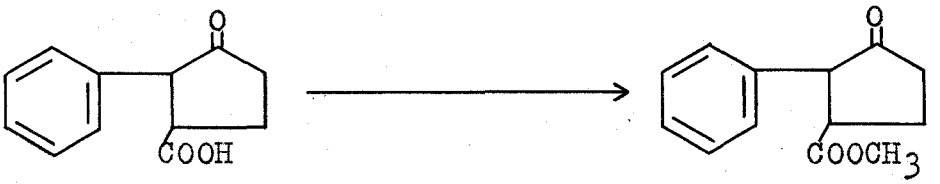
In one experiment, the mixture was kept at 245°C for twenty minutes. When the flask was cooled there appeared a jet-black residue. This was rather brittle and easily removed from the flask. It was digested with small amounts of boiling ligroin (90°-120°C). The extracts were combined and the ligroin evaporated off to result in a black, tarry residue.

In another experiment the mixture was kept at 245°C for only 5 minutes at the end of which time the full reduced pressure (25 mm. of Hg) of a water aspirator applied. The contents swelled in the flask but did not distill. On cooling a black residue resulted but was tarry and not brittle. This was extracted with small portions of boiling ligroin (90-120°C) to give a red-colored filtrate. The

ligroin solution was evaporated down to a smaller volume and then cooled in an ice bath. A small amount of precipitate separated out. This was filtered but found to be a sticky resin.

The rest of the ligroin was evaporated to leave a red-brown oil. This was cooled in an ice bath but did not crystallize. It was then dissolved in alcohol and added to an alcoholic solution of picric acid. The solution was cooled but a picrate did not form; the yellow solution simply became a little cloudy.

17. Esterification of 2-phenylcyclopentan-3-one-1-carboxylic acid, II-43.



II-43 V-1

A solution of 45 grams of the acid, II-43, in 300 ml. of methyl alcohol containing 12 grams of hydrogen chloride was refluxed for 23 hours.

The methanol was removed under reduced pressure and the residual liquid distilled two times with 100 ml. portions of benzene to remove the water. The residual oil was transferred to a beaker and crystallized from 75 ml. of absolute alcohol. A white solid, melting point 75-77°C, was obtained. The weight of the ester was 38 grams or 80% of the theoretical amount.

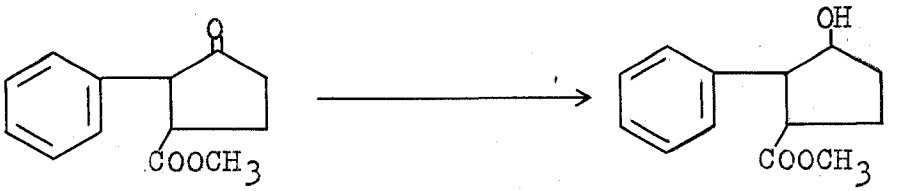
A second recrystallization from 75 ml. of alcohol raised the melting point to 79-80°C.

Analysis:

Calcd. for $C_{13}H_{14}O_3$: C = 71.56 H = 6.47

Found: C = 72.00 H = 6.71

18. Meerwein-Ponndorf reduction of methyl 2-phenyl-cyclopentan-3-one-1-carboxylate, V-1.



V-1 V-2

The method was essentially the same as described on page 89. The materials consisted of 0.1 mole (21.8 grams) of the ester, V-1, 20 grams (0.1 mole) of aluminum isopropoxide and 150 ml. of dry isopropyl alcohol. The reduction was fairly rapid and completed in 2 1/2 hours.

After working up the reaction mixture (as described on page 89) there resulted a yellow oil which distilled over at 145°C under 3 mm. of Hg pressure as a pale-yellow oil. The weight of product was 15.6 grams or 71% of the theoretical amount. Some polymeric material was left in the distilling flask.

