SYNTHESIS

of

POLYMETHYL-NAPHTHALENES

and

TROPOLONES

T H E S I S

submitted by

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P R E F A C E

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C O N T E N T S

PART I.

I N T R O D U C T I O N

In Elsevier's Encyclopaedia[1] descriptions are given of methyl-naphthalenes, from the monomethyl- to the penta methyl- compounds. Much of the synthetic work in this field has been done by Ruzicka,[2],[3],[4],[5],[6], Kloetzel,[8],[9],[10],[11], Darzens,[12],[13], Hewett,[14] and others.[15],[16],[17],[18]

α- and β - methyl-naphthalenes are prepared by a wide variety of methods, of which the direct Friedel-Crafts reaction is the most important.

The higher methyl-naphthalenes are prepared by (1) the dehydrogenation[3],[8],[10],[18],[19],[20],[21] of the dihydro- or tetrahydro-methylated naphthalene, (2) the Grignard reaction[5],[8],[17] on the tetralone derivatives followed by dehydrogenation and (3) the chloro-methylation and reduction of lower methyl-naphthalenes.[12],[13],[14],[22]

Mono-, di- and tri-methyl-naphthalene are obtained from natural sources in large amounts.[23],[24],[25]

α - and β - methyl-naphthalenes, 1:2-, 1:3-, 1:4-, 1:5-, 1:6-, 1:7-, 2:3-, 2:6- and 2:7- dimethyl-naphthalenes and the 1:2:6-, 1:2:7-, 1:6:7-, 1:2:5-, and 2:3:6- tri methyl-

naphthalenes are found in Roumanian asphaltic petroleum, coal tar and petroleum oil.

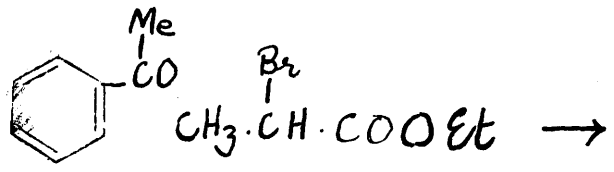
Alkyl-naphthalenes are formed by the dehydrogenation of certain terpenes and give useful information about the structure of the parent terpene.

1:6- Dimethyl-naphthalene is formed from ionone,[2] cadinene[21] and isozingiberene.[7] 2:7- Dimethyl-naphthalene is obtained from tricyclic terpenes. 1:2:7- Trimethyl-naphthalene, or agathelene, is a dehydrogenation product of agathic acid,[3] and is also obtained from squalene[3] by cyclo-isomerisation and dehydrogenation. 1:2:6- and 1:2:7 tri-methyl-naphthalenes (the latter also known as Sapotalin oil) are dehydrogenation products of irone and pentacyclic terenes[5] respectively.

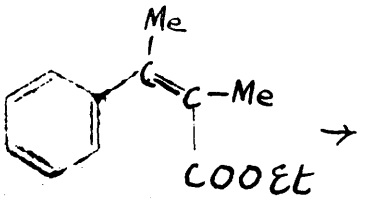
The known 1:2:3:4-,[10],[15],[16] 1:2:4:8-, 1:2:5:6-,[26] 1:2:5:7-, 1:2:5:8-, and 1:2:6:8- tetramethyl-naphthalenes and 1:2:4:5:8- and 1:2:4:6:8- penta methyl-naphthalenes have been mostly synthesised by Ruzicka and co-workers.[3],[5],[6] No higher substituted products are known.

A short summary of the general methods of preparation needs to be given. The most common method used is that of Ruzicka,[2],[3],[4],[5] where the Reformatsky reaction was used to condense appropriate methyl-acetophenones (I) (for

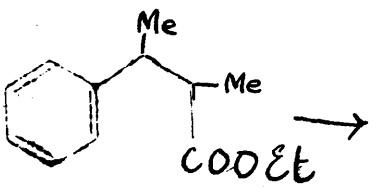
simplicity only acetophenone is formulated) with ethyl-α-bromo-propionate (II).



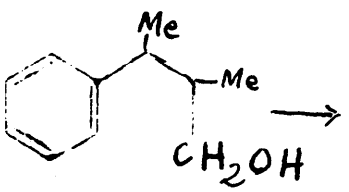
(I) (II)



(III)

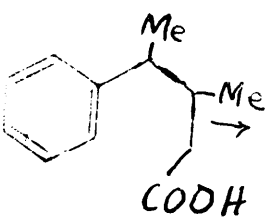


(IV)



(V)

[CH_2Br / CH_2CN]



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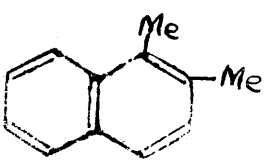
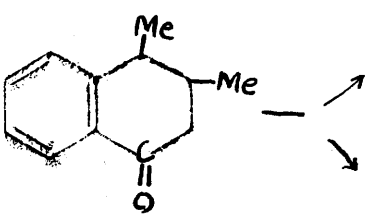
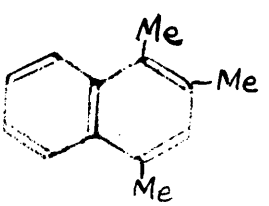


(VIII)



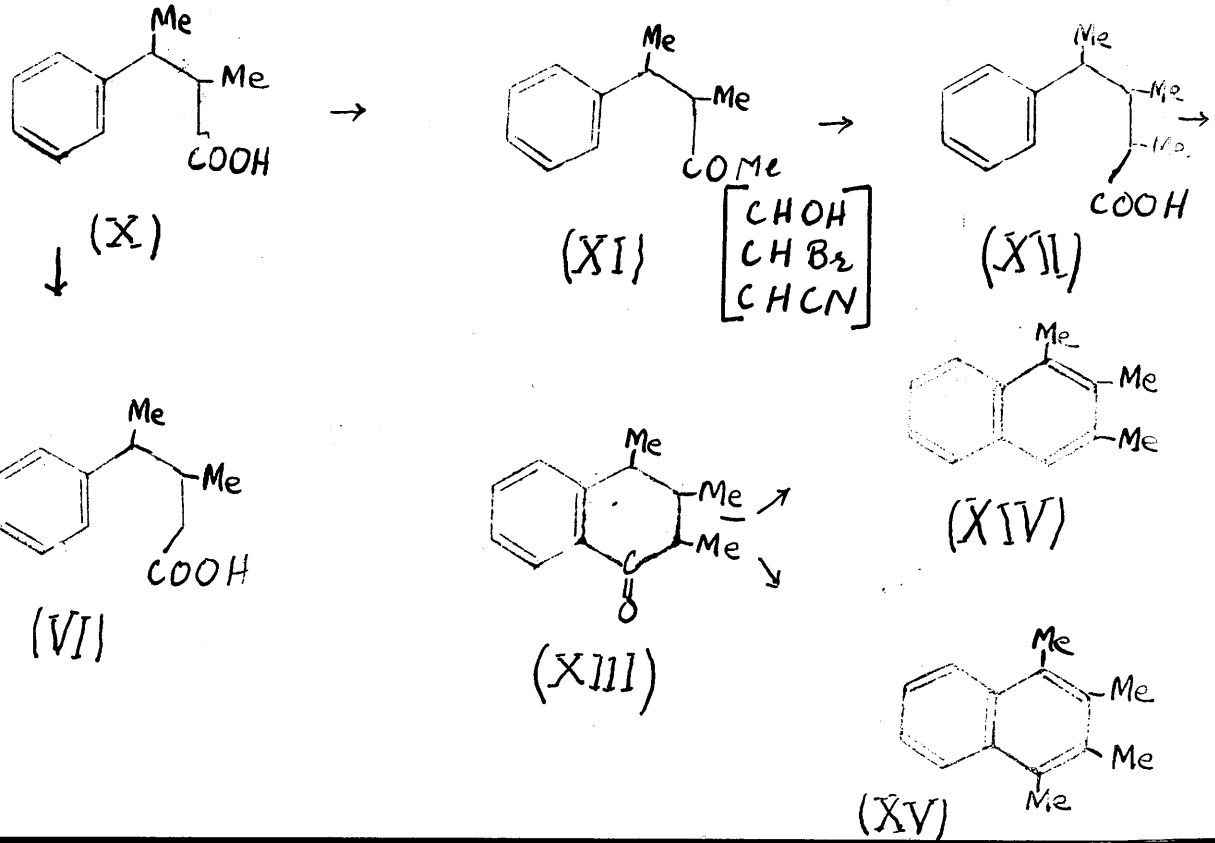
(VII)



(IX)

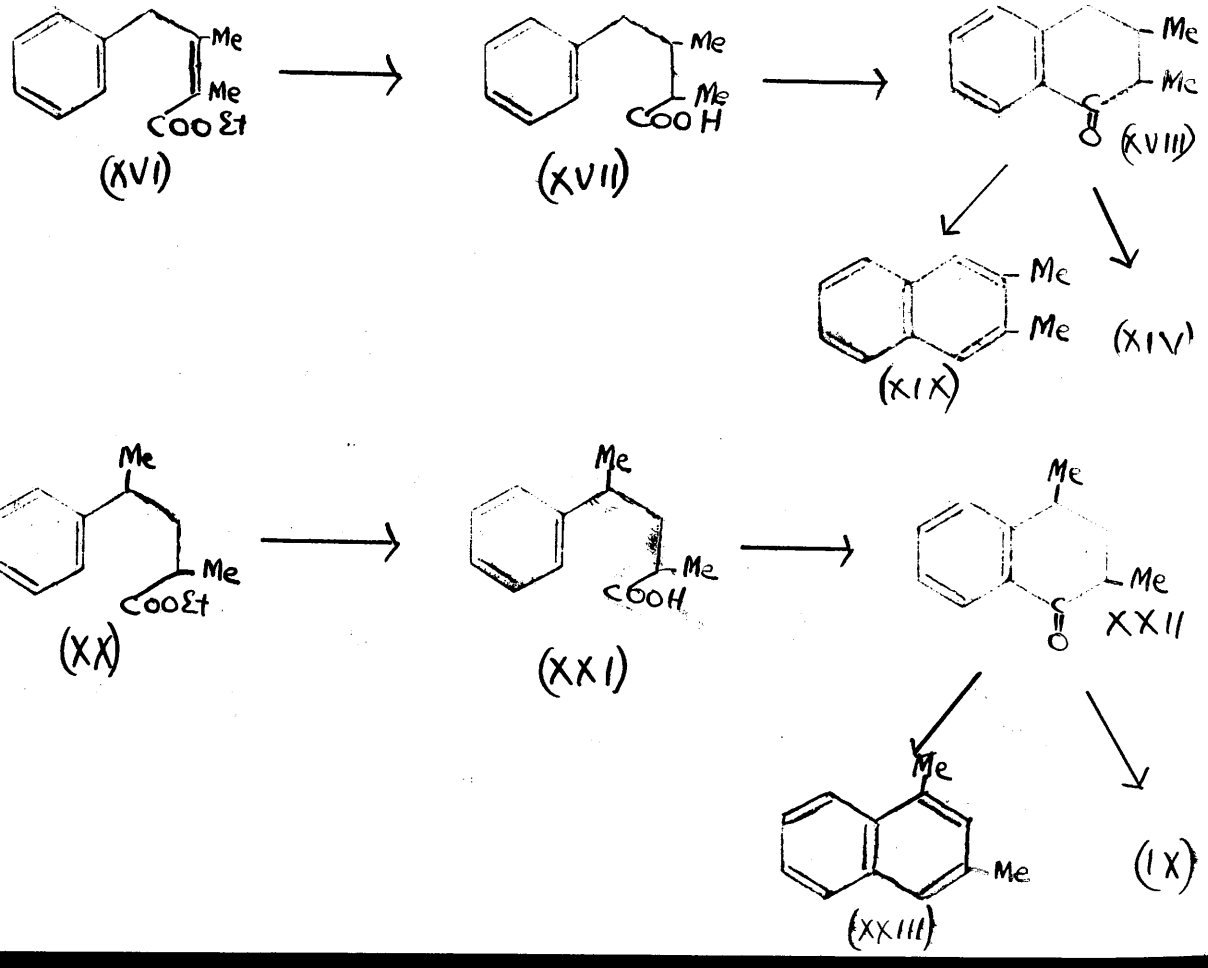
The hydroxy ester obtained was dehydrated to (III) and this was reduced to the dihydrocinnamic ester derivatives (IV). The latter was further reduced by the Bouvealt method to the primary alcohol (V) which was lengthened via the bromide and cyanide to the butyric acid derivative (VI). The keto-tetralin derivative (VII) was either reduced and dehydrogenated to (VIII) or treated with methyl-magnesium iodide and dehydrogenated to (IX).

To introduce a methyl group into the 3-position, Ruzicka[4] hydrolysed (IV) to the dihydrocinnamic acid derivative (X), the acid chloride of (X) reacted with methyl zinc iodide to give (XI).



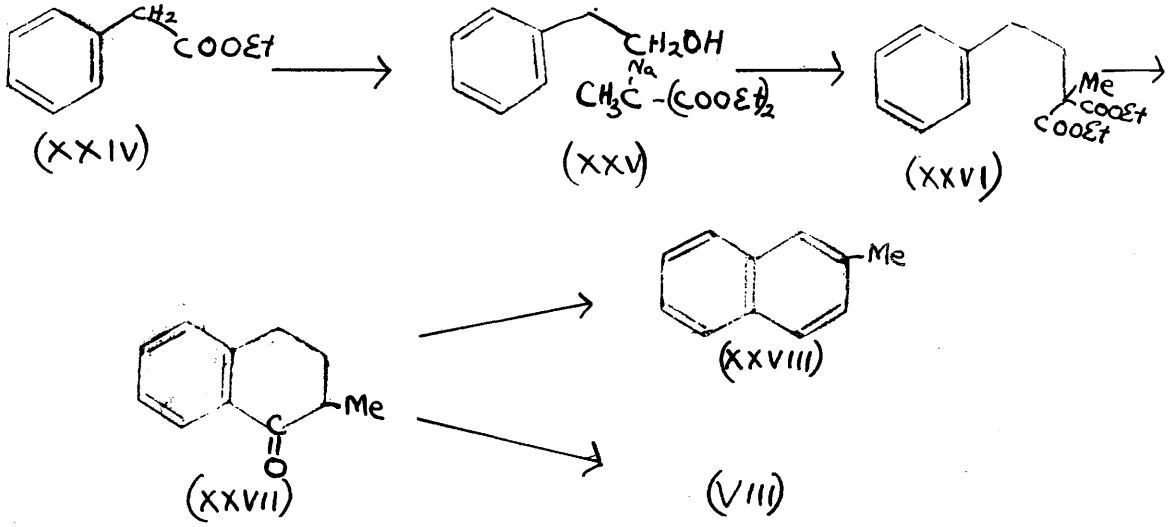
(XI) was reduced to the secondary alcohol and this via the bromide and cyanide derivatives gave the butyric acid derivative (XII). The keto-tetralin (XIII) obtained on ring closure similar to (VII) gave both (XIV) and XV). Kloetzel[8] used the Arndt-Eistert[27] method to enlarge the side chain of the acid (X) to (VI).

Ruzicka has also condensed benzyl acetophenone and p-methyl tropapaldhyde with ethyl-α-bromopropionate. He obtained (XVI) and (XX) respectively, from which (XVII) and (XXI) were obtained on reduction and hydrolysis.



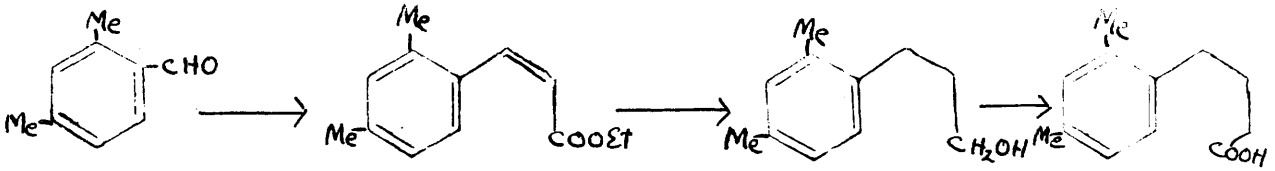
Acid (XVII) was cyclised to the keto-tetralin (XVIII), and this afforded both di-and tri- methyl-naphthalenes (XIX) and (XIV) respectively. The keto-tetralin (XXII) gave similarly (XXIII) and (IX).

In the synthesis of tetra methyl-naphthalenes, Ruzicka[5] reduced phenyl-acetic ester (XXIV) to the alcohol (XXV), and this was condensed with sodio-methyl-malonic ester to give (XXVI). (XXVI) was hydrolysed, decarboxylated and cyclised to the keto-tetralin (XXVII)



(XXVII) afforded both β-methyl-naphthalene (XXVIII) and 1:2-dimethyl-naphthalene (VIII).

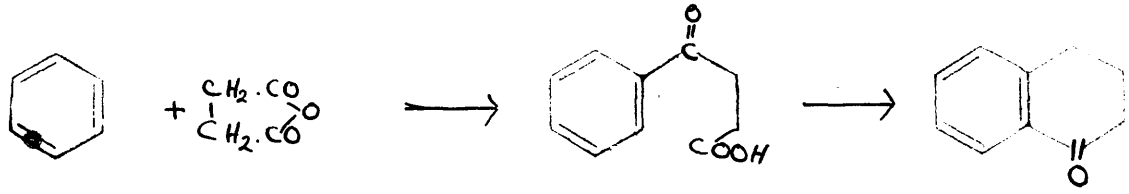
Heilbron,[17] converted 2,: 4 dimethyl-benzaldehyde to the cinnamate derivative (XXIX). He then reduced it to the primary alcohol (XXIX[a]) and this



(XXIX) (XXIX$^{\alpha}$) (XXX)

gave the corresponding acid (XXX) on enlargement of the side chain. From this, 1:3-dimethyl-naphthalene and 1:3:5 trimethyl-naphthalene were obtained by the usual methods.

A common method for alkyl-naphthalene synthesis is the Friedel-Crafts reaction of benzene and alkyl-benzenes with succinic, and substituted succinic anhydrides in presence of aluminiumchloride to give γ-keto-butyric acid derivatives (XXXI) (for simplicity the reaction of benzene with succinic anhydride is formulated.)

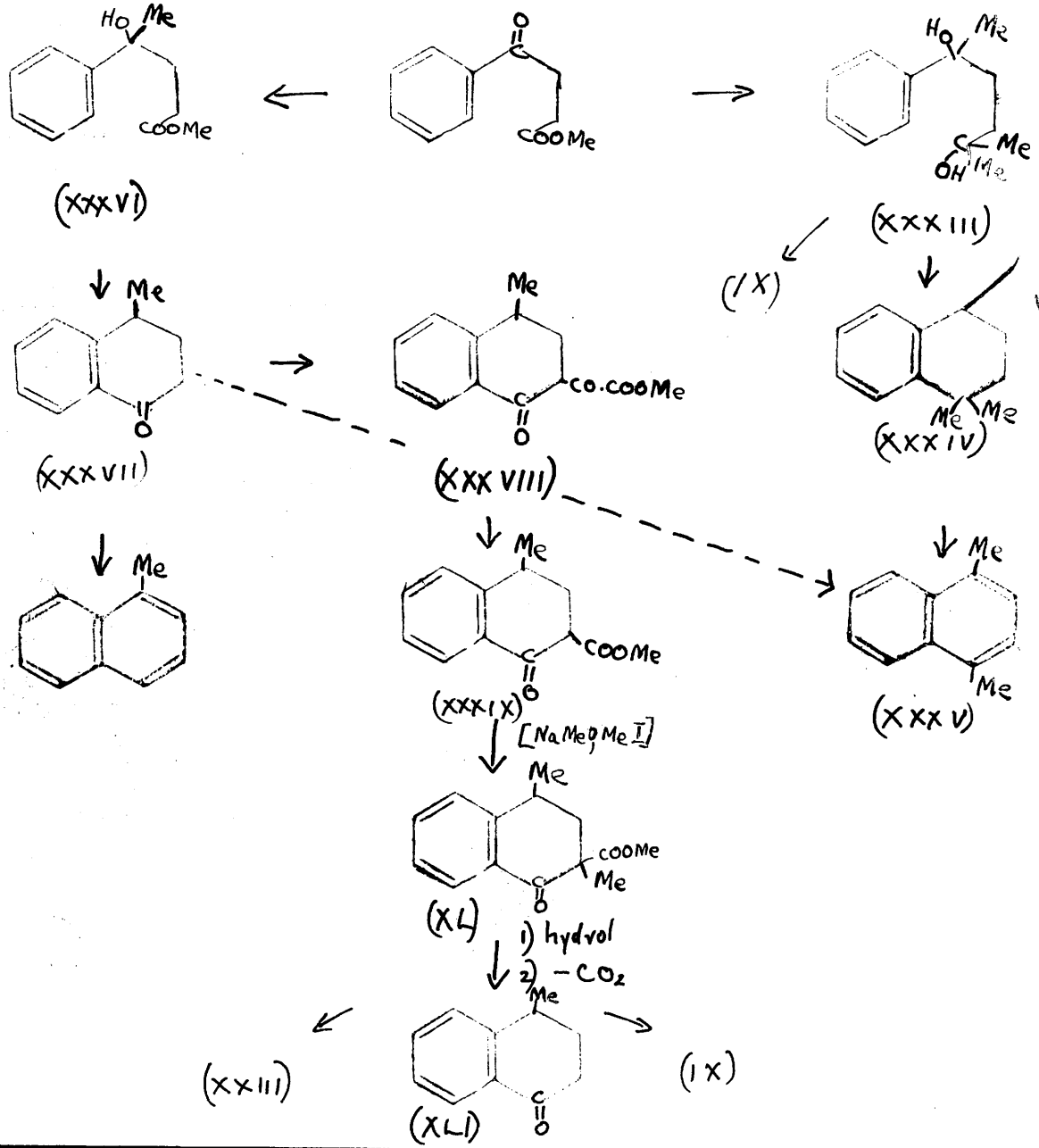


(XXXI) (XXXII)

(XXXI) was reduced to by the Clemmensen method to the corresponding butyric acid derivative which on cyclisation gave the keto-tetralin (XXXII). (XXXII) afforded both naphthalene and α-methyl-naphthalene.

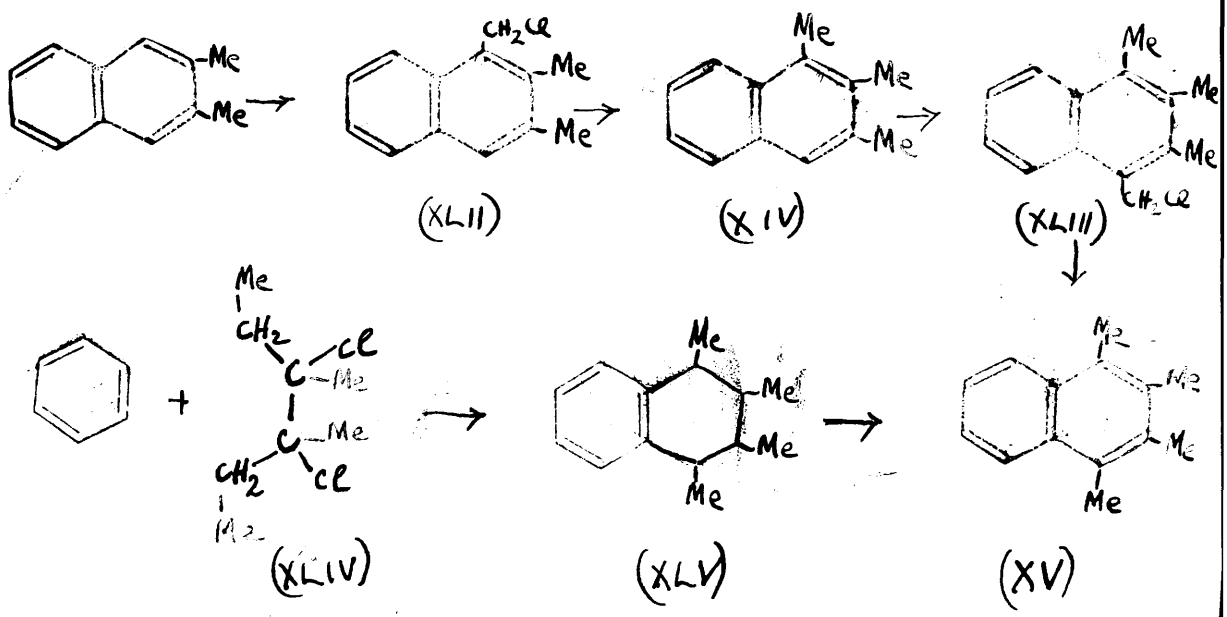
As a modification, Kloetzel[9] used the inverse Grignard reaction of excess methyl-magnesium-iodide on the ester of

(XXXI) to obtain 2-methyl-5-phenyl hexane - 2:5-diol-derivatives (XXXIII) and this with sulphuric or hydrofluoric acids gave both the tetralin derivative (XXXIV) and the aromatic hydrocarbon (IX). The former afforded 1:4- dimethyl-naphthalene on dehydrogenation (XXXV).



Using 1.3 equivalents of methyl magnesium iodide on the ester of acid (XXXI), Kloetzel also obtained the mono addition product (XXXVI). The corresponding acid was then cyclised to (XXXVII); which gave both α -methyl-naphthalene and 1:4-dimethyl-naphthalene (XXXV). To introduce a methyl group in the 3-position, he used the Bachmann and Thomas[28] method, intermediates (XXXVIII) to (XLI). From the keto-tetralin derivative (XLI), both aromatic hydrocarbons (IX) and (XXIII) were obtained.

Hewett[14] described the synthesis of 1:2:3:4-tetra-methyl-naphthalene (XV) by the chloromethylation of 2:3-dimethyl-naphthalene with para-formaldehyde and hydrochloric acid. The 1-chloromethyl-2:3-dimethyl-naphthalene (XLII) obtained was reduced to 1:2:3- trimethyl-naphthalene (XIV). On repeating both the chloro-methylation and reduction (XV) was obtained.



Sisido and Nozaki[15] also obtained (XV) by the Friedel-Crafts reaction between 3:4-dichloro-3:4-dimethyl-hexane (XLIV) and benzene via the 1:2:3:4-tetrahydro-1:2:3:4-tetra methyl-naphthalene (XLV) intermediate. Recently Kloetzel[10] prepared (XV) by the condensation of prehnitene with succinic anhydride.

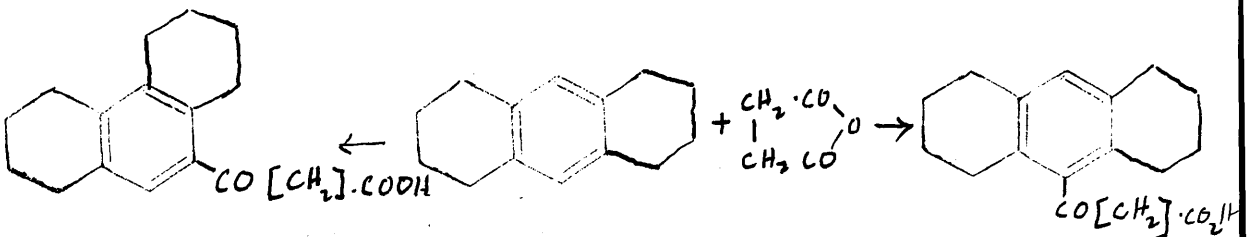
DISCUSSION.

(A) ISOMERISATION REACTIONS PRODUCED IN THE FRIEDEL-CRAFTS REACTIONS WITH DIFFERENT SOLVENTS, and (B) ISOMERISATION REACTIONS IN PRESENCE OF ANHYDROUS HYDROGEN FLUORIDE.

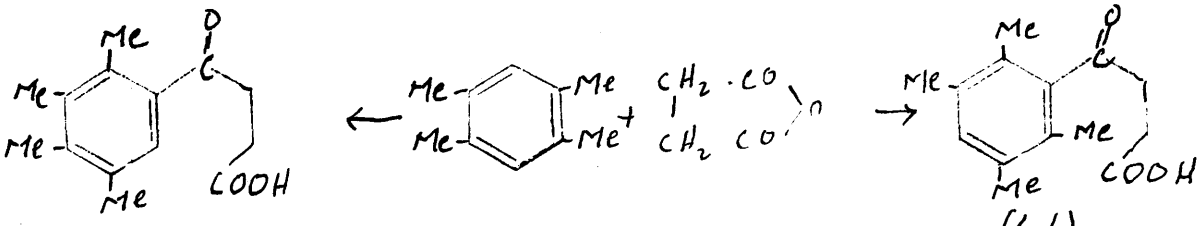
(A) This work related to the condensation of durene (XLIX) with $\alpha:\beta$-dimethyl-succinic anhydride (LII) was undertaken as alternative procedures for the preparation of the new following compounds which are intermediates in the synthesis of poly-methylnaphthalenes.

(1) γ-keto-γ-prehnityl -α ;β - dimethyl-butyric acid (LIV).

(2) 1:2:3:4-Tetrahydro-2:3:5:6:7:8-hexamethyl-naphthalene.



(XLVII) (XLVI) (XLVIII)



(L) (XLIX) (LI)

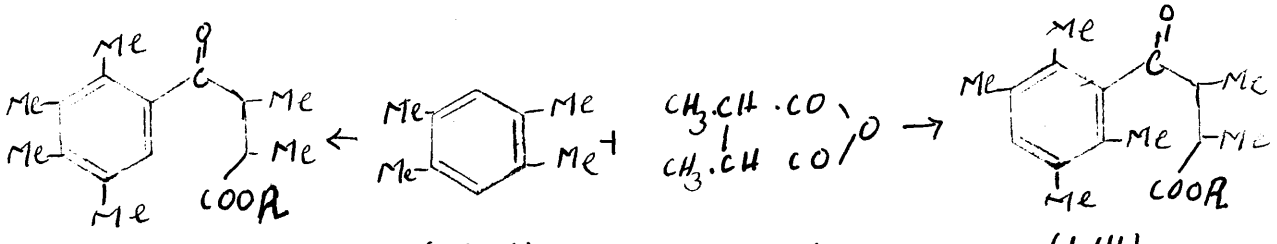
Many recent examples have been quoted regarding the effect of solvents on isomerisations in the Friedel-Crafts condensations. Cook[29] reported the condensation of octahydro-anthracene (XLVI) with succinic anhydride to give in carbon disulphide the unexpected octahydro-phenanthroyl propionic acid (XLVII), instead of the octahydro-anthracene derivative (XLVIII). Under the same conditions, when tetrachloro-ethane was used instead of carbon disulphide, both products were isolated. This isomerisation is in contrast to that of Arnold and Barnes[30], where no isomerisation occurred in the reaction of octahydro-anthracene with acetic anhydride in tetrachloro-ethane, and the only product isolated was 9-acetyl-octa-hydro-anthracene. This result was confirmed by Cook who also found that the same product was only obtained

in carbon disulphide.

Later Cook[31] investigated the Friedel-Crafts reaction between durene (XLIX) and succinic anhydride. In carbon disulphide isomerisation occurred, both the normal condensation product γ-keto-γ-duryl-butyric acid (LI) and the isomerised γ-keto-γ-prehnityl-butyric acid (L) being formed. In tetrachloro ethane, the latter is omer being produced in only a small amount.

CONDENSATION OF DURENE WITH (±)α:β -DIMETHYL-SUCCINIC ANHYDRIDE.

This solvent effect was observed and confirmed here by the author in the condensation of durene (XLIX) with (±)α:β-dimethyl-succinic anhydride (LII).



(LIV) (XLIX) (LII) (LIII)

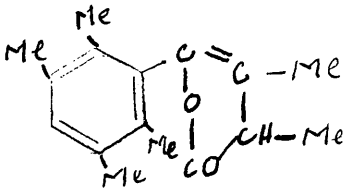
In carbon disulphide, γ-keto-γ-duryl-α:β -dimethyl-butyric acid (LIII) R = H and γ-keto-γ-prehnityl-α:β-dimethyl-butyric acid (LIV) R = H were obtained in the ratio 4:1, the sodium salt of the latter being less soluble. The isolation of both product was confirmed in many ways.

(1) The isomerised acid (LIV) R = H was found to be

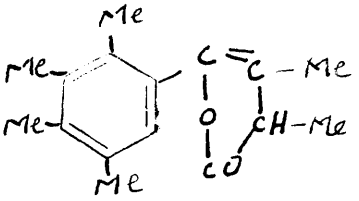
identical with an authentic sample of γ-keto-γ-prehnityl-α:β-dimethyl-butyric acid, one of 2 isomeric acids produced in the condensation of prehnitene with (±)-α:β-dimethyl-succinic anhydride (p.27). Methyl esters (LIV) R = CH_3 were identical.

(2) Both methyl esters (LIII) R = CH_3 and (LIV) R = CH_3 were hydrolysed to the same acids (LIII) R = H and (LIV) R = H respectively.

(3) Two different crotono-lactone derivatives (LV) and (LVI) were obtained from (LIII) R = H and (LIV) R = H respectively.



(LV)



(LVI)

(4) The acids (LIII) R = H and (LIV) R = H on heating with concentrated hydrochloric acid in sealed tubes gave durene and prehnitene respectively.

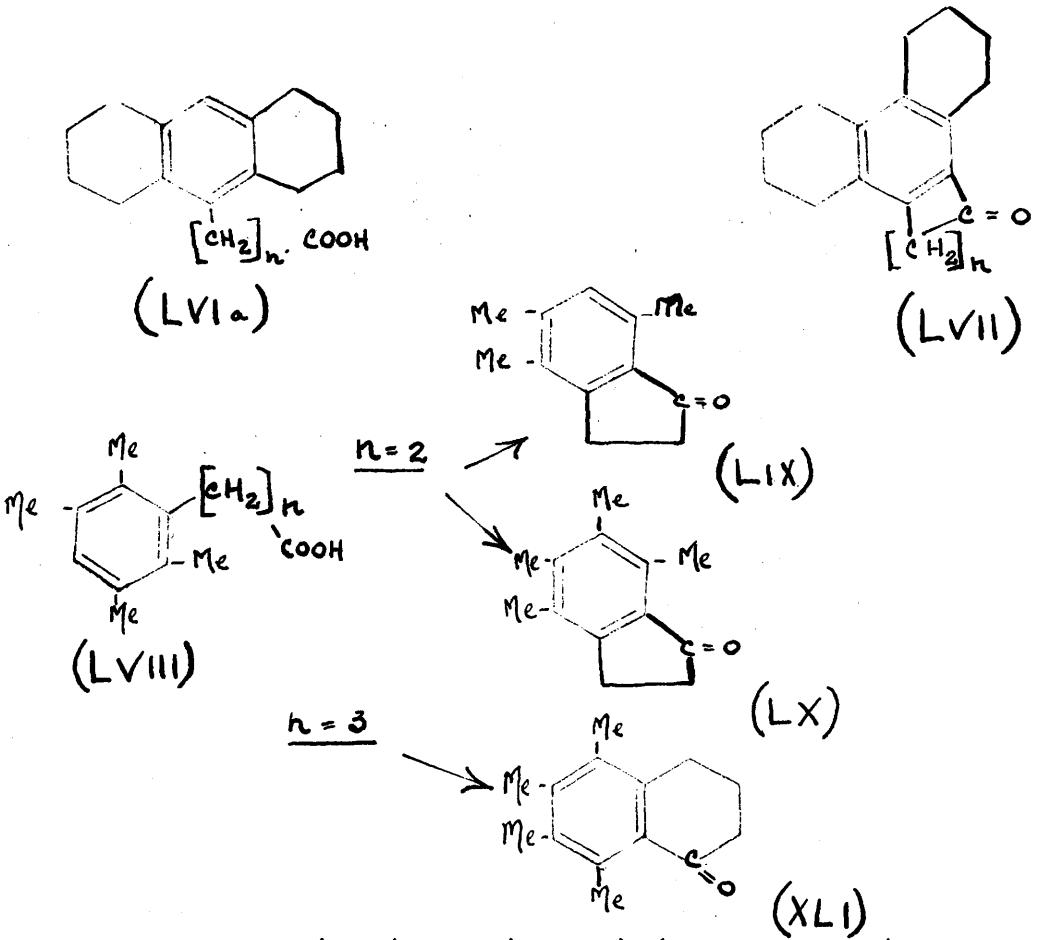
(5) The sodium hypochlorite oxidation of both acids (LIII) R = H and (LIV) R = H gave duryl- and prehnityl-carboxylic acids respectively.

(B) There are similarities between the isomerisation reactions brought about by aluminium chloride, sulphuric acid

and phosphorus pentaoxide and with those newly discovered by Cook.[29,31] using hydrouf luoric acid. Aluminium halides are of outstanding efficacy in bringing about rearrangements and low temperature cyclisations in both aromatic and aliphatic compounds. This property of aluminium halides finds great use in petroleum industry.

The rearrangement of the Jacobsen[32] type (i.e. in sulphuric acid) are either:- (a) Intramolecular, where the migrating groups move from one position to another in the same molecule. (b) Intermolecular where there is a transfer of one or more groups from one molecule to another. The unique importance of the reaction lies in the preparation of vicinal alkylhydrocarbons which otherwise are difficult to prepare.

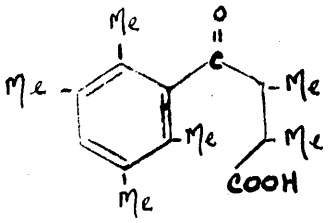
Similar to the Jacobsen reaction, anhydrous hydrogen fluoride[33,34] has no isomerising effect on durene or anthracene[35,36] itself. The former involves the sulphonic acid derivatives. However aluminium chloride[37] brings about directly the rearrangement of the hydrocarbons. The latter HF reagent necessitates cyclisation to occur following the isomerisation reaction, i.e. that the cyclisation is an essential feature in the reaction making it unique for room temperature reactions.



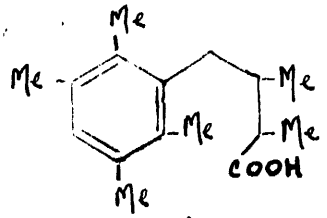
Compounds (LVIa) and (LVIII) (n = 0 and 1) failed completely to isomerise as cyclisation is impossible. Compound (LVIa) (n = 2 and 3) gave octahydro-phenanthryl derivatives (LVII) (n = 2 and 3). Compound (LVIII) (n = 2) gave a mixture of 4:5:7-trimethyl-indane-1-one (LIX) and 4:5:6:7-tetramethyl-indane-tone (LX), the former being formed by the isomerisation, the loss of one methyl group and cyclisation, the latter (main product) by the isomerisation, migration of one methyl group to another position in the same molecule and cyclisation. When (n = 3) in (LVIII), the only product isolated was 1-keto-

5:6:7:8-tetramethyl-tetralin (LXI), formed similar to (LX).

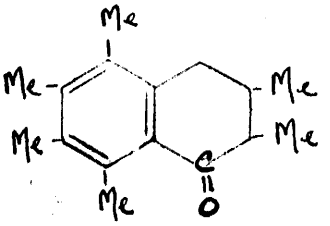
THE ISOMERISATION AND CYCLISATION OF γ-DURYL-α:β-DIMETHYL-BUTYRIC ACID (LXII).



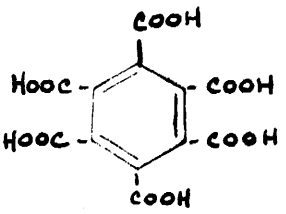
(LIII)



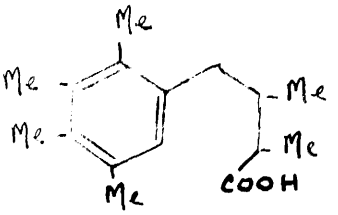
(LXII)



(LXIII)



(LXIV)



(LXXXVI)

In our work here-γ-keto γ-duryl-α:β-dimethyl-butyric acid (LIII) was reduced to γ-duryl-α:β-dimethyl-butyric acid (LXII). The latter in presence of anhydrous hydrogen fluoride was found to give 1:2:3:4-tetrahydro-2:3:5:6:7:8-hexamethyl-naphthalene-1-one (LXIII) in 50% yield. This being produced by the isomerisation, migration of one methyl group to a vicinal position and cyclisation.(LXIII) was

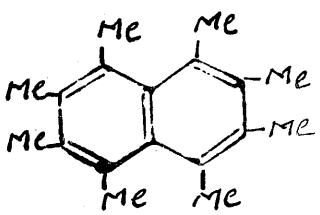
identical with the material obtained from the cyclised γ-prehnityl-α:β-dimethyl-butyric acid (described on page 30). Product (LXIII) was further confirmed by oxidation to mellitic acid (LXIV).

From these results and those obtained by Cook etal, (loc-cit) it can be clearly seen that cyclisation is an integral part in this hydrogen fluoride reaction. Possibility in presence of hydrogen fluoride there is an equilibrium between the original and the isomerised acid. The equilibrium being disturbed by the cyclisation of the latter acid where the driving force of the reaction is the tendency of the side chain(n = 2 and 3) to ring close in the ortho-position. This results in further isomerisation to restore the equilibrium. The alkyl group where cyclisation takes place is either lost or it has migrated to a vacant position.

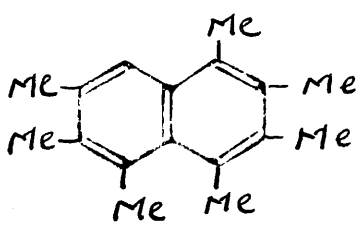
The reduction of γ-keto-γ-duryl-α:β-dimethyl-butyric acid (LIII) has proved to be more difficult than expected. Only the high pressure hydrogenation with copper chromite[38] catalyst of the aqueous sodium salt could give partial reduction. This is due to the very sterically hindered carbonyl group in (LIII). The reduced acid (LXII) was isolated through the less soluble reduced sodium salt. The acidified product was gummy and we were unable to effect its crystallisation. However, in presence of anhydrous hydrogen fluoride, γ-duryl-α:β-dimethyl butyric acid (LXII) (gum) gave a 50% yield of a crystalline 1-keto-tetralin derivative (LXIII).

SYNTHESIS OF POLYMETHYL-NAPHTHALENES.

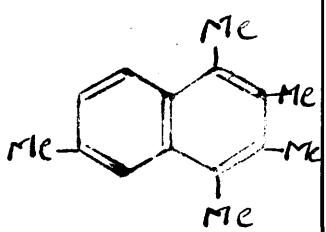
The intention of this work outlined here was mainly the synthesis of octamethyl-naphthalene (LXV). Incidentally, the trial of several methods led us to the synthesis of a hepta-methyl-naphthalene (LXVI), three hexa-methyl-naphthalenes (LXVII), (LXVIII) and (LXIX) and a pentamethyl-homologue (LXX).



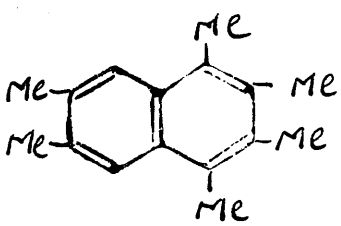
(LXV)



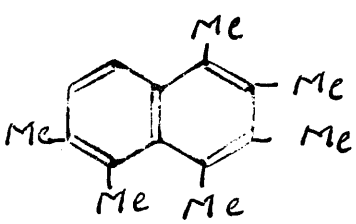
(LXVI)



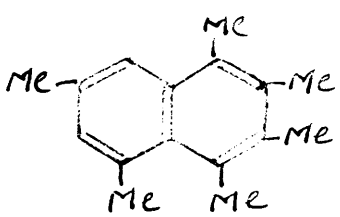
(LXX)



(LXVII)



(LXVIII)



(LXIX)

Octamethyl-naphthalene is of great interest for several reasons:-

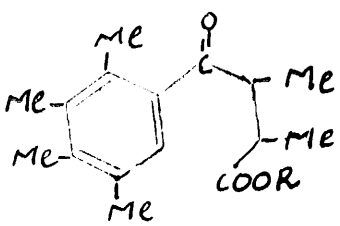
(1) The symmetry and full substitution of the eight positions in the naphthalene nucleus with methyl groups affords possibly an interesting X-Ray study (already a sample has been offered by us to Professor Robertson, Chemistry Department, The University of Glasgow, for X-Ray investigation).

(2) The steric hindrance in the 1:8 and 4:5 positions, in presence of methyl groups in the-β -positions and the difficulty of the introduction of substituents in the above four mentioned positions.

(3) Very few fully substituted naphthalenes are described. These include octadeutero-naphthalene isolated by Clemo[23] in the preparation of hexadeuterobenzene and octachloro-naphthalene[24] obtained from the direct action of chlorine on naphthalene at high temperature.

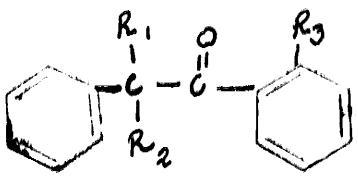
UNSUCCESSFUL ROUTES TO OCTAMETHYL-NAPHTHALENE.

- γ-prehnityl-α:β-dimethyl-succinic ester (LIV) R = Me, was the starting point for several trials. Normally a carbonyl group is more reactive than an ester group and careful control of the Grignard reaction[8] can afford good yields of an addition compound where the Grignard reagent attaches itself preferentially to the carbonyl group next to the phenyl radical. However this was not found to be the case. The carbonyl group has apparently masked carbonyl reactivity (Compare Fieser[39]) and if one equivalent of methyl magnesium iodide is used, the reagent attacks the ester group first and the product is unhydrolysable. The required condensation product could not be



(LIV) R=Me

obtained following either Kloetzel[8] or D'ev's[40] procedures where very good yields of (XXXVI) were obtained from the action of 1.3 moles of methyl-magnesium iodide on the ester of (XXXI). The carbonyl activity in (LIV) R = Me, might be compared with Newman's[41] investigation of the Stobbe condensation of ethyl succinate with compounds of the type (LXXI), where the condensation fails completely in the following cases

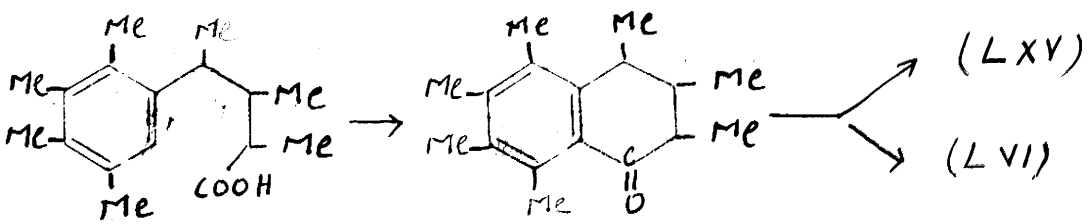


(LXXI)

(a) $R_1 = R_3 = CH_3$ $R_2 = H$ (b) $R_1 = R_2 = R_3 = CH_3$

(c) $R_1 = R_2 = CH_3$ $R_3 H$ (d) $R_1 = R_2 = H$ $R_3 = CH_3$

This might be due to the steric hindrance factors produced from the bulking of the methyl groups around the carbonyl group, thus preventing any reaction to occur. If (LIV) R=Me

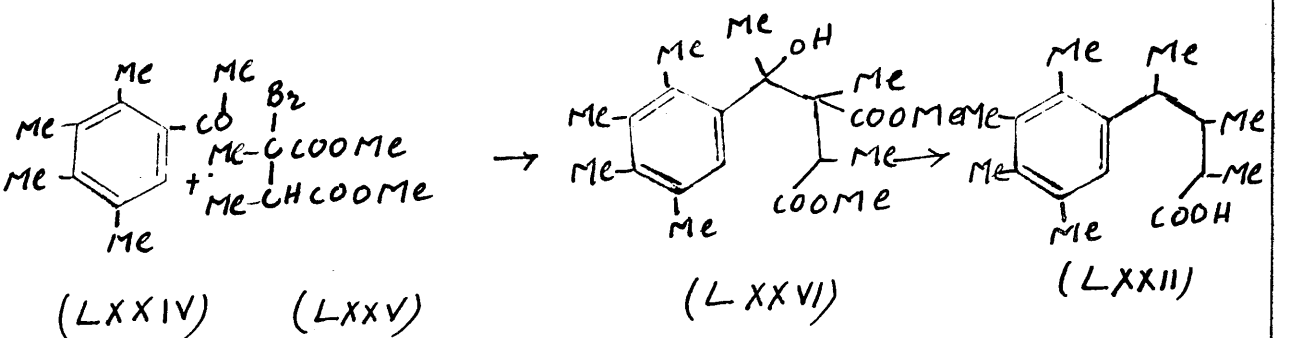


(LXXII) (LXXIII) (LXV) (LVI)

had reacted with methyl magnesium-iodide, the product would be easily dehydrated, reduced and hydrolysed to (LXXII),

from which the 1-keto-tetrahydrine (LXXIII) could be obtained on cyclisation. (LXXIII) can afford both (LXV) and (LXVI).

As a second attempt we tried the Reformatsky reaction, used extensively by Ruzicka (loc. cit) to introduce a methyl group in the hindered position. As an adaptation, acetyl-prehnitene (LXXIV) was condensed with-(±)-α-bromo-α:β-dimethyl-succinate (LXXV). This reaction should give (LXXVI) which on further hydrolysis, decarboxylation dehydration and reduction would afford the desired intermediate γ-prehnityl-α:β:γ-trimethyl-butyric acid (LXXII).

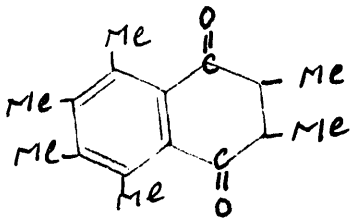


(LXXIV) (LXXV) (LXXVI) (LXXII)

When the highly active zinc recommended by Hoch[42] was used, no condensate could be isolated and most of the starting material was recovered unchanged. The failure of the condensation of (LXXIV) with (LXXV), is probably due to the excessive steric hindrance caused by the bulky groups around the-γ-carbon atom in (LXXVI). Thus the usual low yields obtained in the Reformatsky reaction, together with the steric hindrance to be produced are the main factors for the

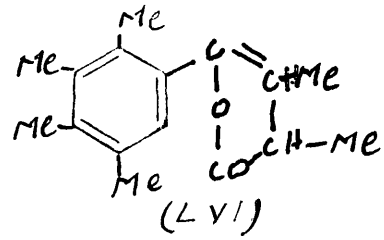
failure of the reaction to occur. That the reaction of (LXXIV) is not inhibited by steric hindrance of the acetyl group is shown by the ease with which such ketonic derivatives, as the semicarbazone, oxime and 2:4-dinitrophenyl-hydrazone are formed. (LXXIV) also reacts with phenyl-magnesium bromide giving an oily addition compound. The formation of derivatives characteristic for carbonyl groups may be explained by the fact that since their formation does not involve branched chains, no steric hindrance is produced. The benzene group in phenyl-magnesium bromide attaches itself vertically to the carbonyl carbon atom and therefore occupies a fraction of the space occupied by a methyl group. The fact that p-xylene-acetophenone [5] has been successfully condensed with ethyl-α -bromo-propionate might have been mainly due to both shorter side chain and a vacant ortho-position, thus causing less interference.

Since the methyl groups are known to activate the ring in the vacant position, in the prehnityl nucleus in (LIV) R = H, an attempt was made to cyclise this product directly before the reduction of the-δ -keto group to obtain a compound as (LXXVII). Such a compound would react with two equivalents of methyl-magnesium iodide to give on dehydration octamethyl-naphthalene (LXV). However (LXXVII) may exist



(LXXVII)

as an enol and would not form addition product. Using anhydrous hydrogen fluoride on (LIV) R = H, a 20% yield of neutral product was obtained which was found to be a crotonolactone derivative (LVI).



(LVI)

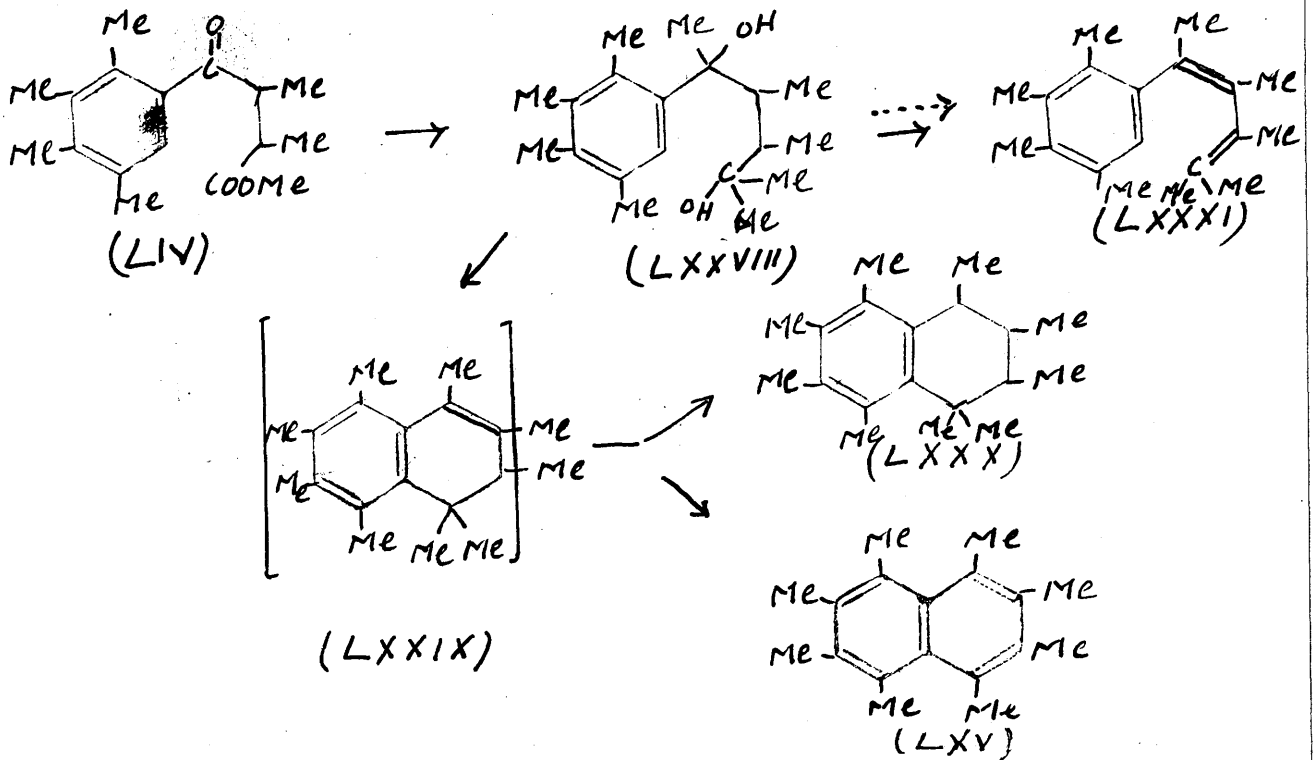
It is known[25] that acids of this type lactonize quickly. The remaining starting material was recovered unchanged. Again it is unusual to obtain cyclization of γ-keto acids as the γ - carbonyl group decativates the ring and thus prevents cyclization, i.e. having a more deactivating effect than the activation caused by the four methyl groups in the prehnityl nucleus.

FIRST ROUTE TO OCTAMETHYL-NAPHTHALENE (AMBIGUITY AND POOR YIELD).

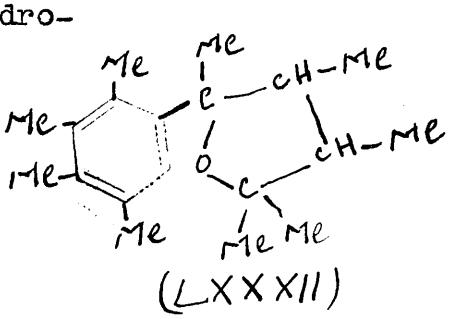
The desired octamethyl-naphthalene (LXV) was first obtained in a few melligrams by a modification of Kloetzel's[9] synthesis of 1:2:4-trimethyl-naphthalene (IX) via the intermediates (XXXIII) and (XXXIV). Using a similar procedure to that of Bogert,[43] Kloetzel found that concentrated sulphuric acid or anhydrous hydrogen fluoride acted on 2-methyl-5-phenyl-hexane-2:5-diol (XXXIII) to give a mixture of nearly equal amounts of 1:1:4-trimethyl-tetralin (XXXIV) and 1:2:4-trimethyl-naphthalene (IX) accompanied by a considerable quantity of resinous material. The prolonged action of hot

phosphoric acid on (XXXIII), on the other hand, gave a mixture of 1:1:4-trimethyl-dihydro-naphthalene and 1:2:4-trimethyl-dihydro-naphthalene. The formation by phosphoric acid of large amounts of resinous substance, together with the last two compounds suggests the mechanism for the sulphuric acid and hydrogen fluoride to be:- (a) direct elimination of one molecule of water from the hydroxyl group in the 2-position and the hydrogen in the aromatic nucleus. (b) the elimination of one molecule of water from the hydroxyl group in the 5-position and a hydrogen in the side chain with the production of an olefin which in turn may isomerise or polymerise. In terpenes and related compounds, isomerisation takes the form of cyclisation to give a dihydro-naphthalene derivative, the latter under the conditions of the reaction, disproportionates to a tetralin and an aromatic derivatives, with the migration of a methyl group to an adjacent position in the aromatic one.

The inverse reaction of excess methyl magnesium iodide on-γ-keto-γ-prehnityl-α:β-dimethyl-butyric ester (LIV) R = Me gave an oily product (LXXVIII) after a prolonged reaction time; both the unreactive carbonyl group and the ester group were slowly attacked. Careful hydrolysis of the Grignard complex is necessary to minimise any dehydration reaction.



This oil (LXXVIII) was found to loose water on distillation to give probably the diene derivative (LXXXI). From the fact that the distillate quickly absorbs about two equivalents of hydrogen in presence of palladised charcoal and instantly decolourises bromine water and potassium permanganate solution suggests that it is (LXXXI), formed by the elimination of two molecules of water from the side chain of (LXXVIII) on distillation. If however a tetrahydrofuran derivative[9] (LXXXII) was formed by the elimination of one molecule of water between the two hydroxyls in (LXXVIII), the product



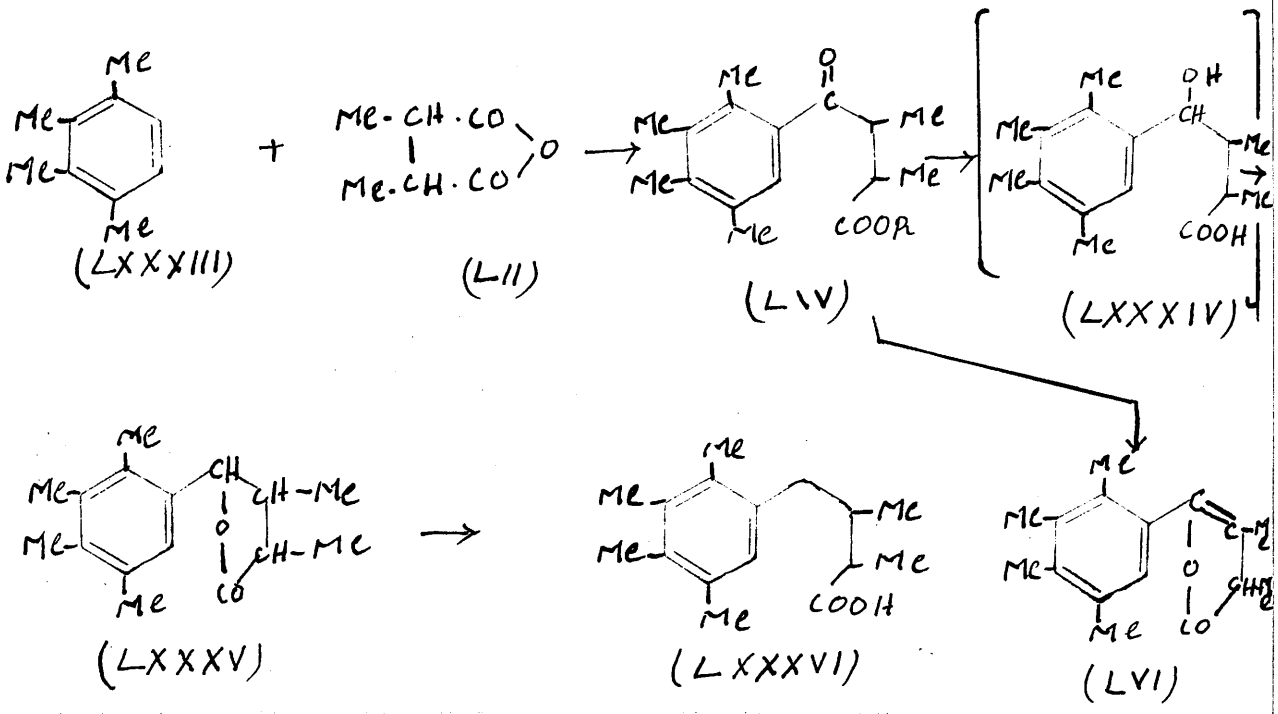
would not decolourise either bromine water or potassium permanganate solution.

The crude oil (LXXVIII) in presence of hydrogen fluoride gave a dark coloured material that was distilled as a yellow oil leaving much polymerised material in the distillation flask. The distillate gave a black crystalline 2:4:7-trinitro-fluorenone complex. The latter was hydrolysed to give octamethyl-naphthalene (LXV). The mother liquor after the isolation of the fluorenone derivative was subjected to two experiments. One part was dehydrogenated with selenium in a sealed tube where a further amount of the same 2:4:7-trinitro-fluorenone of (LXV) was obtained. The other part gave mellitic acid (LXIV) on oxidation.

An explanation of this is that following the prolonged action of excess of methyl-magnesium iodide on (LIV) R = Me, 2:3:4:5-tetramethyl-5-prehnityl-hexane-2:5-diol (LXXVIII) was obtained. The latter in presence of anhydrous hydrogen fluoride gives the intermediate dihydro-compound (LXXIX), which quickly disproportionates to the tetralin derivative (LXXX) and octamethyl-naphthalene (LXV). The formation of (LXXX) is proved both by dehydrogenation to (LXV) and oxidation to mellitic acid (LXIV).

IMPROVED BUT LONGER ROUTE TO OCTAMETHYL-NAPHTHALENE.

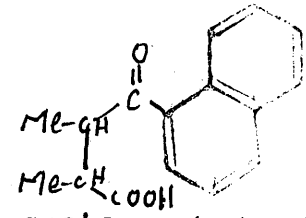
This route has the advantage that all intermediate products were isolated crystalline. The Friedel-Crafts reaction between (±) -α:β -dimethyl-succinic anhydride (LII) and prehnitene (LXXXIII) was carried out in the presence of anhydrous aluminium chloride,.



to give-γ-keto γ-prehnityl-α:β-dimethyl- butyric acid (LIV) R = H. (As far as I am aware this is the first recorded condensation between alkyl benzenes and symmetrically substituted-α:β-dimethyl-succinic anhydride.) with yields as high as 85% in tetrachloro-ethane and 50% in carbon disulphide. The low yield in the latter solvent may be due to the lower

solubility of the anhydride. The acid (LIV) R = H was produced apparently in both isomers[39] as the material isolated melted over a wide range of temperature and only small samples of constant melting points of both isomers were obtained on repeated fractional crystallisation from different proportions of benzene, light petroleum (b.p.60-80) mixture, m.p.s are 168° and 151.5°. As isomerism disappears in the terminal stage of the synthesis, the total isomeric mixture obtained in each intermediate stage was used as such, and no separation of isomers was attempted. Fieser[39] suggests that the formation of diastereoisomers from a homogenous mixture of (±) -α:β -dimethyl-succinic anhydride preparation is due to the racemisation of the acid through the enol form. The esterification of the acid mixture with methanol and sulphuric acid gave a sharp melting ester (LIV) R = Me which was found on hydrolysis to give the lower melting isomer. There was present in the esterification product a liquid, non-acidic fraction which failed to crystallise.

Using the Fisher method of esterification, Fieser isolated a crystalline Enol lactone from acid (LXXXVII), but this failed to give the characteristic Legal[45] test for lactones. On the other hand, the -γ -keto acid (LIV) R = H, gave a crystalline α:β -dimethyl-γ(1-prehnityl)- γ -croton- lactone (LVI) when a solution of the keto-acid in acetic



(LXXXVII)

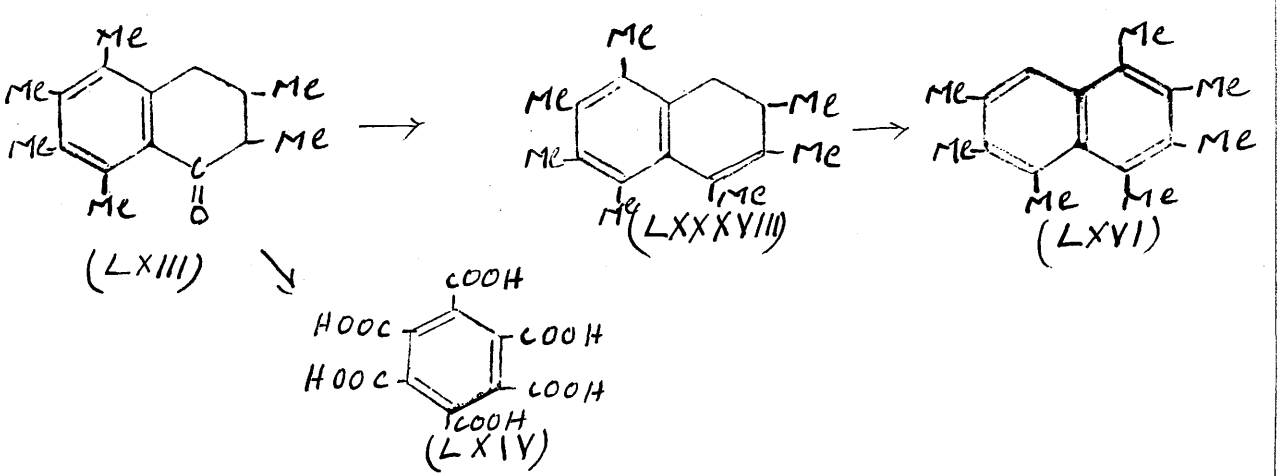
acid acetic anhydride mixture was saturated with anhydrous hydrogen chloride. (LVI) gave a positive Legal-test.

The-γ -keto-acid (LIV) R = H, with its hindered carbonyl group, has proved difficult to reduce. No ketonic reagents reacted to give derivatives. The Clemmensen method[46] of reduction failed completely, and the starting material was recovered unchanged. The Huang-Minlon[47] modification of the Wolff-Kishner reduction gave a 15% yield of a reduction product, accompanied by a considerable amount of high melting non-acidic solid. The latter dissolves slowly in hot dilute caustic soda. On heating with soda-lime, ammonia was evolved. The high percentage of nitrogen shown by the analytical figures, suggests that it is a hydrazide formed from the reaction of hydrazine hydrate present in excess in the reaction mixture with the carboxyl group.

High pressure hydrogenation over copper-chromite catalyst[38] of a neutral sodium salt solution completely reduced the keto group. At 150° absorption was rapid, one mole of hydrogen being absorbed, then it slowed down and temperature had to be maintained at 240° for twelve hours to effect the absorption of the second mole. The optimum temperature and pressure for the latter mole of hydrogen was found to be 240° and 220 atmospheres. It is most likely that reduction proceeds easily to the secondary alcoholic compound (LXXXIV). The latter quickly undergoes lactonisation. The resulting

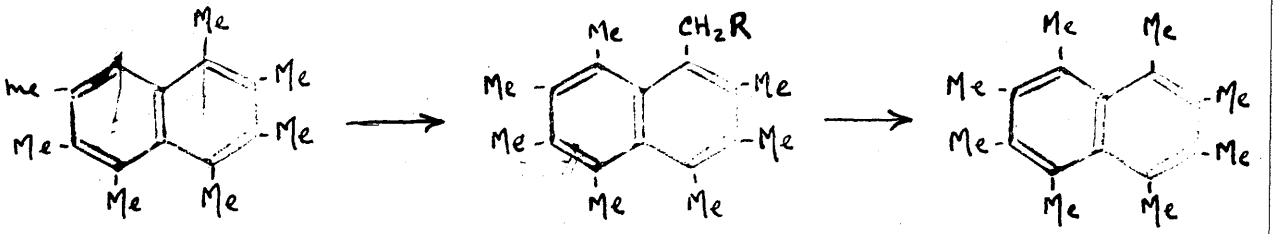
lactone (LXXXV) is expected to undergo difficult and slow reduction to (LXXXVI). This suggestion is supported by the fact that a non acidic material of a slight solubility in ether or benzene was among the reduction products, the fact that this material is soluble only in hot sodium carbonate, and gives a positive Legal test is evidence that it is a lactone (LXXXV) formed as an intermediate in the reduction. The analytical figures are also in support of a lactone formula.

The cyclisation of-γ - prehnityl-$\alpha:\beta$ -dimethyl-butyric acid (LXXXVI) takes place in 80-85% yield both with hydrogen fluoride[48] and Johnson's method[49] of intra molecular acylation of the acid chloride by the inverse Friedel and Craft reaction in presence of aluminium chloride to give 1:2:3:4-tetrahydro-2:3:5:6:7:8-hexamethyl-naphthalene-1-one (LXIII). That the latter did not undergo rearrangement or loss of methyl groups was proved by nitric acid oxidation to mellitic acid (LXIV) isolated as methyl mellitate.



1:2:3:4:5:6:7:- Hepta methyl-naphthalene. (LXVII) was treated with excess methyl magnesium iodide in boiling benzene and on hydrolysis of the complex an oily carbinol was obtained which on dehydration with anhydrous formic acid gave 1:2- dihydro - 2:3:4:5:6:7:8- hepta-methyl-naphthalene (LXXXVIII) as an oil. This was further purified from any oxygenated material by passing through an alumina column and then it was dehydrogenated with palladised charcoal in presence of trichloro benzene as a solvent. The dehydrogenation product heptamethyl-naphthalene (LXVI) was a colourless crystalline solid m.p. 134° and gives the usual aromatic hydrocarbon derivatives, (i.e. picrate, styphnate, 1:3:5-trinitro-benzene and 2:4:7- trinitro-fluorenone derivatives).

OCTAMETHYL-NAPHTHALENE (LXV)

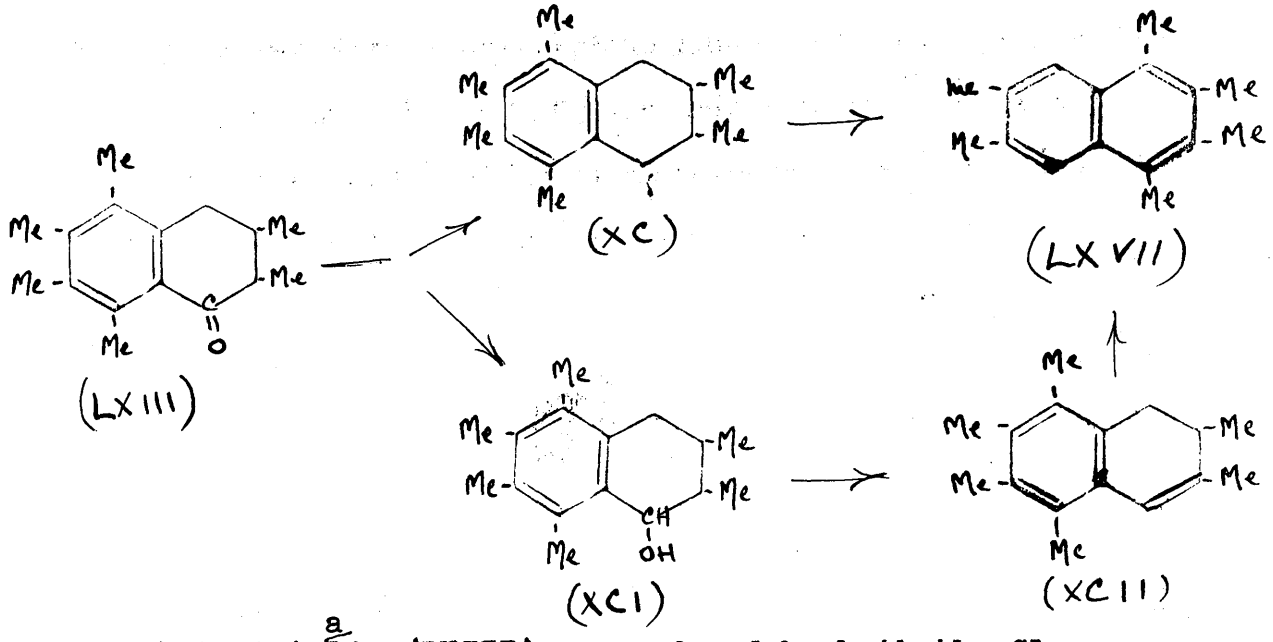


(LXVI) (LXXXIX) R = Cl, OH (LXV)

The chloro-methylation of (LXVI), proved to be a delicate reaction. Of the many procedures for chloromethylation[12],[13],[22],[50] of naphthalene derivatives, that of

Hewett[14] was chosen. Para-formaldehyde in acetic acid solution saturated with hydrogen chloride was used at room temperature as a chloro-methylating agent, thus avoiding the high temperature procedures. The reaction requires one to two days. The chloro-methyl group, introduced in the only vacant α-position, giving (LXXXIX), R = Cl, is very sensitive to hydrolysis and even when ice was used as a diluent the corresponding alcohol (LXXXIX) R = OH was produced in a small amount. Distillation of the oily crude product resulted in extensive decomposition. For purification, the only procedure that could be adopted was boiling with charcoal to remove any resinified material. If purification was carried out through the dissociation of the picrate derivative, hydrolysis of the chloro methyl group might have occurred. The nearly colourless chloromethyl compound (LXXXIX) R = Cl was slowly reduced in presence of palladised calcium carbonate to give a poor yield of octamethyl-naphthalene (LXV) m.p. 174°, together with a small amount of a high melting solid, the latter may be a dimolecular compound. When palladised charcoal was used as catalyst[51] in cyclohexane as solvent, a smooth reduction gave the desired product in better yields.

1:2:3:4:6:7- Hexamethyl-naphthalene. (LXVII)

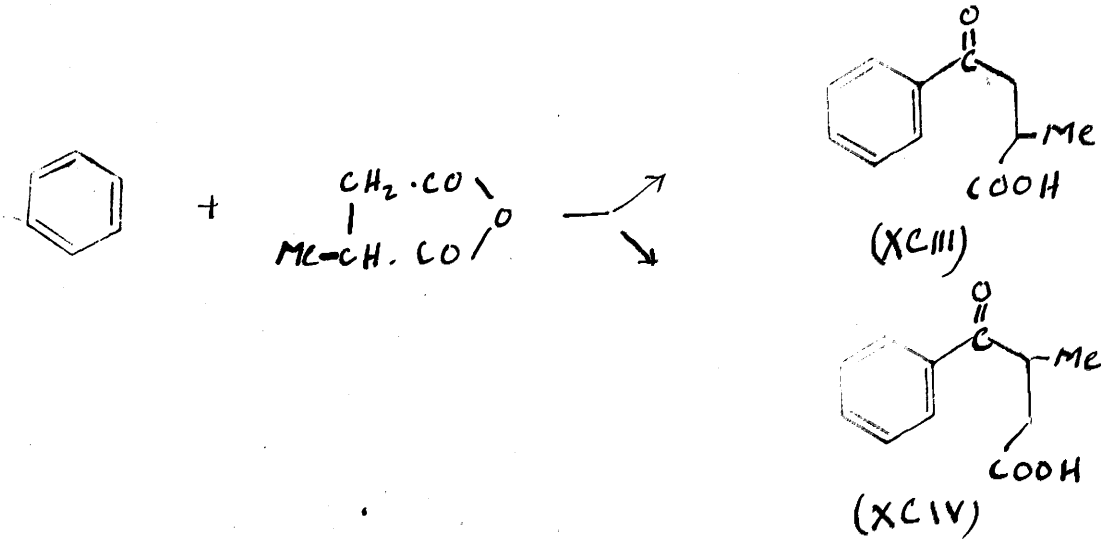


The keto-tetralin (LXIII) was reduced by both the Clemmensen and the Wolff-Kishner methods giving poor yields of 1:2:3:4-tetrahydro- 2:3:5:6:7:8- hexamethyl-naphthalene (XC). However, smooth reduction was obtained using Adam's catalyst[52] in glacial acetic acid and the required one mole of hydrogen was absorbed in 1-2 hours. Removal of the solvent under vacuo, produced a mixture of the secondary alcohol (XC1) and the dihydro-compound (XCII). Both the distillation of the resulting mixture and the formic acid dehydration afforded good yields of 1:2- dihydro- 2:3:5:6:7:8- hexamethyl-naphthalene (XCII). Dehydrogenation of both the tetralin (XC) at 260-300° and the dihydro-compound (XCII) at 200-240° in presence of palladised charcoal[51] gave the same crystalline 1:2:3:4:6:7- hexamethyl-naphthalene (LXVII). It is interesting

to note that the dehydrogenation of 1:2:3:4- tetrahydro-2:3:5:6:7:8- hexamethyl-naphthalene-1-one (LXIII) gave a mixture of the tetralin (XC) and hexamethyl-naphthalene (LXVII) as a result of disproportionation of (LXIII). No phenolic[53] product was isolated.

SYNTHESIS OF TWO HEXAMETHYL-NAPHTHALENES (LXVIII) and (LXIX) AND ONE PENTA METHYL-NAPHTHALENE (LXX).

The condensation of mono-alkyl or mono-aryl succinic anhydride with benzene or alkyl-benzene proceeds into two directions with the production of two isomeric acids. Benzene and



mono-methyl-succinic anhydride condense in the presence of aluminium chloride to give-α -methyl-β-benzyl-propionic

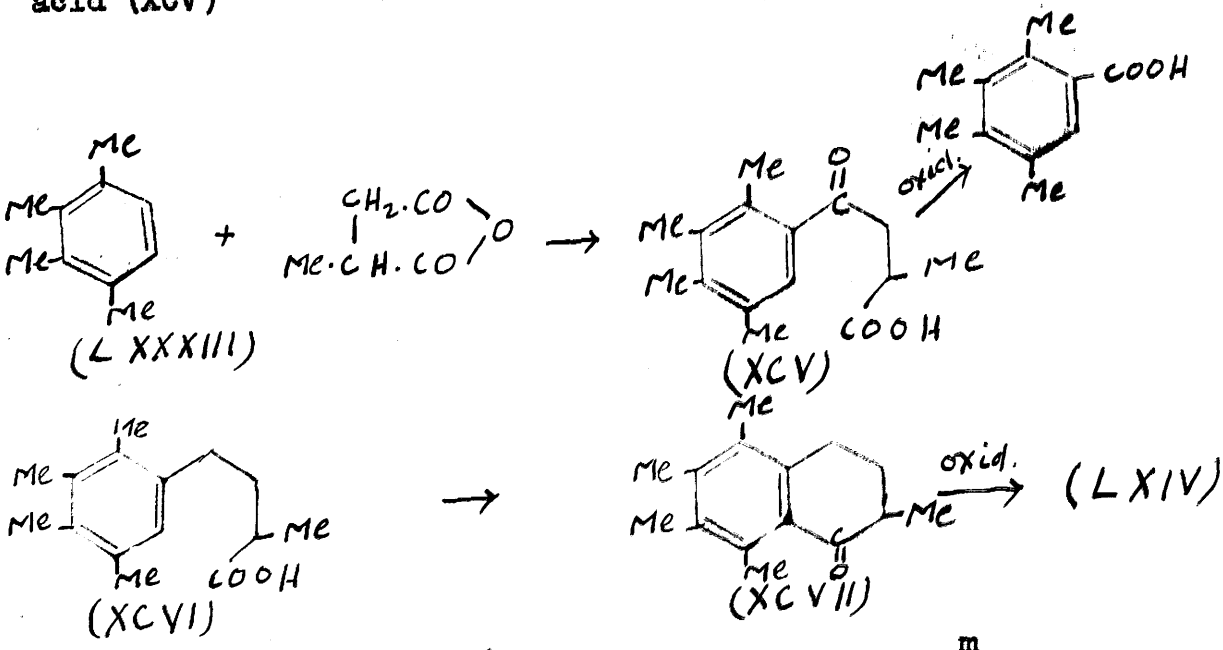
acid (XCIII) and β -methyl-β-benzoyl-propionic acid (XCIV). Although many investigators[40],[55],[56],[57] isolated only the α -methyl-acid, both acids are actually produced.[58] The β -methyl-acid, being more difficult to isolate as it is only formed in a small amount and is also more soluble. It is found that the phenyl group attaches itself to the carbonyl group next to the least alkylated carbon atom, compare Rothein and Sabor,[54] Haworth,[59] Clemo,[60] Dasai and Wali,[61] and Dev.[40]

Phenyl succinic anhydride[60] and benzene, yield different proportions of the isomeric acids in ratios depending upon the solvent used. Both Haworth and Dasai and Wali advance similar mechanisms which ascribe preferential formation of the-α- acid to the repulsive effect of the phenyl anion by the inductive effect of the alkyl group.

Contrasting results have been reported in the literature regarding the condensation of toluene with mono-methyl succinic anhydride. Mayer and Stamm[58] isolated two isomeric-α - and-β - acids in 39.6 and 56.6% yield respectively. However, when this work was repeated by Dev, he obtained only the-α - acid in 85% yield, a higher melting product, which is evidently purer. He confirmed his results by an independent synthesis of the-α - acid.

In our work here results agreeing with those of Dev and others were obtained when prehnitene (LXXXIII) was

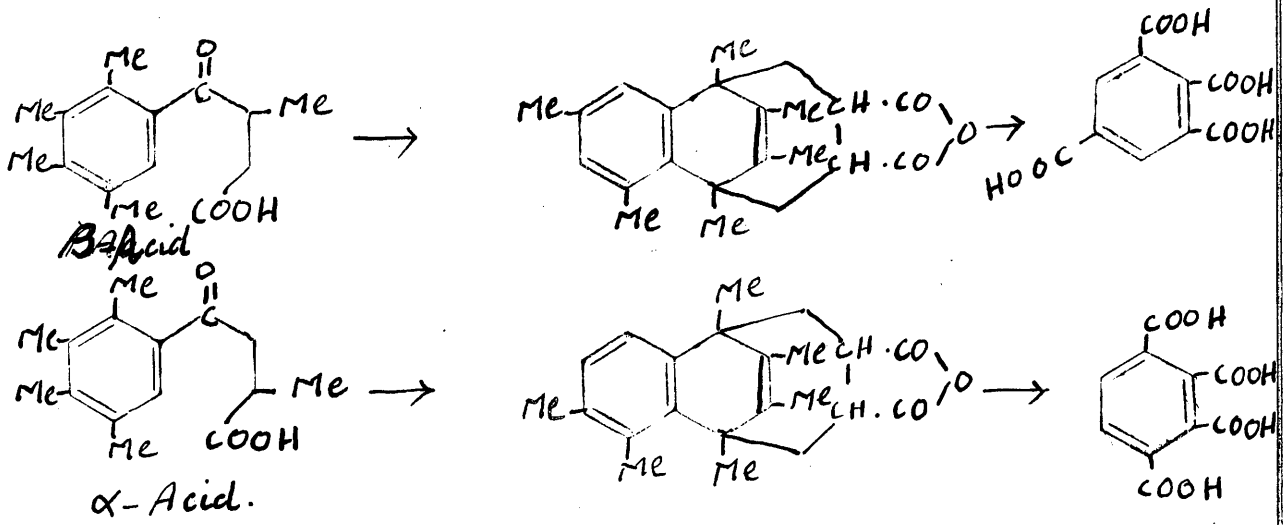
condensed with mono-methyl-succinic anhydride. The only product isolated was- γ -keto- γ -prehnityl -α -methyl-butyric acid (XCV)



in yields as high as 85% using anhydrous aluminium chloride in tetrachloro-ethane. This acid gave a sharp melting homogenous ethyl ester which on hydrolysis afforded the same acid with the same melting point. Mixed melting points were undepressed. That no rearrangement took place was shown by the sodium hypochlorite oxidation in which prehnityl-carboxylic acid was obtained. It is already established in condensation of prehnitene with $\alpha:\beta$ - dimethyl-succinic anhydride, that when the methyl group was occupying the - α - position, the acid produced ~~would have~~ failed to react with carbonyl reagents and remained unreduced by the Clemmensen method. However, it was found that the condensation product

with mono-methyl-succinic anhydride and prehnitene give a quantitative precipitate with 2:4-dinitro-phenyl-hydrazine and could be easily reduced by the Clemmensen method[46] to give -γ - prehnityl -α- methyl-butyric acid (XCVI) in 80% of theory, a percentage reduction which could have never been achieved if the condensation product was a mixture. An indirect proof (see p. 72) that the product is the -α- acid and not the -β -one, is that when the maleic anhydride adduct with the hexamethyl-naphthalene, ultimately produced from the -α-acid was oxidised, it gave the corresponding tetra carboxylic acid (prehnitic acid).

If the product of condensation was the -β -acid, the oxidation product would have been the isodurylic acid.

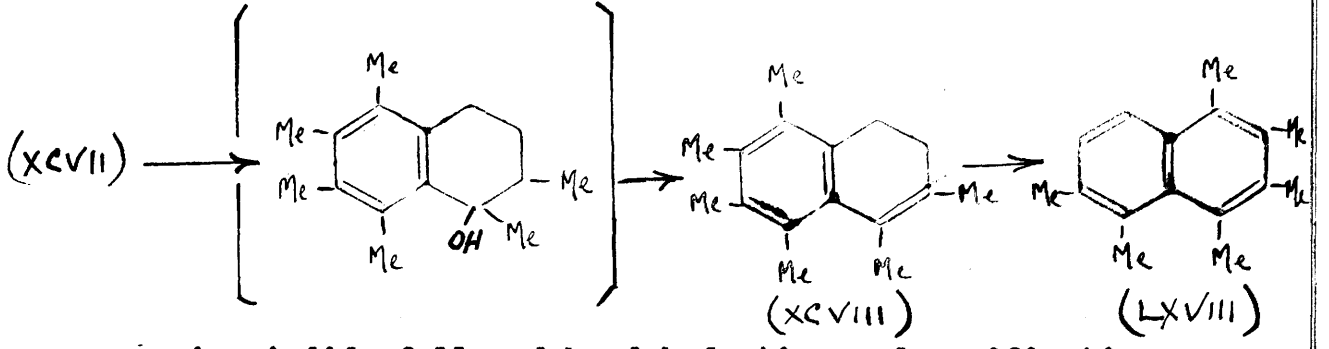


± γ- prehnityl -α- methyl- butyric acid (XCVI) was cyclised both with hydrogen fluoride and by the previously mentioned Johnson's intramolecular acylation procedure of acid chlorides

with aluminium chloride to give 80-85% yield of 1:2:3:4-tetra-hydro- 2:5:6:7:8-pentamethyl-naphthalene-1-one (XCVII). That no rearrangement or loss of methyl groups occurred during the cyclisation was proved by the oxidation of the tetralone (XCVII) to mellitic acid (LXIV).

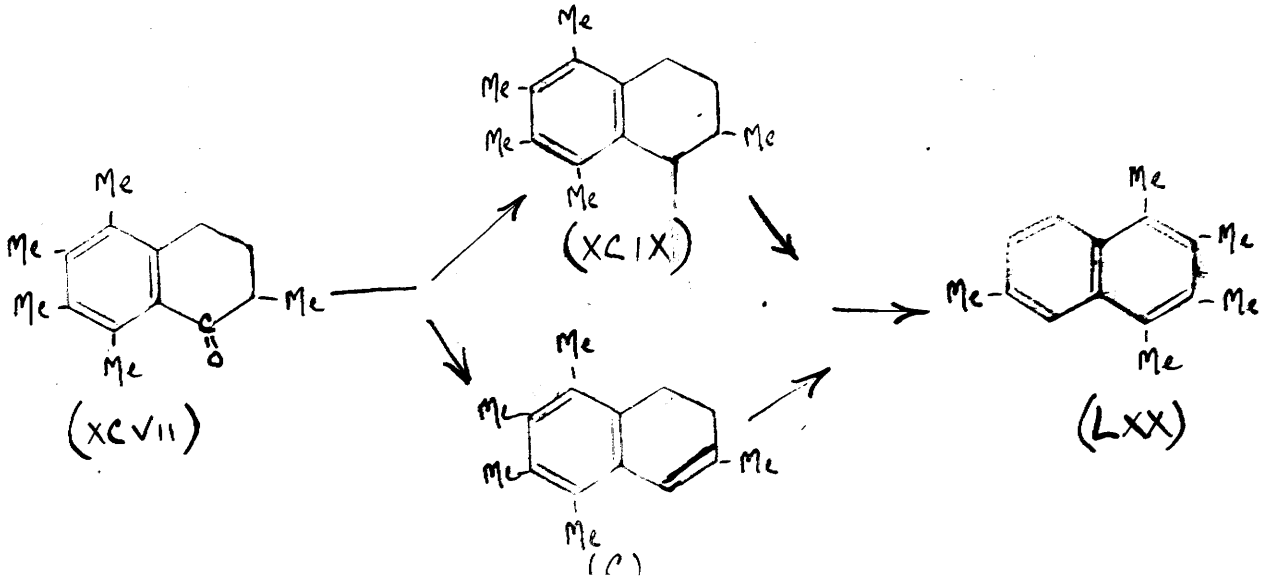
1:2:3:4:5:6- Hexamethyl-naphthalene (LXVIII)

The tetralone (XCVII) on treatment with excess methyl-



magnesium iodide followed by dehydration and purification as described for (LXXXVIII), gave the oily 1:2-dihydro-3:4:5:6:7:8 hexamethyl-naphthalene (XCVIII) which was smoothly dehydrogenated to the hexamethyl-naphthalene (LXVIII).

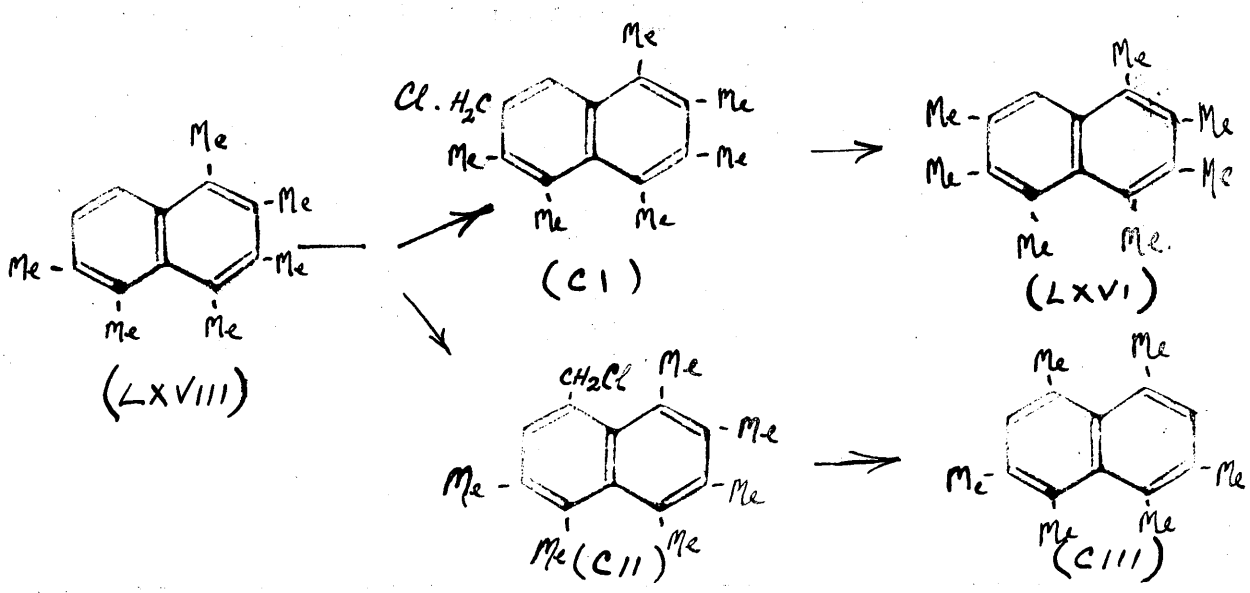
1:2:3:4:6- Pentamethyl-naphthalene (LXX)



The platinum oxide reduction of (XCVII) in acetic acid was smooth; one mole of hydrogen was quickly absorbed. The product was purified as described for (XCII) of the other series to give a crystalline 1:2-dihydro- 3:5:6:7:8- penta methyl-naphthalene(C). The Clemmensen method[46] of reduction and the Huang Minlon[47] modification gave 1:2:3:4-tetra hydro- 2:5:6:7:8- penta methyl-naphthalene (XCIX) as an oily product. Both (XCIX) and (C) were dehydrogenated over palladised charcoal at 260-300° and 200-230° respectively to give the same 1:2:3:4:6 penta methyl-naphthalene (LXX).

ATTEMPTS TO PREPARE 1:2:3:4:5:7 HEPTAMETHYL-NAPHTHALENE (CIII)

The failure of the Stobbe condensation between acetyl-prehnitene (LXXIV) and α-methyl- succinic ester due probably to steric factors and the isolation of only a small amount of an oily lactone from the action of 1 molecule of methyl magnesium iodide on the ester of the acid (XCV), led us to attempt the chloromethylation of 1:2:3:4:5:6- hexamethyl-naphthalene (LXVIII).