$d_4^{25} = 1.269$

$n_D^{20} = 1.5196$ (corrected to benzene)

Analysis:

Calcd. for $C_{13}H_{16}O_3$: C = 70.91 H = 7.33

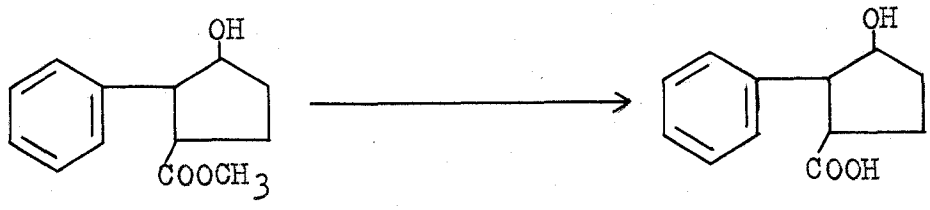
Found: C = 72.59 H = 7.82

Note:

No explanation has been found for the poor analysis. A fractional distillation was attempted on the oil under 1 mm. of Hg pressure but the high boiling point

of the oil caused excessive flooding at the top of the fractionating column resulting in an inefficient purification.

19. Saponification of methyl 2-phenylcyclopentan-3-ol-1-carboxylate, V-2.



V-2 V-3

A mixture of 14.68 grams of the ester, V-2, 34 ml. of methanol and 34 ml. of 45% potassium hydroxide was refluxed for 3/4 hour. The solution turned light red in color but was one phase and clear. The solution was cooled and diluted with 50 ml. of water. Then it was acidified with 100 ml. of dilute hydrochloric acid (70 ml. of water and 30 ml. conc. HCl). A yellow oil settled out which failed to crystallize on cooling the solution in an ice bath. The oil was taken up in ether and the aqueous layer extracted with small portions of ether. The combined ethereal solutions were washed once with 50 ml. of water and then dried over anhydrous calcium chloride.

The ether was distilled off leaving a yellow oil which distilled over at 185°C under 3 mm. of Hg pressure. It was very viscous and pale yellow in color.

The product was still present as a viscous oil the next day. However, some crystals were noticed around the last drop hanging from the arm of the distilling flask. These were used to innoculate the main body of oil;

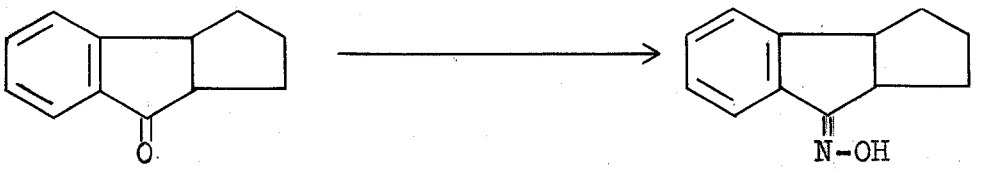
crystallization took place immediately. The pale yellow crystals were dissolved in hot benzene and recrystallized from this reagent. The tendency to super cool was marked and stirring for 15 minutes (and innoculation) was necessary to bring about crystallization. The white crystals were filtered and placed in a vacuum dessicator to be freed from the benzene solvent. The melting point was 107°-110°C.

Analysis:

Calcd. for $C_{12}H_{14}O_3$: C = 69.90 H = 6.85

Found: C = 69.97 H = 6.60

20. Preparation of the oxime of 4-keto-1,2,3,9,10-pentahydrocyclopentindene.



II-52 II-52A

The procedure was similar to that of Fieser (37).

A mixture of 1.04 grams of hydroxylamine hydrochloride and 1.23 grams of sodium acetate in 6 ml. of water was added to 1 gram of the ketone, II-52, dissolved in 5 ml. of absolute alcohol. The resulting solution was refluxed for 3 hours.