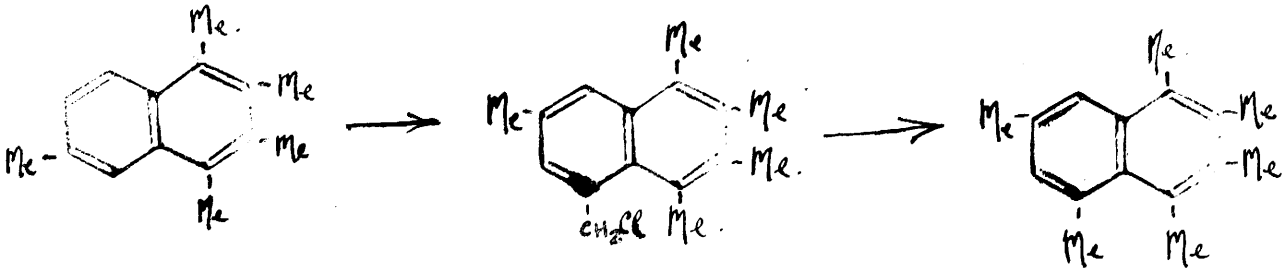


-β-Substitution may give (CI). The latter on reduction affords the already described heptamethyl-naphthalene (LXVI). -α-Substitution on the other hand, may afford (CII) which on reduction gives 1:2:3:4:5:6:8-heptamethyl-naphthalene (CIII) with the only vacant-β-position.

Using a similar procedure to that described for the chloromethylation and reduction of heptamethyl-naphthalene (LXVI) it was found, surprisingly enough, that the only product isolated was the 1:2:3:4:5:6:7:-heptamethyl-naphthalene (LXVI) already described. This was proved by repeated experiments and the identity of the product formed by an authentic specimen. This unexpected result might be explained by the fact that the-α-position is more sterically hindered than the-β-position even though the-α-carbon atom is in order

of reactivity is greater.

1:2:3:4:5:7:- Hexamethyl-naphthalene. (LXIX)



(LXX) (LXV) (LXIX)

Another unusual result was obtained when 1:2:3:4:6-pentamethyl-naphthalene was subjected to chloromethylation and reduction. The only product isolated was found to be a hexamethyl-naphthalene, with a different crystalline form, different melting point of it and its derivatives and different absorption spectra curves from both 1:2:3:4:6:7- and 1:2:3:4:5:6- hexamethyl-naphthalenes (LXVII) and (LXVIII) respectively already described. As the methyl groups 5:6:7:8- are stable and not subject to rearrangement or migration under the reaction conditions used for the chloro-methylation and reduction, then the hexa-methyl-naphthalene isolated must be the 1:2:3:4:5:7- hexa methyl-naphthalene isomer (LXIX). This experimental result shows that the steric hindrance in the α-position is less pronounced when the β- position is vacant. This adding to the greater reactivity

of the α -position directs the chloromethyl group to the 1-position and not the 4-position which is more sterically hindered by the presence of a methyl group in 3-position.

It is interesting to note that there are fifteen possible isomers of hexamethyl-naphthalene, of which three are described here. We were unable to prepare 1:2:3:4:5:6:8-heptamethyl-naphthalene (CIII) by the action of excess of methyl magnesium iodide on the ester of γ -keto-γ -prehnityl-α -methyl-butyric acid due to lack of material.

The mixed melting points of these polymethyl-naphthalenes described here show a depression between 5-15°. Those of the derivatives are between 5-20°. Similar results are recorded by Ruzicka[4],[5] for the tetra and penta-methyl-naphthalenes and derivatives.

The colour reactions with concentrated sulphuric acid are shown in Table I.

Table I.

COLOUR REACTIONS OF POLYMETHYL-NAPHTHALENES WITH CONCENTRATED SULPHURIC ACID

	1:2:3:4:6-pentamethyl-N (LXVII)	1:2:3:4:5:6-hexamethyl-N (LXVIII)	1:2:3:4:5:7-hexamethyl-N (LXIX)	1:2:3:4:6:7-hexamethyl-N (LXVII)	1:2:3:4:5:6:7-heptamethyl-N (LXVI)	0 methyl-N (LXV)
In the cold.	yellow-orange-red-brown-brownish green-dark green, brown-greenish black.	orange-light green.	yellow-orange-red.	orange red-brown-dark brown-greenish black.	brownish red-slightly darker.	red-deep red.
hot	greenish black-black	dark brown-black with yellow fluorescence.	dark brown with green tinge, dark green-black.	dark brown-black	dark brown then black.	dark red-greenish black

STARTING MATERIALS.

The starting materials used in this work were prepared as follows:-

(1) α : β-dimethyl-succinic anhydride - (LII). The method of Bon and Sprankling[62] and Fieser's[39] modification was the best. Compare with the method of Bischoff and Rach[63] where 2 molecules of sodio-methyl-diethyl-malonate were coupled in presence of iodine. The tetra ethyl-ester formed was then hydrolysed and decarboxylated to give α:β- dimethyl-succinic acid. Bon and Perkin[64] and Bischoff and Rach[63] condensed ethyl α-bromo-propionate with sodio-methyl-diethyl malonate. The triethyl-ester formed was hydrolysed and decarboxylated to give α:β-dimethyl-succinic-acid. The latter was refluxed with acetyl-chloride to give the anhydride.

(2) α-Methyl-succinic anhydride was best prepared by the improved procedure of Dev and Guha[65] where sodium malonic ester was condensed with ethyl-α-bromo-propionate, the triester so formed was then hydrolysed and decarboxylated to give α-methyl-succinic acid. This method gave higher yields than that described in Organic Synthesis[66] where crotonic ester and sodium cyanide were used.

(3) α-Bromo-α:β-dimethyl-succinic ester (LXXV)[67],[68] was prepared by the action of bromine and red phosphorus

on $\alpha:\beta$ -dimethyl succinic acid.

(4) Durene, 1:2:4:5- tetramethyl-benzene (XLIX) was prepared as described by Von-Braun[69] by the chloromethylation and reduction of xylene. Better yields were obtained by increasing the reaction time in the chloro-methylation and by using toluene instead of benzene as a solvent in the reduction of the dichloromethyl xylenes. This enabled the use of a higher temperature which favoured reduction. The reduction also depends upon the quality of zinc used.

(5) Durene and Isodurene mixture[70] was prepared by the Friedel-Crafts reaction of m-xylene and mesitylene with methyl chloride in presence of aluminium chloride. In small scale runs, the adjusting of the equivalent amount of methyl chloride is difficult as absorption of the latter is not quick and it usually escaped from the mercury valve before reacting. In one run with m-xylene and the equivalent amount of methyl chloride (2 moles), the only products isolated were penta- and hexamethyl benzene accompanied by with polymerised material. No tetramethyl-benzenes were found among the reaction products. This may be due to the coupling of the m-xylene to give diphenyl derivatives, thus leaving less m-xylene to react with methyl chloride.

(6) Prehnitene, 1:2:3:4- tetramethyl-benzene (LXXXIII) was prepared by the Jacobsen[71],[72] reaction on durene, isodurene and pentamethyl-benzene. Best results were

obtained when a mixture of durene and isodurene[73] was used with 60% oleum.

(7) Acetyl prehnitene (LXXIV) was prepared by the method of Claus and Fohlish[74] by the Friedel-Crafts reaction of prehnitene with acetylchloride. The product was further characterised by new ketonic derivatives.

ANTHRACENES PRODUCED IN ATTEMPTS TO PREPARE POLYMETHYL-NAPHTHALENES

Bruson[75] described the condensation of 1:4-ditertiary glycols (CV) and their derivatives (CV), (CVII) and (CVIII) with various aromatic hydrocarbons (CIX) (R_1R_2,R_3 = H or CH_3) in the presence of aluminium chloride to yield tetrahydronaphthalenes of the type (CX) (R_1,R_2,R_3 = H or CH_3.)

$(Me)_2C(OH).CH_2.CH_2.C(OH)(Me)_2$

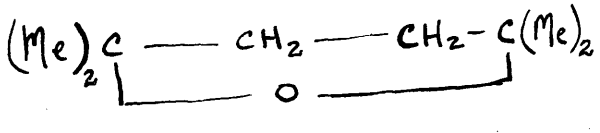
(CV)

$(Me)_2C(Cl).CH_2.CH_2.C(Cl)(Me)_2$

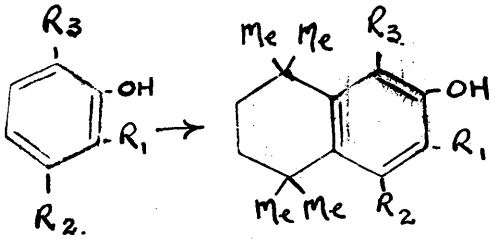
(CVI)

$CH_2=C(Me).CH_2.CH_2.C(Me)=CH_2$

(CVII)



(CVIII)

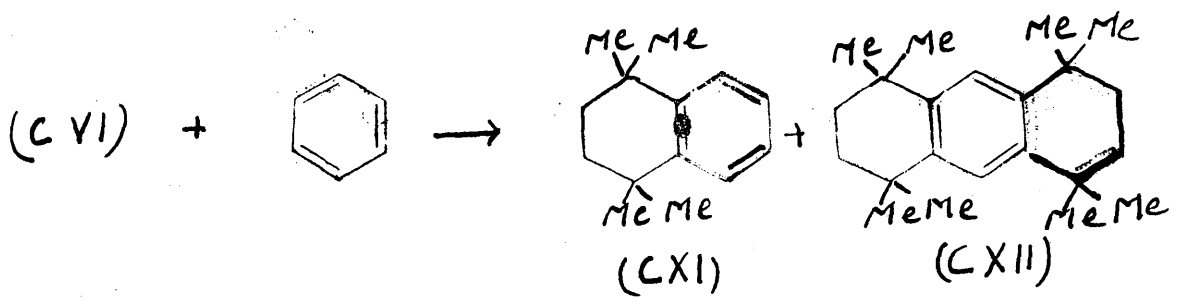


(CIX) (CX)

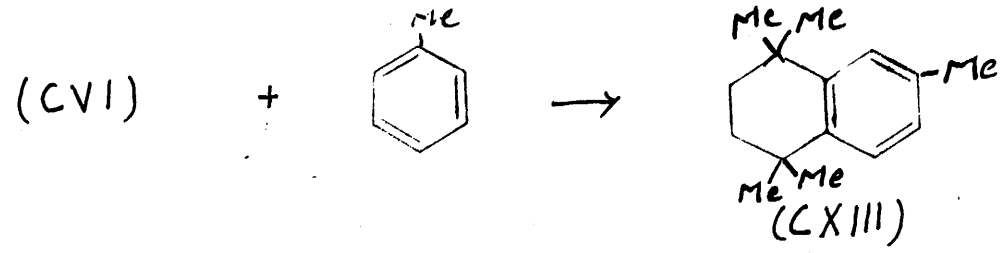
The mechanism suggested was that the aromatic fraction

(CIX) alkylates as usual in the p- position to the hydroxyl group to form the mono-alkyl-derivatives which quickly undergo cyclo-dehydration, cyclo-dehalogenation or cyclo-addition with (CV), (CVI) and (CVII) respectively. The tetra-hydro-naphthalene derivative so formed may react further with one molecule of the alkylating agent to give chromones. The compound (CX) (R_1,R_2,R_3 = H or CH_3) was also oxidised to 1:1:4:4- tetramethyl-adipic acid, which proved that no isomerisation or migration of methyl groups in I' and 4 position had occurred.

Two products (CXI) and (CXII) were formed when benzene was condensed with (CVI), depending on the amount of aluminium chloride used. Catalytic amounts favoured the formation of (CXI), while excess



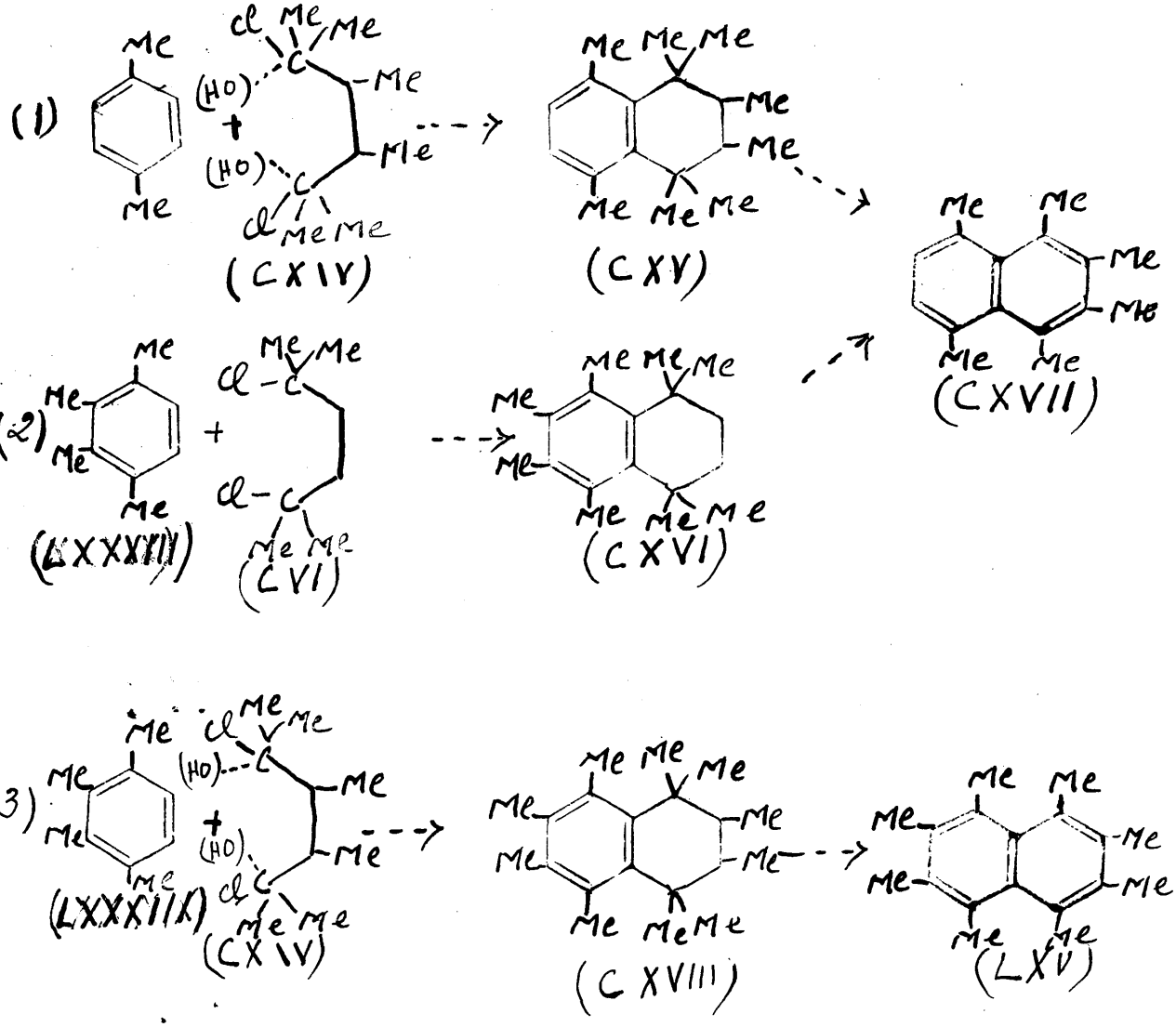
gave (CXII). With toluene and (CVI) only the mono-alkylated product (CXIII) was isolated.



Bogert suggested[76] that with toluene, akylation takes place in the p- position to the methyl group, followed by cyclo-dehalogenation of the alkyl derivative so that ring closure occurred as remote as possible from the substituent already present in the aromatic fraction. We may suggest as an alternative mechanism for these types of reactions that compounds (CV) and (CVI) in presence of aluminium chloride lose two molecules of water and hydrogen chloride respectively to give the diolefin (CVII). The latter then condenses with the aromatic fraction to give the corresponding tetralin derivative. This is supported by the experimental results where it was found that any of the four alkylating agents (CV), (CVI), (CVII) and (CVIII) gave the same condensation product.[75]

Attempts were made to use these methods to synthesise different isomers of polymethyl-naphthalenes by the dehydrogenation of the corresponding tetrahydronaphthalene derivatives. If the reaction follows the course described above, then p-xylene and prehnitene (LXXXIII) should condense with 2:5-dichloro (or 2:5-dihydroxy)-2:3:4:5- tetramethyl-hexane (CXIV) and 2:5 dichloro-2:5- dimethyl-hexane (CVI) respectively

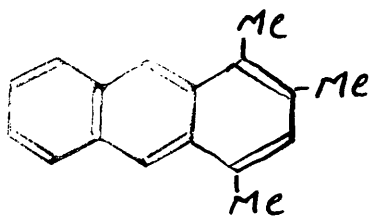
to give the condensation products (CXV) and (CXVI). Both the last two condensates on selenium dehydrogenation would give the same 1:2:3:4:5:8- hexamethyl-naphthalene (CXVII)as in Reaction (1) and (2). Also prehnitene and(CXIV)should condense to give (CXVIII) and the latter may dehydrogenate to octamethyl-naphthalene (LV). As in Reaction (3).



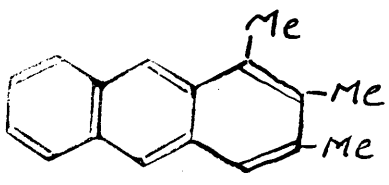
In reaction (3), between 0° and 10°, in absence of solvent, and in presence of aluminium-chloride, no product was isolated and 90% of the starting material was recovered. This may be due to the great steric hindrance which would be introduced if condensation occurred in the 1:8 and 4:5- positions in the tetralin derivative (CXVIII).

In reaction (1), between 50 and 60°, using tetrachloro ethane as a solvent and in presence of aluminium chloride, two products were isolated: A yellow oil (A) (b.p. 140°-160°/4 mms.) and a solid (B) m.p. 241°-2°, together with a considerable amount of tar. (A) on selenium dehydrogenation at 330°, gave a picrate derivative m.p. 183-5°, the latter on dissociation gave a solid m.p. 125-130°.

The compound (B) analysed for the formula $C_{17}H_{16}$ or $C_{18}H_{18}$, gave a wine-red trinitro-benzene complex m.p. 145-7° and a brown-black trinitro-fluorenone complex m.p. 160-2°. Chromic acid oxidation[77] gave a yellow quinone m.p. 155-8°. The absorption spectrum Fig. (1) shows unmistakeably that the compound (B) is an anthracene derivative. A search through the literature showed that there are two trimethyl-anthracenes $C_{17}H_{16}$; 1:2:4- trimethyl-anthracene

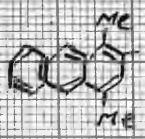


(CXIX)



(CXX)

Fig 1



m.p. 241°

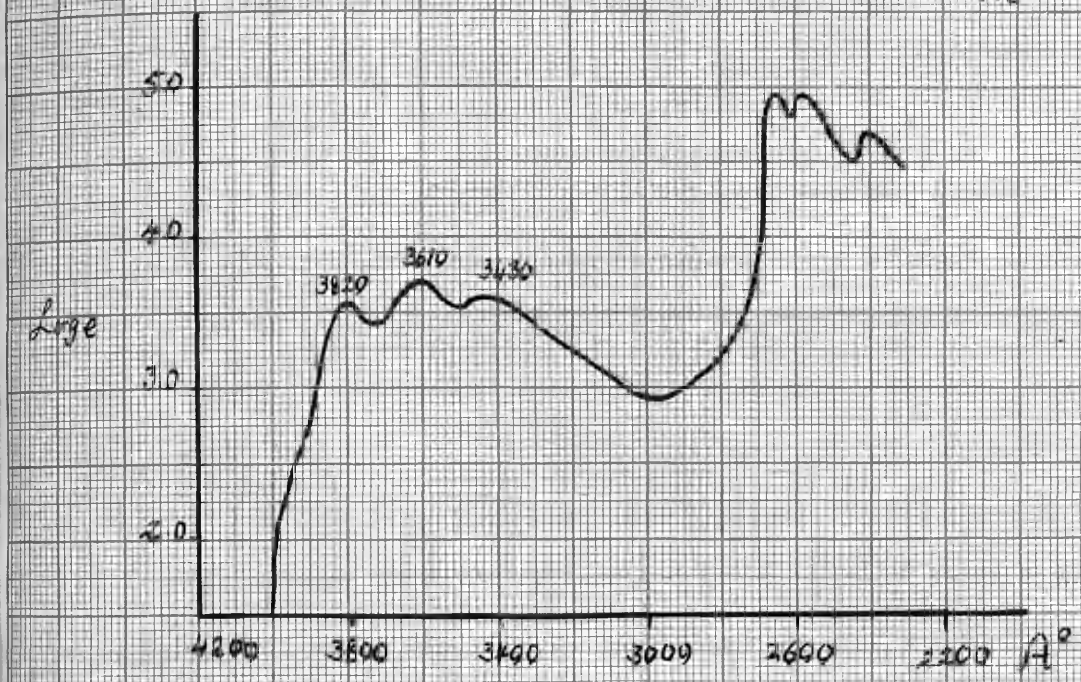
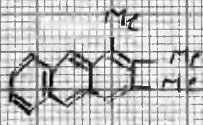
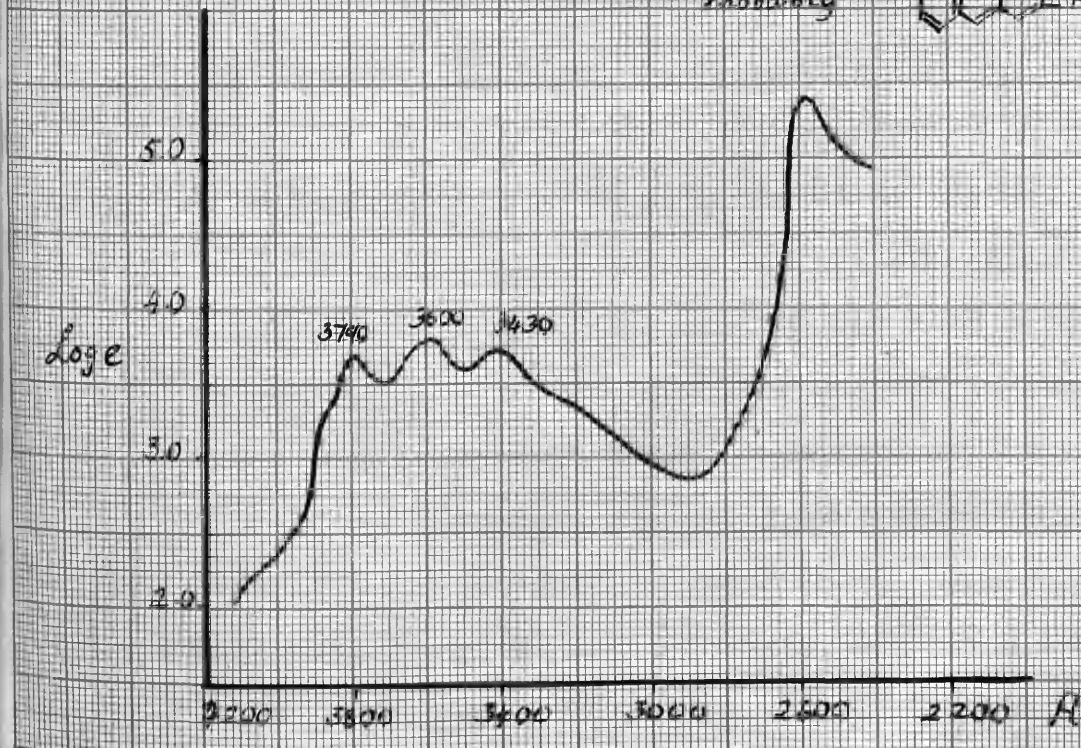


Fig 2

Probably



m.p 236°



(CXIX) m.p. 243[78] or 241[79], quinone, m.p. 160-3° and 1:2:3-trimethyl-anthracene (CXX) m.p. 236°,[80] quinone, m.p. 150°.

Of the described tetramethyl-anthracenes[81],[82],[83] $C_{18}H_{18}$, none has similar properties to our compound (B). There is thus evidence that our anthracene compound (B) is the 1:2:4- trimethyl-anthracene m.p. 241-2°, quinone m.p. 155-8°. Its formation may be explained in two ways:-

(1) ~~a~~ 1:2:3:4- Tetra-methyl-anthracene was first formed by the condensation of two molecules of p-xylene with one molecule of tetrachloro-ethane followed by the migration of one methyl group and the loss of another to give the 1:2:4-trimethyl-anthracene.

(2) ~~The~~ p-xylene in presence of aluminium chloride may give benzene, toluene, 1:2:3- and 1:2:4-trimethyl-benzene. Two moles of these products may condense with one molecule of tetrachloroethane to give the above product (CXIX).

The considerable amount of polymerised material was mainly produced from (CV) and (CVI) as they quickly dehydrate or dehalogenate to give diolefin derivatives which polymerise under such favourable reaction conditions.

In reaction (2), similar reaction conditions to those described for reaction (1) were used. Again two products were isolated:- an oil (C) (b.p. 150-170°/4mm.) and a solid (D) yellow leaflets m.p. 236-7° together with a

considerable amount of tar.

The compound (C) on dehydrogenation gave a product m.p. 125-8°, picrate derivative m.p. 183°.

Both dehydrogenation products of compounds (A) and (C) were found to be identical. The mixed melting points of these dehydrogenation products and picrate derivatives were not depressed. Both have identical absorption spectra and are similar to those of polymethyl-naphthalene.

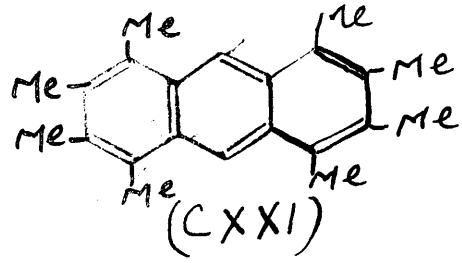
	Maxima				Minima	
	λ	log e	λ	log e	λ	log e
Absorption Spectrum	2360	4.9501	2960	3.81	2570	3.31

We may suggest that in both reactions (1) and (2), the condensation partly proceeded via the intermediate oily tetralin derivatives (CXV) and (CXVI). These substances on dehydrogenation gave the same 1:2:3:4:5:8- hexamethyl-naphthalene (CXVII). Since only minute amounts of the dehydrogenation products of (A) and (C) were available no further work was done on them.

The mixed melting point of compounds (D) and (B) was depressed by 40°. Substance (D), similar to anthracene and its derivatives, had a blue fluorescence in benzene. It formed a wine-red trinitro-benzene complex m.p. 162-4° and a brown black trinitro fluorenone complex m.p. 182-3°. The

spectrum Fig. (2) shows the compound (D) is an anthracene derivative.

This compound is not 1:2:3:4:5:6:7:8-octamethyl-anthracene[84] (CXXI) formed by the condensation of 2 molecules of prehnitene with one molecule of tetrachloroethane as (CXXI) had m.p. 292°.



(CXXI)

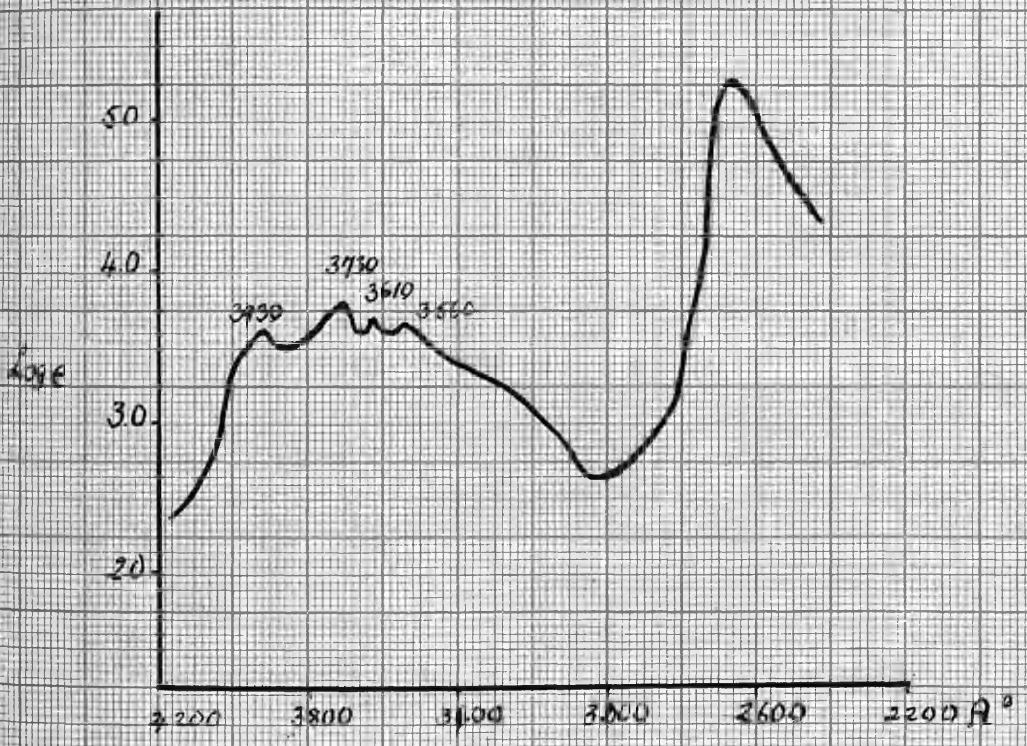
We cannot say that substance (D) is 1:2:3- trimethyl-anthracene[80] m.p. 236° as this requires further evidence. The isolation of compound (D) in a minute quantity made further investigation impossible. 2:5-Dichloro- 2:5-dimethyl-hexane (CVI) and 2:5 dihydroxy- 2:3:4:5- tetramethyl-hexane (CXIV) were prepared by the method of Harris and Weil,[85] by a double Grignard reaction on succinic and $\alpha:\beta$-dimethyl-succinic esters respectively, followed by treatment with hydrogen chloride to replace the hydroxyl groups by chlorine atoms. in (CV).

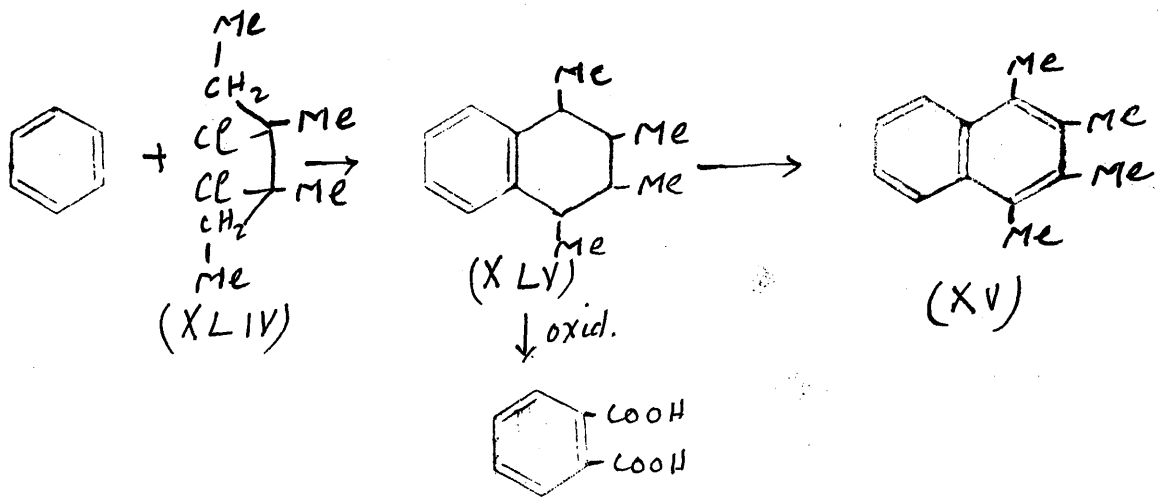
THE ONE STEP SYNTHESIS OF POLYMETHYL-NAPHTHALENES

Sisido and Nozaki,[15] recently report the Friedel-Crafts reaction of 3:4-dichloro-3:4-dimethyl-hexane (XLIV) with benzene. The main condensate was an oil, (XLV).

Fig. 3

Hexamethylanthracene m.p. 236°





The latter on dehydrogenation with selenium gave 1:2:3:4-tetramethyl-naphthalene (XV). This reaction, together with the oxidation of (XLV) to phthalic acid, proved that (XLV) was, 1:2:3:4- tetrahydro- 1:2:3:4- tetramethyl-naphthalene.

A small amount of a high melting condensate was isolated, which may have been obtained through further alkylation of (XLV).

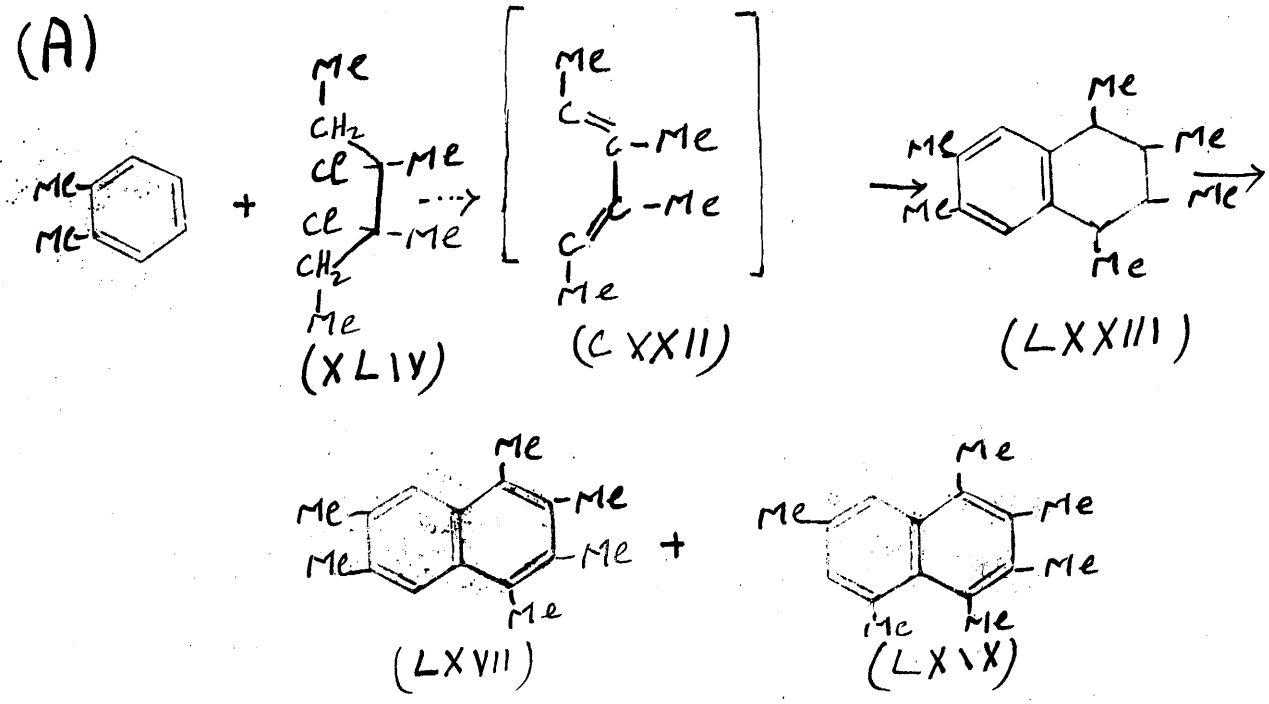
In our work here we investigated two condensations:-

(A) The condensation of (XLIV) with o-xylene.

(B) The condensation of (XLIV) with prehnitene.

Reaction (A) was carried at 40° in absence of solvent. Aluminium chloride was used as catalyst. O-Xylene was present in excess to avoid dialkylation. The oily condensation product was then fractionally distilled into three fractions.

(A)



(XLIV) (CXXII) (LXXIII)

(LXVII) (LXIX)

While the first and second fractions were obtained as impure liquids, the third fraction was a solid ($C_{16}H_{20}$) m.p. 145°. This solid was found to be an aromatic hydrocarbon giving a picrate derivative m.p. 190°. It was identical with 1:2:3:4:6:7- hexamethyl-naphthalene (LXVII) prepared by another method p. (32).

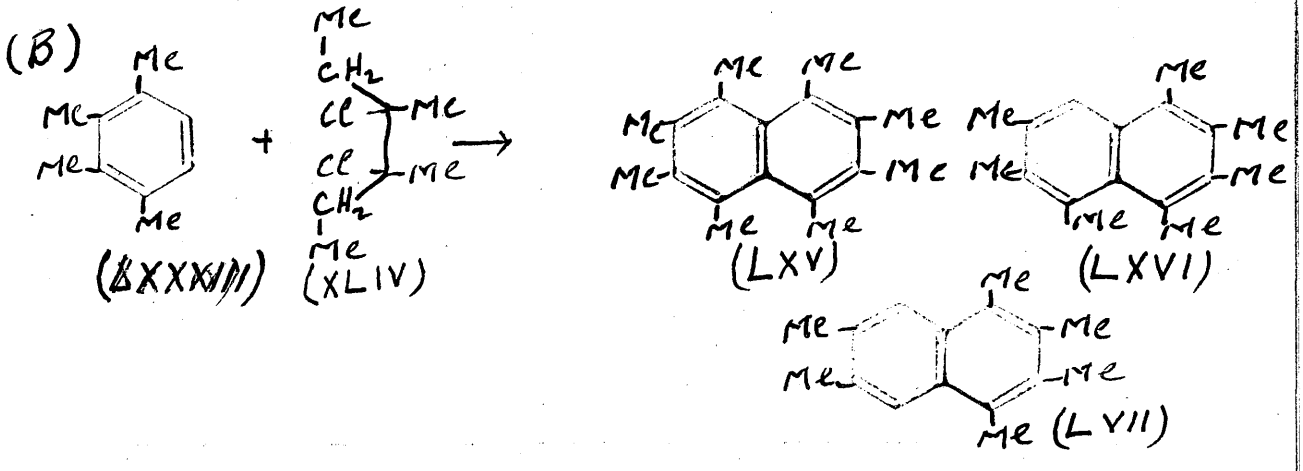
The formation of (LXVII) may be explained by the possibility that the alkylating agent (XLIV) in presence of aluminium chloride lost two molecules of hydrogen chloride to give the diolefin (CXXII). The latter then condensed with o-xylene by addition to give the tetralin derivative (CXXIII) which simultaneously dehydrogenated to (LXVII).

After selenium dehydrogenation, the first fraction gave

only a faint colour with picric acid and no derivative was isolated.

The dehydrogenation of the second fraction gave a small amount of brick coloured needles of 2:4:7-trinitro-fluorenone complex. Dissociation gave a solid m.p. 135-137° identical with the corresponding 1:2:3:4:5:7- hexamethyl-naphthalene (LXIX). This reaction may be explained by assuming the isomerisation of o-xylene in presence of aluminium chloride to p- and m-xylene followed by the condensation of the latter with (XLV) to give 1:2:3:4-tetrahydro- 1:3:5:6:7:8-tetramethyl-naphthene. This dehydrogenated to (LXIX).

Reaction (B) was interesting. In one run at 40°, C., a slight excess of (XLIV) was used. The oily condensate obtained



gave no picrate. It was dehydrogenated with selenium and the product was carefully fractionated. Four fractions were collected.

From the first fraction no picrate could be obtained. The second formed a red picrate m.p. 190°. The latter on dissociation gave a hydrocarbon m.p. 145° and was identified as 1:2:3:4:6:7- hexamethyl-naphthalene (LXVII). The third fraction gave a dark brown 2:4:7- trinitrofluorenone complex m.p. 210°-212°. Dissociation gave a hydrocarbon m.p. 132-4° identical with 1:2:3:4:5:6:7- heptamethyl-naphthalene (LXVI) prepared by another method described on page (31). The fourth fraction gave a black picrate from which a very small amount of a hydrocarbon m.p. 170-3° was obtained. It was identified as octamethyl-naphthalene prepared by another method p. (31). Identity of these polymethyl-naphthalene was fully confirmed by mixed melting points of hydrocarbons and derivatives and by ultra violet absorption spectra. The proposed course of reaction between prehnitene and (XLIV) is summarised below.

(a) Prehnitene in presence of aluminium chloride is liable to lose methyl-groups to give lower methylated benzenes.

(b) The high temperature required in the selenium dehydrogenation may result in the loss of the strained methyl groups in the 1:8- and 4:5- positions.

(c) The condensation product might have lost one or two methyl groups to facilitate condensation.

(d) The great steric hindrance in 1:8 and 4:5 positions

may cause the loss of some of these methyl groups to give a less strained structure.

Again the hydrocarbons isolated are a very minute fraction of the bulk of the condensate and this may invalidate this interpretation.

The condensation of prehnitene and (XLIV) was repeated at 65° C. for seven hours and was then left overnight at 35-40°. Fractionation of the oily product followed by attempted isolation of derivatives showed that:- With the first fraction although no derivative could be isolated it gave a deep red colour with picric acid. The second fraction gave a 2:4:7-trinitrofluorene derivative from which a hydrocarbon m.p. 132-4° was obtained. The latter was identified as 1:2:3:4:5:6:7- heptamethyl-naphthalene (LXVI). The third fraction gave a black picrate derivative which was dissociated to a solid m.p. 173-4° and was identified as octamethyl-naphthalene (LXV). The fourth fraction which was the main product was obtained as a yellow solid. This gave a deep blue fluorescence in benzene solution. It was insoluble in ligroin, methyl and ethyl alcohol, soluble in hot benzene. The compounds, $C_{20}H_{22}$ m.p. 236-7° gives a black picrate m.p. 214°, a greenish black trinitrofluorenone complex m.p. 228-9° and a wine-red trinitrobenzene complex m.p. 224°. The absorption spectrum Fig. (3) resembles those of anthracene derivatives. Chromic acid [77] oxidation of the

compound gave a yellow solid $C_{20}H_{20}O_2$. This oxidation showed that there was no loss of carbon atoms. This together with the analytical figures shows that the product obtained in the fourth fraction was a hexamethyl-anthracene with both the 9-and 10-positions vacant. A large number of isomeric hexamethyl-anthracenes are possible and our compound could not be identified as any of the previously described hexamethyl anthracenes.

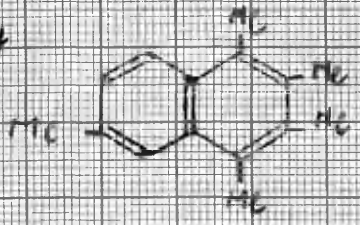
3:4 Dichloro-3:4- dimethyl-hexane[86] (XLIV) was prepared by the reduction of methyl-ethyl ketone[87] using similar procedure to that described for pinacole hydrate,[88] followed by saturation with hydrogen chloride.

ABSORPTION SPECTRA OF METHYL-NAPHTHALENES

The absorption spectra of six polymethyl-naphthalenes were investigated and the curves are shown in Figs. 10-15. The results are also compared both with those of Morton,[89] Gavat[90] and Mayneord[91] for naphthalene, mono-, di- and tri-substituted naphthalenes and with those of Ruzicka[6] for the higher substituted products.