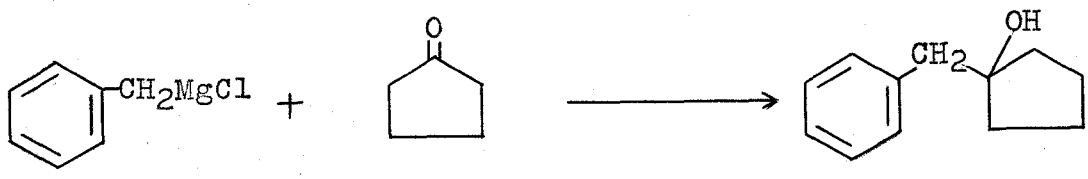
On cooling the solution and stirring white crystals were obtained. These were recrystallized from a small amount of methanol. They melted at 116-117°C.

Analysis:

Calcd. for $C_{12}H_{13}NO$: N = 7.49

Found: N = 7.24

21. Preparation of 1-benzylcyclopentan-1-ol.



Denissenko (39) reported this compound as an oil distilling at 129-30°C under 11 mm. of Hg pressure and having a density of 1.0218 at 20°C. Our experiments led to a white solid having a melting point of 59.5-60.5°C.

Eighteen grams of magnesium (50% excess of magnesium was used in order to minimize the coupling reaction that leads to dibenzyl) were suspended in about 100 ml. of anhydrous ether contained in a 1-liter, 3-necked flask equipped with mercury-sealed stirrer, condenser with calcium chloride drying tube attached and dropping funnel. One-half of a mole (63.3 grams) of freshly distilled benzyl chloride was dissolved in about 300 ml. of anhydrous ether. Approximately 15 ml. of this solution were added to the ether suspension of magnesium at room temperature to initiate the reaction. Then the reaction flask was immersed in an ice bath and the remainder of the benzyl chloride solution added over a period of five hours. (This slow addition and the low temperature had the purpose of minimizing coupling.) After the addition of all of the benzyl chloride solution, one-half of a mole (42 grams) of

cyclopentanone was added dropwise to the cold Grignard reagent over a period of one hour. The ice bath was replaced by a warm water bath and the ether solution gently refluxed for one-half hour. A white precipitate resulted from the reaction.

The contents of the flask were poured into a mixture of 400 grams of ice and 300 ml. of 10% sulfuric acid. The layers were separated and the aqueous layer extracted two times with 150 ml. portions of ether. The combined ether solutions were washed once with 50 ml. of distilled water, once with 50 ml. of 5% sodium bicarbonate solution and finally, with 50 ml. of water. Then it was dried over anhydrous sodium sulfate.

The ether was distilled over leaving a residual oil. This was distilled under a reduced pressure of 13 mm. of Hg and came over at 135°-138°C. The distillate crystallized readily in the receiving flask. The product was recrystallized twice from ligroin (40°-60°C). Slow crystallization gave beautiful hexagonal plates which melted at 59.5°-60.5°C. The weight of recrystallized product was 40 grams or 46% of the theoretical amount. The compound has an agreeable sweet odor.

Analysis:

Calcd. for $C_{12}H_{16}O$: C = 81.76 H = 9.16

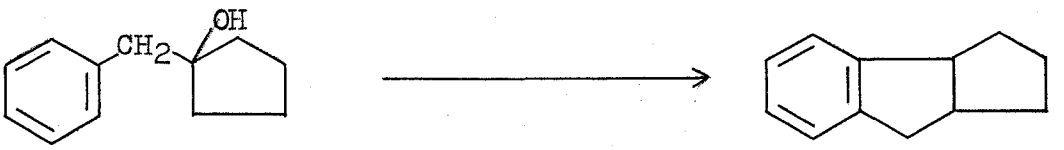
Found: C = 81.98 H = 8.94

Note:

This compound was dehydrated readily by distilling it with a few crystals of iodine at atmospheric pressure. The distillate (olefin and water vapor) came over at 230°C under 744 mm. of Hg pressure (barometric pressure). It was contaminated with some iodine the latter being removed by washing the ether solution with a sodium thiosulfate solution. After drying the ether solution over anhydrous sodium sulfate and removal of the ether, the olefin distilled over at 111°-117°C under 17 mm. of Hg pressure as a rather fluid, colorless oil having a very sweet odor. When it was redistilled it came over at this same temperature range.

The olefin, when dissolved in cold carbon tetrachloride, decolorized bromine instantly.

22. Attempted conversion of 1-benzylcyclopentan-1-ol to 1,2,3,4,9,10-hexahydrocyclopentindene, I-37.



I-37

The procedure for this attempted Bogart-Cooke reaction is similar to that of Perlman, Davidson and Marston (40).

Forty milliliters of an 85% sulfuric acid solution were cooled in an ice bath and 10 grams of 1-benzylcyclopentan-1-ol added slowly to the well stirred solution over a period of 20 minutes. The solution became red-colored with the organic portion becoming thick and viscous. The solution was brought to room temperature and agitated an additional 20 minutes.

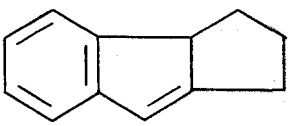
Ligroin (40°-60°C) was added to extract the organic portion but very little, if any, dissolved. (In the separatory funnel there were three layers, namely, the red-colored sulfuric acid layer, a red-colored thick, viscous oily layer and finally, the ligroin layer.) The acid was drawn off and ether added to the remaining two layers. Complete miscibility resulted. This solution was washed three times with ice-cold 85% sulfuric acid followed by 10% sodium carbonate solution and finally, water. It was dried over anhydrous sodium sulfate.

After the removal of the ether there remained a viscous red-colored oil. A distillation was attempted on this oil but with little success. When the pot temperature reached 240°C only a few drops of a liquid distilled over at 112°C under 18 mm. of Hg pressure. The oil-bath was removed and the flask heated with the free flame. A polymer distilled over at 248°-276°C under 18 mm. of Hg pressure which was red in color and extremely viscous. A considerable amount of residue remained in the distilling flask which was completely solid at room temperature.

IV SUMMARY AND CONCLUSIONS

Two main approaches to the synthesis of cyclopentindene were studied. The first one involved indene derivatives with the subsequent formation of the outer five-membered ring to give the carbon framework represented by II-1. The second approach was concerned with phenylcyclopentane derivatives with the subsequent formation of the inner five-membered ring. Our experiments indicated that the second method of approach was the more successful.

The compound, 1,2,3,9-tetrahydrocyclopentindene, II-54, was



II-54

prepared in our laboratories but we were unable to dehydrogenate the outer five-membered ring without causing excessive polymerization. Dehydrogenation of II-54 with sulfur at 245°C and with chloranil in boiling xylene respectively led to polymeric products. Also, the compound, II-54, did not react with N-bromosuccinimide. The brominated product would have been an intermediate in the indirect dehydrogenation of II-54 and may have led to the final compound, II-1.

A number of new compounds were prepared as intermediates in the various routes investigated for the attempted synthesis of cyclopentindene. They are listed in Table I.

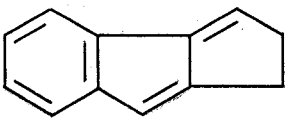
In addition, four possible new compounds were prepared whose structures have not been completely elucidated (see pages 78 to 88).

TABLE I

Compound	Formula Number	Page Number	Physical Constants
1. Indene-2-propenoic acid	II-24	52	Pale-yellow solid m.p. = 237-239°
2. Indene-2-propenyl chloride	II-24A	55	Yellow solid m.p. = 136-138°
3. 1-keto-hydrindene-2-acetic acid	II-34	76	White solid m.p. = 148-151°
4. Oxime of 4-keto-1,2,3,9,10-pentahydrocyclopentindene	II-52A	103	White solid m.p. = 116-117°
5. 4-hydroxy-1,2,3,9,10-pentahydrocyclopentindene	II-53	89	Colorless oil B.P. = 110°/3mm.Hg n^{20}_D = 1.5680 d^{25}_4 = 1.287 Crystallizes on long standing m.p. = 57-58°
6. 1,2,3,9-tetrahydrocyclopentindene	II-54	91	Colorless oil B.P. = 78°/3mm.Hg n^{20}_D = 1.5878
7. Methyl 2-phenylcyclopentan-3-one-1-carboxylate	V-1	98	White solid m.p. = 79-80°
8. Methyl 2-phenylcyclopentan-3-ol-1-carboxylate	V-2	99	Pale-yellow oil B.P. = 145°/3mm.Hg n^{20}_D = 1.5196 d^{25}_4 = 1.269
9. 2-phenylcyclopentan-3-ol-1-carboxylic acid	V-3	101	White solid m.p. = 107-110°