In Figs. 10-12 are shown the absorption spectra curves of different polymethyl-naphthalenes to give a clear picture

Fig. 4



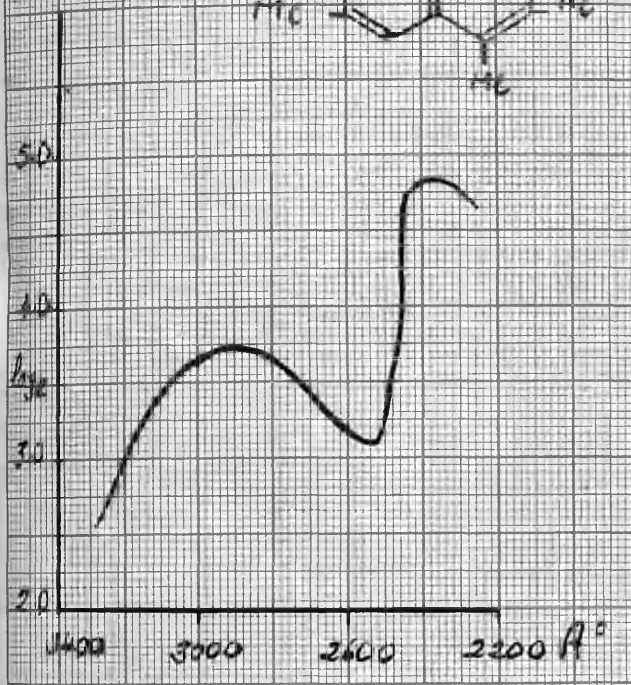
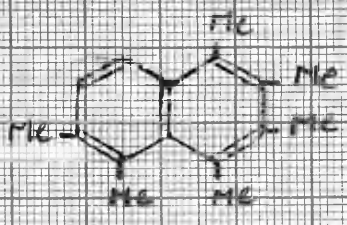


Fig. 5



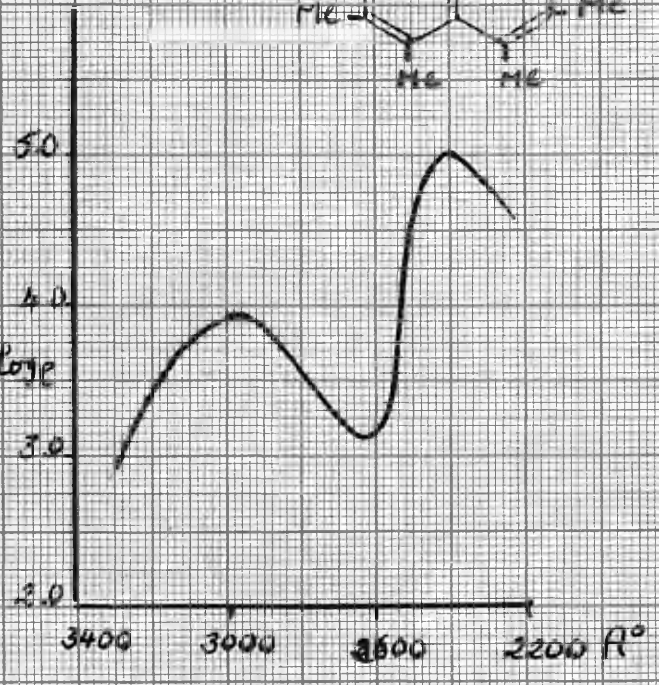


Fig. 6

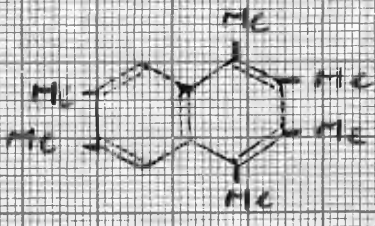


Fig. 7

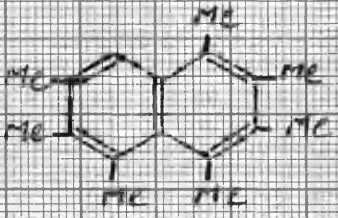


Fig. 8

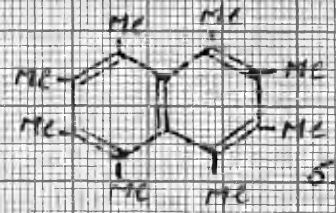

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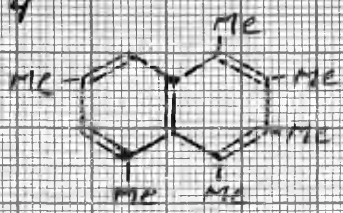
Fig. 4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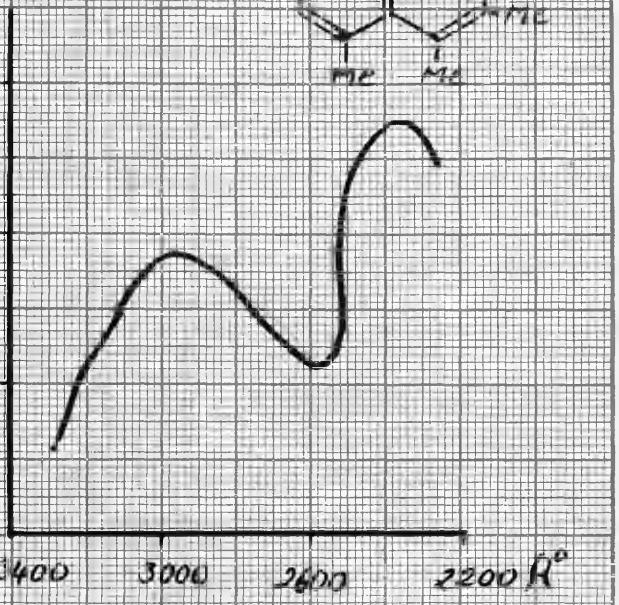
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Fig. 10

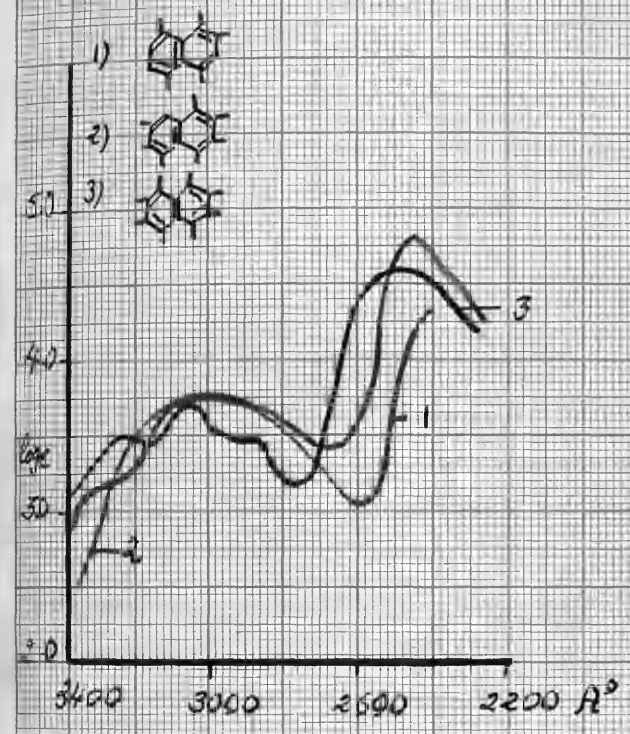


Fig. 11

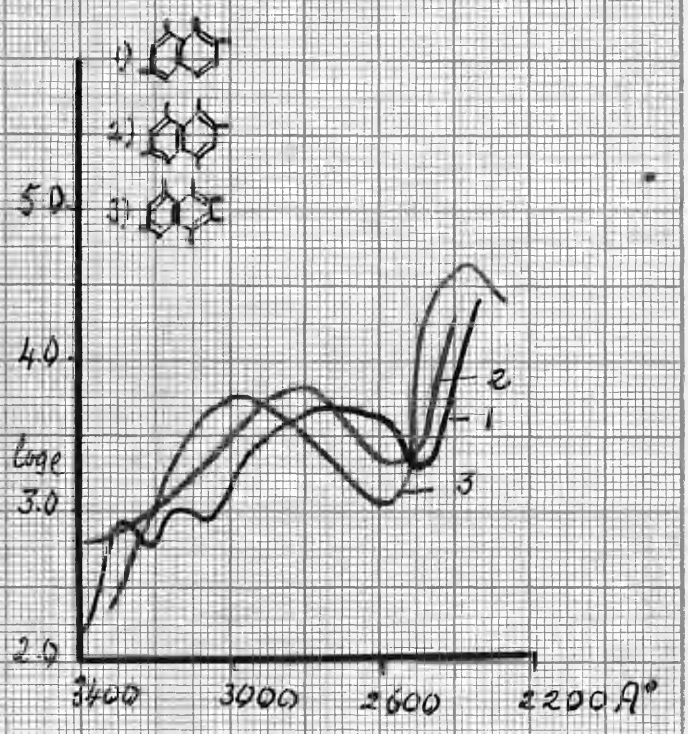


Fig. 12

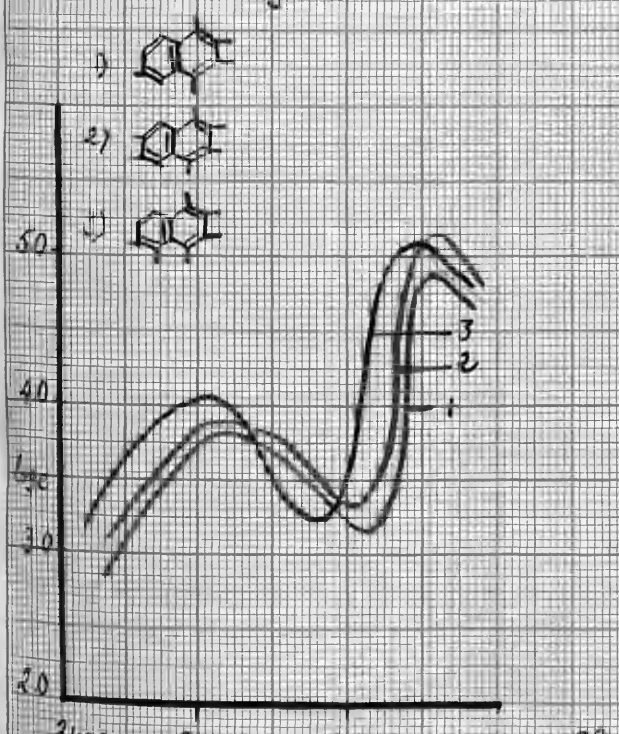


Fig. 13

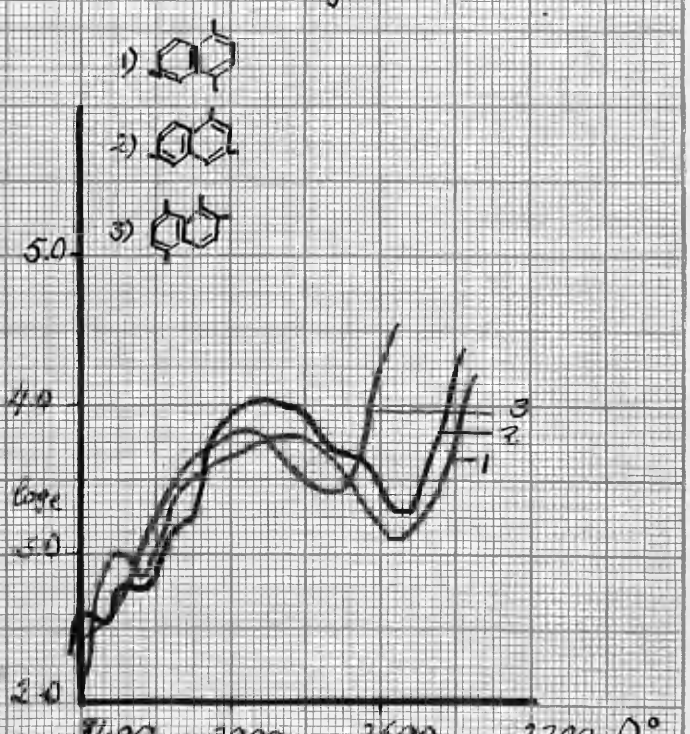


Fig. 14

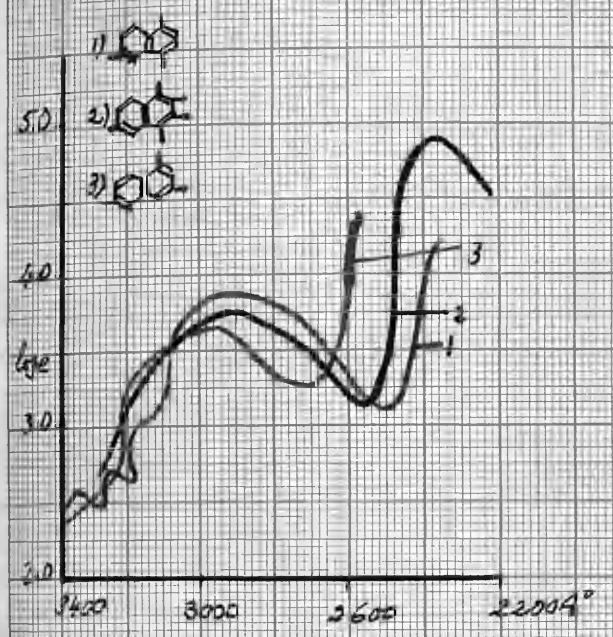


Fig. 15

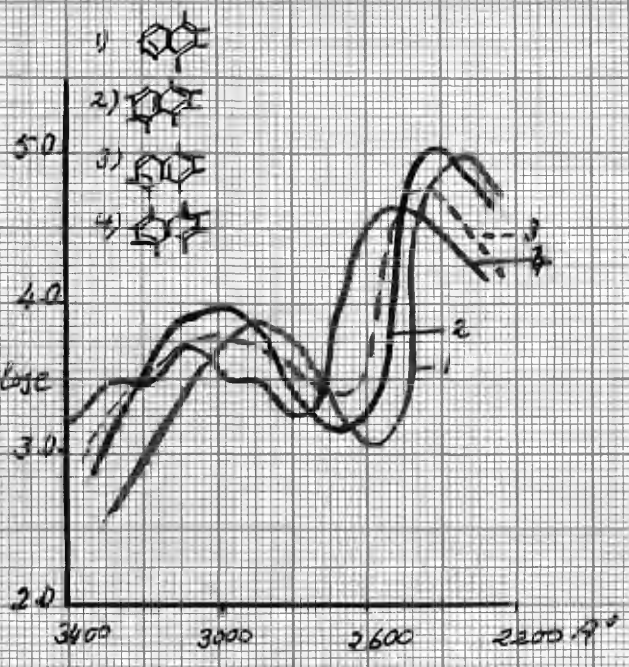


Fig. 16

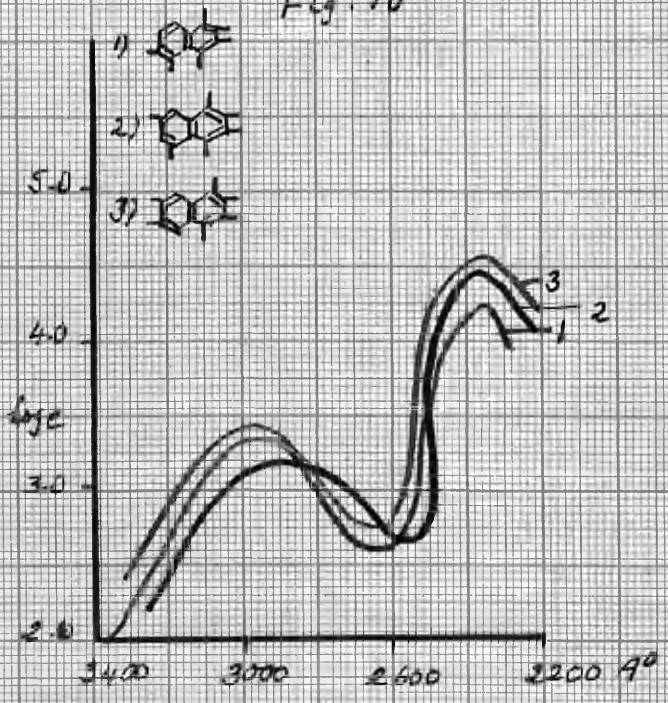


Fig. 17

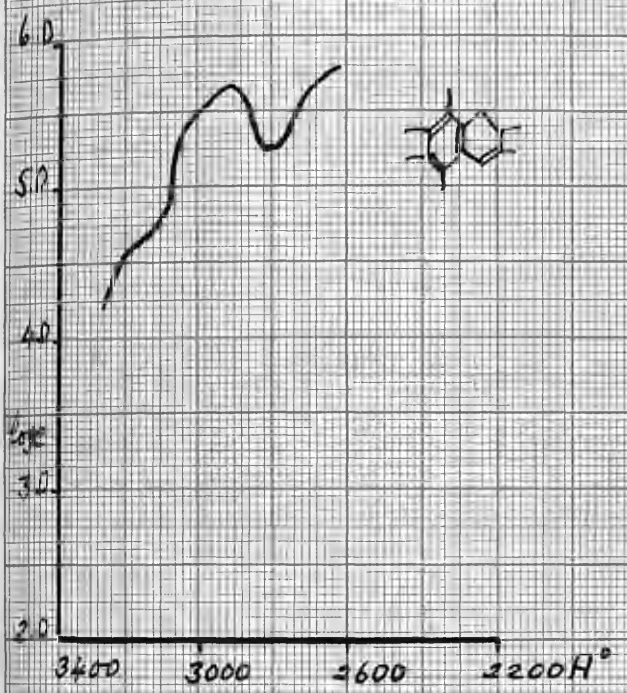


Fig. 18

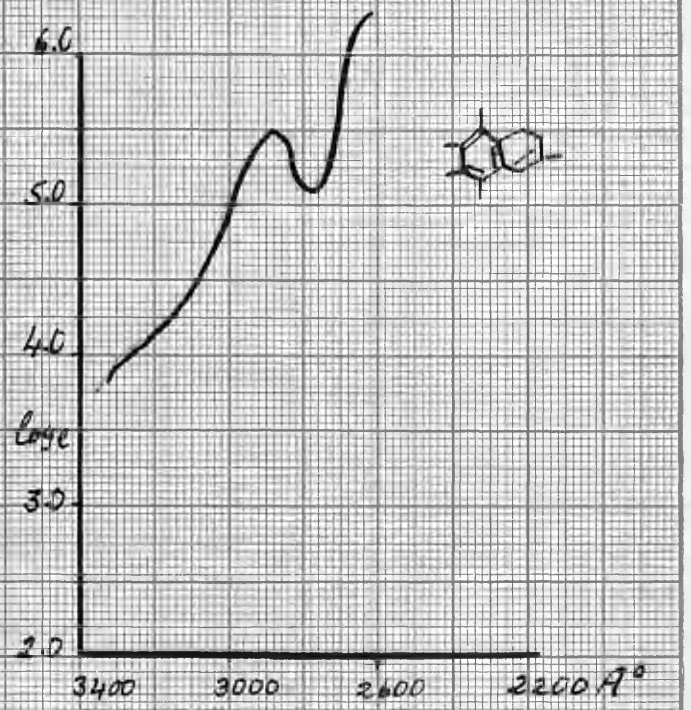


Fig. 19

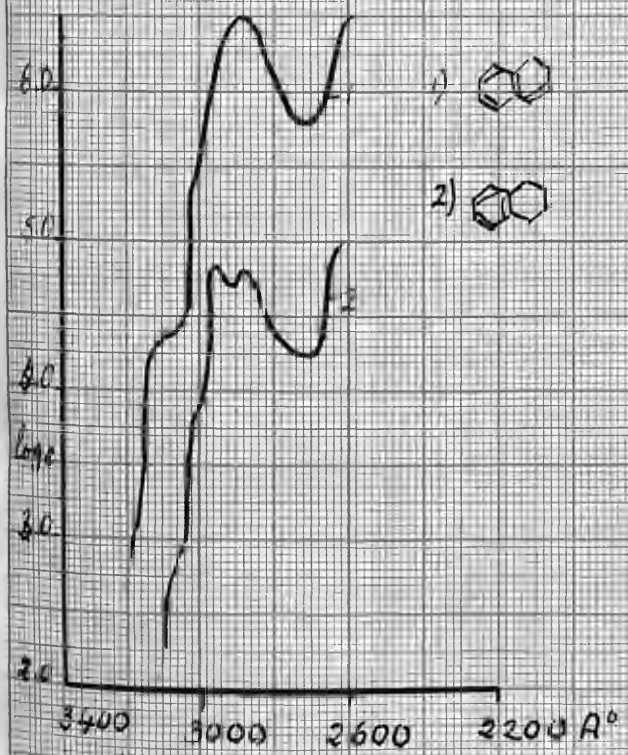
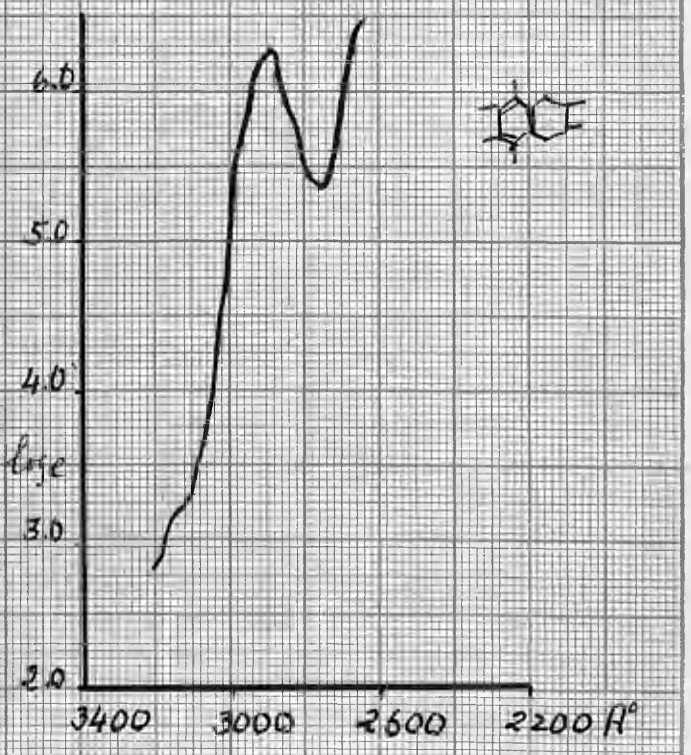


Fig. 20



of the variation in these curves with the differently substituted polymethyl-naphthalenes.

TableII shows only the main two maxima and a minimum for naphthalene to octamethyl-naphthalene.

The introduction of alkyl groups into the naphthalene nucleus only relatively produces slight changes in the absorption spectra curves. The degree of resolution in the middle part of the spectrum differs from derivative to derivative, and there is no observed regularity.

All compounds studied by us, similar to described alkyl-naphthalenes showed three regions of absorption

(a) (3250-2950A°) low log e values.

(b) (2500-2950A°) Moderate log e values.

(c) (below 2500A°) High log e values.

In the mono-substituted compounds the only significant difference is that λ max. peak B. for 1-methyl-naphthalene is increased from 2755 to 2810A°.

In the di-substituted products, λ max. are approximately the same, but log e is slightly lower.

In the tri-substituted naphthalenes there is an increase in λ max. for peak A for both the 1:3:5- and the 1:3:8- trimethyl compounds, but for 2:3:5- trimethyl-naphthalene λ max. peak A reverts to a value between that for naphthalene and those for the former compounds.

In the different isomers of tetramethyl-naphthalenes

λ max. peak B. increases from 2755 to 2820A° for 1:2:3:4-tetramethyl-naphthalene and to 2900A° for 1:2:6:8- tetra-methyl-naphthalene. In the 1:2:3:4:6- penta methyl-naphthalenes λ max. for peak A was still higher than those for the tri-substituted product, but λ max. for peak (B) is the same as B. On the other hand, λ max. for peak B increased from 2850 to 2980° and 3020A° for 1:2:4:6:8- and 1:2:4:5:8- pentamethyl-naphthalenes respectively, log e being nearly constant (3.70-3.80).

In the hexamethyl-naphthalenes λ max. for peak A increased from 2210A° for naphthalene to 2440A° in 1:2:3:4:5:6-hexamethyl-naphthalene, log e = 4.86. λ max. for peak B is nearly the same as those of tetra- and pentamethyl-naphthalene.

In hepta methyl-naphthalene λ max. peak A was 2420A° but log e was slightly lower than the corresponding values for polymethyl-naphthalenes. Again λ max. for peak B increased to 3020A°.

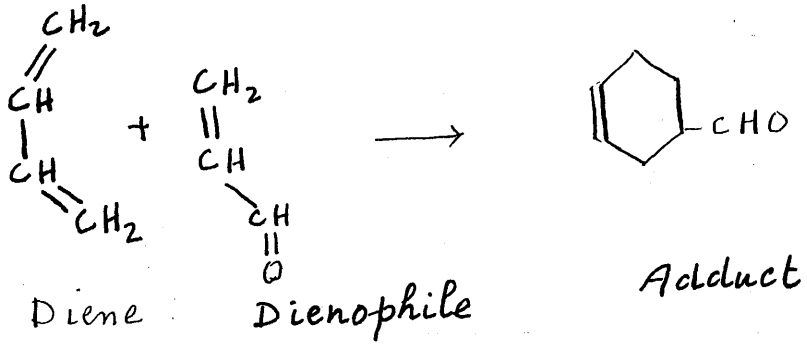
TABLE I I

Compound	Maxima Peak (A)	log e	Peak (B)	log e	Minima	log e
Naphthalene	2210	5.18	2755	3.9	2565	3.70
1-Methyl-	2205	4.98	2810	3.71	2705	3.69
2-Methyl-	2208	4.98	2750	3.71	2660	3.68
2:6- Dimethyl-	-	-	2725	3.68	-	-
2:7- Dimethyl-	-	-	2750	3.60	-	-
1:4:6- Trimethyl-	-	-	2980	3.81	2520	3.05
1:3:5- Trimethyl-	2315	5.30	2890	3.97	2772	3.86
1:3:8- Trimethyl-	2315	5.12	2850	3.83	2775	3.79
2:3:5- Trimethyl-	2253	5.06	2838	3.89	2648	3.73
1:2:3:4- Tetramethyl-	2260	4.90	2820	3.85	2580	3.00
1:2:3:5- Tetramethyl-	-	-	2920	3.75	2560	3.00
1:2:6:8- Tetramethyl-	-	-	2900	3.70	2500	3.21
1:2:4:5:8- Pentamethyl-	-	-	3620	3.83	260	3.2
1:2:4:6:8- Pentamethyl-	-	-	2980	3.80	2670	3.15
1:2:3:4:6- Pentamethyl-	2360	4.867	2880	3.69	2540	3.20
1:2:3:4:5:7-Hexamethyl-	2380	4.82	2980	3.85	2570	3.14
1:2:3:4:6:7-Hexamethyl-	2360	5.13	2940	3.73	2560	3.24
1:2:3:4:5:6-Hexamethyl-	2440	4.86	2980	3.87	2600	3.19
1:2:3:4:5:6:7-Hepta-methyl	2420	4.74	3020	3.70	2630	3.30
Octamethyl-	2540	4.7	3080	3.70	2740	3.31

In octamethyl-naphthalene λ max. for peak B is at a rather high wave length 2540A°. In the middle part of the spectrum there are two maxima at wave lengths 2920A° log e = 3.56 and 3080A° log e = 3.72).

THE REACTION OF MALEIC ANHYDRIDE WITH POLYMETHYL-NAPHTHALENES

In 1928 Diels and Alder[92] discovered that compounds containing double or triple bonds, usually activated by other centres of unsaturation in the $\alpha:\beta$-position, add to the 1:4- positions of a conjugated system, e.g.

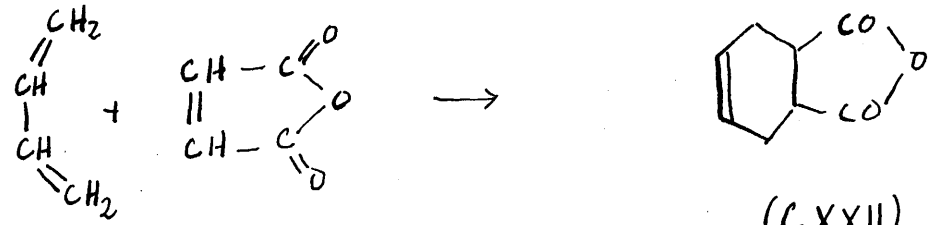


Among the substances that have been employed most frequently as dienophiles are maleic anhydride and other closely related dicarboxylic acid derivatives.

The adduct formed in the Diels-Alder reaction may involve transfer of electrons from the diene to the dienophile to form an adduct complex, so formed, as to hold the maximum attractive forces[93],[94]. This is followed by stabilization of the ionic complex to a stable adduct. This mechanism is supported by such features observed in the reaction as colour change[95] and the isolation of ionic compounds. The nature of the solvent and its effect on the ionic

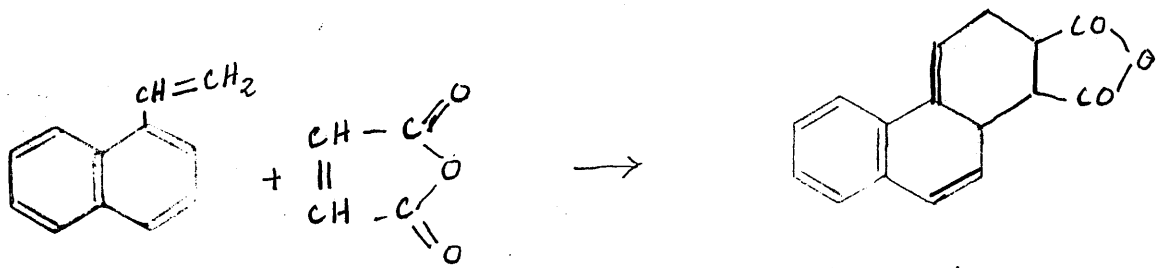
compounds isolated in the heterocyclic additions and the effect of catalyst may give some indication of ionic mechanism.

Butadiene reacts quickly with maleic anhydride to give a quantitative yield of cis- 1:2:3:6- tetra-hydrophthalic anhydride (CXXII)[92],[96],[97].



(CXXII)

However a true diene is not essential, for one of the double bonds may be an aromatic double bond conjugated with an ethylenic linkage. Thus extranuclear unsaturation in conjugation with the naphthalene or phenanthrene nucleus produces a diene system which is reactive towards maleic anhydride.

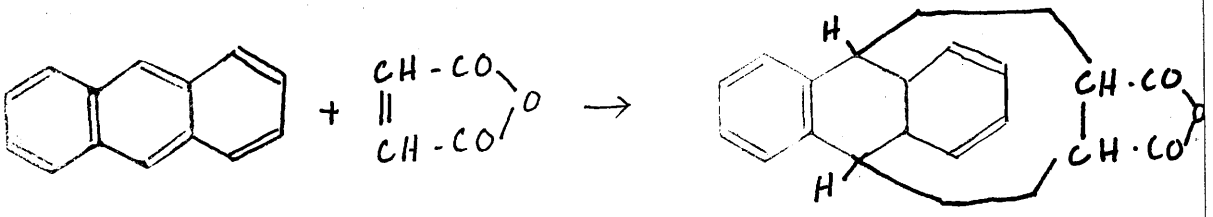


(CXXIV) (CXXV)

In boiling toluene or xylene for example, maleic anhydride reacts with 1- vinylnaphthalene (CXXIV) to yield a 1:2:3:11-

tetrahydro-phenanthrene derivative (CXXV).[98],[99]

Also, both double bonds of the diene may form part of an aromatic ring. The central ring of the anthracene nucleus contains a characteristic diene system and maleic anhydride adds to



(CXXVI)

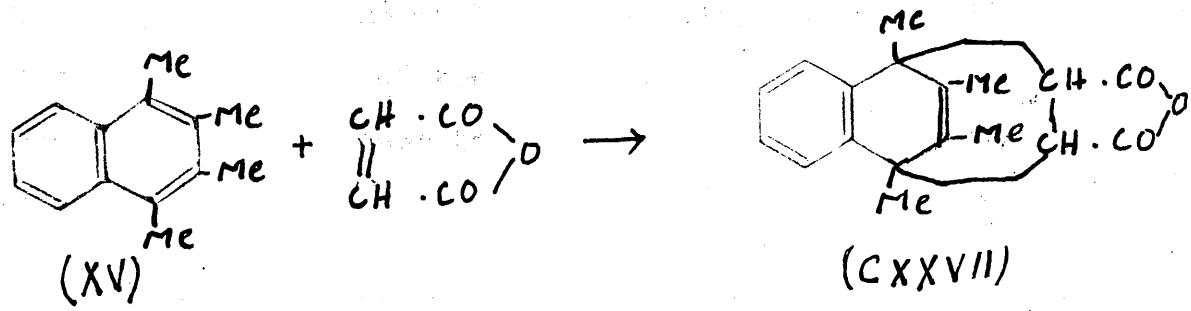
anthracene to give 9:10-dihydroanthracene- 9:10- endo-α :β- succinic anhydride (CXXVI).[100] The latter showed unmistakeably[101] the absorption spectrum of a simple benzene derivative.

Anthracene derivatives differ widely in their rate of reaction with maleic anhydride. While alkyl groups in the mesoposition facilitate addition, phenyl groups retard the reaction. Thus 9- methyl-anthracene reacts more quickly than anthracene, and the 9:10 dimethyl-anthracene reacts rapidly at room temperature. On the other hand, 9-phenyl-anthracene reacts much more slowly than anthracene and the reaction between equimolecular quantities of maleic anhydride and 9:10-diphenyl anthracene is incomplete even after refluxing for many days.

The reaction of maleic anhydride with polycyclic aromatic hydrocarbons is reversible.[102] Identical equilibrium mixture

of hydrocarbon, maleic anhydride and adduct are obtained by heating xylene solutions of either adduct or equimolecular amounts of the components.

Mameli and Panetto[103] reported that no adduct product is formed when naphthalene is heated with maleic anhydride. However, Kloetzel[11] recently isolated 1% adduct product using excess of maleic anhydride. He also found that with the introduction of methyl groups in the naphthalene nucleus, (cf. the effect of the methyl groups in the meso-position in amthracene) the rate of the reaction rapidly increased with successive methyl groups to reach a maximum in 1:2:3:4- tetramethyl-naphthalene.



(XV) (CXXVII)

With 1:2:3:4-tetramethyl-naphthalene (XV) and a thirty-fold molar excess of maleic anhydride, Kloetzel obtained a 90% yield of the adduct 1:2:3:4- tetramethyl- 1:4-dihydro-1:4-endo-α:β- succinic anhydride (CXXVII)[10] From Kloetzel's work one can make the following conclusions:-

(a) Maximum yield of adduct is obtained when maleic anhydride is present in large excess, i.e. the equilibrium is shifted towards adduct formation.

(b) Higher reaction temperature favours dissociation.

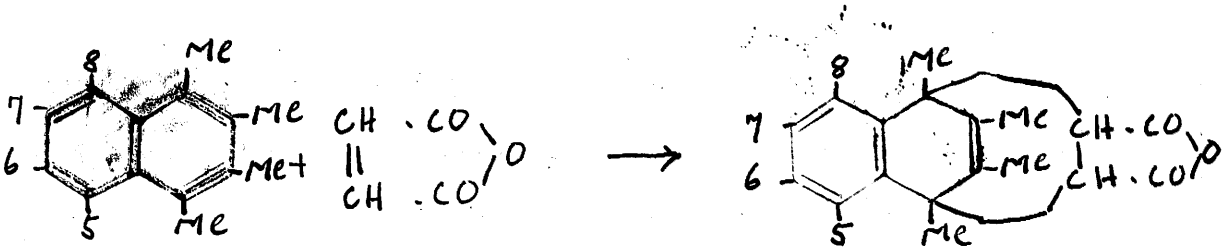
(c) Mono-β substitution favours the reaction more than mono-α-substitution; the β-methyl-compounds are nearly as active as 1:4-dimethyl-naphthalene.

(d) 1:2:3:4- Tetra-methyl-naphthalene shows the most rapid and favourable equilibrium.

(e) Ethyl-groups, though larger than methyl-groups, activate the nucleus more than the latter.

It appeared of some significance to determine whether more methyl groups in the naphthalene nucleus would or would not promote similar reactions with maleic anhydride, and then to correlate the dienoid activity of the naphthalene nucleus with the extent and position of such substituents.

The reaction of maleic anhydride with a penta methyl-, two hexamethyl-, a hepta methyl- and an octa methyl-naphthalene was therefore investigated. This work was limited to some extent by the small amounts of these polymethyl-naphthalenes available. Their synthesis described on p.27 was in progress when Kloetzel's work was published.[10],[11]



(CXXVIII) (CXXIX)

pentamethyl-N	5,7,8 = H; 6 = Me	(LXX)
Hexamethyl-N	5,6 = Me; 7,8 = H	(LXVIII)
Hexamethyl-N	5,8 = H; 6,7 = Me	(LXVII)
Heptamethyl-N	5,6,7 = Me; 8 = H	(LXVI)
Octamethyl-N	5,6,7 and 8 = Me.	(LXV)

The reaction of polymethyl-naphthalenes (CXXVIII) with maleic anhydride give adduct (CXXIX).

The Table (LII) shows the extent to which each hydrocarbon reacted with maleic anhydride. A thirty-fold molar excess of maleic anhydrids was used in presence of benzene as a diluent. The percentages of adduct- and unreacted hydrocarbon were determined after 48 and 72 hours.

TABLE (III)

Derivatives of Naphthalene	After 48 hours		After 72 hours	
	% Adduct	% Hydrocarbon recovered	% Adduct	% Hydrocarbon recovered
1:2:3:4:8- Pentamethyl (LXX)	50	35	42	40
1:2:3:4:5:6- Hexamethyl- (LXVIII)	68	15	65	20
1:2:3:4:6:7- Hexamethyl- (LXVII)	45	35	42	41
1:2:3:4:5:6:7- Heptamethyl (LXVI)	60	20	55	23
Octamethyl- (LXV)	62	17	60	18

The adduct anhydrides were isolated by first diluting the reaction products with excess water to dissolve the great excess of maleic anhydride, followed by extraction with ether. The product obtained, containing both adduct and unreacted hydrocarbon, was then hydrolysed with 5% potassium hydroxide and the unreacted hydrocarbon extracted. The adduct dicarboxylic acid, liberated by acidification of the alkaline solution, was then weighed and the percentage calculated.

An alternative purification of the adducts was to dissolve with gentle heating the adduct dibasic acids, isolated in the above described fashion, in a small volume of ethyl acetate containing acetic anhydride or acetyl

chloride. The anhydride usually crystallised in nearly quantitative yield after cooling.

A quantitative yield of the respective hydrocarbon was obtained when each adduct was heated above its melting point under vacuo. Thus the maleic anhydride reaction is a possible alternative method for purification of these hydrocarbons.

That all adducts failed to give a colour with picric acid or 2:4:7- trinitro-fluorenone and no corresponding derivatives were obtained on cooling excludes the presence of a naphthalene nucleus.

Attempts made to obtain the pure dibasic acids were unsuccessful as the latter partially reverted to the anhydride on crystallisation.

The correlation of the results in Table (III) must not be based on activation of the naphthalene nucleus with increase in the number of substituents. On the other hand, these bulky groups may hinder sterically the formation of the corresponding adducts.

Although with 1:2:3:4- tetramethylnaphthalene (XV),), Kloetzel reported nearly a quantitative yield of adduct, with 1:2:3:4:6- pentamethyl-naphthalene (LXX), the yield dropped to 50%. Thus, further β - substitution has deactivated the nucleus. This is in contrast with the observation that β - methyl substitution is as effective in promoting maleic

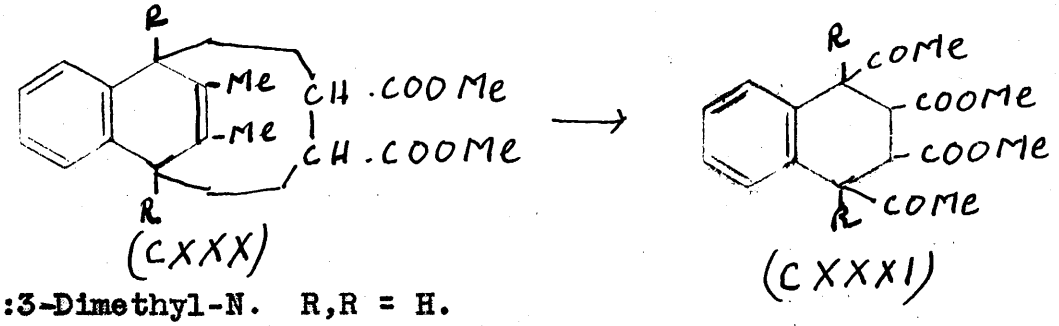
anhydride addition as is the simultaneous introduction of two methyl groups in the 1- and 4- positions. With 1:2:3:4:6:7- hexamethyl-naphthalene (LXVII), the yield of adduct is still lower. It is evident here that the substitution of methyl groups in both the -6- and 7- positions greatly deactivated the nucleus. This result is the opposite to that expected by analogy with 2:3- dimethyl-naphthalene which gave a 43% yield of adduct, i.e. even two substituents were sufficient to activate the naphthalene nucleus.

On the other hand, 1:2:3:4:5:6- hexamethyl-naphthalene (LXVIII) gave a 68% yield of adduct. It would seem that the α-methyl group introduced in 5-position is responsible for the activation of the nucleus. With heptamethyl-naphthalene (LXVI) a 60% yield of adduct was obtained compared with a yield of 19% with 1:2:3- trimethyl-naphthalene, i.e. the introduction of four more methyl groups into trimethyl-naphthalene increased the yield of adduct by 40%. In octamethyl-naphthalene (LXV) reaction, despite the great steric hindrance produced in the adduct, it was obtained in 62% yield.

It is also clear from table (III) that equilibrium was reached after 48 hours, further heating favoured slow dissociation. The addition of maleic anhydride to 2:3- dimethyl- and 1:2:3:4- tetramethyl-naphthalene involved the substituted ring. With polymethyl-naphthalenes (CXXVIII),

the addition involved the fully substituted and not the partially substituted ring. These conclusions are supported by the following results:-

(1) Both 2:3- dimethyl- and 1:2:3:4- tetramethyl-naphthalene adduct anhydrides were hydrolysed to the corresponding dibasic acids, which with diagomethane gave the diesters (CXXX;R,R = H or Me).



2:3-Dimethyl-N. R,R = H.

1:2:3:4-Tetramethyl-N. R,R = Me.

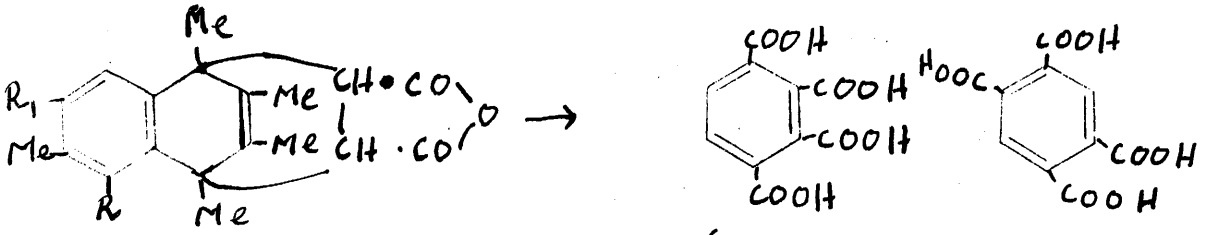
Both esters on ozonolysis gave a diketone (CXXXI; R,R = H or Me) which formed a dioxime. The failure of this product to show aldehydic reactions makes it unlikely that the maleic anhydride added to the unsubstituted ring.

(2) The oxidation of the corresponding dicarboxylic acids of (CXXX;R,R = H or Me) gave only phthalic acid.

(1) and (2) results were reported by Kloetzel (loc. cit.)

(3) The oxidation of the dicarboxylic acid adducts of 1:2:3:4:5:6- and 1:2:3:4:6:7- hexamethyl-naphthalenes (CXXXII; R = Me, R_1 = H) and (CXXXII; R = H, R_1 = Me) gave

prehnitic[104] (CXXIII) and pyromellitic acids[105] (CXXIV) respectively.



(CXXXII) (CXXXIII) (CXXXIV)

1:2:3:4:5:6- Hexamethyl-naphthalene (R = Me, R_1 = H)

1:2:3:4:6:7- Hexamethyl-naphthalene (R = H, R_1 = Me)

The structures (CXXIX) for dipotassium salts adducts of polymethyl-naphthalenes (LXV), (LXVI), (LXVII), (LXVIII) and (LXX) are supported by absorption spectra curves Figs. 23-25 respectively. In each figure is shown the ultra violet absorption spectra curves from 2400-2900A° for adduct dipotassium salts in aqueous solution. A close correspondence is evident between the maxima in these curves (between 2580-2700A° log e = 2.7-3.0) and the maxima in similar curves for anthracene maleic anhydride adducts[101] (λ = 2590-2740A°) and for simple alkyl benzenes[106]. In all the adducts prepared, similar to the latter two compounds, absorption rapidly dropped beyond (λ = 2800A°) to a negligible value.

The sparing solubility of the adduct dipotassium salts in water limited the accuracy of the curves. However they

Fig. 21

1) 1:2:3:4:6-Pentamethyl-N.

2) Adduct dipotassium salt

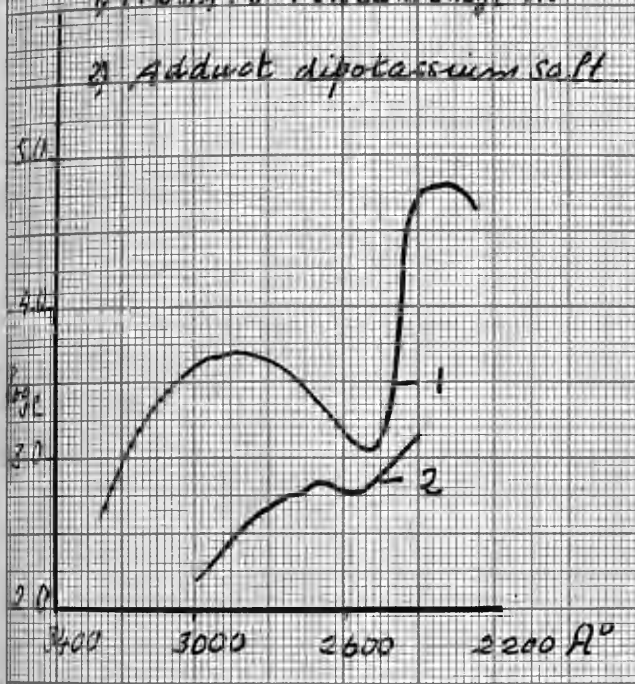


Fig. 22.

1) 1:2:3:4:5:6-Hexamethyl-N.

2) Adduct dipotassium salt.

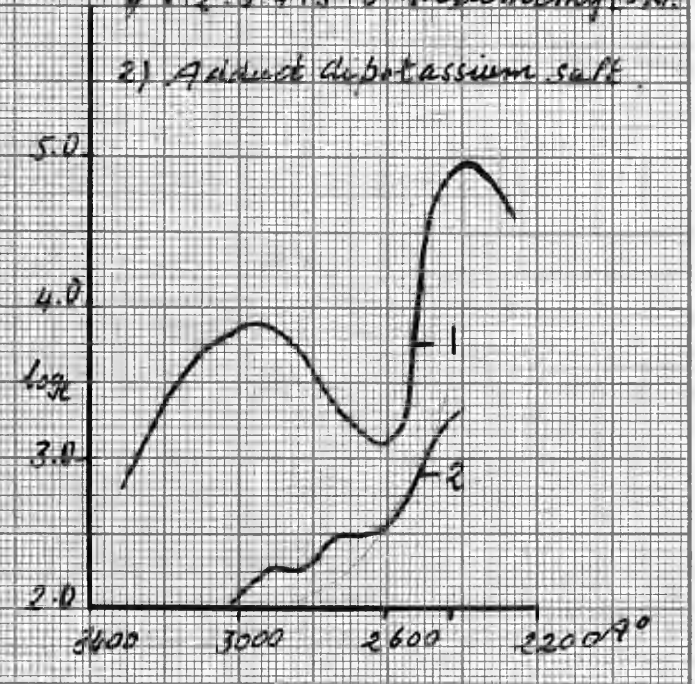


Fig. 23

1) 1:2:3:4:6:7-Hexamethyl-N.

2) Adduct dipotassium salt.

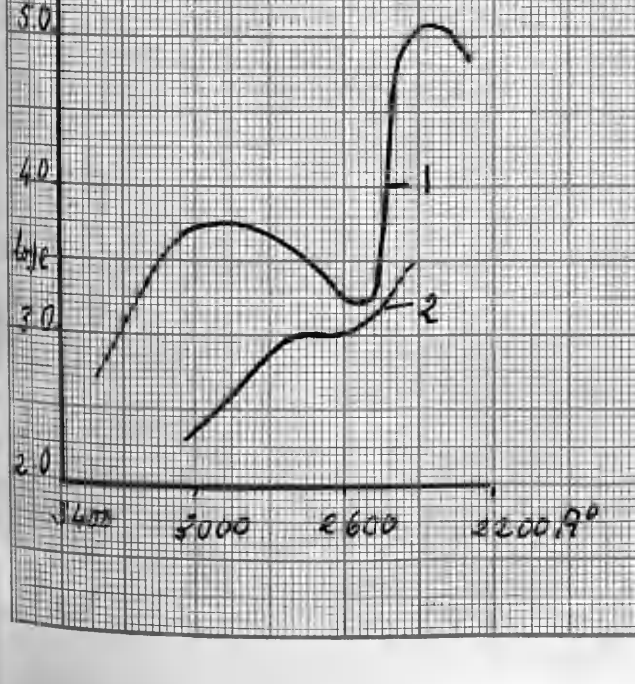


Fig. 24

1) 1:2:3:4:5:6:7-Heptamethyl-N.

2) Adduct dipotassium salt.