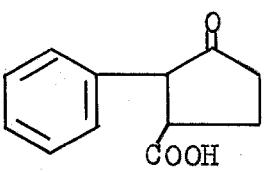
V SUGGESTIONS FOR FURTHER RESEARCH

1. The inability to obtain cyclopentindene was due to excessive polymerization of either the olefin, II-54, or cyclopentindene, itself. If one double bond could be introduced in the outer five-membered ring under mild conditions so as to yield the compound, II-46,

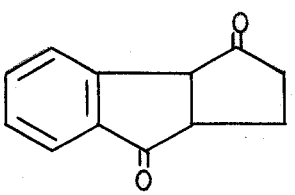


II-46

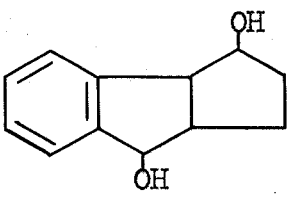
then it seems fairly reasonable that the last double bond should be introduced under much milder dehydrogenation conditions (such as the use of chloranil in toluene) to yield cyclopentindene. This plan was already considered when method # 3A was investigated but the ring closure experiment of the acid, II-43, did not result in the diketone, II-44,



II-43



II-44



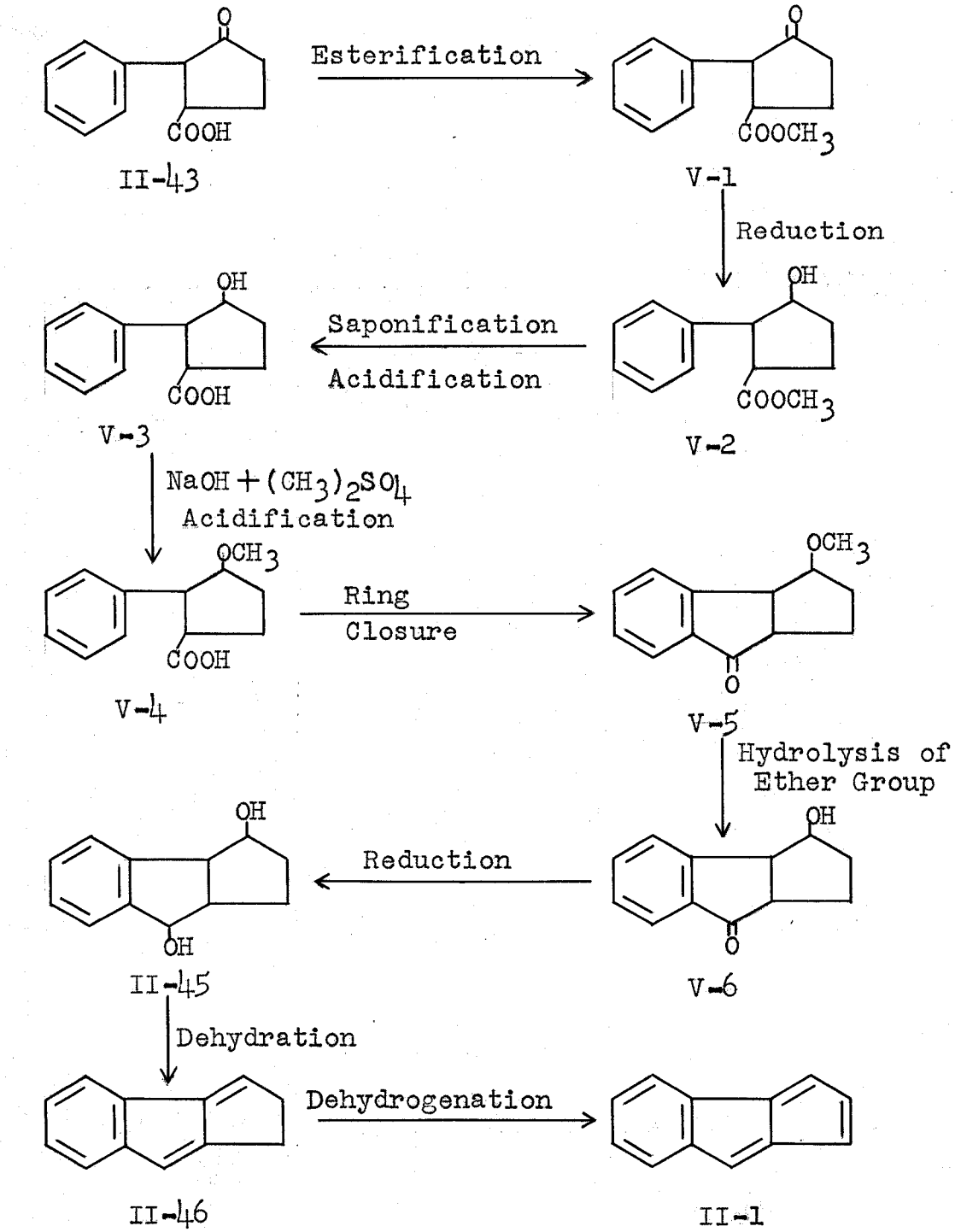
II-45

as explained previously. The next step would have been the preparation of the -diol, II-45. The preparation of the latter compound may be possible by another route stemming from the acid, II-43. Some work has already been done on this route but is incomplete at the present time. Should further