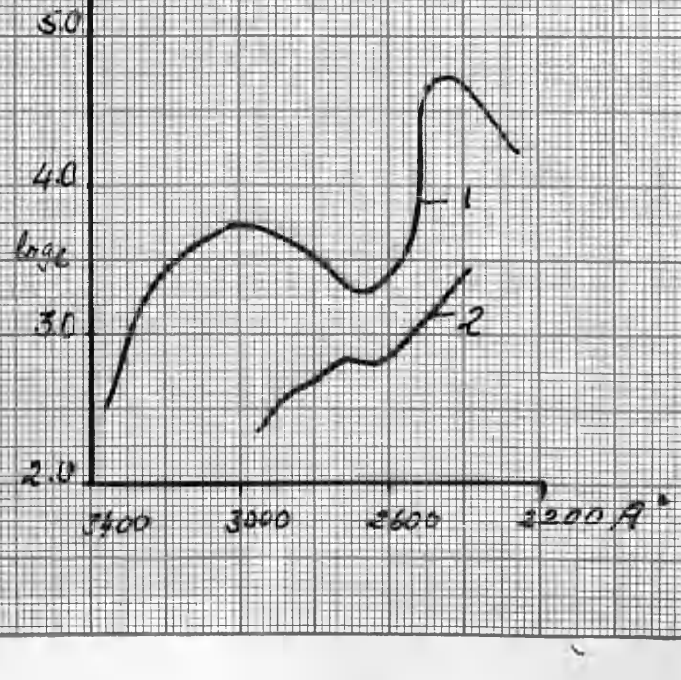


Fig. 25

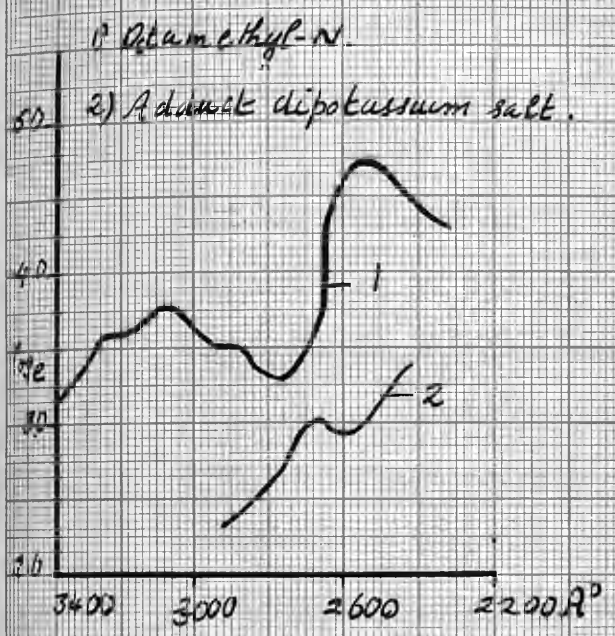
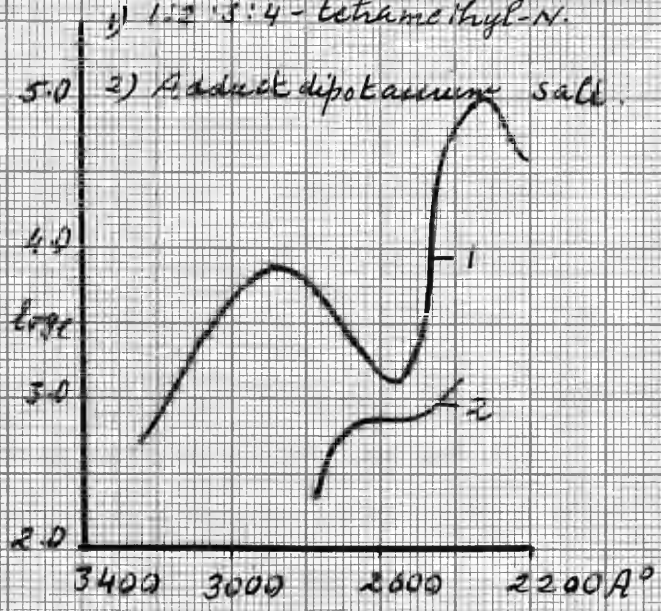


Fig. 26



Klaczel, J. Amer. Chem. Soc., 1950, 72, 273.

are satisfactory for comparison with the corresponding pure hydrocarbons. In 95% ethanol, the latter showed strong absorption in the range (λ = 2700-3200A°, log e = 3.5-4.0). This broad band is characteristic of these polymethyl-naphthalene as well as other naphthalene derivatives[89],[90]. Naphthalene itself shows a series of maxima in this region.

It is clearly evident from comparison of these curves that no adduct retains the absorption spectrum of the naphthalene nucleus. The curves of the adducts are characteristic of simple alkyl-benzene derivatives.

It is interesting to mention that an attempt was made to apply the activating effect of methyl substituents in the anthracene and naphthalene series to the alkyl-benzenes. Hexamethyl-benzene, was refluxed with a thirty-fold molar excess of maleic anhydride for periods of 24, 48 and 72 hours. Careful analysis of the products, gave no trace of adduct formation and hexamethyl-benzene was quantitatively recovered.

EXPERIMENTAL

(±) -α : β-Dimethylsuccinic anhydride (LII).

(After Bon and Sprankling[62] and Fieser[39]).

Sodium (6.8 g.) was dissolved in absolute alcohol (95 c.c.). When cold, ethyl-cyanoacetate (33 g.) was added during 40 mins. with stirring, followed by ethyl-α-bromopropionate (50 g.) over a period of 2 hours. The ester fraction b.p. 130-170°/14 mm. was collected (47 g.). This was added over 1 hour with ice cooling to sodium (5 g.) dissolved in absolute alcohol (50 c.c.) followed by methyl-iodide (39 g.). The ester so formed b.p. 150-160°/16 mm. (39 g.) was hydrolysed by refluxing overnight with concentrated hydrochloric acid (150 c.c.). The dibasic acid crystallised out (20 g.) after concentration and cooling. It was refluxed with acetyl-chloride (30g.) for 1 hour. The fraction b.p. 224-240°/760 mm. was collected. It was crystallised from benzene light petroleum to give (LII) (11 g.) m.p. 70-80°, a (d,l) mixture.

α-Methylsuccinic anhydride.

(After Dev and Guha[65],).

Sodium (11 g.) was atomised under xylene. After decanting, toluene (500 c.c.) was added followed rapidly by diethyl malonate (80 g.) with stirring. After half an hour,

the mixture was refluxed for 3 hours. After cooling, ethyl α-bromo-propionate (90 g.) was slowly added during 2 hours. The product was left standing overnight, then it was refluxed (10 hours) with concentrated hydrochloric acid (150 c.c.). The aqueous solution was evaporated. Then nitric acid was added slowly to oxidise the impurities. The acid solidified (110 g.) m.p. 104-108°. After refluxing for 2 hours with acetyl chloride (750 c.c.), the anhydride was obtained as a colourless oil b.p. 118-120°/7 mm. (78 g.). On crystallisation from light petroleum the anhydride (50 g.) was obtained m.p. 31-3°, b.p. 247°/760 mm.

Dimethyl-α-Bromo-$\alpha:\beta$-dimethylsuccinate (LXXV).

Carefully dried ($\pm$)-$\alpha:\beta$-dimethyl-succinic acid (22 g.) was mixed with red phosphorus (4 g.) in a double neck flask with a dropping funnel and a condenser. Bromine (80 g.) was added drop wise (40 min.) to the solid mixture with continuous shaking (the reaction is exothermic). The excess bromine was removed on a steam bath leaving the monobromodimethylsuccinylbromide. The latter was poured into boiling water (120 cc.). It was filtered and extracted with ether (5 x 50 c.c.). The combined ether extract was dried (Na_2SO_4) and concentrated. The residue was crystallised from ether or water to give α-bromo-$\alpha:\beta$-dimethylsuccinic acid in colourless plates m.p. 90°. The latter

(10 g.) was refluxed for 2 hours with methyl alcohol (20 c.c.) and a few drops of concentrated sulphuric acid. The product was distilled as a colourless liquid b.p. 92-94°/15 mm.

Dimethyl-α-Methylsuccinate.

α-Methylsuccinic acid was treated as above to give a colourless liquid b.p. 196°-198°/760 mm. (literature, b.p. 197-198.5°/760 mm.).

Durene, 1:2:4:5- tetra methylbenzene (XLIX)

(After Von Braun[69]).

Commercial xylene (90%; m-isomer) (275g.), formalin (546 g.) and concentrated hydrochloric acid (1365 g.) were heated with mechanical stirring at 70-80° C. on a water bath (7 hours). Formalin (547 g.) was then added and hydrogen chloride was bubbled through the mixture during 35-40 hours, with stirring. Distillation of the organic layer gave a mixture of dichloro-methylxylenes (600 g.) b.p. 150°/14 mm. The latter (100 g.) in toluene (150 c.c.) was added dropwise to a solution of zinc (200 g.) in water (3500 c.c.) and caustic soda (400g.) with stirring (10 hours). The reaction mixture was refluxed for a further 12 hours. The organic distillate b.p. 200-215° was collected. It rapidly crystallised from ethanol to give durene (30 g.) m.p. 80°.

Durene, 1:2:4:5- tetramethyl-benzene and Isodurene, 1:2:3:5-tetramethyl-benzene.

(Modified. Smith[70]).

Xylene (400 g.) and mesitylene (175 g.) were mixed with freshly pulverised anhydrous aluminium chloride (175 g.) Methyl chloride gas (520 g.) was bubbled into the mixture at 90-95° (60 hours) under a slight pressure (10 cm. of mercury). The reaction mixture was poured into a mixture of concentrated hydrochloric acid and chopped ice. Distillation of the organic layer afforded a mixture of durene and isodurene b.p. 185-205°/760 mm. (300 g.). Another fraction distilled at 205-220°/760 mm. and consisted of pentamethyl-benzene (100 g.) m.p. 52°.

Prehnitene, 1:2:3:4-tetramethylbenzene (LXXXIII)

(After Smith and Cass[72] and Smith and Lux[73]).

The above mixture (100 g.), concentrated sulphuric acid (60 c.c.), fuming sulphuric acid (40 c.c.; 60%) was shaken (5 mins.), then heated at 80° (17 hours). The resulting black viscous material was poured on to chopped ice (500 g.). The filtrate was then cooled to 0° and concentrated sulphuric acid (250 c.c.) was added slowly with strong cooling. The dark crystalline sulphonic acid which floated to the top was collected and pressed dry (65g.). A similar procedure was employed for pentamethyl-benzene, where the latter (100 g.) was heated to 65° and concentrated

sulphuric acid (300 c.c.) was added. The mixture was shaken vigorously and was then left standing at room temperature (24 hours) and worked up as above.

Prehnitene sulphonic acid was then converted to the sodium salt via the calcium salt. The former was hydrolysed by the flash steam method. Superheated steam was passed through a mixture of concentrated sulphuric acid and water maintained at 150-160° while a thin paste of sodium prehnitene sulphonate (100 g.) was slowly added. A yellow oil was collected (45g.) which was purified by distillation through a Widmer column. The fraction b.p. 202-204°/760 mm., m.p. - 9° was collected (literature b.p. 204°/760 mm., m.p. -5°).

1-Acetyl-prehnitene (LXXIV)

(Modified Claus and Fohlich[74]).

Acetyl chloride (3.5 g.), was added dropwise to a suspension of freshly powdered anhydrous aluminium chloride (10g.) in tetrachlorethane (25 c.c.). Prehnitene (3 g.) was now added (40 mins.) with stirring and ice cooling. Stirring was continued for a further 4 hours. The reaction mixture was then poured over crushed ice (50 g.) and concentrated hydrochloric acid (25 c.c.). The inorganic layer was extracted once with ether and the latter added to the organic layer. The solvent was then removed. The residual oil gave on distillation a yellow oil (3.5 g.) b.p. 145°/

15 mm., b.p. 258°/760 mm. (literature b.p. 258°/760 mm.)

The 2:4-dinitrophenylhydrazone was crystallised from acetic acid/ethanol in fine orange crystals m.p. 155-156°. (Found: N, 15.42. $C_{18}H_{19}O_4N_4$ requires N, 15.70%).

The oxime formed a white crystalline solid from ethyl alcohol m.p. 122° (Found = N, 6.96. $C_{12}H_{17}ON$ requires N, 7.30%).

The semicarbazone was obtained as colourless prisms from ethanol m.p. 203°. (Found: N, 18.2 $C_{13}H_{19}ON_3$ requires N, 18.0%).

γ-Keto- γ-duryl-α:β-dimethylbutyric acid (LIII; R = H) and γ-keto- γ-prehnityl-α:β-dimethylbutyric acid (LIV; R = H)

(1) In carbon disulphide as solvent.

To a stirred ice cold suspension of freshly powdered aluminium chloride (10 g.) in dry carbon disulphide (70 cc.) was added at intervals separate portions of durene and α:β-dimethyl-succinic anhydride totalling (3.3 g.) and 3.2 g.) respectively over 40 mins. Stirring was continued 4 hours longer then the reaction mixture was left overnight at room temperature. The solvent was then decanted and the sticky residue was decomposed with ice and concentrated hydrochloric acid. The white gummy product obtained after decantation of the aqueous layer was boiled with sodium carbonate, cooled, then extracted with ether to remove unreacted

durene. It was then clarified by boiling with charcoal, and then filtrated. The bulk of aqueous solution was evaporated to (15 c.c.), made just alkaline and then left in the ice chest overnight. The powdery precipitated solid was filtered (0.8 g.). This on acidification gave γ-keto-γ-prehnityl-α:β-dimethyl-succinic acid in colourless stout needles from benzene/light petroleum m. 151-152°. (Found: C, 73.6; H, 8.55. $C_{16}H_{22}O_3$ requires C, 73.3; H, 8.4%). A sample of the above acid was undepressed on admixture with a sample of γ-keto- γ-prehnityl-α=β-dimethyl succinic acid prepared as described on p. 86 .

The filtrate from the alkaline extract was acidified to give a white solid (2.4 g.; 42%). It was crystallised from dioxan to give γ-keto-γ-duryl-α:β-dimethylsuccinic acid in thick needles m.p. 147-148°. (Found: C, 73.7; H, 8.7. $C_{16}H_{22}O_3$ requires C, 73.3; H, 8.4%). Admixture with the above acid depressed the m.p. to 120-125°.

(2) In tetrachloroethane as solvent.

A sludge of the anhydride (LII) (2 g.) in tetrachloroethane (10 c.c.) was added (40 mins.) to a mechanically stirred ice cold suspension of freshly powdered anhydrous aluminium chloride (6 g.) and durene (2 g.) in tetrachloroethane (15 c.c.). Stirring was continued (4 hours) at 0° and the reaction mixture was left overnight at room temperature.

The products were worked up as above, the solvent being removed by distillation with steam. From the residue (LIII; R = H) and (LIV; R = H) were obtained (2.2 g.) and (0.2 g.) respectively. Over-all yield 60%.

Methyl-γ-keto-γ-duryl-α:β dimethylbutyrate (LIII; R = Me) (LIII; R = H) (0.5 g.), absolute methyl alcohol (4 c.c.) and few drops of concentrated sulphuric acid were refluxed (2 hours) on a steam bath. It was then cooled, diluted with water and extracted with ether. The ether layer was then extracted with sodium bicarbonate and dried (Na_2SO_4). A colourless oil was obtained which quickly solidified. It crystallised in colourless prisms (methanol). m.p. 103° (Found: C, 73.85; H, 8.5. $C_{17}H_{24}O_3$ requires C, 73.9; H, 8.7%).

Methyl-γ-keto-γ-prehnityl-α:β dimethylbutyrate (LIV; R = Me)

This was prepared as for (LIII; R = Me). in colourless plates m.p. 88° from methanol. (Found: C, 73.6; H, 8.85. $C_{17}H_{24}O_3$ requires C, 73.9; H, 8.7%).

Both above esters (200 mg.) were hydrolysed to the corresponding pure acids with 10% alcoholic caustic soda to give identical samples of the original acids.

α:β dimethyl-γ-(1-duryl)-$\Delta^{\alpha\beta}$- Crotonolactone (LV).

(After Fieser and Daudt[39]).

γ-Keto-γ-duryl-α:β-dimethyl butyric acid (100 mg.)

glacial acetic acid (3 cc.), and acetic anhydride (0.2 c.c.) were saturated with anhydrous hydrogen chloride. After standing overnight the acetic acid was removed in vacuo. Benzene (10 c.c.) was added, then distilled off; this was repeated twice. The oily residue quickly solidified. Crystallisation from benzene/light petroleum gave α:β-dimethyl-γ-(1-duryl)-Δβ-crotono-lactone in colourless shining leaflets m.p. 119°. (Found: C, 74.0; H, 7.84 $C_{16}H_{20}O_2$ requires C,78.65; H,8.02%). A positive Legal test[44),45)] was observed, (a pink colour with alkaline sodium nitroprusside which persists after acidification with acetic acid).

α:β- Dimethyl-γ-(1- prehnityl)-Δβ-crotono-lactone (LVI)

This was prepared as above from γ-keto-γ-prehnityl-:-dimethyl-butyric acid and was obtained as stout, colourless needles from benzene light petroleum. m.p. 114.5°. (Found: C,78.70; H,7.93 $C_{16}H_{20}O_2$ requires C, 78.65; H, 8.02%). The compound gave a positive Legal test.

Sodium hypobromite oxidation.

(I) γ-keto-γ-duryl-α:β-dimethyl-butyric acid (200 mg.) was added to an ice cold solution of 10% sodium hybobromite (20 c.c.). The resulting mixture was gradually heated to 100° with occasional shaking. It was maintained at 100° (4 hours). After cooling, it was filtered and acidified. The precipitated material was extracted with ether and ether

extract was dried (Na_2SO_4). After removal of ether, the residue was scratched. It was crystallised from ligroin and gave duryl carboxylic acid as needles m.p. 176-178°. A sample was not depressed by an authentic specimen of duryl carboxylic acid (Literature,[107],[108] 177-178°).

(2) γ-keto-γ-prehnityl-α:β-dimethyl-butyric acid was oxidised as above to give prehnityl carboxylic acid as needles from ligroin m.p. 166-168°, undepressed on admixture with an authentic specimen of prehnityl carboxylic acid (literature [109], m.p. 169°). The amide was obtained by refluxing the acid (50 mg.) with thionyl chloride (1 hour), followed by shaking with ammonium hydroxide. Prehnityl carboxylamide crystallised as plates m.p. 220°. (literature[110] m.p. 222°).

Removal of the side chain with concentrated hydrochloric acid.

(1) γ-keto-γ-duryl-α:β-dimethyl-butyric acid (200 mg.) was heated (5 hours) with concentrated hydrochloric acid in a sealed tube at 150°. The reaction mixture was diluted and extracted with ether. The ether was dried (Na_2SO_4) and removed. The residue was crystallised from methanol to give durene (5 mg.) m.p. 79-80° (literature, 80°).

(2) γ-keto-γ-prehnityl-α:β-dimethyl-butyric acid (500 mg.) similar to above gave prehnitene, b.p. 202°/760°mm. (literature, 204°/760 mm.)

γ-Duryl-α:β-dimethyl-butyric acid (LXII)

γ-keto-γ-duryl-α:β-dimethyl butyric acid (3.5g) was dissolved in aqueous sodium hydroxide. Excess alkali was carefully neutralized by adding dilute hydrochloric acid with continuous shaking (B.D.H. universal colour indicator). Copper-chromite catalyst[38] (2.5g) was then added and the mixture heated in a bomb at an initial hydrogen pressure of 130 atmospheres. The temperature was raised slowly to 240° and maintained for 12 hours. The reaction mixture was then filtered from catalyst, clarified with charcoal and the aqueous solution reduced (25 c.c.). A brownish sodium salt separated overnight. The latter was acidified and was obtained as a gummy white material (1 g.) which resisted all attempts to crystallise. The aqueous filtrate was acidified to give the original acid (1.2 g.) m.p. 147°.

Isomerization and cyclization with hydrofluoric acid.

The above gummy product (1 g.) was cautiously added to hydrofluoric acid (25 c.c.) in a platinum crucible (24 hours). Excess acid was then destroyed with alkali and the residual material was extracted with benzene. The benzene solution was then washed with alkali and water and dried (Na_2SO_4). After removal of the benzene, the residue b.p. 180° (air bath temperature)/4 mm. was a colourless oil (0.35 g.) which solidified when scratched. Crystallisation

from light petroleum gave 1:2:3:4- tetrahydro- 2:3:5:6:7:8- hexamethyl-naphthalene-1-one (LXIII), as stout long needles m.p. 120° and was not depressed on admixture with an authentic specimen p. 89 .

Condensation of Prehnitene with α:β - Dimethyl-Succinic Anhydride.

γ-Keto- γ-prehnityl-α:β- dimethyl butyric acid (LIV R = N).

In a three neck flask, provided with a sealed mechanical stirrer, a dropping funnel and a calcium chloride guard tube, (*t*)-α:β-dimethyl-succinic anhydride (16 g.) in pure tetrachloroethane (120 c.c.) was stirred and kept cool with ice; Prehnitene (16.5 g.) was added (1 hour) and at the same time freshly powdered anhydrous aluminium chloride (50 g.) in 5 portions (10 g.) (1 hour). Stirring was continued (6 hours). The reaction mixture was then left overnight at room temperature. The complex was then decomposed and the solvent removed in steam. The product was extracted with boiling sodium carbonate and filtered (charcoal). The clear filtrate was acidified and the sticky white solid was strongly cooled and scratched. The crude powdered acid was filtered (29 g. = 88%-) m.p. 140-160°. On fractional crystallisation from different proportions of benzene/light petroleum 2 isomeric crystalline products of γ-keto- γ-prehnityl-α:β-dimethyl-butyric acid were obtained.

One as stout needles m.p. 151.5-152° (main product) (Found: C, 73.0; H,8.2. $C_{16}H_{22}O_3$ requires C, 73.3; H, 8.4%). The other as small colourless plates m.p. 167-168° (Found: C, 73.4%; H, 8.3. $C_{16}H_{22}O_3$ requires C, 73.3; H, 8.4%).

Action of hydrofluoric acid.

The above acid m.p. 151.5° (1 g.) and hydrofluoric acid (25 c.c.) in a platinum crucible were allowed to stand at room temperature (30 hours). Excess acid was destroyed with alkali and the neutral material was extracted with benzene. On removal of the benzene, the residue (200 mg.) was crystallised from benzene light petroleum in stout needles m.p. 113-114° and was undepressed on admixture with α:β- dimethyl- γ-(1-prehnityl)-▷β- crotonolactone (p. 83. The aqueous extract was acidified to give the original acid (0.5 g.)

Reduction.

(1) Clemmensen method.[46] γ-Keto-γ-prehnityl-α:β-dimethyl-succinic acid (1 g.), zinc amalgam (10 g.), concentrated hydrochloric acid (50 g.), toluene (8 c.c.) and ethanol (2 c.c.) was boiled under reflux for 48 hours. Unchanged acid was recovered m.p. 145-160°. Undepressed on admixture with the original keto-acid.

(2) The Copper-chromite method: A neutral aqueous solution (150 c.c.) of the sodium salt of γ-keto-γ-prehnityl-α:β-dimethyl butyric acid (10 g.) prepared as described

for γ-keto- γ-duryl-α:β-dimethyl- butyric acid, and copper chromite catalyst (6 g.) were heated in a bomb. The initial hydrogen pressure was 130 atmospheres at 140°. Absorption was rapid and hydrogen consumption was equivalent to 1 mole. The temperature was then raised to 240° (15-18 hours). The pressure was 225-200 atmospheres. After cooling, hot water was added to dissolve the precipitated materials, and the catalyst removed by filtration. The filtrate was clarified with charcoal. It was now evaporated on a steam bath to (50 c.c.) and left to cool in the ice chest over night. The crystallised solid was filtered, dissolved in hot water, cooled and acidified. A mixture of a white solid and a gummy material was obtained. The mixture was agitated twice with ether (50 c.c.) and filtered. The solid was dried (0.6 g.). It was sparingly soluble in ether and benzene, insoluble in cold sodium carbonate. It gave a positive Legal test. Crystallisation from methanol gave α:β-dimethyl- γ-(1-prehnityl)- lactone (LXXXV) as colourless prisms m.p. 131-132°. (Found: C, 77.85; H, 9.1. $C_{16}H_{22}O_2$ requires C, 78.06; H, 8.9%).

The ether extract was dried (Na_2SO_4) and evaporated to give a white solid (6 g.). Crystallisation from benzene gave γ- prehnityl-α:β-dimethyl-butyric acid (LIV) as stout rosettes of fine needles. m.p. 135-6°. (Found: C, 77.2; H, 9.6. $C_{16}H_{24}O_2$ requires C, 77.4; H, 9.7%).

Admixture with the above lactone gave a depression in the m.p. (10-15°). From the original aqueous filtrate obtained after separation of the above two products the unchanged acid (1 g.) was obtained m.p. 165°-166° corresponding to the higher melting isomer of the γ-keto-acid and was undepressed on admixture with an authentic specimen.

Cyclisation of γ-prehnityl-α:β-dimethylbutyric acid (LXXXVI).

(1) Using hydrofluoric acid.

(After Fieser and Hersberg.[48])

The above acid (3 g.) and hydrofluoric acid (70 c.c.) were allowed to stand for 30 hours in a platinum crucible. The excess acid was destroyed and the neutral material was extracted with benzene. The benzene was dried (Na_2SO_4) and evaporated. The residual colourless oil (2.38 = 82%) b.p. 180° (air bath temperature)/ 4 mm. quickly solidified. Crystallisation from ligroin gave 1:2:3:4- tetra hydro -2:3:5:6:7:8- hexamethyl-naphthalene-1-one (LXIII) as colourless stout needles m.p. 120°. (Found: C, 83.2; H, 9.3 $C_{16}H_{22}O$ requires C, 83.4; H, 9.55%).

(2) Using anhydrous aluminium chloride.

(After Johnson and Green.[49])

To phosphorus pentachloride (3 g.) in a dry flask with a calcium chloride guard, was added dry benzene (10 c.c.) and the above acid (3 g.). After 15 mins. more benzene was added (30 c.c.) and then removed in vacuo at 60-70°

This was repeated three times. The residual acid chloride was cooled, dissolved in dry benzene (20 c.c.) and was added dropwise (15 mins.) to a suspension of freshly powdered aluminium chloride (35 g.) in benzene (50 c.c.) in a flask fitted with a mercury sealed stirrer and moisture guard at 0-10°, stirring was continued (5 hours). The complex was then decomposed with hydrochloric acid (1:1) at 0-10°. The organic layer was then washed twice with hydrochloric acid (1:1) (20 c.c. lots), then with saturated sodium carbonate solution followed by 5% potassium hydroxide solution and finally with water. It was then clarified with charcoal and dried (K_2CO_3). On removal of the benzene the residual oil rapidly solidified (2 g.; 71%). Crystallisation from light petroleum gave 1:2:3:4- tetrahydro -2:3:5:6:7:8- hexamethyl-naphthalene -1-one (LXIII) as stout needles m.p. 120° undepressed on admixture with the above product.

Oxidation of 1:2:3:4- tetrahydro -2:3:5:6:7:8- hexamethyl-naphthalene -1- one (LXIII).

The above ketone (0.2 g.) was heated with nitric acid (2 c.c.) (S.G. 1.42) and water (2 c.c.) in a sealed tube at 175° (6 hours). The resulting solution was evaporated to dryness and the residue was esterified with diazomethane. The product formed stout plates m.p. 184-6°, not depressed on admixture with an authentic specimen of methyl mellitate (literature m.p. 186°).

1:2-dihydro -2:3:4:5:6:7:8- heptamethyl-naphthalene(LXXVIII).

In an atmosphere of dry nitrogen in a flask fitted with a mercury sealed mechanical stirrer, dropping funnel and a double surface condenser with a moisture guard, an excess of Grignard solution was prepared from magnesium turnings (0.6g.), methyl iodide (3.5 g.) and ether (40 c.c.). To this was added a solution of 1:2:3:4- tetrahydro -2:3:5:6:7:8- hexamethyl-naphthalene-1-one in ether (20 c.c.) during 20 mins. The ether was removed and replaced by thiophene free dry benzene (30 c.c.). Refluxing was continued (36 hours). The reaction mixture was cooled in ice and decomposed with an ice cold saturated solution of ammonium chloride. The combined ether extracts of the aqueous layer were dried (Na_2SO_4). To the residual oil anhydrous formic acid was added (2 c.c.) and the mixture left at room temperature (2 hours), then it was diluted with water (10 c.c.), extracted with ether and the ether extract washed with sodium bicarbonate solution. The residual oil was then dissolved in ligroin and passed through an alumina column. The eluate was concentrated and the residual yellow oil distilled to give an almost colourless oil b.p. 170° (air bath temperature) /2 mm. which failed to crystallise.

1:2:3:4:5:6:7- Heptamethyl-naphthalene (LXVI)

The above oil (0.6 g.), palladised charcoal[51] (0.15 g.) and trichlorobenzene (3 c.c.) were refluxed (2 hours).

Hydrogen was evolved and was equivalent to one mole. The product was then diluted with benzene and filtered free from catalyst. The trichlorobenzene was removed in vacuo to give a liquid that rapidly crystallised (0.4 g. ≡ 66%). This was dissolved in benzene and passed through an alumina column. The eluate was concentrated and the residue crystallised from benzene/methanol to give heptamethyl-naphthalene m.p. 134°. An analytical specimen, prepared by the dissociation of a benzene solution of the picrate over alumina, formed colourless shining needles m.p. 134° (Found: C, 90.0; H, 9.5 $C_{17}H_{22}$ requires C, 90.2; H, 9.8%).

The picrate crystallised from methanol as dark brown needles m.p. 184.5° (Found: N, 9.6 $C_{23}H_{25}O_7N_3$ requires N, 9.5%).

The 1:3:5- trinitrobenzene complex was crystallised from benzene as orange red needles m.p. 210° (Found: N, 9.55 $C_{23}H_{25}O_6N_3$ requires N, 9.5%). The 2:4:7- trinitrofluorenone complex was obtained by mixing equimolecular quantities of trinitrofluorene and heptamethyl-naphthalene in glacial acetic acid. It was obtained as brown black light needles m.p. 212°. (Found: N, 7.5 $C_{30}H_{27}O_7N_3$ requires N, 7.75%).

The styphnate was crystallised from methanol as dark red needles m.p. 168°. (Found: N, 9.1, $C_{23}H_{25}O_8N_3$ requires 8.9%).

1-Chloromethyl-2:3:4:5:6:7:8- heptamethyl-naphthalene (LXXXIX).

(After Hewett[14]).

Heptamethyl-naphthalene (0.3 g.) and an ice cold solution of paraformaldehyde (100 mg.) in glacial acetic acid (3 c.c.) saturated with anhydrous hydrogen chloride until solution was clear, was shaken at room temperature (24 hours). The hydrocarbon formed a fine suspension and the solution became very dark. Hydrogen chloride was again passed through the reaction mixture (2 mins.) and shaking was continued for 24 hours. The reaction product was then cooled, diluted with ice and extracted with ether. The ice-cold ether extract was washed with ice-cold dilute sodium bicarbonate, iced water and then dried (Na_2SO_4). After removal of the ether, the dark oily residue was dissolved in cyclohexane and purified with charcoal. The nearly colourless oily residue (0.150 g.) decomposed on attempted distillation. Attempted crystallisation was unsuccessful.

The 1:3:5-trinitro-benzene complex crystallised out when a hot mixture of the oily product and trinitro-benzene in benzene was left to cool. It was crystallised from benzene/hexane to give dark red needles m.p. 160° decomp.) (Found: N, 8.8 $C_{24}H_{26}O_6N_3Cl$. requires N, 8.6%).

In one experiment, dilution of the reaction mixture of the chloro-methyl-compound with tap water gave a small amount

of a slightly yellow crystalline material m.p. 146-148°. This did not contain chlorine and analytical figures corresponded approximately with 1-hydroxymethyl- 2:3:4:5:6:7:8-heptamethyl-naphthalene. (Found: C, 82.8 ; H, 8.9 $C_{18}H_{24}O$ requires C, 84.3; H, 9.4%).

Octamethyl-naphthalene (LXV).

The above oily chloromethyl-compound (0.1 g.), purified cyclohexane (15 c.c.), 20% palladised charcoal (50 mg.) were shaken in presence of hydrogen at room temperature. Reduction was smooth and complete (1 mole of hydrogen) in 30 mins. After filtration from catalyst and removal of solvent, the residue was dissolved in hot methanol. Addition of a hot solution of picric acid in methanol yielded a black crystalline picrate derivative which was recrystallised from methanol. It was then dissolved in benzene and passed through an alumina column. The eluate was concentrated and the residue crystallised from benzene/light petroleum in long flat greenish plates. m.p. 174° (25 mg.). (Found: C, 89.9; H, 10.2 $C_{18}H_{24}$ requires C, 89.9; H, 10.1%).

The picrate formed short black needles (methanol). Softens at 173° and melts at 193°. (Found: N, 9.1 $C_{24}H_{27}O_7N_3$ requires 8.9%).

The 1:3:5- trinitro-benzene complex crystallised from benzene as dark red prisms m.p. 192-193°. (Found: C, 63.5; H, 6.2 $C_{24}H_{27}O_6N_3$ requires C, 63.6; H, 6.1%).

The 2:4:7- trinitro-fluorenone complex was obtained as black shining crystals (acetic acid) m.p. 209°. (Found: N, 7.7 $C_{31}H_{29}O_7N_3$ requires N, 7.6%).

1:2:3:4-tetrahydro -2:3:5:6:7:8-hexamethyl-naphthalene (XC).

(1) Clemmensen method. 1:2:3:4-Tetrahydro-2:3:5:6:7:8-hexamethyl-naphthalene-1-one (0.5g.), zinc amalgam (5g.), concentrated hydrochloric acid (25 c.c.), toluene (4 c.c.), ethanol (1 c.c.) were refluxed for 36 hours, further quantities of zinc amalgam (2g.) and concentrated hydrochloric acid (5 c.c.) were added, and reflux was continued 12 hours more. The ether extract was washed with a saturated solution of sodium bicarbonate and then with water. On removal of solvent, an oil (0.35g.) was obtained which was crystallised by rubbing with light petroleum. Crystallisation from methanol afforded light colourless needles (100 mg.) m.p. 108°. Further crystallisation from methanol (3 times) gave 1:2:3:4- tetra hydro-2:3:5:6:7:8- hexamethyl-naphthalene m.p. 111°. (Found: C, 88.9; H, 10.95 $C_{16}H_{24}$ requires C, 88.8; H, 11.2%).

(2) Huang-Minlon modification[47]. 1:2:3:4-Tetrahydro-2:3:5:6:7:8- hexamethyl-naphthalene-1-one (0.5), 90% hydrazine hydrate (2 c.c.), potassium hydroxide (0.3g.) and diethylene glycol (10 c.c.) were heated in the fashion described by Huang-Minlon (4 hours). The reaction mixture was then cooled, diluted with water and extracted with ether. The

ether extract was evaporated and the residue (0.3g.) was crystallised from methanol to give 1:2:3:4- tetrahydro-2:3:5:6:7:8- hexamethyl-naphthalene as colourless needles m.p. 109-111°. A sample of the latter was undepressed on admixture with a specimen obtained by the Clemmensen method.

1:2-Dihydro-2:3:5:6:7:8-hexamethyl-naphthalene (XCI)

1:2:3:4 Tetrahydro- 2:3:5:6:7:8-hexamethyl-naphthalene -1-one (1g.), glacial acetic acid (30 c.c.), platinum oxide catalyst[113] (.15g.) were shaken at room temperature. Absorption was quantitative (2 hours). The solution was now filtered from catalyst and the acetic acid removed in vacuo. The remaining oil was dehydrated with formic acid as described for 1:2-dihydro-2:3:4:5:6:7:8- heptamethyl-naphthalene. As an alternative procedure for dehydration, the former product was distilled b.p. 200° (air bath temperature)/4 mm. Product from each procedure was dissolved in benzene light petroleum (2:1) and passed through a column packed with alumina. The eluate was concentrated and the residue (0.7g.) was crystallised from methanol (3 times) to give colourless needles m.p. 117°, depressed to 104° on admixture with 1:2:3:4-tetrahydro- 2:3:5:6:7:8- hexamethyl-naphthalene. (Found: C, 89.4, H, 10.3 $C_{16}H_{22}$ requires C, 89.65; H, 10.35%).

1:2:3:4:6:7-Hexamethyl-naphthalene (LXVII).

(1) From 1:2 dihydro compound (XCI). The latter (0.6g.)

20% palladised charcoal (0.15g.) were heated gradually to 200° then kept between 200°-220° (2 hours). Hydrogen evolved corresponded to one mole. The product was dissolved in benzene, filtered from catalyst and clarified with charcoal. The solvent was removed and the solid thus obtained was crystallised from methanol (3 times) to give slightly green shining leaflets. Further purification by formation and dissociation of the picrate yielded crystals m.p. 145°. (Found: C, 90.6; H, 9.5 $C_{10}H_{20}$ requires C, 90.5, H, 9.5%).

(2) 1:2:3:4-Tetrahydro- 2:3:5:6:7:8-hexamethyl-naphthalene (XC).

The above compound (0.3g.), 20% palladised charcoal catalyst (50 mg.) was heated in carbon dioxide in a strong tube in a metal bath. The temperature was raised slowly to 250°, kept between 250-280 (2 hours), then heated finally at 300° (10 mins.) Evolution of hydrogen corresponded approximately to 2 moles. 1:2:3:4:6:7-Hexamethyl-naphthalene crystallised in leaflets m.p. 145° (0.2g.) and was undepressed on admixture with the above hydrocarbon.

The picrate crystallised from methanol in dark red needles m.p. 190.5°. (Found: N, 9.8 $C_{22}H_{23}O_7N_3$ requires N, 9.5%).

The 1:3:5- trinitrobenzene complex was obtained as orange needles (methanol) m.p. 215°. (Found: N, 9.9 $C_{22}H_{23}O_6N_3$ requires N, 9.9%).

The 2:4:7-trinitrofluorenone complex crystallised in dark brick needles (acetic acid). m.p. 210°. (Found: N, 8.4 $C_{29}H_{25}O_7N_3$ requires 8.0%).

Dehydrogenation of 1:2:3:4-tetrahydro- 2:3:5:6:7:8-hexa methyl-naphthalene-1 one (LXIII)

The above ketone (0.4g.) was dehydrogenated as described for the above tetrahydro-naphthalene. The product was then dissolved in benzene, filtered from catalyst and the solvent evaporated. The residue dissolved in hot methanol, was treated with a slight excess of picric acid, in methanol, and cooled. The dark red crystalline picrate was filtered (100 mg.) m.p. 190°. It was then dissociated by passing through a column packed with alumina to give 1:2:3:4:6:7-hexamethyl-naphthalene m.p. 145° undepressed on admixture with an authentic specimen. The filtrate mother liquor was freed from picric acid by shaking with ammonia solution. It was then extracted with ether. The ether was dried (Na_2SO_4) and evaporated. The residue was crystallised to give 1:2:3:4-tetra hydro-2:3:5:6:7:8-hexamethyl-naphthalene as colourless needles (40 mg.), m.p. 108-110° undepressed on admixture with an authentic specimen.

γ-Keto- γ-prehnityl-α-methyl-butyric acid (XCV)

Prehnitene (12 g.) was slowly added (40 mins.) to a stirred suspension of freshly powdered anhydrous aluminium chloride (40.5) and α-methyl-succinic anhydride (10g.) in tetrachloro-ethane (100 c.c.). Stirring was continued (5 hours) at 0°, the reaction mixture left overnight then decomposed as usual. The solvent was distilled in steam and the residue dissolved in sodium carbonate solution and filtered (charcoal). The filtrate was concentrated and left to crystallise in the refrigerator. As no sodium salt separated from the concentrated solution, it was acidified. A white gum precipitated which solidified on scratching (18g. = 82%). Crystallisation from benzene gave γ-keto- γ-prehnityl-α-methyl-butyric acid as prisms m.p. 130-131°. (Found: C, 72.55; 8.1 $C_{15}H_{20}O_3$ requires C, 72.55; H, 8.1%). Fractional crystallisation from benzene/light petroleum or methyl alcohol gave no other product.

Ethyl- γ -keto- γ -prehnityl-α -methyl butyrate (XCV; R = C_2H_5).

The above acid (0.3g.) was esterified with ethyl alcohol as described for γ -keto- γ duryl- α : β -dimethyl-butyric acid. The ethyl ester was obtained as colourless short rods from ethanol. m.p. 68.5°. (Found = C, 73.5; H, 8.9 $C_{12}H_{22}O_3$ requires C, 73.8; H, 8.8%).

The original acid m.p. 130-131° was regenerated when the above ester was hydrolysed.

Sodium hypobromite oxidation.

γ-Keto- δ -prehnityl- α-methyl-butyric acid was oxidised as described for γ-keto- δ -prehnityl- α : β -methyl butyric acid. It gave prehnityl carboxylic acid[109] m.p. 165-168° undepressed on admixture with an authentic specimen. From the latter, prehnityl carboxylamide m.p. 220-222° was obtained. (literature[110], 222°)

γ-prehnityl-α-methylbutyric acid (XCVI)

γ-Keto- δ -prehnityl-α -methylbutyric acid (15g.), was added slowly to a mixture of zinc amalgam (90g.), concentrated hydrochloric acid (250 c.c.), toluene (20 c.c.) and ethanol (5 c.c.) then refluxed for 36 hours. Concentrated hydrochloric acid (100 c.c.) was then added and reflux was continued 12 hours more. The product was now extracted with ether and the ether extract dried (Na_2SO_4) and evaporated. The residue quickly solidified (12g. = 86%). Crystallisation from methanol gave white leaflets m.p. 106-107°. (Found: C, 76.6; H, 9.6 $C_{15}H_{22}O_2$ requires C, 76.9; H, 9.5%).

1:2:3:4-tetrahydro-2:5:6:7:8-pentmethyl-naphthalene-1-one (XCVII)

(1) Using hydrofluoric acid[48]

The above acid (5.g.), hydrofluoric acid (100 c.c.) in

a platinum crucible was left at room temperature (24 hours). The cyclised product obtained (3.8g. = 83%) was crystallised from ligroin (4 times) to give colourless small needles m.p. 78.5° (Found: C, 83.2; H, 9.2 $C_{15}H_{20}O$ requires C, 83.4; H, 9.3%).

(2) Using anhydrous aluminium chloride.[49]

The above acid (5g.) was cyclised as described for 1:2:3:4-tetrahydro 2:3:5:6:7:8-hexamethyl-naphthalene -1-one gave a material b.p. 170° (air bath temperature)/4 mm. (3.5g. = 75%). Crystallisation from ligroin affords 1:2:3:4-tetrahydro-2:5:6:7:8-pentamethyl-naphthalene-1-one as stout needles m.p. 78.5° undepressed on admixture with the above sample.

Oxidation of 1:2:3:4-tetrahydro-2:5:6:7:8-pentamethyl-naphthalene-1-one.

The above ketone (0.2g.) was oxidised with nitric acid to give mellitic acid isolated as methyl mellitate plates m.p. 186° undepressed on admixture with an authentic specimen, (literature, 186°).

1:2:3:4-Tetrahydro-2:5:6:7:8-hexamethyl-naphthalene (XCIX)

(1) Clemmensen method. The above cyclised ketone (1.2g.) was reduced as described for 1:2:3:4-tetrahydro-2:3-5:6:7:8-hexamethyl-naphthalene gave an oil (0.8g.) which failed to crystallise after distillation and rubbing with

ligroin.

(2) Huang-Minlon modification. The above cyclised ketone (XCVII) (0.5g.) gave an oily product (0.3g.) which failed to crystallise.

1:2-dihydro-3:5:6:7:8-pentamethyl-naphthalene (C)

The above cyclised ketone (XCVII) (1.2g.), glacial acetic acid (30 c.c.), Adam's catalyst (0.12g.) absorbed 1 mole of hydrogen (2.5 hours). The product after removal of solvent in vacuo was dehydrated with anhydrous formic acid then passed through a column packed with alumina. The eluate was concentrated and the residue crystallised from methanol as colourless needles m.p. 64° (0.63g.) (Found: C, 89.7; H, 10.1 $C_{15}H_{20}$ requires C, 89.9; H,10.1%).

1:2:3:4:6-Pentamethyl-naphthalene (LXX)

(1) From 1:2:3:4-tetrahydro-2:5:6:7:8-Pentamethyl-naphthalene (XCIX)

The above oily product (0.5g.) and 20% palladised charcoal (80 mg.) were heated slowly in carbon dioxide in a strong tube in a metal bath. The temperature raised to 250°, kept between 250-280° (2 hours) and finally at 300° (10 mins.) Evolution of hydrogen corresponded to 2 moles. The product was crystallised from methanol as colourless rhombohedra m.p. 83-85° (0.25g.) A sample purified via the picrate gave m.p. 85°. (Found: C, 90.7; H, 9.35 $C_{15}H_{18}$ requires C, 90.85; H, 9.15%).

(2) From 1:2-dihydro-3-5:6:7:8-pentamethyl-naphthalene (C).

The above dihydro-compound (XCI) (0.4g.) and 20% palladised charcoal (0.1g.) was heated gradually to 200° then kept between 200-220° (2 hours). Hydrogen evolved corresponded to 1 mole. The product was now cooled, dissolved in benzene and filtered from catalyst. The benzene was evaporated and the residue (0.3g.) was crystallised from methanol to give 1:2:3:4:6-penta methyl-naphthalene as colourless rhombohedra m.p. 85° identical with the above product.

The picrate crystallised from methanol in light red needles m.p. 176° (Found: N, 10.0%; $C_{21}H_{21}O_7N_3$ requires N, 9.8%).

The 1:3:5-trinitro benzene complex was obtained as yellow needles from benzene m.p. 187°. (Found: N, 10.0 $C_{21}H_{21}O_6N_3$ requires N, 10.2%).

The 2:4:7-trinitrofluorenone complex was crystallised as red needles from acetic acid m.p. 174° (Found: C, 8.4 $C_{28}H_{23}O_7N_3$ requires 8.2%).

1:2-dihydro-3:4:5:6:7:8-hexamethyl-naphthalene (XCVIII)

1:2:3:4-Tetrahydro-2:5:6:7:8 pentamethyl-naphthalene -1-one (XCVII) (1.5g.) was treated with excess methyl magnesium iodide as already described for 1:2-dihydro-2:3:4:5:6:7:8-heptamethyl-naphthalene (LXXVIII), an oil b.p. 170° (air bath temperature)/4 mm. (0.gg.) The latter failed to

crystallise after several attempts.

1:2:3:4:5:6-hexa methyl-naphthalene (LXVIII)

The above dihydro compound (0.gg.), trichlobenzene (3 c.c.), 20% palladised charcoal (0.15g.) were refluxed (2 hours). The product was worked up as described for 1:2:3:4:5:6:7:8-heptamethyl-naphthalene (LXVI). The hydrocarbon was further purified by the dissociation of its picrate derivatives to give colourless needles (methanol) m.p. 81.5°. (Found: C, 90.3; H, 9.4 $C_{16}H_{20}$ requires C, 90.5; H, 9.5%).

The picrate was crystallised in dark red needles (methanol), m.p. 167-8°. (Found: N, 9.6 $C_{22}H_{23}O_7N_3$ requires N, 9.5%)

The 1:3:5-trinitobenzene complex was obtained in orange needles from benzene m.p. (186°). (Found: N, 9.8 $C_{22}H_{23}O_6N_3$ requires N, 9.5%).

The 2:4:7-trinitrofluorenone complex was crystallised from acetic acid m.p. 181° (Found: N, 7.8 $C_{29}H_{25}O_7N_3$ requires 7.95%).

The Maleic anhydride adduct and its oxidation to prehnitic acid is described on p.122 .

1-Chloromethyl-3:5:6:7:8-pentamethyl-naphthalene (CIV)

1:2:3:4:6-Pentamethyl-naphthalene (0.3g.) was chloromethylated as described for 1-chloromethyl-heptamethyl-naphthalene (LXXXIX) to give an oil which quickly became

brown in colour.

1:2:3:4:5:7- Hexamethyl-naphthalene (LXIX)

The above oily chloromethyl-compound (150 mg.) was reduced as described for octamethyl-naphthalene (LXV) to give a solid m.p. 135-7° (50 mg.) Purification via the picrate gave colourless cubes from methanol m.p. 140°. (Found: C, 90.45; H, 9.45 requires C, 90.5; H, 9.5%). Mixed melting point with 1:2:3:4:5:6-hexamethyl-naphthalene 60-65°. Mixed melting point with 1:2:3:4:6:7- hexamethyl-naphthalene 132-134°.

The picrate crystallised as dark red needles (methanol) m.p. 188°. (Found: N, 9.75 $C_{22}H_{23}O_7N_3$ requires N, 9.5%)

The 1:3:5-trinitrobenzene complex was obtained as light orange needles from benzene m.p. 207°. (Found: N, 9.9 $C_{22}H_{23}O_6N_3$ requires N, 9.9%).

The 2:4:7-trinitrofluorenone complex crystallised as stout brown needles from acetic acid. 199°. (Found: N, 7.85 $C_{29}H_{25}O_7N_3$ requires N, 7.95%)

2-Chloromethyl-3:4:5:6:7:8-hexa methyl-naphthalene (CI)

1:2:3:4:5:6-Hexamethyl-naphthalene (LXVIII) (0.3g.) was chloromethylated as described above to give a brown oily product.

The picrate crystallised in dark brick needles m.p. 178-180° decomp. (Found: N, 8.9 $C_{23}H_{24}O_7N_3Cl$ requires N, 8.6%).

The 1:3:5-trinitrobenzene complex was obtained as red needles from benzene m.p. 188° decomp. (Found: N, 9.1 $C_{23}H_{24}O_6N_3Cl$ requires N, 8.9%).

Reduction of 2-chloromethyl-3:4:5:6:7:8-hexamethyl-naphthalene (CI)

The above product (150 mg.) was reduced as described for the above chloromethyl compound to give 1:2:3:4:5:6:7-heptamethyl-naphthalene m.p. 134° (50 mg.) undepressed on admixture with an authentic specimen.

The picrate derivative m.p. 184.5°. The 2:4:6-trinitro-fluorenone complex m.p. 212°. Mixed melting points were undepressed on admixture with authentic specimens.

Octamethyl-naphthalene from 2:3:4:5-tetramethyl-5-prehnityl-hexane 2:5-diol (LXXVIII).

Methyl- γ-keto- δ-prehnityl-α: β-dimethyl-butyrate (LIV R = Me) (3g.) was added to excess methyl magnesium iodide as described for (LXXVIII). The reaction mixture was then refluxed for 60 hours.

The product was decomposed with cold saturated solution of ammonium chloride. The ether extract was evaporated to give an oil (2.4g.) which quickly darkened. Water was formed on the sides of the receiver on distillation.

The oily distillate rapidly decolourised both bromine water and potassium permanganate solution. With palladium black as catalyst, 2 equivalents of hydrogen were absorbed.

The crude oil from the Grignard reaction (1.5g.) and hydrofluoric acid (40 c.c.) were left in a platinum crucible (36 hours). Excess of acid was destroyed with dilute alkali and the product extracted with ether. Ether extracted was dried (Na_2SO_4) and evaporated. The residual gummy material (1.2g.) failed to crystallise.

To a hot solution of the above product in acetic acid, a hot solution of 2:4:7-trinitrofluorenone was added. The colour of the solution became black and on cooling the complex crystallised in black prisms m.p. 207-209° (30 mg.). The hydrocarbon was not dissociated by passing a benzene solution of the above complex in a column packed with alumina. However dissociation was effected by boiling the fluorenone complex with a mixture of stannous chloride, hydrochloric acid and acetic acid for 15 mins. The neutral organic extract deposited a powder m.p. 170-172° (5 mg.) crystallisation from methanol gave octamethyl-naphthalene (LXV) m.p. 172-3° undepressed on admixture with an authentic specimen. The 1:3:5-trinitrobenzene complex m.p. 192-193° was undepressed on admixture with an authentic specimen.

The mother liquor obtained after filtration of the fluorenone complex was freed from 2:4:7-trinitrofluorenone by reduction of the latter, to give an oil (LXXX) (0.5g.) which did not crystallise.

The above oil (LXXX) (0.2g.) was oxidised with nitric

acid in a sealed tube as described for 1:2:3:4-tetrahydro-2:3:5:6:7:8- hexamethyl-naphthalene-1-one (LXIII) to give mellitic acid isolated as methyl-mellitate m.p. 183-185°. Undepressed on admixture with an authentic specimen.

The above oil (LXXX) (0.4g.) was heated with selenium (0.5g.) in a sealed tube at 310-340° (24 hours). The product was dissolved in benzene, filtered and clarified with charcoal. The benzene was evaporated and the residue dissolved in acetic acid (2 c.c.) and added to 2:4:7-trinitrofluorenone. On cooling, the complex crystallised in black crystals m.p. 209°. Dissociation as described before gave octamethyl-naphthalene m.p. 171-3° (6 mg.) undepressed on admixture with an authentic specimen.

The picrate was obtained as black needles from methanol m.p. 193° undepressed on admixture with an authentic specimen.

2:5-Dihydroxy-2:5-dimethylhexane (CV)

(After Harris and Weil[85]).

To a Grignard solution prepared from magnesium (6.g.), dry ether (120 c.c.) and methyl iodide (35g.), succinic ester was added (11g.) (20 mins.) The mixture was refluxed for 30 mins. The complex was then decomposed with an ice cold saturated solution of ammonium chloride. The ether extract was evaporated. The residual solid crystallised with 6 moles of water. The anhydrous compound was obtained by heating the crystallised material on a water bath in vacuo. 2:5-dihydroxy- 2:5-dimethyl-hexane crystallised in plates from light-petroleum m.p. 89° (8g. = 45%) (literature[85],[75] 89°).

2:5-dichloro-2:5-dimethylhexane (CVI)

(After Bruson and Kroeger[75]).

The above dihydroxy compound (4g.) was dissolved in concentrated hydrochloric acid (20 c.c.) and hydrogen chloride was passed through the mixture (15 mins.). The precipitated material was filtered, washed with water and methanol and dried in vacuo (4.g. = 90%). The product was obtained as white leaflets m.p. 63-64°. (literature 64°).

2:3-Dihydroxy-2:3:4:5-tetramethylhexane (CXIV)

Methyl-(±)-α:β-dimethyl succinate (10g.) (b.p. 200°/760 mm. was treated with a Grignard solution as described above

to give an oil b.p. 55-60°/10-12 mm. (literature b.p. 55°/12 mm.)

Condensation of p-xylene with 2:5-dihydroxy-2:3:4:5-tetramethyl hexane (CXIV)

Dry tetrachloroethane (15 c.c.), anhydrous aluminium chloride (5g.) and p-xylene (4.g.) were stirred at room temperature while (CXIV) was added (1.5g.) (10 mins.) The water bath temperature was now raised slowly to 60° and kept constant (5 hours). The reaction mixture was then left overnight and the complex was decomposed with ice and hydrochloric acid. Tetrachloroethane was removed in steam. The residue was fractionally distilled to give an oil (A) b.p. 140-160° (oil bath temperature)/2 mm. (0.5g.) and a semi-solid (B) b.p. 200°/2 mm., and tarry residue (2.5g.) Oil (A) (0.5g.), selenium (0.5g.) was heated in a sealed tube at 330° (24 hours). The product was dissolved in benzene and filtered from selenium and clarified with charcoal. The solvent was removed. The residue failed to crystallise. The latter was then dissolved in hot methanol and added to a solution of picric acid in methanol; a deep red colour developed and on cooling deep red crystals of a picrate derivative was obtained (8 mg.) m.p. 182-185°. The latter was dissociated over an alumina column to give a white powder m.p. 125-130° (3 mg.) Absorption spectrum in cyclohexane showed a strong broad band between 2750 and 3100A°.

Semisolid (B) was crystallised from benzene/ligroin, then from benzene to give yellowish shining leaflets m.p. 241-242° having a strong blue fluorescence in benzene solution. (Found: C, 92.7; H, 7.65. $C_{17}H_{16}$ requires C, 92.7; H, 7.3%).

(1:2:4-Trimethylanthracene m.p. 241,[79] 243[78].

The 1:3:5-trinitrobenzene complex was obtained as wine-red prisms from benzene m.p. 146-148° decomp.

The 2:4:7-trinitrofluorenone complex was crystallised as brownish black needles from acetic acid m.p. 160-162° decomp. (Found: N, 7.75 $C_{30}H_{21}O_7N_3$ requires N, 7.8%).

Absorption spectrum for compound (B) is shown in Fig. 1 95% Ethyl alcohol was used as solvent.

~~Oxidation of oil (B) ethyl was used as solvent.~~

Chromic acid oxidation of compound (B)

(After Morgan and Coulson[77]).

To a boiling solution of the above compound (50 mg.) in acetic acid (3 c.c.) a concentrated solution of chromic anhydride (0.1g.) in dilute acetic acid (1 c.c.) was gradually added. After one hour, the product was cooled, and poured into water, then extracted with ether. The ether extract was washed with water, dilute sulphuric acid, aquous sodium bicarbonate and again with water. The ether was then dried (Na_2SO_4) and evaporated leaving a yellow solid m.p. 155-158°. (1:2:4-trimethylanthraquinone[78] m.p. 161-163°.

The condensation of prehnitene (LXXXIII) with 2:5-dihydroxy-2:5-dimethylhexane (CVI)

Prehnitene (2.3g.), anhydrous aluminium chloride (8g.) and tetrachloroethane (20 c.c.) were mechanically stirred while 2:5-dihydroxy-2:5-dimethyl hexane (2g.) was added dropwise. The above procedure for the p-xylene condensation was then followed exactly. The hydrolysed material was fractionally distilled to give a yellow oil (C) b.p. 130-150° (oil bath temperature)/2 mm. (0.8g.), a dark yellow solid (D) b.p. 200°/2 mm. (0.1g.) and a tarry residue (3g.)

Oil (C) (0.5g.) and selenium (0.5g.) were heated in a sealed tube at 330° (24 hours). From the reaction mixture, a dark red picrate was obtained m.p. 183-185° (10 mg.) undepressed with the picrate obtained from the dehydrogenation product of oil (A).

Dissociation of the picrate derivative on an alumina column gave a solid hydrocarbon m.p. 125-128°, undepressed on admixture with the hydrocarbon obtained from (A).

Oxidation of oil (C) (0.3g.) gave mellitic acid isolated as methyl mellitate m.p. 183-185 undepressed on admixture with an authentic specimen.

Compound (D) was crystallised from benzene in light yellow leaflets having a strong blue fluorescence m.p. 236-237°, depressed by 40° on mixing with compound B. (not sufficient for analysis).

1:3:5-Trinitrobenzene complex was crystallised in wine-red prisms from benzene m.p. 162-4°.

2:4:7-Trinitro-fluorenone complex was crystallised in black brown needles. m.p. 183-185°.

Absorption spectrum curve is shown in Fig. 2. 95% ethyl alcohol was used as solvent.

3:4-Dimethylhexane-3:4-diol

(After Whitby and Macallum[87]).

The procedure used is similar to that described for pinacole-hydrate[88]. b.p. 195°/760 mm., 123°/25 mm. (literature 123°/125 mm.)

3:4 Dichloro-3:4-dimethylhexane (XCIV)

(After Bruson and Kroeger[75]).

3:4-Dimethylhexane-3:4 diol (20g.), concentrated hydrochloric acid (25 c.c.) were shaken while passing hydrogen chloride through the solution (20 mins.) Separation of 2 layers occurred. The organic layer was washed with water, dried and distilled, b.p. 65-75°/10-12 mm. 163-5°/760 mm. (16g.) (literature[86] b.p. 114-115°/18 mm., 165-166°/760 mm.)

Condensation of o-xylene with 3:4-dichloro-3:4-dimethylhexane (XLIV)

o-Xylene (80g.), anhydrous aluminium chloride (10g.) were stirred at room temperature, then 3:4 dichloro-3:4-dimethylhexane (18g.) was added slowly (2 hours). The temperature of the reaction mixture was then raised to 40° and

maintained for 6 hours then left overnight at room temperature. The reaction products were decomposed with ice and hydrochloric acid. Unreacted starting materials were distilled. The remaining oil was carefully fractionated in a special distillation flask, 3 fractions were collected.

(1) B.p. 110-130° (oil bath temperature)/8 mm. (5g.)

(2) B.P. 130-150°/ /8 mm. (10g.)

(3) B.P. 150-170° /6 mm. (7g.)

Fraction (1) gave no colour with picric acid after dehydrogenation.

Fraction (2) (5g.) and selenium (8g.) were heated in a sealed tube (24 hours). The product was dissolved in acetic acid, filtered and concentrated. To the residue was added a solution of 2:4:7-trinitrofluorenone, a dark red colour was formed and crystalline dark red needles of the fluorenone complex were obtained m.p. 203-204° (40 mg.) (Found: N,8.15 $C_{29}H_{25}O_7N_3$ requires N, 8.0%). The complex was boiled with a mixture of stannous chloride, hydrochloric acid and acetic acid to give a hydrocarbon m.p. 133-135° (10 mg.) (Found: C, 89.7; H, 10.0 $C_{16}H_{20}$ requires C, 90.5; H, 9.5%) Analytical figures are approximately correct for hexamethylnaphthalene. Admixture with 1:2:3:4:5:7-hexamethyl-naphthalene (LXIX) and the corresponding trinitrofluorenone complex and picrate produced no depression. Identical absorption spectrum was obtained for the 2 samples Fig. 9.

The picrate was obtained as red needles from methanol m.p. 187-188°. (Found: N, 9.6 $C_{22}H_{23}O_7N_3$ requires N, 9.5%).

Fraction (3) solidified after distillation. It was first crystallised from ligroin m.p. 142°, then from methanol m.p. 144-145° (300 mg.). A sample obtained by the dissociation of the picrate gave shining leaflets of 1:2:3:4:6:7-hexamethyl-naphthalene (LXVII) m.p. 145° (Found: C, 90.1: H, 9.75 $C_{16}H_{20}$ requires C, 90.5; H, 9.5%)

The picrate was obtained in red needles (methanol) m.p. 190-191°. (Found: N, 9.5 $C_{22}H_{23}O_7N_3$ requires N, 9.5%)

The 2:4:7-trinitrofluorenone-complex crystallised from acetic acid in dark brick coloured needles m.p. 210°. Both hydrocarbon and corresponding derivatives were undepressed on admixture with authentic specimens of 1:2:3:4:6:7-hexamethylnaphthalene and derivatives. Identical absorption spectra curves were also obtained Fig. 6.

Condensation of prehnitene (LXXXIII) with 3:4-dichloro-3:4-dimethylhexane (XLIV)

(A) At 35-40°. Prehnitene (10g.) and anhydrous aluminium chloride (10g.) were stirred at room temperature 3:4-dichloro-3:4-dimethylhexane (XLIV) was then added slowly (2 hours) (15g.). Hydrogen chloride fumes were evolved and the reaction mixture became warm. The temperature was then raised to 40° and kept constant for 5 hours. The complex was decomposed in the usual way and the unreacted materials

were removed. The oily residue was faintly coloured with picric acid solution and no picrate was isolated. The above residue (8g.), selenium (8g.) was heated in a sealed tube at 340° for 24 hours. The purified product was then distilled carefully, 4 fractions were collected:-

(1) B.p. 110-130° (oil bath temperature)/2 mm. (2g.)

(2) B.p. 130-150° /2 mm. (1.5g.)

(3) B.p. 150-160° /2 mm. (1g.)

(4) B.p. above 160° /2 mm. (0.5g.)

Fraction (1) gave no picrate.

Fraction (2) gave a red picrate m.p. 140-1° (40 mg.) The latter was dissociated to 1:2:3:4:6:7-hexamethyl-naphthalene (LXVII) m.p. 144-145°. (10 mg.)

Fraction (3) formed a brown black 2:4:7-trinitrofluorenone complex (50 mg.) m.p. 210-212°. The dissociation of the latter gave 1:2:3:4:5:6:7-heptamethyl-naphthalene (LXVI) as colourless leaflets m.p. 132-3° (5 mg.)

Fraction (4) gave 2:4:7-trinitrofluorene complex (10 mg.) m.p. 207-209°. The dissociation of the latter gave octamethyl-naphthalene (LXV) m.p. 171-173°. (2 mg.)

Full identity was established by mixed melting point of hydrocarbons and derivatives.

Absorption spectra curves are shown in Figs. 6, 7 and 8 for (LXVII), (LXVI) and (LXV) respectively.

(B) At 60°. Prehnitene (10g.), anhydrous aluminium

chloride (10g.) were stirred, 2,:4-dichloro-3:4-dimethyl-hexane (XLIV) (15g.) was added (2 hours). The temperature was maintained at 60° for 7 hours then the reaction mixture was left at 35-40° overnight. The complex was decomposed and unreacted materials were removed. The oily residue was distilled carefully and 4 fractions collected.

(1) B.P. 110-130° (oil bath temperature) /1 mm. (2.5g.)

(2) B.p. 130-150° /1 mm. (2.g.)

(3) B.p. 150-170° /1 mm. (0.7g.)

(4) B.p. above 170° /1 mm. (2.g.)

Fraction (1) gave no picrate.

Fraction (2) gave a dark brick red picrate m.p. 184-185° (20 mg.) which on dissociation gave 1:2:3:4:5:6:7- heptamethyl-naphthalene (LXVI).

Fraction (3) gave small black needles of 2:4:7-trinitro-fluorenone complex. m.p. 208 (30 mg.) which on dissociation gave octamethyl-naphthalene (LXV).

Full identity is established by mixed melting points of hydrocarbons and derivatives with authentic specimens.

Fraction (4) solidified after distillation. It gave a blue fluoresence in benzene solution. Crystallisation from benzene gave colourless shining plates(having a blue fluores-ence) of a hexamethylanthracene m.p. 236-237°. (Found: C, 91.5; H, 8.5 $C_{20}H_{20}$ requires C, 91.5; H, 8.5%).

The picrate was obtained as black crystals from methanol

m.p. 214° (Found: N, 8.7° $C_{26}H_{25}O_7N_3$ requires N, 8.58%).

The 1:3:5-trinitrobenzene complex was obtained as wine-red needles from benzene. (Found: N, 8.85 $C_{26}H_{25}O_6N_3$ requires N, 9.0%)

The 2:4:7-trinitrofluorenone complex crystallised in brownish black crystals from acetic acid. m.p. 228°. (Found: N, 7.4 $C_{33}H_{27}O_7N_3$ requires N, 7.3%).

The absorption spectrum curve is shown in Fig. 3. 95% ethanol was used as solvent.

Chromic acid oxidation of fraction (4).

After Morgan and Coulson[77].

Above hydrocarbon m.p. 236 (0.2g.) was oxidised with a mixture of chromic anhydride (0.4g.) in dilute acetic acid (3 c.c.). From the ether extract a yellow solid was obtained. The latter was purified by sublimation and crystallisation from methanol to give yellow crystals of a hexamethylanthraquinone m.p. 199°. (Found: C, 82.9; H, 7.4. $C_{20}H_{20}O_2$ requires C, 82.2; H, 6.9%).

THE CONDENSATION OF POLYMETHYL-NAPHTHALENES WITH MALEIC ANHYDRIDE.

A mixture of each hydrocarbon (200 mg.) (1 mole), freshly distilled maleic anhydride (3g.) (30 moles) and dry thiophene-free benzene (4 c.c.) was refluxed (48 and 72 hours). A colour change was noticed on mixing the reactants. It gradually deepened from yellow to deep red or greenish red. The benzene was then either removed in vacuo or evaporated by a current of air.

Either of the following procedures was followed:-

(A) The reaction mixture was diluted with excess water and shaken for 10 mins. until all maleic anhydride had dissolved. The adduct and unchanged hydrocarbon floated on the top. In most cases it was solid mixed with droplets of oil. This was extracted once with ether. The ether extract was dried (Na_2SO_4) and distilled off to leave a mixture of adduct and hydrocarbon. It was now boiled (5 mins.) with 5% potassium hydroxide. The unchanged hydrocarbon was then extracted from the mixture with ether (twice). After drying and removal of the ether, this gave the weight of the recovered hydrocarbon. The aqueous layer was acidified and cooled. The precipitated adduct dibasic acid was filtered. The aqueous layer was also extracted with ether and the ether was dried and removed. The combined yields of filtered material and residue of the ether extract corresponded to the weight

of adduct. It may be weighed as anhydride by dissolving the crude adduct in ethylacetate containing a few drops of acetic anhydride. On concentration, a quantitative yield of adduct anhydride was obtained.

(2) To the reaction mixture, 40% potassium hydroxide (10 c.c.) was added slowly and then the reaction product was boiled (5 mins.) The product was now cooled in the ice chest for several hours and the precipitated dipotassium salt was filtered and washed with ether. It can be weighed as such, or acidified and obtained as the adduct dibasic acid or anhydride. The alkaline layer was extracted with ether. The combined ether extract and washings gave on evaporation, the weight of the recovered hydrocarbon.

The adduct dibasic acids were difficult to purify. With ethyl acetate or light petroleum they either reverted partially to the anhydride.

The adduct anhydride in each experiment was obtained by first crystallising the crude adduct dibasic acid from ethyl acetate containing a few drops of acetic anhydride or acetyl chloride, followed by the use of an appropriate solvent.

The reversibility of the reaction was shown in each adduct by distilling the latter (50 mg.) at 150-180° (oil bath temperature)/2-4 mm. The distillate was then dissolved in 5% potassium hydroxide and extracted with ether. The ether extract after drying and evaporation gave 90% of pure hydrocarbon.

The rate of reaction of each hydrocarbon with maleic anhydride is shown in table (IV) both after 48 and 72 hours of reflux.

TABLE (IV)

Polymethyl Naphthalene	solvent and crystalline form	m.p. of adduct	Formula	Found%		required %	
				C	H	C	H
1:2:3:4:6-Pentamethyl-	acetone (white powder)	138-139°	$C_{19}H_{20}O_3$	76.3	7.3	77.0	6.8
1:2:3:4:5:6-Hexamethyl-	ethyl-acetate (prisms)	134-136°	$C_{20}H_{22}O_3$	77.15	7.35	77.4	7.15
1:2:3:4:6:7-Hexamethyl-	ethyl-acetate (cubes)	170° decomp.	$C_{20}H_{22}O_3$	77.25	7.25	77.4	7.15
1:2:3:4:5:6:7-Heptamethyl	ethyl acetate (prisms)	160 decomp.	$C_{21}H_{24}O_3$	77.65	7.6	77.7	7.45
Octamethyl-	light petroleum (prisms)	176-168° decomp.	$C_{22}H_{26}O_3$	77.8	7.8	78.05	7.7

To each adduct (3 mg.) a hot solution of picric acid in methanol and separately 2:4:7-trinitrofluorenone in acetic acid were added. No change in colour was observed nor could any derivative be isolated.

For absorption spectra of adducts, each adduct was dissolved in the minimum volume of warm 5% aqueous potassium hydroxide with the aid of methanol (5 c.c.). The solution was then diluted with distilled water to 1000 c.c. This gave an approximately 10^{-3} molar solution of the adduct

dipotassium salts. The spectra of the hydrocarbons were determined in cyclohexane.

Oxidation of 1:2:3:4:5:6-hexamethyl-1:2-dihydro-naphthalene-1:4-endo-α:β-succinic acid (CXXII, R = Me, R_1 = H)

To the above adduct dibasic acid (300 mg.) in a solution of sodium hydroxide (2g.) in water (20 c.c.) there was slowly added with stirring an 8% solution of potassium permanganate. The latter was quickly decolourised, and manganese dioxide precipitated. The reaction mixture was stirred and heated on a steam bath for 16 hours, then cooled and methanol added (5-10 c.c.). The mixture was warmed until complete decolourisation and the product was filtered and purified with charcoal. The colourless filtrate was concentrated on the steam bath and acidified. The ether extract was dried (Na_2SO_4) and evaporated. The remaining residue crystallised from water to give prehnitic acid (CXXIII) as colourless prisms m.p. 235-237° undepressed on admixture with an authentic specimen prepared by the oxidation of prehnitene (literature[104] 238°).

Oxidation of 1:2:3:4:6:7-hexamethyl-1:4-dihydronaphthalene-1:4-endo-α:β-succinic acid (CXXII, R = H, R_1 = Me).

The above adduct (300 mg.) was oxidised as described before to give pyromellitic acid (CXXIV) m.p. 271-273° undepressed on admixture with an authentic specimen prepared by the oxidation of durene (literature[105] 275°).

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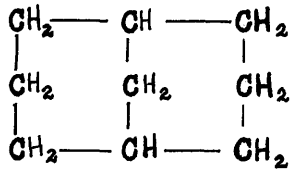
PART II.

BICYCLO-(1::5::5)-NONANES.

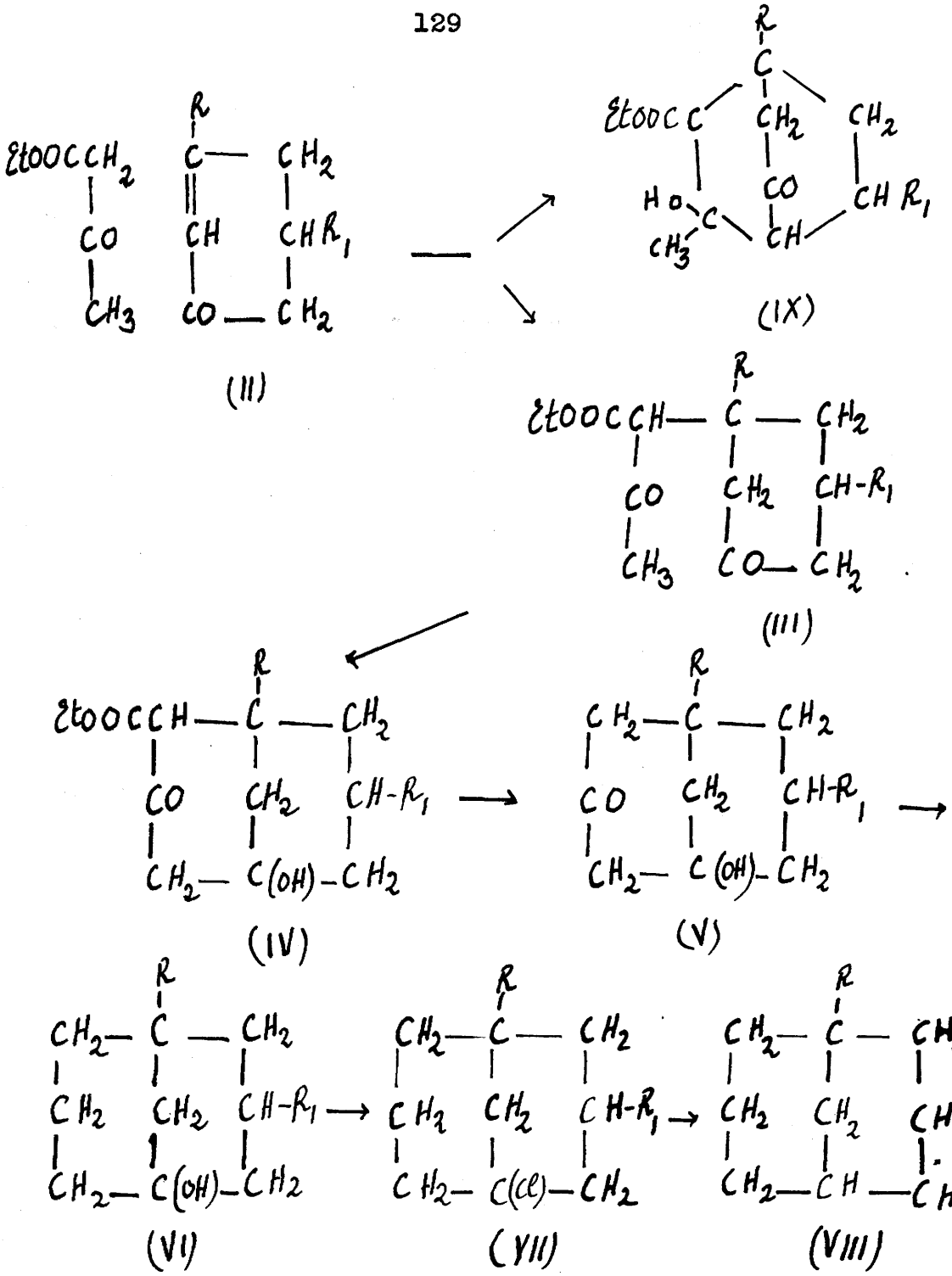
Bicyclononane (I) was first synthesised unambiguously by Meerwein[1]



(I)

Later Rabe[2],[3],[4],[5], condensed 2-cyclohexene-1-one derivatives (II) with ethyl acetoacetate and assigned to his products formulae based on bicyclononane skeleton. Although he was well aware that condensation might have led to cyclo-octane derivatives he considered that the reactions of his intermediates could more satisfactorily be explained on bicyclo nonane formulation. Since he was unable to obtain the unsubstituted 2-cyclohexane-1-one in quantity, he was unable to compare his end product directly with that of Meerwein. Now that 2-cyclo hexen-1-one is available by catalytic oxidation of cyclo hexene with cobalt resinate, it seemed worth while repeating the steps of Rabe's synthesis with a view to a direct comparison of the end products of his series with Meerwein bicyclo-nonane.

The steps of Rabe's most recent synthesis are described by formulae (III) to (VIII) (R, R_1 = Me). His condensate (IV) and his penultimate and final products (VII) and (VIII) respectively are oils.



Rabe [5] has shown that 1-5 diketones (III) rapidly condense to the cyclic oxy-ketone form (IV).

All the products described below were well crystalline solids but unfortunately the final oxygen atom could not be completely removed in the last stage. Lack of time and material made further work impossible.

2-Cyclohexen-1-one (11,R, R_1 = H) was condensed with ethyl acetoacetate in presence of sodium ethoxide as a condensing agent to give the bridged compound (IV, R, R_1 = H) in 40% yield via the intermediate diketone (III, R, R_1 = H).

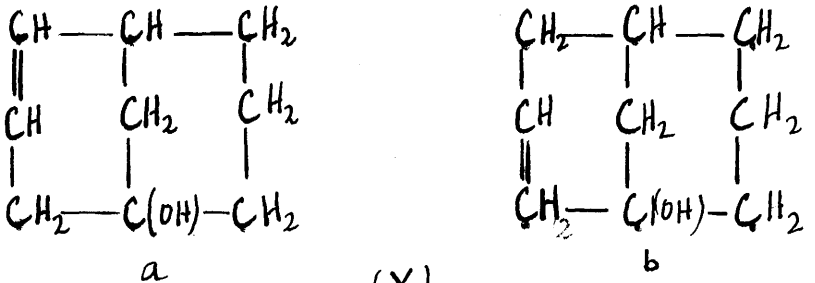
Inferior yields of (IV, R, R_1 = H) were obtained when dioxan or ether was used as a solvent instead of alcohol. (IV, R, R_1 = H) was hydrolysed and simultaneously decarboxylated to (V, R, R_1 = H) by heating with 6% aqueous alcoholic potash.

Three different routes were explored to convert the hydroxyketone (V, R, R_1 = H) to bicyclo-(3:3:3)-nonane (I).

(A) The reduction of the carbonyl group in (V, R, R_1 = H) proved to be difficult. Repeating Rabe's procedure[5] as carefully as possible, i.e. heating the hydrazone in nitrogen without addition of alkali gave no reduction product. Both the Clemmensen[6] and the Meerwein-Ponndorf[7] methods also failed. The Wolff-Kishner method[8] in a sealed tube and the Huang-Minlon modification[9] gave unsaturated oily products.

On the other hand, high pressure hydrogenation in presence of copper chromite catalyst gave an 80% yield of

(VI, R, R_1 = H). The reaction was drastic and reduction was only achieved when a large proportion of catalyst and a high temperature (240°) and pressure (200 atmospheres) were used. (VI, R, R_1 = H) was distilled as a colourless glassy oil. Analytical figures are in accordance with formula (VI, R, R_1 = H). A small amount of a colourless crystalline solid was among the reduction products. It rapidly decolourised bromine water and potassium permanganate solution. Analytical figures agree with formula (X) a and b. Compound (x) a and b

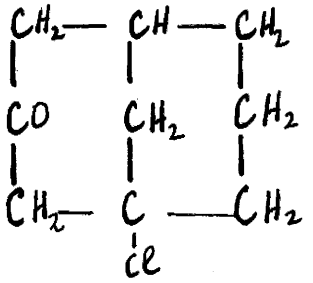


a (X) b

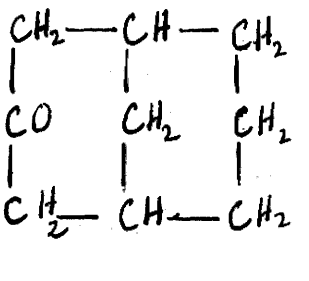
May have been formed by the dehydration of the glycol (XIII) intermediate in the reduction of (V, R, R_1 = H) during the distillation. (VI, R, R_1 = H) with phosphorus pentachloride gave a brown oil corresponding to formula (VII, R, R_1 = H). The latter was reduced with Raney nickel

catalyst to give a product* which, even after exhaustive distillation over sodium, contained oxygen and unfortunately neither time nor material sufficed to repeat.

(B) In view of the difficulty in obtaining solid products, the action of phosphorus pentachloride on the above hydroxy ketone (V, R, R_1 = H) was tried. This gave 5-chlorobicyclonon-7-one (XI). Attempts to reduce the chloro-compound using



(XI)



(XII)

palladised-calcium carbonate as catalyst, gave no reduction products. Sodium in alcohol method gave an uncrystallisable product, possibly a mixture of both reduced material and the ether of (V, R, R_1 = H). However an alkaline alcoholic solution of (XI) was reduced to the ketone (XII) in 70% yield

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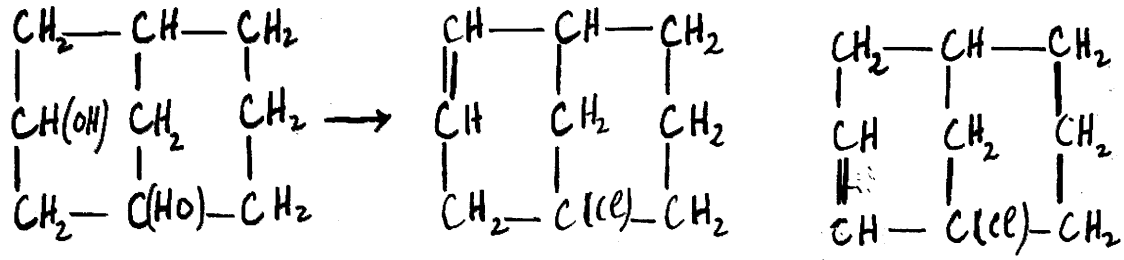
*Although this product actually melted at 146° and did not depress the m.p. 146° of a sample of bicyclononane prepared by Meerwein's route, Meerwein has noted in his extensive work on bicyclononane derivatives, several examples of different compounds which failed to depress each other's melting points. However the b.p. 168°/760 mm. of our compound agreed exactly with that of the Meerwein hydrocarbon. Also our product similar to bicyclononane had a strong camphor-like odour.

by the high pressure hydrogenation in the presence of Raney nickel catalyst. (XI) was obtained as colourless diamonds m.p. 49°. Analytical figures showed that itwas impure. An attempt to convert (XI) to bicyclononane (I) gave a product* having identical properties to bicyclononane. Analytical figures showed that it was impure.

(C) Compound (VI, R, R_1 = H) was reduced to the glycol (XIII) with sodium in alcohol at 0°. Inferior yields were



(XIII) (XIV)

obtained when either sodium in wet ether or sodium amalgam in alcohol was used. At higher temperature sodium in alcohol reduction gave only polymerised material. Several attempts were made to replace the two hydroxyl groups in (XIII) by chlorine (a) when (XIII) was refluxed with thionylchloride, an oil containing 0.5 atom of chlorine was obtained. (b) Phosphorous trichloride and pyridine on (XIII) gave a brown oil with 0.7 atoms of chlorine. (c) With phosphorus pentachloride, a mixture of a solid (A) and an oil (B) were obtained. The compound (A) contained one chlorine atom and

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*See Footnote, p. 132.

one double bond. It rapidly decolourised bromine water. It is suggested that compound (A) is (XIV, a and b) formed by the dehydration of the secondary alcoholic group and the replacement of the tertiary one by chlorine. All attempts to obtain it in quantity were unsuccessful.

The oil (B) was also unsaturated and found to contain one chlorine atom. On catalytic dehydrogenation in presence of palladised calcium carbonate it absorbed 1.7 moles of hydrogen. Attempted purification gave a colourless oil b.p. 160-170°/760 mm. It had a strong camphor-like odour. The oil failed to crystallise even after distillation over sodium and seeding with a crystal of the Meerwein bicyclononane.

2-cyclohexene-1-one was prepared by the air oxidation of cyclohexene in presence of cobalt resinate as catalyst.

EXPERIMENTAL

Cyclohexen-1-one (II, R, R_1 = H).

Cyclohexene, (300 c.c.), and finely powdered cobalt resinate catalyst (9g.) were stirred at 62-65°. Dry oxygen was passed into the mixture for 15 hours. Another quantity of cobalt resinate (4.5g.) was added and the reaction continued 7 hours more. The reaction mixture was filtered free from solid materials and distilled with a Widmer column. Cyclohexen-1-one was obtained as a yellow oil b.p. 56-59°/ 13 mm. (105g.= 35%).

Condensation of cyclohexen-1-one with ethyl aceto acetate.

(1) Using absolute alcohol as solvent.

In an ice-cooled dry swept flask,(nitrogen,) with a mechanical stirrer were mixed, dry alcohol (50 c.c.) and clean-cut sodium (2.5g.). After the sodium had dissolved, ethylacetate (26.8g.) was added dropwise followed by cyclohexen-1-one (20g.). Stirring and ice cooling was continued a further 3 hours. The reaction mixture was then left 3-4 days at 0°. The formed crystalline material was filtered, washed with water, and dried to give 8-carbethoxybicyclo-(1:3:3)-non-5-ol-7-one (IV, R, R_1 = H) as colourless needles m.p. 133.5° (19g. = 40%).

(2) Using dry ether as solvent.

The above procedure was used,(IV, R, R_1 = H) was obtained

as colourless needles m.p. 134.5 (139. = 27%).

In boiling ether or adding the ingredients at the same time, the products were uncrystallisable, probably, cyclohexenone was reduced to cyclohexanone in presence of nascent hydrogen.

(3) In pure dioxane as solvent.

The above procedure was used, (IV, R, R_1 = H) was obtained in needles, m.p. 134°. (12g. = 24%)

Bicyclo-(1:3:3)-non-5-ol-7-one (V, R, R_1 = H)

A mixture of potassium hydroxide (15g.), water (150 c.c.), and ethyl alcohol (100 c.c.) was cooled and nitrogen passed into the solution then (IV, R, R_1 = H) (10g.) was added. The reaction mixture was loosely stoppered and heated on a water bath at 65° for 20 hours. The product was cooled, and carbon dioxide gas passed into the solution. The precipitated potassium carbonate was filtered off, and the filtrate concentrated. The residue was then extracted with ether in a continuous liquid extractor for 24 hours. The dried ether extract was evaporated, and the residue sublimed at 100-120° (oil bath temperature)/1 mm. to give bicyclo-(1:3:3)-non-5-ol-7-one as a white solid m.p. 233°, (5.2g. = 79%) extremely soluble in water.

The semicarbazone was obtained as colourless prisms from alcohol m.p. 206°. (Found: C, 56.9; H, 7.8; N, 19.9.

$C_{10}H_{17}O_2N_3$ requires C, 56.9; H, 8.0; N, 20.0%). The hydrazone was difficult to purify. After four crystallisations from alcohol a sample was obtained m.p. 80-100°. (Found: N, 14.5 $C_9H_{16}ON_3$ requires N, 16.6%).

Attempted reduction of bicyclo-(1:3:3)-non-5-ol-7-one (V, R, R_1 = H)

(1) After Rabe and Klaus Appuhn[5].

The above hydrazone (0.5g.) was heated first at 180° (oil bath temperature) then at 150° in presence of a current of dry nitrogen. The distillate was found to contain nitrogen. Attempted crystallisation was unsuccessful.

(2) Huang-Minlon Modification.[9] The above hydroxyketone (3g.), sodium hydroxide (3g.), 90% hydrazine hydrate (3 c.c.) and diethylene glycol were heated as described by Huang-Minlon. The product was diluted with water, acidified, and extracted with ether. The ether extract was dried (Na_2SO_4) and ether removed. The residual material decolourised bromine water. On microhydrogenation half a molecule of hydrogen was absorbed.

(3) The Wolff-Kishner method[8]. The above semicarbazone (1g.), absolute alcohol (4 c.c.) and sodium hydroxide (1g.) were heated in a sealed tube at 200° for 8 hours. The brown oily product obtained contains a mixture of uncrystallisable materials. On micro hydrogenation, hydrogen (0.6) mole was absorbed.

(4) The copper chromite method.

The above hydroxyketone, (5g.) absolute alcohol (75 c.c.) and copper chromite catalyst (5g.) were heated and stirred in an autoclave in presence of hydrogen at an initial pressure of 130 atmospheres. The mixture was heated to 240° and maintained at that temperature for 24 hours. The product was filtered free from catalyst and the solvent removed in vacuo. The remaining colourless glassy material was then transferred to a flask with an efficient column and three fractions were collected.

The first fraction b.p. 50°/10 mm. was impure.

The second fraction b.p. 68°/10 mm. distilled as a colourless glassy oil of bicyclo-(1:3:3)-nonane-5-ol (VI, R, R_1 = H). The latter is very soluble in most organic solvents (3.4g. = 80%). (Found: C, 76.6; H, 11.4 $C_9H_{16}O$ requires C, 77.0; H, 11.4%).

The third fraction (X a and b) was obtained as colourless crystals m.p. 137° (0.1g.) (Found: C, 78.2; H, 10.1. $C_9H_{14}O$ requires C, 78.25; H, 10.1%).

Attempted reduction of bicyclo-(1:3:3)-nonane-5-ol. (VI, R, R_1 = H). To the above hydroxy compound (2g.) and methylene chloride (30 c.c.), was added powdered phosphorus pentachloride (5.g.). The reaction went quickly and heat was developed. The product was left overnight at room temperature and then refluxed on the steam bath (30 mins.). It

was cooled, diluted with ice and the mixture was shaken twice with ether. The organic layer was dried and concentrated to give 5-chloro bicyclo-(1:3:3)-nonane (VII, R, R_1 = H) as a yellow oil on distillation. (Found: Cl, 22.0 $C_9H_{15}Cl$ requires Cl, 22.4%).

The above chloro compound (1g.), absolute alcohol (25 c.c.), potassium hydroxide (1g.) and Raney nickel catalyst (1g.) were shaken in an autoclave in presence of hydrogen at 80° and 50 atmospheres for 10 hours. The reaction product was filtered, a few drops of dilute sulphuric acid were added and the solvent distilled in vacuo. The residue was extracted with ether, dried (Na_2SO_4) and ether was removed. The residualmaterial was heated with sodium (0.5g.) for one hour, then the product was sublimed at 40°/12 mm. to give colourless needles m.p. 146° undepressed on admixture with a specimen of Meerwein's[1] bicyclo-(1:3:3)-nonane. It had a strong camphor-like odour, extremely volatile and soluble in organic solvents, insoluble in water.

5-Chlorobicyclo-(1:3:3)-non-7-one (X).

The hydroxyketone (V, R, R_1 = H) (2g.) was treated with phosphorus pentachloride as described for 5-chlorobicyclo-(1:3:3)-nonane to give 5-chlorobicyclo-(1:3:3)-nonane, as colourless crystals from light petroleum m.p. 117° (1.8g. = 80%). (Found: Cl, 19.3 $C_9H_{14}OCl$ requires Cl, 20.5%).

The 2:4-dinitrophenyl hydrazone was obtained as orange crystals from methanol, m.p. 144.5° (Found: N, 17.4;

$C_{15}H_{17}O_4N_4Cl$ requires N, 17.2%).

Reduction of 5-chlorobicyclo-(1:3:3)-nonane-7-one (XI)

The above chloro-compound (2g.) was reduced as described for 5-chlorobicyclo-(1:3:3)-nonane gave bicyclo-(1:3:3)-non-7-one (XI) as colourless diamonds, m.p. 49° (1.2g., 70%).

The semicarbazone was obtained as needles from aqueous ethanol m.p. 173. (Found: C, 59.5; H, 8.25; $C_{10}H_{17}O N_3$ requires C, 61.5; H, 8.8%).

Attempted reduction of bicyclo-(1:3:3)-non-7-one (XII)

The above semicarbazone (0.3g.), freshly cut sodium (0.3g.) and dry alcohol (6 c.c.) were heated in a sealed tube for 8 hours at 220°. The reaction mixture was diluted with water. The aqueous material was distilled in steam, with an ice trap to catch any volatile materials. The distillate was extracted with ether and the ether was dried (Na_2SO_4) and removed. The remaining material was distilled b.p. 168°/760 mm. and the product was crystallised to give colourless needles m.p. 146°. Admixture with Meerwein's bicyclononane produced no depression.

Bicyclo-(1:3:3)-nonane-5-7-diol (XIII)

(1) Using sodium in Alcohol at 0°.

To a mixture of bicyclo-(1:3:3)-non-5-ol-7-one (V, R, R_1 = H) (5g.), dry alcohol (250 c.c.) was added slowly clean slices of sodium (15g.) over a period of 10 hours. The reaction mixture was stirred 3 hours more and

then diluted with water. Carbon dioxide gas was then passed through the mixture until no further precipitate of sodium carbonate is formed. The solution was now filtered and the filtrate was distilled with steam. Distillation was stopped when the distillate became turbid. The distillate was concentrated and extracted with ether in a liquid liquid extractor for 2 days. The ether extract was dried (Na_2SO_4) and distilled off to give Bicyclo-(1:3:3)-nonane-5-7-diol (XIII) as a white solid m.p. 193 (2g. = 40%). This was further purified by crystallisation from ether followed by extracting the impurities with benzene in a soxhlet. (Found: C, 69.65; H, 10.2 $C_9H_{16}O_2$ requires C, 69.25; H, 10.3%).

(2) Sodium in wet ether.

Following the above procedure, the above hydroxyketone (V, R, R_1 = H) (5g.), 5% wet ether (300 c.c.) and sodium (15g.) gave bicyclo-(1:3:3)-nonane-5:7-diol (XIII) m.p. 193°. (1g. = 20%). Undepressed on admixture with the above diol.