work be resumed on the synthesis of cyclopentindene, this route offers possibilities.

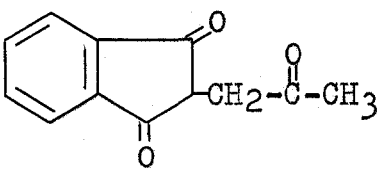
It may be outlined as follows:

Method #3C



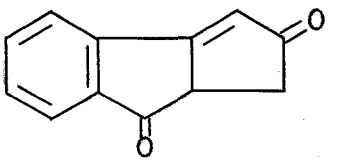
It is apparent that such a synthesis would be a long and tedious one (seventeen steps from benzaldehyde), nevertheless, it may represent the best route to the final compound, II-1. We have proceeded as far as the acid, V-3, in this research work.

2. The compound, 2-acetonyl-1,3-diketoindane, V-7,



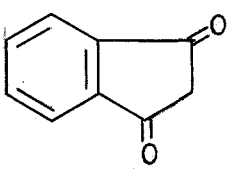
V-7

may be a possible intermediate in the synthesis of cyclopentindene for should ring closure occur by an intramolecular condensation there would result compound, V-8,



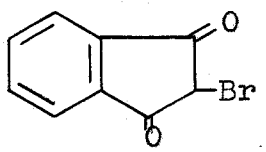
V-8

which appears to be an excellent intermediate. Baker and Leeds (24) apparently had this in mind when they synthesized compound, V-7. However, they obtained this compound in only a 1.8% yield from 1,3-diketohydrindene, V-9,