(3) Sodium Amalgam in alcohol.

To a solution of the hydroxyketone (V, R, R_1 = H), absolute alcohol (200 c.c.) was added 5% powdered sodium amalgam (300g.) over 15 hours with continuous stirring and ice-cooling. After the amalgam had dissolved, the solution was separated from the recovered mercury. The product was then worked up as in (1) to give Bicyclo-(1:3:3)-nonane-5:7-diol (XIII) (1.5g. = 30%).

Attempted chlorination of bicyclo-(1:3:3)-nonane-5-7-diol (XIII).

(1) Using thionyl chloride.

The above diol (1g.), thionyl chloride (15 c.c.) and thiophene-free benzene (10 c.c.) were refluxed (2 hours). The excess of thionyl chloride was removed in vacuo. The product was distilled b.p. 70-80°/10 mm. to give an oily product which contained 0.5 gm. atoms of chlorine.

(2) Using phosphorus trichloride in pyridine.

The above diol (1g.), phosphorus trichloride (2 c.c.), pyridine (2 c.c.) and benzene (5 c.c.) were refluxed for 2 hours. The excess reactants removed in vacuo and the residue distilled to give a brown oil which contained 0.7 gm. atoms of chlorine.

(3) Using phosphorus pentachloride.

The above diol (1g.), methylene chloride (25 c.c.) and phosphorus pentachloride (3g.) were left overnight at room temperature, then refluxed for 1 hour. The product was cooled, washed with iced water, ice cold sodium bicarbonate, and then dried (Na_2SO_4). The solvent was evaporated and the residue was sublimed to give colourless leaflets m.p. 120° probably (XIV a, b) (50 mg.) (Found: Cl, 22.3 $C_9H_{14}Cl$ requires Cl, 22.6%). This product quickly decolourised bromine water and potassium permanganate solution. The main bulk of the reaction products distilled as an oil b.p. 75-80°/

10 mm. This substance was also unsaturated towards bromine water. (Found: Cl, 22.4; $C_9H_{14}O$ requires Cl, 22.6%).

The oily product (0.5g.), alcohol (50 c.c.) and 3% palladised calcium carbonate (100 mg.) were shaken in presence of hydrogen at room temperature. Absorption corresponded to 1.7 moles of hydrogen (4 hours). The product was then filtered from catalyst and the alcohol removed in vacuo. The remaining oil was distilled to give a colourless oil b.p. 158°/760 mm. having a strong camphor-like odour. The compound failed to crystallise after several attempted purifications.

Bicyclo-(1:3:3)-nonane m.p. 145° for comparison was prepared as described by Meerwein[1].

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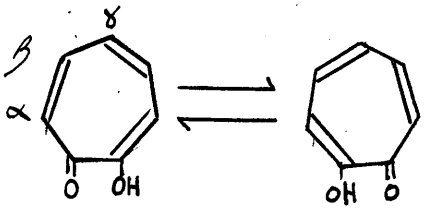
PART III.

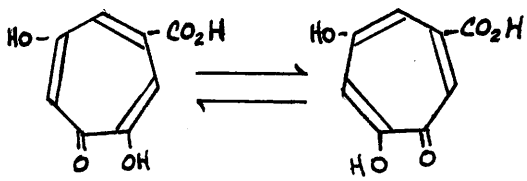
TROPOLONES

INTRODUCTION

The tropolone concept was first suggested by Dewar[1] in 1945 to interpret the recorded chemical behaviour of stipitatic acid.[2] He concluded that the properties of this acid are explained by formula (II, IIa) and that tropolone (1, 1a) represents a new type of aromatic structure.

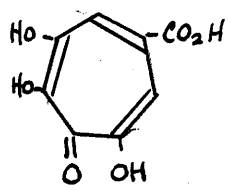


(I) (Ia)

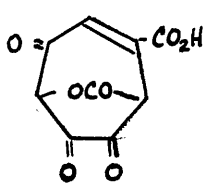


(II) (IIa)

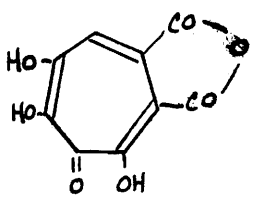
Two mould products puberulic[3] and puberulonic acid[3] resembled stipitatic acid chemically. Structure (III) was determined by Todd et al.[4] for the former acid. Structure (IV) was suggested by the same authors[5] for the latter acid, but Aulin-Erdtman[6] proved that the actual structure is that shown in (V).



(III)

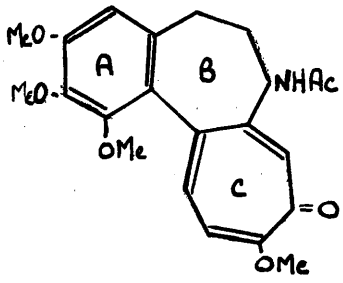


(IV)

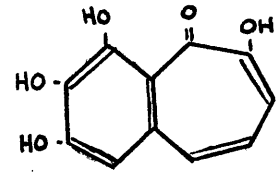


(V)

Dewar[7] also suggested that a tropolone methyl ether

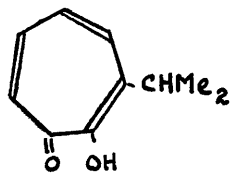


(VI)

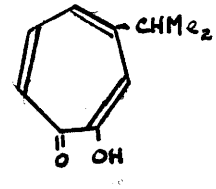


(VII)

structure best interpreted the chemical behaviour of ring (C) in colchicine (VI). This structure has now been confirmed by X-ray analysis. For purpurogallin, Haworth[8] and co-workers confirmed structure (VII) formulated by Barltrop and Nicholson.[9]



(VIII)



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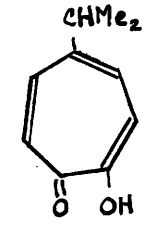
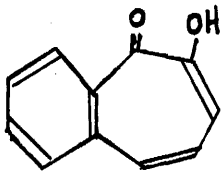


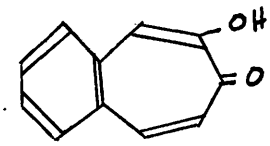
(X)

Structures (VIII), (IX) and (X) were established for the α-, β-and γ- thujaplicins respectively, both by dehydrogenation[10],[11] and by synthesis.[12].

Synthetic tropolones. The first successful synthesis tropolone was that of α : β-benztropolone (XI) by Cook,[13] followed by the β : γ-isomer (XII) by Tarbell et al.[14]

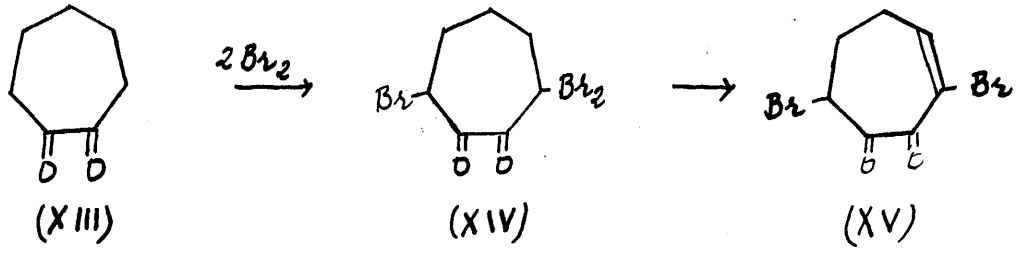


(XI)

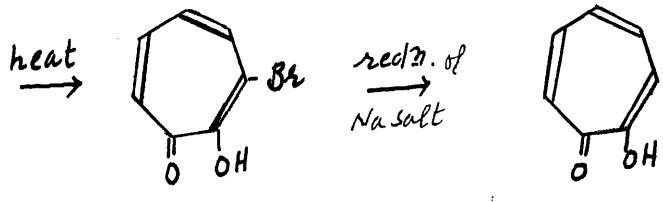


(XII)

This was followed in 1950 by three almost simultaneous but distinct syntheses of tropolone (1, 1a) by Doering[15] in America, Cook et al.[16] and Haworth et al.[17] in Britain. A similar synthesis to that of Cook was published by Nozoe[18] in Japan who also recorded the synthesis of α-, β - and γ - thujaplicins.



(XIII) (XIV) (XV)



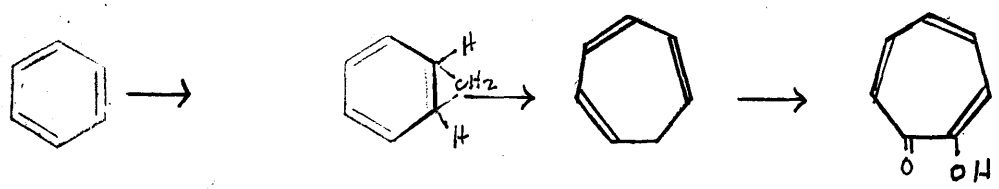
(XVI) (I)

Cook's method follows the above route.

The addition of bromine to (XIII) is complex and depends on the proportion of bromine used and in addition to

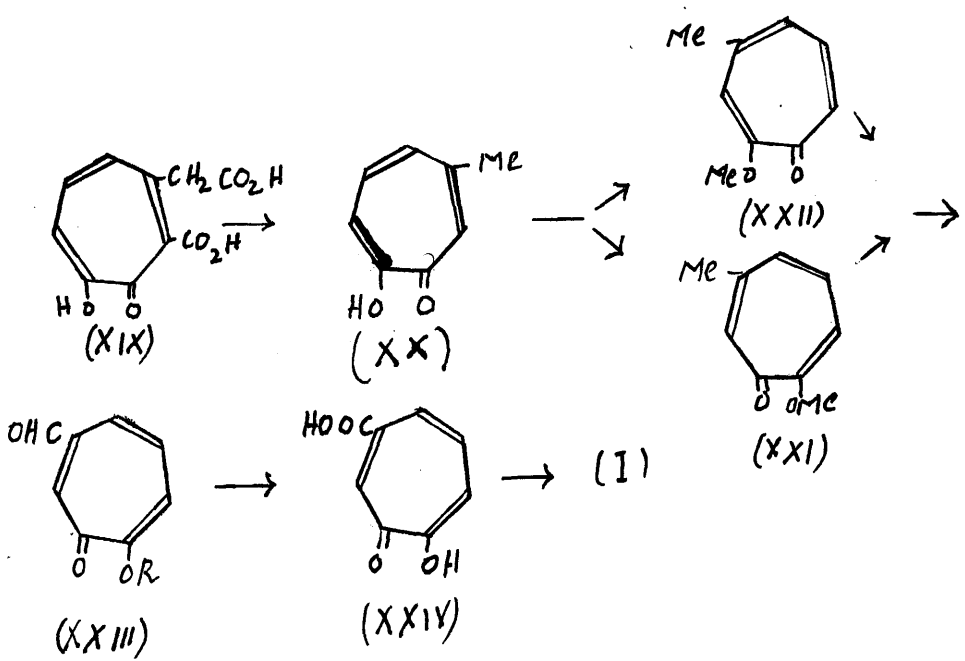
tropolone, mono-, di- and tribromotropolones were isolated. Sodium bromotropolone (XVI) is highly cystalline. It is smoothly reduced to tropolone.

Doering irradiated benzene solutions of diazomethane with ultraviolet light whereby he obtained a compound, probably (XVII) or (XVIII). This on oxidation with potassium permanganate gave tropolone in 1% yield.



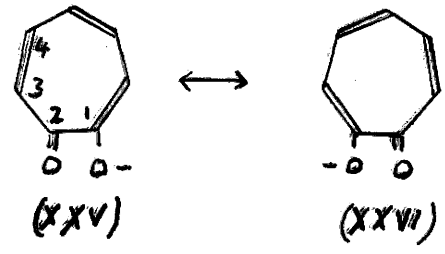
(XVII) (XVIII) (I)

Haworth synthesised tropolone from the monocyclic oxidation product (XIX) of purpurogallin as follows:-



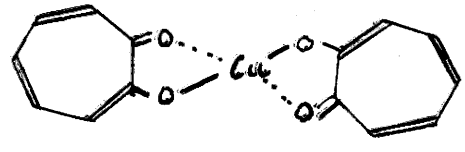
General properties of tropolones. Tropolones are crystalline, easily sublimable solids of various colours. They are more readily soluble in hydroxylic solvents than in ether or hydrocarbon solvents.

As enols, tropolones form coloured salts in alkali that are deeper in colour than the parent tropolone. This is due to the increased resonance in the anions as illustrated by formulae (XXV) and (XXVI).



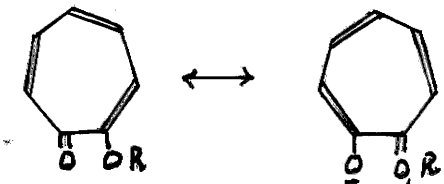
(XXV) (XXVI)

Most tropolones give positive colour tests with ferric chloride. They form chelate compounds. Structure (XXVII) is possibly the copper complex of tropolone.



(XXVII)

They have acidic strength with values that are generally intermediate between those of phenol (pK 10.0) and acetic acid (pK 4.8). Tropolones differ in solubility in sodium bicarbonate, some being insoluble. Molecular weight determinations show that they are monomeric.



(XXXVIII) (XXIX)

The ethers like esters are readily hydrolysed and are more soluble than the parent tropolone. Dewar regards the

ionic resonance exemplified by structures (XXVIII) and (XXIX) as best interpreting the high solubility of the ether.

Considered as a means of elucidating structures, perhaps the most important reaction is the benzilic acid rearrangement whereby the tropolone seven membered ring is contracted to a six membered one.

Hydrogenation has different effects on different tropolones, and the result depends on the catalyst used.

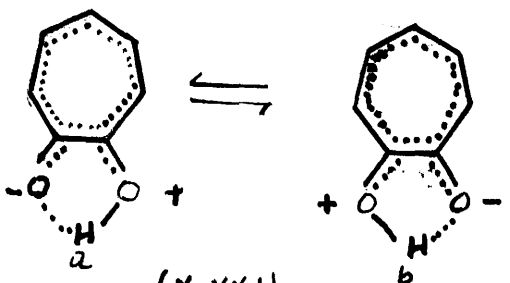
Tropolones do not react with any of the usual carbonyl reagents, but β : γ -benztropolone and dibenztropolone are exceptions. However the carbonyl activity is revealed frequently in the reduction products. The tropolone ring system is stable towards mild oxidising agents.

Electrophilic reagents attack the tropolone molecule. Dewar suggested that mono-substitution should occur almost exclusively in the p -position. However on nitration both the O- and p- positions are attacked.

Generally tropolone, β -methyltropolone and β -thujaplicin (hinokitiol) were found to undergo nitration and coupling with diazotates, halogenation and sulphonation.

Robertson[19] has investigated the X-ray structure of copper tropolone and shown that the ring system is a flat regular heptagon, with two attached oxygen atoms of which one is more closely implicated than the other in binding the copper atom. The 1:2- bond is therefore not a "long" bond,

devoid of double bond character, as is implied in the chemical formula for tropolone, but appears indeed to be indistinguishable from the other bonds in the ring. The aromatic structure of tropolone



(XXXI)

can be represented by structure (XXXI a,b). The latter accommodate the properties discussed here.

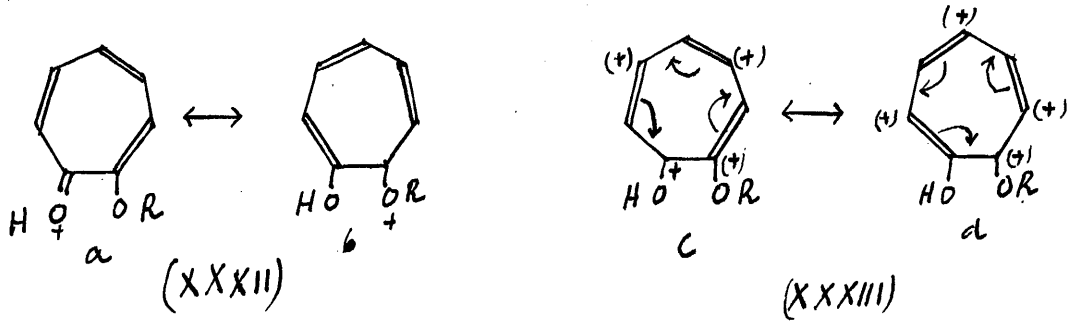
DISCUSSION

The following discussion is based upon my experimental findings which were carried before any similar results were published by other workers.

The acidic character of tropolone and α-bromotropolone is manifested by the ready salt formation. With ammonia solution, both give yellow cystalline ammonium salts which are sparingly soluble in water. The melting points of ammonium tropolone and ammonium bromotropolone are much lower than those of the sodium or copper salts. Ammonium bromotropolone crystallises from ethanol with half a molecule of solvent of crystallisation thus lowering its melting point from 195° to 150°.

On the other hand, the basic character of tropolones is revealed in the formation of salts with acids. A benzene or ether solution, saturated with hydrogen chloride and tropolone precipitates a colourless hydrochloride. From acetic acid-hydrogen chloride solution tropolone hydrochloride crystallises with one molecule of acetic acid. Tropolone hydrochloride is unstable at room temperature and evolves hydrogen chloride. It sublimes with extensive decomposition. On the other hand tropolone hydrobromide and hydrofluoride are very stable and sublime undecomposed. Bromotropolone hydrochloride is very unstable, on sublimation, bromotropolone is quantitatively obtained. Both bromotropolone and tropolone hydrochlorides give with ferric chloride a blood-red precipitate that slowly redissolves to give green solutions.

This remarkable basic character of tropolone can be explained by the suggestion that the positive charge can be borne by the two oxygen atoms structures (XXXII a, b: R = H). These two structures have counterparts in the conjugate acid of β -diketones but do not suffice to confer a comparable

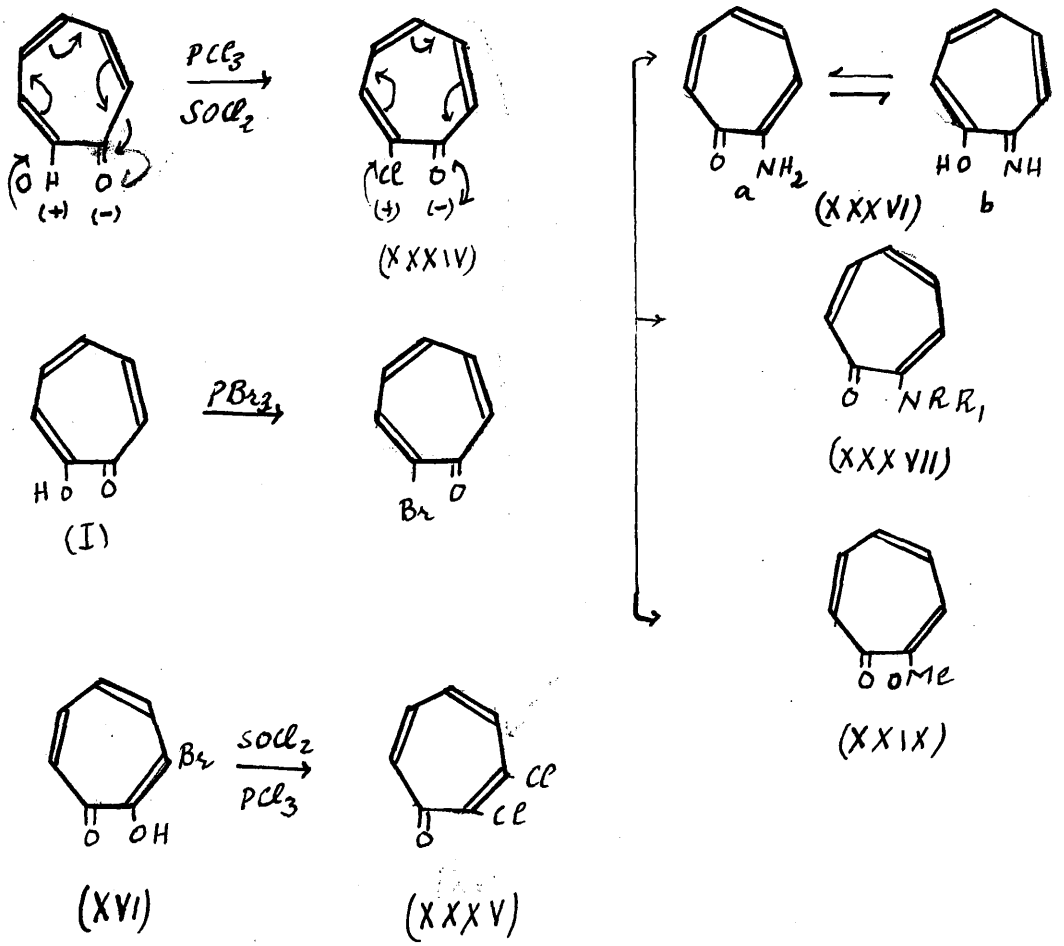


basicity (XXXIII c, d; R = H). This remarkable resonsnce possibility is "aromatic" in the sense of requiring a ring for its existence and of involving the stable molecular orbital of six electrons.

The Action of Thionyl Chloride, Phosphoruss trichloride and tribromide on Tropolone and Bromotropolone.

Tropolone may be considered as a cyclic vinylogue of a carboxylic acid. As with all acids, the above reagents should easily replace in tropolone and bromotropolone the hydroxyl group conjugated to the carbonyl group to give the corresponding acid chloride.

Tropolone reacts with thionyl chloride in benzene solution at room temperature to give tropolone hydrochloride. This may have been produced from the hydrogen chloride that is always present in even the purest reagent.



Crystallisation of tropolone hydrochloride from hydrogen chloride-free hydrocarbon solvents progressively lowered the melting point and after four crystallisations, a new compound m.p. 64° was obtained. This no longer gives a colour with ferric chloride. It was found to be 2 -chloro-cyclohepta-trien-1-one (XXXIV).

The chloride ion from the hydrogen chloride molecule

bound to the tropolone nucleus in the form of hydrochloride must have replaced the hydroxyl group at the higher temperature of crystallisation. On gentle refluxing, with thionyl chloride, the precipitated hydrochloride redissolved and hydrogen chloride was evolved and again (XXXIV) was isolated in good yields.

Like tropolone, bromotropolone gives with thionyl chloride in the cold the corresponding hydrochloride. With gentle refluxing for three to four hours 2:3-dichloro cyclohepta-2:4:6-trien-1-one (XXXV) is obtained. The hydroxyl group and the bromine atom are both replaced by chlorine ions. The replacement of bromine by chlorine in (XXXV) is explained by the fact that the latter is more reactive than the former. Formula (XXXV) is supported by experimental evidence described on p.162 .

At room temperature, both phosphorus trichloride and tribromide give unstable hygroscopic complexes with tropolone and bromotropolone. Hydrogen chloride or bromide is quickly evolved and a dark viscous material remains.

At higher temperature, with phosphorus trichloride and tribromide, tropolone gives 2-bromo-and 2-chloro-cyclohepta -2:4:6- trien-1-one respectively.

With phosphorus trichloride, bromotropolone gives 2:3-dichloro cyclohepta -2:4:6-trien-1-one (XXXV).

2-Chlorocyclohepta-2:4:6-trien-1-one (XXXIV)

Although (XXXIV) is a vinglogue of an acid chloride, its chemical properties lie between those of an acid chloride and an alkyl halide. It undergoes the following reactions:-

(1) The ketonic property that is masked in tropolone is revealed in 2-chlorocyclo-heptatrienone as the latter gives a yellow precipitate with ethanolic 2:4-dinitrophenyl hydrazine sulphate.

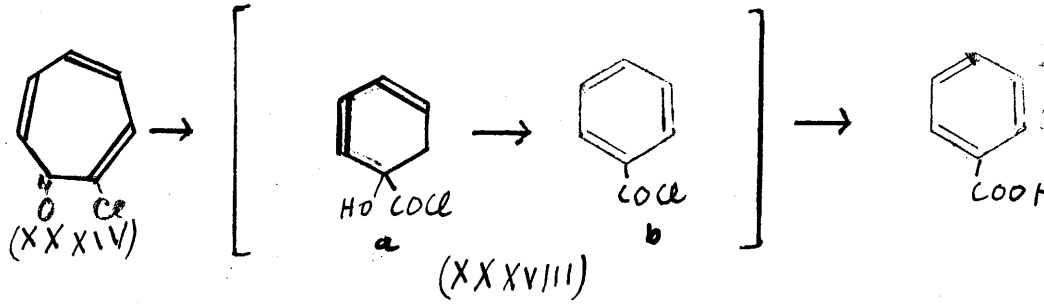
(2) With 10% anhydrous methanolic ammonia, 2-amino cyclohepta-2:4:6-trien-1-one (XXXVI, a) is obtained. There is no evidence to indicate that the actual product is not the tautomer (XXXVI, b). Compound (XXXVI a or b) was obtained by Doering[15b] by the action of 5% anhydrous methanolic ammonia on tropolone methyl ether. 2-aminocyclohepta-2:4:6-trien-1-one dissolves in acids to give the soluble hydrochlorides. With ferric chloride, it gives a deep green colour. Like acid amides it can be hydrolysed with alkali to tropolone.[15b]

(3) With methylamine, dimethylamine and propylamine the corresponding 2-n-alkylcycloheptatrienones were obtained.

These are deep yellow viscous liquids; like aminocycloheptatrienone, they dissolve in acids and give deep green ferric chloride colour reactions. They also give yellow crystalline picrates. (These compounds are not analytically pure and lack of material prevented further purification).

(4) With absolute methanolic sodium methoxide, tropolone methyl ether is obtained. The latter is easily hydrolysed by acids or alkali to tropolone.

(5) 2-chlorocyclohepta - 2 :4:6-trien-1-one undergoes a benzilic acid rearrangement under remarkably mild conditions. On warming with dilute alkali or even boiling with water, ring contraction takes place to give benzoic acid as the main product and a very small amount of a white crystalline solid m.p. 90°. The latter was not identified. On refluxing with anhydrous methanol, methyl benzoate is detected, and on hydrolysis the latter gives benzoic acid.



Compounds (XXXVIII a and b) are possible intermediates in the benzilic acid rearrangement. Compound (XXXVIII, a) may arise from the reaction of a hydroxide ion with the anion of (XXIV). (XXXVIII a) undergoes rapidly dehydration to (XXXVIII, b) which hydrolyses to benzoic acid. This

facile rearrangement may be compared with the observations that tropolone which is the more acidic, requires considerably more severe reaction conditions, (i.e. 220° and strong alkali) while the less acidic β-diketones normally rearrange with alkali between 100-150°. Then (XXXIV) should rearrange under much milder conditions than β-diketones.

(6) On boiling (XXXIV) with silver nitrate, a voluminous precipitate of silver chloride is obtained.

(7) Gentle heating with ammonium chloride solution, (XXXIV) gave a low yield of tropolone isolated as the copper salt.

(8) The reduction of 2-chlorocyclohepta-2:4:6-trien-1-one is very sensitive to reaction conditions:-

(a) Hydrogenation was carried out in cyclohexane as solvent in presence of palladised charcoal. The reaction was stopped after one equivalent of hydrogen was absorbed and a crystalline product* m.p. 100° was obtained. No satisfactory explanation can be suggested here on the basis of the analytical data available.

(b) In benzene solution, similarly a solid m.p. 145° was isolated in a small amount. The main product was

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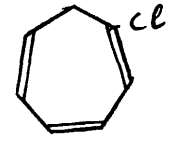
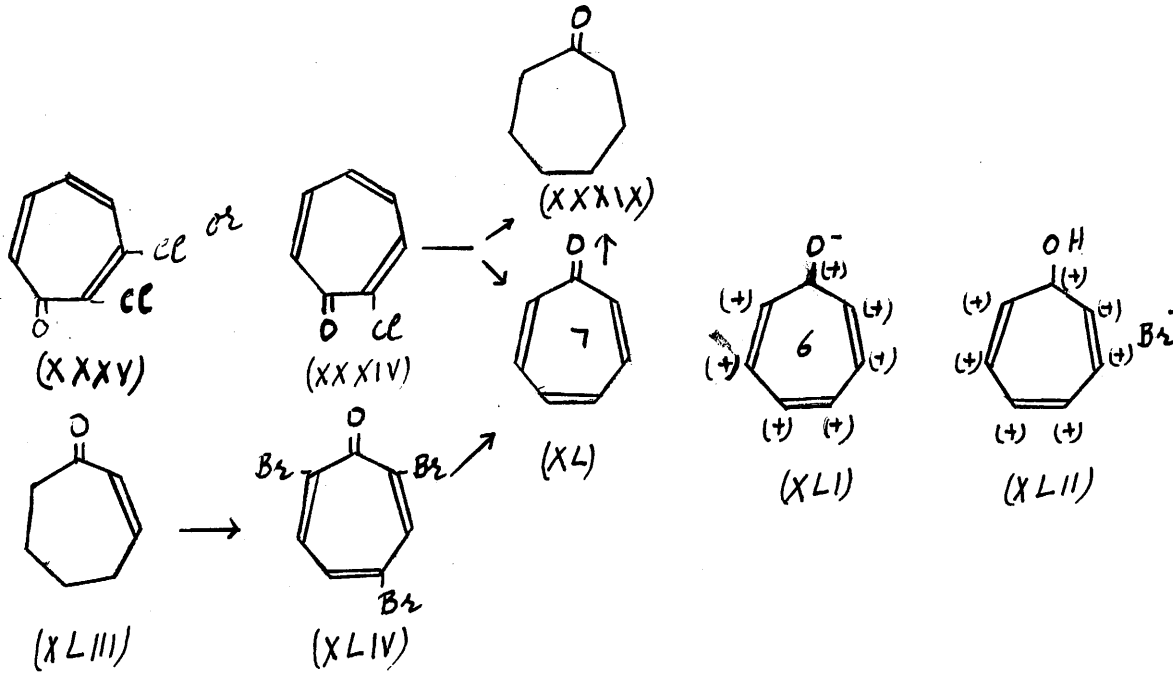
*This product may possibly be chlorocycloheptatrienone formed by the reduction of the carbonyl group in (XXXIV)



a high boiling material. I was unable to identify the above solid due to the lack of material.

(c) In anhydrous ethanolic potassium acetate in presence of palladised charcoal, 4 equivalents of hydrogen were absorbed to give cycloheptanone (XXXIX), isolated as the semicarbazone. However, if the reaction was interrupted after one molecule of hydrogen was absorbed, a colourless viscous oil b.p. 104-105°/10 mm. was obtained. This is expected to be cyclohepta-2 :-4:6-trien-1-one, (tropone) (XL).



This oil (XL) agreed in physical and chemical properties with that described by both Doering[20] and Dauben[21] by two different synthesis from the above, and a fourth in which

2:3-dichlorocyclohepta-2:4:6-trien-1-one (XXXV) was reduced under similar conditions to those described for (XXXIV). However our product was not analytically pure, possibly because it is very hygroscopic.

Doering's synthesis was rather remarkable. Hydroxycycloheptatrienylium bromide (XLII) was obtained from methoxytropilidene prepared by the photochemical decomposition of diazomethane in anisole. Treatment with one equivalent of bromine, either directly or after preliminary acid hydrolysis yielded cycloheptadienone. Compound (XLII) is a colourless, sublimable salt from which sodium bicarbonate liberates cycloheptatrienone (XL).

Dauben's synthesis requires the bromination of cyclohepten-1-one (XLIII) with four equivalents of bromine in acetic acid to give 2:4:7-tribromotropone (XLIV) after prolonged heating. This was hydrogenated with palladised barium sulphate to give (XL). Hydrogen consumption was stopped after three equivalents of hydrogen had been absorbed.

Tropone (XL) is a colourless, viscous very hygroscopic oil with a characteristic smell b.p. 115°/12 mm., $n^{20}D$ 1.6081 m.p. - 5,8° from ether. It rapidly absorbs two molecules of water from the atmosphere. It is soluble in water. Tropone gives a hygroscopic sublimable hydrochloride in ethereal hydrogen chloride. (XL) forms a yellow picrate m.p. 100° (not analysed as it was isolated in small amount).

The carbonyl reactivity in tropone is masked although it is revealed in the hydrogenation and substitution products. Tropone rapidly decolourised potassium permanganate solution. Dauben (loc. cit.) also reports that (XL) decolourizes benzenediazonium chloride in aqueous sodium acetate, forms a picrylsulphonyl derivative m.p. 266-267° and is reduced to cycloheptanone (XXXIX). He also found that bromination at 25° is moderately rapid in water, slow in aqueous acetic acid and very slow in carbon tetrachloride to give addition products that eliminate hydrogen bromide to give in turn bromotropones.

Doering (loc. cit) considers that an extreme electronic structure (XLI) and not (XL) satisfactorily explains:-

(a) the basicity, which reflects a high electron density on oxygen and a stabilization of positive charge (XLII). (b) the large dipole moment implied by the high boiling point (cf. benzaldehyde, b.p. 68°/15 mm.), miscibility with water and the large exaltation. (c) the shift of the carbonyl frequency in the ultra violet spectrum.

The stability of (XLI) relative to (XL) and the very existence of the cycloheptatrienone in contrast to the non-existence of cyclopentadienones find insufficient theoretical explanation in terms of resonance structure (XLI) alone, but are explained by the molecular orbital theory which predicts peculiar stability from six electrons in a cyclic resonating

system. Due to the lack of material and time the reactions of (XL) were not thoroughly investigated.

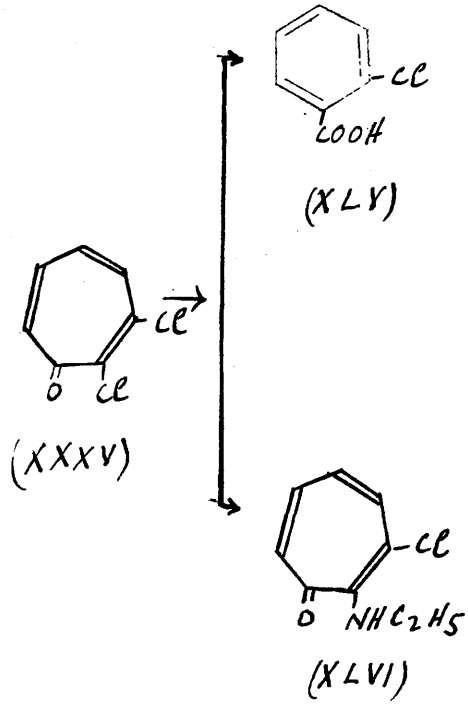
2:3-Dichlorocyclohepta-2:4:6-trien-1-one (XXXV)

The reactions of the above compound are very similar to (XXXIV):-

(1) With 2:4-dinitrophenylhydrazine, a yellow precipitate is quickly formed.

(2) On boiling (XXXV) with silver nitrate, silver chloride is formed.

(3) As with (XXXIV), warming with dilute alkali, produces a benzilic acid rearrangement to give O-chlorobenzoic acid (XLV) in moderate yield.



(4) Only one chlorine atom is easily replaced by alkyl groups. Ethylamine replaces one chlorine atom to give probably 2-ethylamino-3-chlorocyclohepta-2:4:6-trien-1-one (XLVI) as a viscous yellowish green oil. The latter is soluble in acids and gives a green ferric chloride colour reaction.

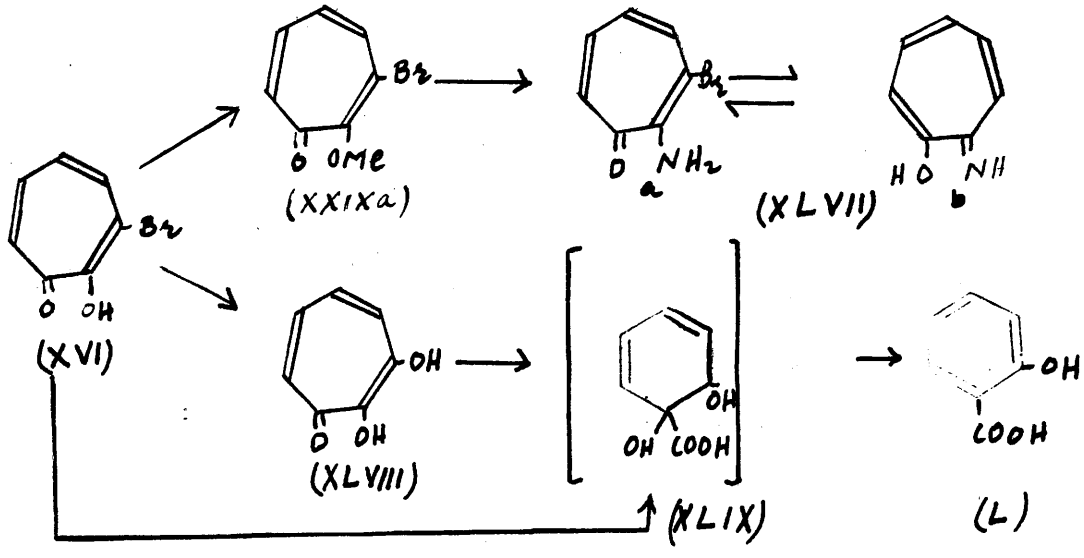
(5) Compound (XXXV) absorbs five equivalents of hydrogen

in absolute methanolic potassium acetate in presence of palladised charcoal to give cycloheptanone (XXXIX); interruption of the reaction after the consumption of two equivalents of hydrogen furnished tropone (XL).

REPLACEMENT REACTIONS OF O-BROMOTROPOLONE.

(1) 2-Amino-3-bromo-cyclohepta-2:4:6-trien-1-one (XLVII)

Bromotropolone methyl ether (XXIXa), like esters, reacts smoothly with 10% anhydrous methanolic ammonia to give 2-amino-3-bromocyclohepta-2:4:6-trien-1-one (XLVII) as a yellow crystalline solid. Compound (XLVII) is sparingly



soluble in hydrocarbon solvents, very soluble in hydroxylic

solvents, soluble in acids, and gives a green ferric chloride colour reaction. It is remarkable that the bromine atom is so unreplaceable, since the reaction conditions were rather vigorous. (10% absolute methanolic ammonia was heated with the methyl ether of (XVI) in a sealed tube at 100° for 10 hours).

(2) α -Hydroxytropolone (XLVIII)

On refluxing bromotropolone with 50% alkali for a prolonged time, α -hydroxytropolone (XLVIII) was obtained in a poor yield. It was also produced when bromotropolone was fused with alkali at 230-250° for 15 minutes. When bromotropolone was heated in a sealed tube with dilute alkali or even water at 200°, only a tar was produced.

α -Hydroxytropolone, like all tropolones is very soluble in hydroxylic solvents. It is a cream coloured sublimable solid with a relatively high melting point (244° decomp.). It gives a brown ferric chloride colour reaction.

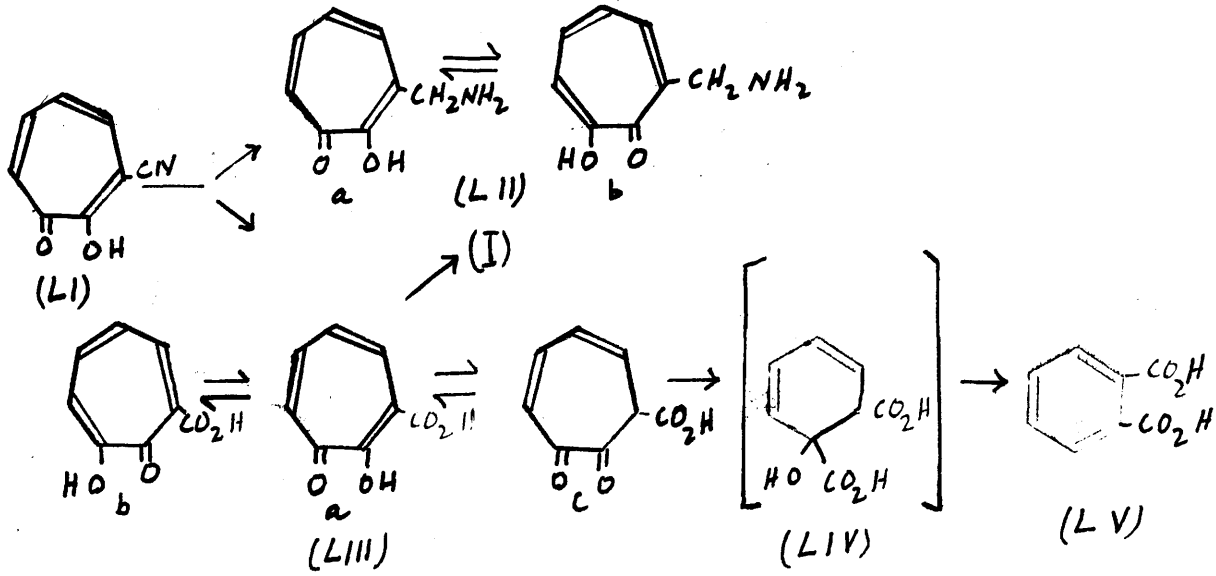
α -Hydroxydroxytropolone undergoes a benzilic acid rearrangement under much more severe conditions than tropolone to give salicylic acid (L). Only fusion with alkali at 300° for 15 minutes could produce the latter.

Similarly bromotropolone was found to give salicylic acid under these vigorous reaction conditions. It is clear that ring contraction took place only after the transformation of bromotropolone to hydroxytropolone, the latter via

the intermediate (XLIX) yielding (L). The reaction products were carefully examined but no o-bromobenzoic acid could be isolated.

(ʒ) α-Cyanotropolone (LI)

The replacement of the halogen in bromotropolone by a cyano group is interesting. Fusion of (XVI) with cuprous or potassium cyanide gave only 1 or 2% of (LI). Refluxing with a pyridine solution containing cuprous cyanide, furnished only unchanged material. Refluxing in benzyl cyanide as solvent resulted in extensive decomposition. However, when sodium bromotropolone instead of bromotropolone was used in pyridine as solvent and in presence of excess cuprous cyanide, all suspended materials dissolved, and an 80% yield of cyanotropolone (LI) was obtained as a yellow sublimable solid. It was difficult to obtain analytical pure even after several sublimations. Cyanotropolone is only soluble in hydroxylic solvents and gives



a brown ferric chloride colour reaction.

Attempted reduction of cyanotropolone (LI)

No crystalline reduction product of the cyano group could be obtained. Reduction of cyanotropolone with both lithium aluminium hydride and palladised charcoal gave a red gummy material. It also formed in neutral ethanolic solution a red colour that persisted even after clarification with charcoal. This product is probably (LII). It was found to be amphoteric, dissolving in acids to give a colourless solution and in alkali to give a reddish colour. Attempts to obtain the diacetate or the diphthalate of (LII) in a crystalline form was unsuccessful.

(4) Tropolone α-carboxylic acid (LIII).

When cyanotropolone (LI) was refluxed with 50% alkali; tropolone α-carboxylic acid (LIII) was obtained. With concentrated hydrochloric acid only a low yield of (LIII) was isolated. Tropolone α-carboxylic acid is a crystalline yellow solid m.p. 213°, soluble only in hydroxylic solvents. It sublimes in vacuo without decomposition and gives a brown ferric chloride colour reaction.

When tropolone α-carboxylic acid was heated in an oil bath above its melting point, tropolone was obtained.

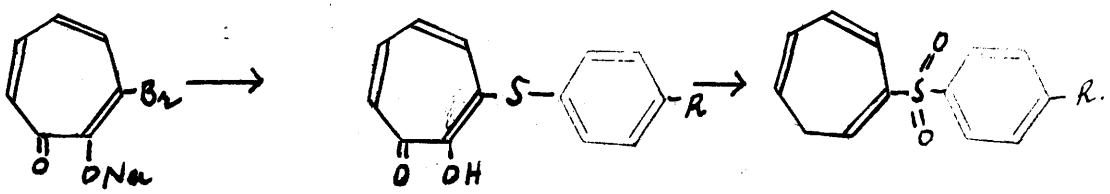
Similar to α-hydroxytropolone, only vigorous reaction conditions bring about benzilic acid, rearrangement. Thus when (LIII) was fused with alkali at 310°, phthalic acid (LV)

was obtained, being isolated as the anhydride. A rearrangement mechanism for (LIII) may be posulated similar to that of stipitatic acid. Thus, when applied to (LIII;a) or the diketoform (LIII;c), benzilic acid change proceeds via the intermediate (LIV). The latter would be expected to undergo ready dehydration to give phthalic acid. This is in accordance with the experimental results.

The action of diazo methane on (LIII) gave a yellow gummy uncrystallisable product. The latter neither gave a ferric chloride colour reaction nor was soluble in sodium bicarbonate. There are presumably in the reaction mixture two methyl ethers corresponding to structures (LIII, a and b). The above gummy products were easily hydrolysed to the original acid (LIII).

(5) <u>α-Thiotropolones (LIX)</u>.

A remarkable reaction was the replacement of the halogen in bromotropolone by p-thiocresol and thiophenol



(LVI) (LVII)

A very simple modification was adopted. Sodium bromotropolone was refluxed with thiophenol and p-thiocresol in pyridine. Replacement of the bromine quickly took place and the hydrogen bromide formed in the reaction mixture reacted with the sodium ion to give the free thiotropolone (LVI, R = H or R = Me) and sodium bromide.

α-Substituted thiotropolones are highly crystalline solids soluble in hydroxylic solvents. They give a greenish brown ferric chloride colour reaction.

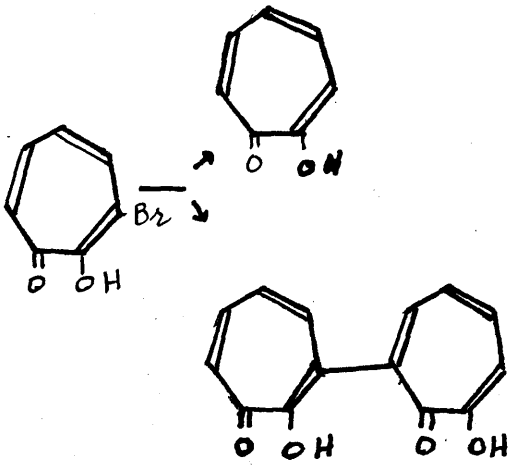
With Raney nickel in ethanol, (LVI, R = Me) gave a low yield of tropolone, the rest being unchanged material. However when the sodium salt was used, instead of the free tropolone a better yield of tropolone was obtained.

Attempts were made to oxidise (LVI, R = H and R = Me) with 30% hydrogen peroxide in acetic acid solution to obtain the corresponding sulphone (LVII); a white amorphous material was obtained. The latter was soluble in alkali and sodium bicarbonate, but failed to give a colour reaction with ferric chloride. It was decomposed on sublimation. Possibly the tropolone ring system was destroyed by the rupture of the ring.

(6) COUPLING OF BROMOTROPOLONE.