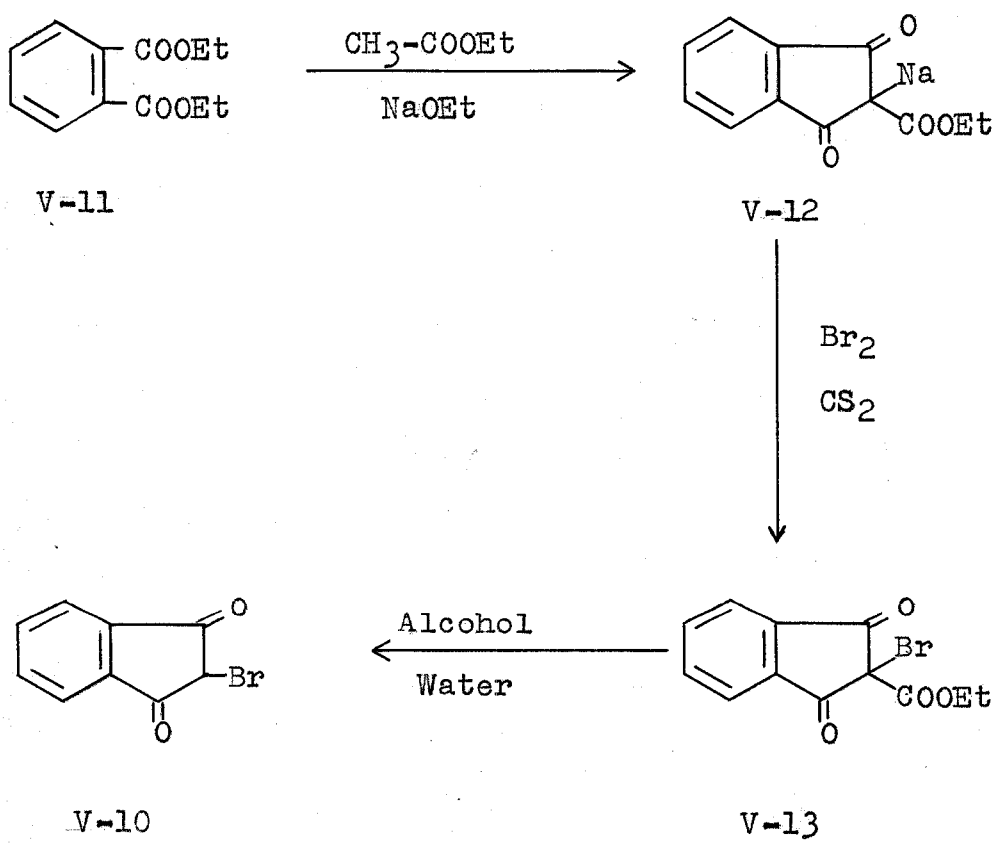
V-9

by a condensation of the latter with bromoacetone. A method which may give a higher yield of the compound, V-7, is a condensation of 2-bromo-1,3-diketoindane, V-10,



V-10

with ethyl sodium acetoacetate followed by ketone hydrolysis. The compound, V-10, has been prepared through a very interesting series of reactions. They may be outlined as follows:



V-11 V-12 V-13 V-10

The conversion of V-11 to V-12 was accomplished by Wislicenus (41) whereas Flatow (42) was responsible for the synthesis of V-10 from V-12. It should be noted that we carried out a few experiments in this series but the work was too incomplete to show any definite conclusions. For example, we found the compound, V-12, very stable, in fact, it did not seem to react with bromoacetone in benzene solution when the latter was refluxed overnight. Also, it appeared that the compound, V-13, when treated with ethyl sodium acetoacetate in alcohol solution regenerated the stable compound, V-12, rather than react in the customary fashion with this reagent.

3. The proof of structure of the olefin, II-54, would show whether or not a rearrangement took place during the dehydration of the alcohol, II-53.

4. Further dehydrogenation studies on the olefin, II-54, such as the utilization of platinum catalysts, may prove worthwhile.

5. It would be interesting to prove the structure of the ketone, $C_{11}H_{10}O$, that we obtained by the attempted ring closure of 2-phenylcyclopentan-3-one-1-carboxylic acid as described on pages 36 and 78.

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