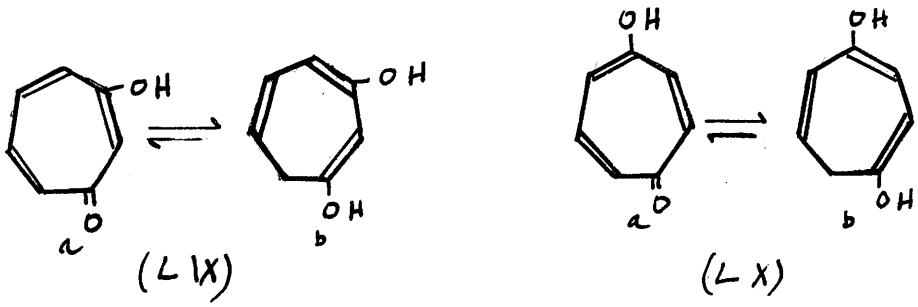
It was of interest to see whether bromotropolone coupled with itself in presence of copper powder to give ditropolone (LVIII), similar to the reaction of bromobenzene

to give diphenyl. However, when sodium bromotropolone was fused with copper powder at 250°, only tropolone was isolated. A similar result is sometimes met in benzenoid compounds.



(LVIII)

ISOTROPOLONES



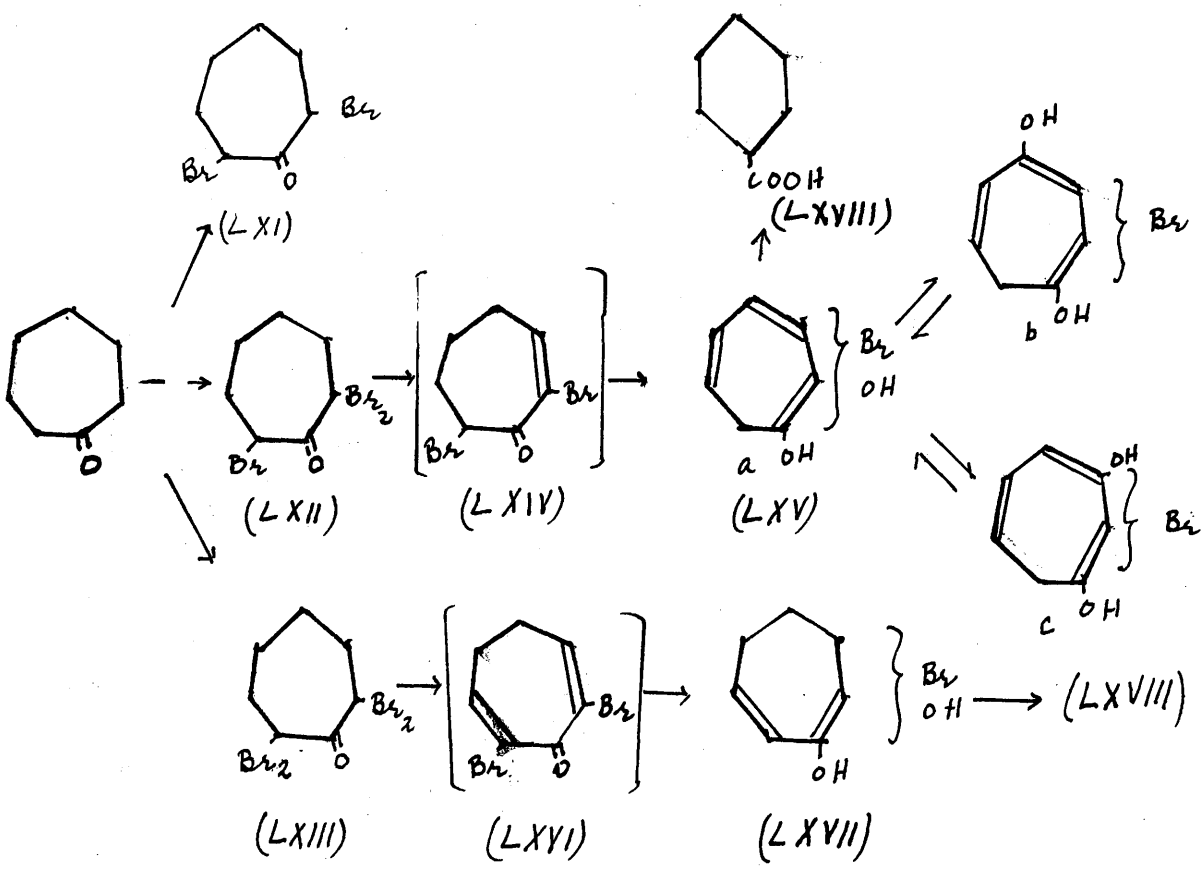
Theoretically there are 2 possible formulae for isotropolone (LIX; a and b) is the m-isotropolone and (LX; a and b) is the p-isomer. It is interesting to prepare such compounds and compare their physical and chemical properties with those of tropolone.

Although the main target was the synthesis of tropone (XL), compounds which may be substituted isotropolones were produced.

Bromination of cycloheptanone in acetic acid at 0^{o} proceeded smoothly to give colourless crystalline bromocycloheptanones. With two, three and four equivalents of bromine, a dibromo- (LXI), a tribromo- (LXII) and a tetrabromo-cyclo heptanone (LXIII) were obtained respectively.

All the three brominated compounds were dehydrobrominated with collidine.

From the dibromocycloheptanone (LXI), an impure liquid



was obtained which was found to contain bromine. Tribromocycloheptane (LXII) gave 2 colourless crystalline solids m.p.105° and 140° respectively, both were soluble in most organic solvents. Analytical figures for both agreed with formula (LXV). These dehydrobrominated compounds were soluble in alkali and sodium bicarbonate but did not give a colour reaction with ferric chloride. When they were boiled with silver nitrate, silver bromide was obtained. Both products were recovered unchanged after heating with

dilute alkali, refluxing with chloranil in xylene or heating with palladised charcoal in trichlorobenzene. With p-thiocresol, the halogen in compound m.p. 105° was replaced to give a bromine free thioderivative which was soluble in alkali and sodium bicarbonate.

On reduction of the two dehydrobromination products (LXV) in ethanol solution in presence of triethylamine and palladised charcoal as a catalyst, four equivalents of hydrogen were absorbed to give hexahydrobenzoic acid (LXVIII) isolated as the anilide. The anilide was found to be identical with an authentic specimen.

Tetrabromo cycloheptanone (LXII) was dehydrobrominated to give a crystalline product m.p. 95°. Analytical figures agree with formula (LXVII). It was soluble in alkali and sodium bicarbonate but failed to give a ferric chloride colour reaction. On reduction, the smell of hexahydrobenzoic acid was clearly detected. The latter was isolated as the anilide and was found identical with an authentic specimen.

No crystalline solid was obtained when the hydrogenation of either (LXV) or (LXVII) was stopped after one equivalent of hydrogen was absorbed.

The bromination of cycloheptanone most likely proceeds in the more active positions o and o' to give the substituted cycloheptanones (LXI), (LXII) and (LXIII) Compounds (LXII)

and (LXIII) on heating with collidine would be expected to give possibly the intermediate dibromo compounds (LXIV) and(LXVII) respectively. One of the bromines in the latter two compounds may be easily hydrolysed under the reaction conditions used, where concentrated hydrochloric acid was added to the reaction products to dissolve excess of the collidine.

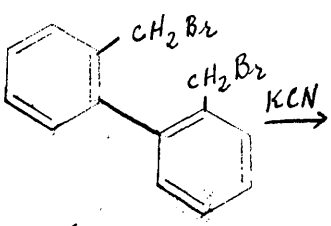
The rearrangement of both (LXV) and (LXVIII) to hexahydrobenzoic acid is unexpected as such products would require the existence of two adjacent hydroxyl groups. However, migration of the hydroxyl groups may have occurred.

3:4:5:6-DIBENZTROPOLONE

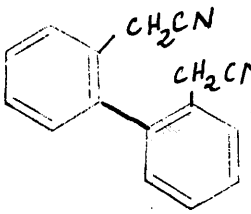
3:4:5:6-Dibenztropolone (LXXV) is the first synthetic tricyclic tropolone. It is interesting to compare its properties with colchicine (VI), the only known tricyclic tropolone, with other synthetic and natural tropolones and with benzylphenyl diketone and its enolone (LXXIX; a, b) One may mention at this point the possible effect of the two phenyl radicals linked to the tropolone system.

Dibenztropolone was prepared by the selenium dioxide oxidation of 3:4:5:6-dibenzcyclohepta-3:5-dien-1-one (LXXIII)[23]. The oxidation is not simple and is very sensitive to both solvents and reaction conditions.

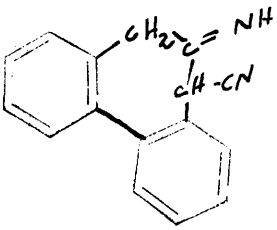
The two methylene groups situated on either side of the carbonyl group in (LXXIII) are equally reactive as they are equally activated by both the carbonyl group and the two phenyl groups. In benzene or ethanol solution, no oxidation product was isolated. In glacial acetic acid phenanthraquinone (LXXVII) was the only oxidation product. In both aqueous acetic acid and aqueous dioxane several products other than dibenztropolone were isolated, viz.,

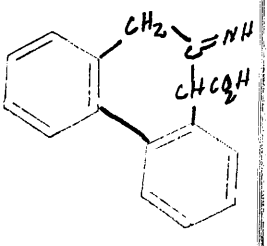


KCN

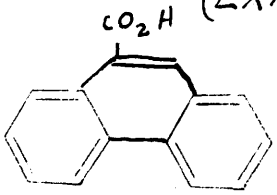


NaOEt



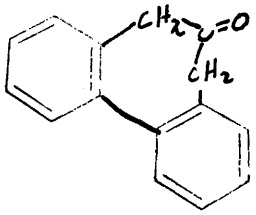


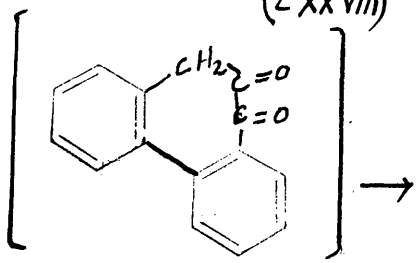
(LXIX) (LXX) (LXXI) (LXXII)

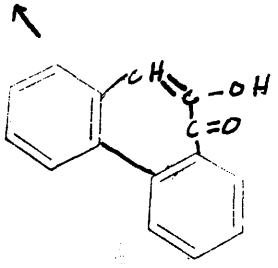


(LXXVIII)

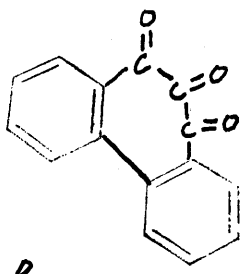
50% H_2SO_4



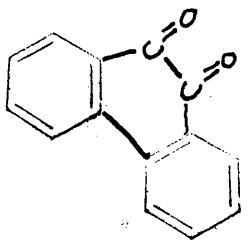




(LXXIII) (LXXIV) (LXXV)



H^+



$ph.CH_2.CO.CO.ph \rightleftharpoons ph.CH=\overset{OH}{\overset{|}{C}}.\overset{O}{\overset{\|}{C}}.ph$ (LXXVI)

(a) (b)

(LXXVII)

(LXXIX)

$ph.CO.CO.CO.ph \xrightarrow{H^+} ph.CO.CO.ph$

(LXXX) (LXXXI)

(1) 9-Phenanthrene carboxylic acid (LXXVIII). This may have been produced in the alkali extraction process of the acidic products as dibenztropolone readily undergoes a benzilic acid rearrangement to (LXXVIII).

(2) Phenanthraquinone (LXXVII). As a possible route (LXXIII) may have been partly oxidised in both active centres (i.e. the two methylene groups on either side of the carbonyl group) to give a triketone (LXXVI) which possibly rearranged to phenanthraquinone. This may be compared with benzoyl-phenyl diketone (LXXX)[24] which in presence of hydrogen ions loses a carbonyl group to give diphenyl diketone (LXXXI). Phenanthraquinone was isolated both free and as the o-phenylene diamine derivative.

(3) A cream-coloured crystalline solid m.p. 218°. Analytical figures show that it is approximately $C_{15}H_8O_3$. It is insoluble in both sodium bicarbonate and alkali and gives no ferric chloride colour reaction. It forms a gummy precipitate with 2:4-dinitrophenyl hydrazine. It may be suggested that it is the triketone (LXXVI) formed as described in (2). Since this product was isolated in minute quantity I was unable to establish complete identity with (LXXVI).

(4) 3:4:5:6-Dibenztropolone (LXXV; a) was obtained as a yellow crystalline solid m.p. 115-116°. It has the following properties:-

(a) It is soluble in alkali but insoluble in sodium bicarbonate. (b) It gives a brown ferric chloride colour in aqueous ethanol. (c) a green chloroform soluble copper salt is obtained on shaking with copper acetate solution. (d) It gives a red 2:4-dinitrophenyl hydrazone m.p. 234°. (e) Dibenztropolone quickly undergoes a benzilic acid rearrangement in dilute alkali to give 9-phenanthrene carboxylic acid (LXXVIII) in nearly quantitative yield. The author was unable to obtain a crystalline methyl ether, possibly because of the instability of the molecule and the methyl ether, if formed, would be rather susceptible to hydrolysis under mild conditions.

Comparing the properties of dibenztropolone with those of benzylphenyl diketone and its enolone (LXXIX; a, b) the latter is soluble in alkali but insoluble in sodium bicarbonate. It gives a brown ferric chloride colour reaction. On the other hand (LXXIX: a, b) does not give a chloroform soluble copper salt.

(5) A selenium complex with dibenztropolone which partly hydrolysed with sulphuric acid to give dibenztropolone and elementary selenium.

Only about 70% of the selenium dioxide used in the reaction has been accounted for in terms of elementary selenium separated from the reaction mixture; the rest may be in the form of a strongly bound complex, or as unreacted selenium.

dioxide.

3:4:5:6-Dibenzcyclohepta-3:5-dien-1-one was kindly supplied by Dr. J. D. Loudon and I understand that it was prepared by the method of Kenner and Turner[23] via the intermediate (LXIX) to (LXXII).

Benzyl phenyldiketone and its enolone (LXXIX) were prepared from chalcone via benzalacetophenone oxide by the method described by Kohler[22a,b].

The selenium complexes formed in the selenium dioxide oxidation of (LXXIII) caused a severe eczema, which disappeared only after prolonged treatment with boric acid and calamine lotion.

EXPERIMENTAL

Tropolone hydrochloride. (a) In ether or benzene as solvent. Dry hydrogen chloride was bubbled through a solution of tropolone (30 mg.) in dry ether or benzene (3 c.c.). Colourless crystals precipitated at once. These were filtered dry and crystallised from dry etheal hydrogen chloride in colourless needles m.p. 124-126°. (Found: C, 52.8; H, 5.15 $C_7H_7O_2Cl$ requires C, 53.0, H, 4.5%) With ferric chloride, the hydrochloride gives a blood red colour which slowly becomes green. It was unstable at ordinary temperature and decomposed slowly with the evolution of hydrogen chloride. On sublimation of the hydrochloride, there was extensive decomposition and tropolone was obtained.

(b) In acetic acid tripolone hydrochloride prepared as described above in acetic acid gave colourless needles m.p. 120-130° containing one molecule of acetic acid. (Found: C,50.6; H, 5.2 $C_9H_{11}O_4Cl$ requires C, 49.4; H, 5.1%). On admixture with the above hydrochloride the m.p. was depressed 10°.

Bromotropolone hydrochloride. Prepared as described for tropolone, was obtained in cream coloured needles. m.p. 150-160° (decomp.). The hydrochloride is very unstable at room temperature and on sublimation pure bromotropolone m.p. 105-108° was obtained.

Ammonium tropolone: To pure tropolone (20 mg.) in water (0.5c.c.), concentrated ammonia (1 c.c.) was added; a yellow crystalline product was obtained. It was filtered dry and dried at 100° C. m.p. 145-150°. (Found: C,60.81; H, 6.35. $C_7H_9O_2N$ requires C, 60.51; H, 6.4%). When it was crystallised from ammoniacal ethanol, the melting point was progressively lowered. m.p. 125-130°.

Ammonium bromotropolone: was prepared as described for ammonium tropolone, and was obtained as a yellow crystalline solid m.p. 185-190°. (Found: C, 38.9; H, 3.25 $C_7H_8O_2NBr$ requires C, 38.55; H, 3.7%). Crystallisation from ammoniacal methanol gave yellow long needles containing half a molecule of ethanol m.p. 145-150°. (Found: C, 39.5; H, 4.6 $C_7H_8O_2NBr\frac{1}{2}C_2H_5OH$ requires C, 39.8; H, 4.6%).

Action of thionyl chloride: (1) At ordinary temperature. (a) Tropolone: To tropolone (50 mg.) in dry thiophene free benzene (2 c.c.), thionyl chloride (0.5 c.c.) was added. The white crystalline precipitate formed was filtered dry, washed with benzene and then dry ether. It was obtained in colourless needles m.p. 119-25°. (Found: C, 53.4; H, 5.0. $C_7H_7O_2Cl$ requires C, 53.0; H, 4.5%).

The above product was undepressed on admixture with tropolone hydrochloride and when it was crystallised from benzene/light petroleum, colourless crystalline needles of 2-chlorocyclohepta-2:4:6-trien-1-one (XXXIV) m.p. 63-64°

were obtained after four crystallisations. Analytical figures are approximate to (XXXIV). (Found: C, 58.6, H, 3.6 C_7H_5OCl requires C, 59.65, H, 3.6%).

(b) Bromotropolone. Bromotropolone hydrochloride was obtained by the same method. m.p. 150-160°.

(2) At higher temperature. (a) Tropolone. A mixture of tropolone (1g.), purified thionyl chloride (10 c.c.) and thiophene free dry benzene (10 c.c.) were gently refluxed on a water bath (3 hours). The white precipitate formed at the time of mixing slowly redissolved on heating. Excess of thionyl chloride and benzene were removed in vacuo. Fresh benzene was added and this was also removed (twice). The residue was then redissolved in benzene and decolourised with charcoal. The solvent was removed and residue distilled b.p. 70° (oil bath temperature)/1 mm. to give 2-Chlorocyclohepta-2:4:6-trien-1-one (XXXIV) as a colourless oil. The latter quickly solidified. It was crystallised from benzene/light petroleum as colourless crystalline needles m.p. 64° (0.5g. = 53%). (Found: C, 59.8; H, 3.7 C_7H_5OCl requires C, 59.75; H, 3.6%). (XXXIV) gave no colour with ferric chloride and when boiled with silver nitrate, silver bromide was precipitated.

(b) Bromotropolene. A mixture of bromotropolone (1g.) thionyl chloride (10 c.c.) and benzene (10 c.c.) were refluxed for 4 hours. The product on distillation gave

2:3-dichlorocyclohepta-2:4:6-trien-1-one (XXXV) as a yellow oil b.p. 110° (oil bath temperature)/1 mm. The latter was crystallised from benzene to give cream-coloured shining needles m.p. 130° (0.5g. = 50%) (Found: C, 47.2, H, 2.45 $C_7H_4OCl_2$ requires C, 48.0, H, 2.3%).

Action of Phosphorous trichloride.

(1) At Ordinary temperature. (a) Tropolone gave an unstable white crystalline solid m.p. 87-90°. This quickly darkened and became viscous on exposure to air.

(b) Bromotropolone gave a dark-clouded hygroscopic complex. m.p. 50-120°.

(2) At higher temperature. (a) Tropolone. A mixture of tropolone (0.5g.), dry benzene (15 c.c.) and phosphorous trichloride (4 c.c.) was refluxed on a water bath (1 hour). The product was then worked as described for (XXXIV). The sublimed residue gave 2-chlorocycloheptatrienone (XXXIV) in colourless needles m.p. 64° and was undepressed on admixture with a sample obtained by the thionyl chloride experiment. Analysis is approximate for (XXXIV). (Found: C, 58.8; 3.7 C_7H_5OCl requires 6, 59.75; H, 3.6%).

Action of phosphorous tribromide. A mixture of tropolone (200 mg.), phosphorous tribromide (0.5 c.c.) and benzene (5 c.c.) were treated as described above to give 2-bromocyclohepta-2:4:6-trienone as colourless shining

leaflets m.p. 117-9°. (Found: C, 45.9,5 H, 2.5 C_7H_5OBr requires C, 45.4; H, 2.7%).

Reactions of 2-chlorocyclohepta-2:4:6-trienone (XXXIV)

(1) The above compound (200 mg.) was heated in a sealed tube with 10% absolute methanolic ammonia (5 c.c.) at 100° for 4 hours. The solvent and excess of ammonia were then removed. The red residue partially crystallised with light petroleum on scratching. This product was sublimed at 80°/1 mm. The yellow powder obtained was crystallised from benzene/methanol to give yellow needles of 2-amino-cyclohepta-2:4:6-trien-1-one (XXXVII) m.p. 100-101° (Found: C, 69.9; H, 5.8 C_7H_7ON requires C, 69.4; H, 5.8%). (XXXVII) Is sparingly soluble in hydrocarbon solvents, very soluble in hydroxylic solvents, and soluble in acids. It gives a green colour with ferric chloride in ethanol.

(2) 2-n-Alkylcyclohepta-2:4:6-trien-1-one (XXXVII)

To a mixture of chlorocycloheptatrienone (150 mg.),and benzene (2 c.c.), alkylamine (2 c.c.) was slowly added. The reaction developed heat and akyl amine hydrochloride was formed. The reaction mixture was heated (30 mins.) on the steam bath and then filtered. The filtrate was washed with water until free from alkylamine. The benzene extract was dried (Na_2SO_4) and solvent removed. The yellow brown residue was distilled. The alkylamine derivatives were

obtained as yellow-green viscous oils. They give a green ferric chloride colour reaction and are soluble in acids.

2-Methylaminocyclohepta-2:4:6-trien-1-one (XXXVII, R = H, R_1 = Me) b.p. 70° (oil bath temperature)/1 mm. (Found: C, 70.0, H, 7.25 $C_8H_9ON_3$ requires C, 71.05; H, 6.7%) The picrate was obtained as yellow needles m.p. 130°. It was analytically impure.

2-Dimethylaminocyclohepta-2:4:6-trien-1-one (XXXVII, R, R_1 = Me) b.p. 90° (oil bath temperature)/1 mm. was analytically impure. The picrate was obtained as yellow needles from methanol m.p. 148° decomp. (Found: C, 46.9; H, 3.8 $C_{15}H_{14}O_8N_4$ requires C, 47.9; H, 3.75%).

2-Propylaminocyclohepta-2:4:6-trien-1-one (XXXVII, R = H, R_1 = C_3H_7). b.p. 100° (oil bath temperature)/1 mm. (Found: C, 72.0; H, 8.0 $C_{10}H_{13}ON$ requires C, 73.6; H, 8.0%) (Analytically impure). The picrate was obtained as yellow needles m.p. 145° decomp. (Found: C, 49.5, H, 4.5 $C_{16}H_{16}O_8N_4$ requires C, 49.0: H, 41%)

(3) A mixture of chloro cycloheptatrienone (100 mg.) and 15% sodium methoxide in absolute methanol were heated in a sealed tube at 80° (4 hours). The product was extracted with ether. From the ether extract tropolone methyl ether hemihydrate (XXIX) m.p. 35-36° was obtained and was undepressed on admixture with an authentic ether obtained by the action of diazomethane on tropolone.

(4) The reaction of alkali and water on 2-chlorocyclo-heptatrienone (XXXIV). (XXXIV) (100 mg.) and 3% sodium hydroxide were heated (30 mins.) on a water bath at 50-60°. The product was acidified and extracted with ether. The dried ether extract was evaporated and the residue fractionally crystallised from benzene/light petroleum to give (a) benzoic acid, m.p. and mixed m.p. with an authentic specimen 119-120°. (b) colourless crystalline needles, m.p. 90°. The latter was soluble in sodium hydroxide and bicarbonate and did not give a ferric chloride colour reaction. It was insufficient for analysis.

When chlorocycloheptatrienone was boiled with water, the two above products were also obtained. On refluxing with methanol, methylbenzoate could be clearly detected and acid hydrolysis gave benzoic acid m.p. and mixed m.p. 118-120°.

(5) When 2-chloro-cyclohepta trienone (50 mg.) was heated with a saturated solution of ammonium chloride followed by acidification and ether extraction, tropolone was isolated as the copper salt (2 mg.)

(6) Reduction of chlorocycloheptatrienone.

(1) In cyclohexane as solvent, chloro cycloheptatrienone (150 mg.) in cyclo hexane (10 c.c.) was reduced in presence of palladised charcoal catalyst (30 mg.) Hydrogenation was interrupted after 1 mole of hydrogen (24 c.c.) was consumed.

The product was sublimed and crystallised from cyclohexane to give colourless needles m.p. 96° (Found: C, 65.6, H, 5.0 C_7H_7Cl requires C, 66.4; H, 5.5%) (analytically impure) This product showed no ketonic properties and was found to contain chlorine. It is suggested to be chloro cyclohepta-triene.

(b) In benzene as solvent. On reduction of (XXXIV) (150 mg.) as above a solid m.p. 145° was obtained (4 mg.) together with a high boiling residue. The former gave no satisfactory formula based on analysis.

(c) In ethanol. 2-chlorocycloheptatrienone (100 mg.), anhydrous potassium acetate (0.5g.), absolute ethanol (10 c.c.) and palladised charcoal catalyst were shaken in presence of hydrogen. Absorption was smooth (64 c.c., 4 moles) in 1½ hours. After filtration of catalyst and removal of solvent, water (3 c.c.) was added and then the mixture was extracted with ether. The dried ether extract was evaporated and the residue distilled to give cyclohept-anone (XXXIX) b.p. 175-178°. (literature, b.p. 174-180°). The semicarbazone had m.p. 162-3° undepressed on admixture with an authentic specimen.

When the hydrogenation of (XXXIV) (100 mg.) was interrupted after hydrogen (16 c.c., 1 mole) was absorbed and then following the above procedure, cyclohepta 2:4:6-trien-1-one (XL) was obtained as a colourless viscous oil b.p. 115

-115°/12 mm. $N^{20}D$ 1.6082. (10 mg.) (literature,[21],[21] b.p. 104-105°/10 mm., $N^{25}D$ 1.6070, $N^{22}D$ 1.6170). The latter was very hygroscopic and analytically figures showed that it contained 2 molecules of water and was impure (Found: C, 59.6; H, 5.3 $6_7H_{10}O_3$ requires C, 59.2; H, 7.0%). Neither time nor material was available for repeating this experiment. Cycloheptatrienone gave no ketonic derivatives and was rapidly decolourised with dilute potassium permanganate solution. The hydrochloride was prepared in ether solution and formed a white crystalline solid that rapidly absorbed moisture and darkened.. On sublimation a crystalline hydrochloride was obtained but it was difficult to isolate as it was very hygroscopic. The picrate derivative was obtained as pale yellow needles m.p. 100-101° from aqueous methanol. (literature,[20],[21] m.p. 100-101°).

Reactions of 2:3-dichlorocyclohepta-2:4:6-trien-1-one (XXXV)

(1) Action of alkali or water. 2:3-dichlorocycloheptatrienone (100 mg.) was heated with 3% alkali at 60° for 1 hour. O-Chlorobenzoic acid (XLV) was obtained (50mg.) m.p. and mixed m.p. with an authentic specimen 143-145°.

Boiling (XXV) with water also yielded o-chlorobenzoic acid.

(2) Reaction with ethylamine. This was carried out as described for (XXXIV) to give 2-ethylamino-3-chlorocyclo-

heptane-2:4:6-trienone (XLVI) as a yellowish-green oil b.p. 110° (oil bath temperature)/2mm. (Found: C, 57.85; H, 5.0 $C_9H_{10}ONCl$ requires C, 58.85; H, 5.45%).

(3) Reduction of (XXXV) (200 mg.) in absolute ethanolic potassium acetate in presence of palladised charcoal, gave (after 5 moles of hydrogen were absorbed) cycloheptanone (50 mg.) b.p. 176-178° (literature, b.p. 179-180). The semicarbazone had m.p. and mixed m.p. with an authentic specimen 162-163°.

When absorption of hydrogen was interrupted after hydrogen (2 moles) was absorbed, cycloheptatrienone b.p. 104-105°/10 mm. $n^{20}D$ 1.6081 (10 mg.). (literature, b.p. 104-105°/10 mm., $n^{22}D$ 1.6172[20], $n^{25}D$ 1.6070[21]) was isolated.

Replacement reactions of α-bromotropolone.

(1) 2-Amino-3-bromocyclohepta-2:4:6-trien-1-one (XLVII) Bromotropolone methyl ether[16] (200 mg.) was heated with 15% anhydrous methanolic ammonia (5 c.c.) at 110° for 8 hours. The solvents were removed and the red residue crystallised on addition of ligroin and scratching. The brown solid was sublimed at 110° (oil bath temperature)/1 mm. to give a yellow powder. The latter was crystallised from benzene/methanol to give yellow crystalline needles m.p. 140°. (Found: C, 41.0; H, 3.0 C_7H_6ONBr requires C, 42.0, H, 3.0%). 2-amino-3-bromocycloheptatrienone is soluble in hydrochloric acid, and gives a green ferric chloride colour in ethanol.

It is sparingly soluble in hydrocarbon solvents, very soluble in hydroxylic solvents.

The above product (20 mg.) and 10% sodium hydroxide (1 c.c.) were heated on the steam bath (2 hours). Bromotropolone m.p. and mixed m.p. 103-108° was obtained.

(2) ∝-Hydroxytropolone (XLVIII)

Sodium bromotropolone (0.5g.) and 50% sodium hydroxide solution (5 c.c.) were refluxed (15 hours). The product was acidified with sulphuric acid and extracted with ether in a continuous liquid-liquid extractor (48 hours). Then the ether extract was dried (Na_2SO_4) and the ether removed. The dark brown residue was sublimed at 150°/1 m.m. to give a yellow solid m.p. 230-4 (50 mg.). This was crystallised from benzene methanol mixture to give ∝-hydroxytropolone (XLVIII) as a yellow cystalline solid m.p. 244° decomp. (Found: C, 60.6; H, 4.5 $C_7H_6O_3$ requires C, 60.85, H, 4.4%)

∝-Hydroxytropolone is very soluble in hydroxylic solvents, soluble in sodium bicarbonate and gives a brown ferric chloride colour reaction.

(XLVIII) was also obtained in low yield when bromotropolone was fused with alkali at 230-250° for 15 mins.

Fusion of hydroxytropoline with alkali. ∝-Hydroxytropolone (30 mg.) was fused with sodium hydroxide (2g.) and water (1 c.c.) in a nickel crucible at 300-310° (25 mins.) The dark brown melt was cooled, dissolved in water, acidified

and extracted with ether. The ether extract was dried and evaporated to give a brownish residue. The latter was sublimed to give salicylic acid (L) (2mg.), m.p. and mixed m.p. with an authentic specimen 160°.

Fusion of Bromotropolone with alkali. α-Bromotropolone (250 mg.), potassium hydroxide (2 g.) and water (1 c.c.) were fused as described above to give salicylic acid (L) m.p. and mixed m.p. 160° (10 mg.). The latter gave a violet ferric chloride colour reaction.

(3) α -Cyanotropolone (LI)

Sodium bromotropolone (4g.), pure pyridine (20 c.c.) and cuprous cyanide (5g.) were refluxed (15 hours). The suspended starting material slowly dissolved on heating (15 mins.) and the solution was coloured deep yellow.

After cooling, the product was carefully acidified under a hood with hydrochloric acid. Then it was extracted with ether in a continuous liquid-liquid extractor. The ether extract was dried (Na_2SO_4) and the ether removed. The residual solid was sublimed at 130-150° (oil bath temperature)/ 2 mm. to give α-cyanotropolone (LI) as a yellow powder m.p. 150-160° (2g. 80%). The latter was sublimed and crystallised several times from benzene/methanol to give yellow leaflets which although sharp-melting, did not analyse satisfactorily. m.p. 165° (Found: C, 63.2; H, 3.3 $C_8H_5O_2N$ requires C, 65.3; H, 3.4%).

α-Cyanotropolone gives a greenish brown ferric chloride colour reaction.

When α-bromotropolone was fused with cuprous or potassium cyanide at 200-220°, 1.5% of α-cyanotropolone was obtained as a yellow powder m.p. 160-165°.

Tropolone-α-carboxylic acid (LIII)

α-Cyanotropolone (1g.) and 30% potassium hydroxide solution (5 c.c.) were refluxed (12 hours). The product was acidified with sulphuric acid and extracted with ether in a continuous liquid-liquid extractor (48 hours). The ether extract was dried (Na_2SO_4) and the ether removed. The residual brown solid was sublimed at 140-160 (oil bath temperature)/1-2 mm. when small yellow needles were obtained (0.5g. = 40%). The latter was crystallised from benzene to give tropolone-α-carboxylic acid (LIII) as yellow needles from benzene methanol m.p. 212-213° decomp. (Found: C, 58.0; H, 3.8 $C_8H_6O_4$ requires C, 57.85; 3.65%).

Tropolone-α-carboxylic acid is soluble in both sodium hydroxide and sodium bicarbonate. Sparingly soluble in hydrocarbon solvents and ether, very soluble in hydroxylic solvents and gives a brown ferric chloride colour reaction.

When cyanotropolone was refluxed with concentrated hydrochloric acid, tropolone-α-carboxylic acid was obtained in 20% yield.

Decarboxylation of tropolone-α-carboxylic acid. The

above acid (LIII) (100 mg.) was heated in an oil bath in a sublimation tube at 240-250°; the material quickly decomposed and a white oily solid was obtained. The latter was dried on a porous plate and the residue crystallised from light petroleum (b.p. 40-60°) to give tropolone as colourless crystalline needles m.p. 49° undepressed on admixture with an authentic specimen of tropolone.

Fusion of Tropolone-∝-carboxylic acid with alkali. The above acid (100 mg.) was fused in a nickel crucible as described for ∝-hydroxytropolone (XLVIII) to give on sublimation phthalic anhydride m.p. 130° (5 mg.) undepressed on admixture with an authentic specimen m.p. 131°. Boiling with water, phthalic acid m.p. 228° was obtained undepressed on admixture with an authentic specimen m.p. 231°.

When tropolone-∝-carboxylic acid was treated with diazomethane, a yellow gummy residue was obtained. The latter was distilled b.p. 110° (oil bath temperature)/1 mm. to give a yellow uncrystallisable oil. This oil was insoluble in alkali and no longer gave a ferric chloride colour reaction. On hydrolysis of the oil, tropolone-∝-carboxylic acid was obtained m.p. and mixed m.p. 212°.

Tropolone-∝-(p-thiocresol). (LVI, R = Me)

Bromotropolone (1g.), p-thiocresol (1g.) and pyridine (10 c.c.) were refluxed for 1 hour. The product was filtered free from precipitated sodium bromide. Excess pyridine

was removed in vacuo and the residual solid was crystallised from methanol in green-brown crystals. When powdered, it appeared yellow. m.p. 175° (lg. 81%) (Found: C, 69.0; H, 5.25. $C_{14}H_{12}O_2S$ requires C, 68.8; H, 4.95%). With thiophenol, tropolone-α-thiophenol (LVI, R = H) was obtained in yellow crystalline needles m.p. 58°., However, the product was not analytically pure. (Found: C, 67.65; H, 5.6 $C_{13}H_{10}O_2S$ requires C, 67.8; H, 4.4%).

Both above products were soluble in alkali and gave a brown colour with ferric chloride.

Desulphurization of Tropolone-α-(p-thiocresol)

The sodium salt of the above product (100 mg.) was refluxed with Raney nickel (200 mg.) in ethanol (5 c.c.) for 2 hours. The product was filtered and the ethanol removed. On sublimation of the residue, tropolone was obtained m.p. 49° undepressed on admixture with an authentic specimen.

Fusion of α-bromotropolone with copper powder: Sodium bromotropolone (100 mg.) and copper powder (200 mg.) were heated in pyrex tube in an oil bath at 250° (2 hours). The product was acidified and extracted with ether. The ether extract was dried and ether removed.

The residue on fractional sublimation gave tropolone, subliming at 40°/1 mm. (5 mg.) m.p. and mixed m.p. 49° and bromotropolone subliming at 85°/1 mm.-m.p. and mixed m.p.

103-105 (20 mg.)

α-Bromotropolone and tropolone used in the reactions described here were prepared by the method of Cook[16a] et al.

α,α'-Tetrabromocycloheptanone (LXIII). To an ice cold solution of cycloheptanone (5g.) in glacial acetic acid (5 c.c.) was added a solution of bromine (28.6g.) in glacial acetic acid (15 c.c.) for 30 mins. At first the reaction mixture became red, then a sudden reaction took place and the reaction mixture was decolourised. After complete addition of bromine, the reaction product was viscous and red. The product was left overnight in a flask protected with a guard tube and was then heated on a steam bath (20 mins.). Dense fumes of hydrogen bromide were evolved. The product was then concentrated in vacuo to one-third of its bulk and then extracted with ether. The ether extract was first washed with sodium bicarbonate then with water and dried (Na_2SO_4). The ether was removed and the residual reddish oil quickly solidified on cooling. The latter was crystallised from benzene/light petroleum to give α, α' tetrabromo cycloheptanone as colourless cubes m.p. 79° (5.1g. = 19%). (Found: C, 20.15, H, 2.15. $C_7H_8OBr_4$ requires C, 19.65; H, 1.9%).

2;2'-tribromocyclohexanone (LXII). To cycloheptanone (5g.) in glacial acetic acid (5 c.c.), bromine (21.4g. in acetic acid (10 c.c.) was added. The reaction was carried out as described above to give colourless leaflets or prisms, m.p. 72° (5g. = 28%). (Found: C, 24.2; H, 2.4. $C_7H_9OBr_3$ requires C, 24.1; H, 2.6%).

2;2'-Dibromocyclo-heptanone (LXI). To cycloheptanone (5g.) in glacial acetic acid (5 c.c.), bromine (14.3g.) in acetic acid (10 c.c.) was added. The product was worked up as described above to give colourless prisms from light petroleum (80-100°) m.p. 71° (3g. = 25%). (Found: C, 31.6; H, 4.1. $C_7H_{10}OBr_2$ requires C, 31.2; H, 3.75%).

Dehydrobromination of 2,2'-tetrabromocycloheptanone (LXIII). The above product (3g.) and collidine (40 c.c.) were heated in an oil bath with gentle reflux. After nearly 15 mins. collidine hydrobromide was precipitated. Refluxing was continued for 30 mins. more. The reaction product was cooled and filtered, the solid material was washed with benzene. To the combined filtrate and washings, concentrated hydrochloric acid (50 c.c.) was added. The reaction mixture was shaken and the benzene layer separated. The latter was then washed with dilute hydrochloric acid then with water. The benzene extract was dried (Na_2SO_4), decolourised with charcoal, and filtered. The bright yellow filtrate was

evaporated and the residue distilled in vacuo at 80-100° (oil bath temperature)/1 mm. The distillate was obtained as a colourless oil which quickly crystallised. Crystallisation from light petroleum, colourless crystals of (LXVII) were obtained m.p. 95° (0.5g. = 38%). (Found: C, 41.25 H, 4.4. $C_7H_9O_2Br$ requires C, 41.0, H, 4.4%). The above product was soluble in sodium hydroxide, sodium bicarbonate, but did not give a ferric chloride colour reaction. On addition of silver nitrate to a boiling solution of the above product in nitric acid silver bromide was obtained.

Dehydrobromination of 0.0'-tribromocycloheptanone (LXII).

The above product (3g.) and collidine (40 c.c.) were heated together and worked up as described for (LXVII). The product was fractionally distilled to give a fraction b.p. 90-110° (oil bath temperature)/1-2 mm. This was fractionally crystallised from benzene/light petroleum to give (a) colourless needles m.p. 105° (0.5g. = 31%). (Found: C, 41.05, H, 3.75. $C_7H_7O_2Br$ requires C, 41.4; H, 3.5%). (b) colourless cubes m.p. 140° (0.1g. = 6%) (Found: C, 40.9; H, 3.7. $C_7H_7O_2Br$, requires C, 41, 4; 3.5%). Both products (a) and (b) corresponded to formula (LXV,a). Both products were soluble in sodium hydroxide and sodium bicarbonate but did not give a ferric chloride colour reaction.

Fusion of product m.p. 105 with alkali. This was carried out as described for α-hydroxytropolone (XLVIII).

A crystalline solid m.p. 100° was obtained from light petroleum. Admixture with the starting material the former gave a depression of 30°. The product was also soluble in sodium bicarbonate and did not give a ferric chloride colour reaction. (Found: C, 52.88; H, 7.8. $C_7H_{12}O_4$ requires C, 52.5; H, 7.55%).

Reaction of solid m.p. 105° with p-thiocresol. This was carried out as described for (LVI) to give colourless crystals m.p. 198° which were analytically impure. (Found: C, 67.0; H, 5.5 $C_{14}H_{14}O_2S_2$ requires C, 68.25; H, 5.7 %). This product was soluble in both alkali and sodium bicarbonate and had no colour reaction with ferric chloride solution.

Reduction of solid m.p. 105°; (LXV) (100 mg.), ethanol (15 c.c.), triethylamine (0.5 c.c.) and palladised charcoal (25 mg.) were shaken in the presence of hydrogen. Absorption stopped after the consumption of 4 equivalents of hydrogen. The product was then filtered from catalyst and solvent was removed in vacuo. The colourless residue had a smell of that of hexahydrobenzoic acid. It distilled at 220-230° under ordinary pressure [cyclohexane-carboxylic acid. b.p. 230°/760 mms]. This residue was then refluxed with thionyl chloride and the acid chloride produced was heated with aniline (½ hour). The product was then diluted with water and extracted with ether. The residue gave cyclohexane-carboxylanilide m.p. 135-138°. Admixture with an authentic

specimen gave no depression.

When the consumption of hydrogen was interrupted after the absorption of one equivalent of hydrogen, the only products that could be detected were cyclohexane carboxylic acid and the starting material.

Reduction of solid m.p. 140°. This was carried as described above to give hexahydrobenzoic acid b.p. 225/760 mm. The anilide m.p. 135-137°. The latter product was undepressed on admixture with an authentic specimen.

3:4:5:6-Dibenztropolone (LXXV)

(1) In Dioxane. To 3:4:5:6-dibenzcyclohepta 3:5-dien-1-one (LXXIII) (200 mg.) dissolved in dioxan (3 c.c.), was added a solution of selenium dioxide (85 mg.) in water (1 c.c.). The reaction mixture was then heated on the steam bath for 8 hours. Selenium black was precipitated. The product was then left overnight at room temperature. It was filtered from selenium (40 mg.), diluted with water (3 c.c.) and extracted with ether (3 times). The combined ether extract was then extracted with sodium bicarbonate, followed by sodium hydroxide till no colour appeared in the alkaline extract. The straw-coloured sodium bicarbonate extract was acidified, and then extracted with ether. The residue was sublimed at 180°/1 mm. to give yellow needles of 9-phenanthrene-carboxylic acid (LXXVIII) m.p. 253-256°

(6 mg.). Admixture with an authentic specimen produced no depression in the melting point. The sodium hydroxide extract was quickly filtered through charcoal and the deep yellow filtrate was quickly acidified and extracted with ether. The ether extract was dried and ether evaporated. The residue was fractionally crystallised from ether to give yellow needles of 9-phenanthrene-carboxylic acid (LXXVIII) m.p. 254-256° (4 mg.) and yellow prisms (15 mg.) The latter were crystallised from benzene/light petroleum to give 3:4:5:6- dibenztropolone (LXXV) m.p. 115-116°. (Found: C, 80.75; H, 4.4. $C_{15}H_{10}O_2$ requires 81.05; H, 4.5%).

The 2:4-dinitropheny hydrazone was obtained as red leaflets from methanol/benzene m.p. 234°. (Found: C, 62.6; H, 4.05. $C_2H_{15}O_5N_4$ require C, 62.5; H, 3.7%).

Dibenztropolone was found to have the following properties:-

(1) Gives a brown ferric chloride colour reaction. (2) Gives a yellow sodium salt in solution. (3) Forms a green copper complex in presence of copper acetate which is soluble in chloroform. It was insoluble in sodium bicarbonate, soluble in sodium hydroxide.

The neutral ether extract was once washed with water then was dried (Na_2SO_4) and the ether evaporated. The yellow gummy product was extracted once with light petroleum. The

latter on slow evaporation gave dibenzcyclohepta-3:5-diene (unchanged material) m.p. 75-78° (20 mg.) and was undepressed on admixture with an authentic specimen. The remaining material was then fractionally crystallised from benzene/cyclohexane to give (a) phenanthraquinone (LXXVII) which was purified by sublimation and crystallisation m.p. 195-197°. The O-phenylenediamine derivative gave m.p. 217°. Admixture of both above specimens with authentic specimens of phenanthraquinone and the O-phenylene diamine derivatives respectively were not depressed. (b) Cream coloured prisms m.p. 218° (8 mg.) possibly the triketone (LXXVI) (Found: C, 75.45; H, 3.95. $C_{15}H_8O_3$ requires C, 76.2; H, 3.4%). The latter was insoluble in alkali and gave a gummy precipitate with 2:4-dinitrophenyl hydrazine.

The residual product was scratched in ligroin. A fine powder was obtained m.p. 145-150°. The latter was refluxed with dilute sulphuric acid (2 hours). The ether extract gave dibenztropolone m.p. 115-116° and red selenium (2 mg.)

(2) In aqueous acetic acid. The above detailed procedure was followed using 3:4:5:6-dibenzcyclohepta-3:5-dien-1-one (200 mg.) in acetic acid (3 c.c.) and a solution of selenium dioxide (85 mg.) in water (2 c.c.). The following products were obtained. (a) Dibenztropolone (LXXV) (15 mg.) (b) 9-phenanthrene-carboxylic acid (LXXVIII) (12 mg.) (c) Phenanthraquinone (LXXVII) (5 mg.) (d) Unchanged

dibenzcycloheptadienone (LXXIII) (20 mg.) (4) The triketone (LXXVI) (5 mg.) and (f) a selenium complex.

(3) In glacial acetic acid Dibencyclohepta-3:5-dien-1-one (LXXIII), glacial acetic acid (3 c.c.) and selenium dioxide (85 mg.) were heated on a steam bath (8 hours). The product became deep red and elementary selenium was precipitated. The reaction mixture was then treated as described above to give phenthraquinone (LXXVII) (25 mg.) and starting material (50 mg.) as the sole products.

Reaction of Alkali on dibenztropolone (LXXV).

Dibenztropolone (10 mg.) and 3% sodium hydroxide were heated on a water bath at 50° (30 mins.) The product was acidified and extracted with ether. The residue was sublimed to give 9-phenanthrene-carboxylic acid (LXXVIII) m.p. and mixed m.p. 254-256°.

Attempts were made to prepare dibenztropolone methyl ether by the action of diazomethane on dibenztropolone. However the product failed to crystallise. No colour reaction was obtained with ferric chloride. On hydrolysis of the gummy methyl ether with dilute sulphuric acid, dibenztropolone was obtained m.p. and mixed m.p. 115-116°.

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