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THE FRIEDEL–CRAFTS CONDENSATION OF THE LACTONE OF 4-METHYL-2-HYDROXYCYCLOHEXANE ACETIC ACID WITH AROMATIC HYDROCARBONS—I

BENZENE AND TOLUENE[1]

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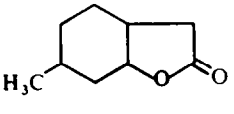
Abstract—The cationic nuclear alkylation of benzene with the lactone (I) has been found to give a stereoisomeric mixture containing 4-methyl-2-phenylcyclohexyl acetic acid (II) and 4-methyl-3-phenylcyclohexyl acetic acid (III). The former has been cyclized, reduced and dehydrogenated to 3-methyl phenanthrene. A similar condensation between the lactone (I) and toluene afforded a mixture of 4-methyl-2-*o*-tolyl-, 4-methyl-2-*p*-tolyl- and 4-methyl-3-*p*-tolyl-cyclohexyl acetic acids. The structures of the former two acids were confirmed by their cyclization to ketohydrophenanthrenes (VIII) and (IX) and their subsequent conversion to 3,5-dimethyl- and 2,6-dimethyl phenanthrenes respectively. A possible mechanism for the abnormal Friedel–Crafts reaction is discussed.

THE aluminium chloride-catalysed alkylation of aromatics with simple unsubstituted alicyclic lactones has been found to afford a mixture of secondary monoalkylates consisting of the normal and rearranged condensation products of which the former have been successfully converted to polycyclic compounds via the polycyclic hydroaromatic ketones.[1b] Phillips and Chatterjee[2a, b] studied the $AlCl_3$-catalysed alkylation of aromatics with the lactone of *trans*-cyclohexanol-2-acetic acid and observed that the alkylation was attended with extensive rearrangement yielding minor amounts of the expected *trans*-2-arylcyclohexane acetic acids which could be cyclized to polycyclic ketones and comparatively large amounts of rearranged products consisting of 4-arylcyclohexane acetic acids and the 3-aryl isomers, thereby limiting the use of cationic nuclear alkylation in the synthesis of polycyclic compounds. In order to develop it into a useful process for the synthesis of polycyclic compounds *via* cyclic ketones, the lactone of 4-methyl-2-hydroxy cyclohexane acetic acid (I) has been prepared with a view to studying the $AlCl_3$-catalysed alkylation of various aromatics with it. The observation made by Friedman *et al.*[3, 4] that in the alkylation of aromatics with branched cycloolefins like methylcyclohexenes, strong Lewis acid type of catalysts like $AlCl_3$-HCl largely produce secondary alkylate and very little of the tertiary alkylate, prompted us to select this particular lactone.

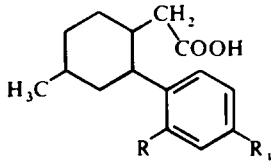
The lactone (I) has been prepared from 4-methylcyclohexane-2-one-1-acetic acid, synthesized by an improvement of the method of Kotz and Kayser.[5] The Friedel–Crafts condensation of the lactone (I) with benzene gave a stereoisomeric inseparable mixture of 4-methyl-2-phenylcyclohexyl acetic acid (II) and the 3-phenyl isomer (III) as a colourless thick oil, isolated through the ethyl ester in 50% yield. Somewhat lower yield of the product may be ascribed to the disproportionation of a part of the lactone (30%) to 4-methylcyclohexane acetic acid evidently arising out of hydride transfer to the tertiary

carbonium ion.[3, 6, 7] The presence and the relative proportion of the components in the mixture was ascertained by cyclization of the acidic mixture with the polyphosphoric acid when 35% of the material cyclized giving predominantly *trans*-3-methyl-9-keto-1,2,3,4,9,10,11,12-octahydrophenanthrene (IV). The structure of the ketone was established by its reduction and dehydrogenation to 3-methyl phenanthrene as well as by an unequivocal synthesis from ethyl 4-methyl cyclohexane-2-one-1-acetate and PhMgBr by an adaptation of the method of Buchta and Ziener.[8] The condensation led to the formation of the lactone of 4-methyl-2-hydroxy-2-phenylcyclohexane acetic acid in 58% yield, which on Clemmensen reduction gave 4-methyl-2-phenylcyclohexane acetic acid (II) in 60% yield in stereoisomeric forms. Although no stereochemically pure homogeneous solid acid could be isolated from this mixture, it consisted predominantly of the *trans*-phenyl cyclohexyl acetic acid as it could be cyclized in 82% yield to a pure homogeneous keto hydrophenanthrene identical with that obtained from the acidic mixture of $AlCl_3$-catalysed condensation reactions.

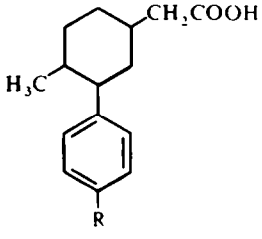
The determination of the identity and relative proportion of the 3-phenyl isomer in the acid mixture was more difficult as synthesis of stereochemically pure acid was not easy. However the problem was solved by the dehydrogenation of the acid recovered from the cyclization experiment, which amounted to 60% of the acidic mixture obtained from the condensation reactions, whereby it could be dehydrogenated to 2,5-dimethyl biphenyl which on oxidation by alkaline $KMnO_4$ followed by esterification of the dicarboxylic acid gave dimethyl biphenyl-2,5-dicarboxylate.



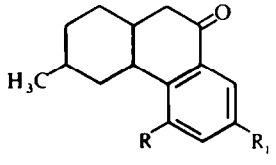
I



II: R = R_1 = H
V: R = CH_3; R_1 = H
VI: R = H; R_1 = CH_3



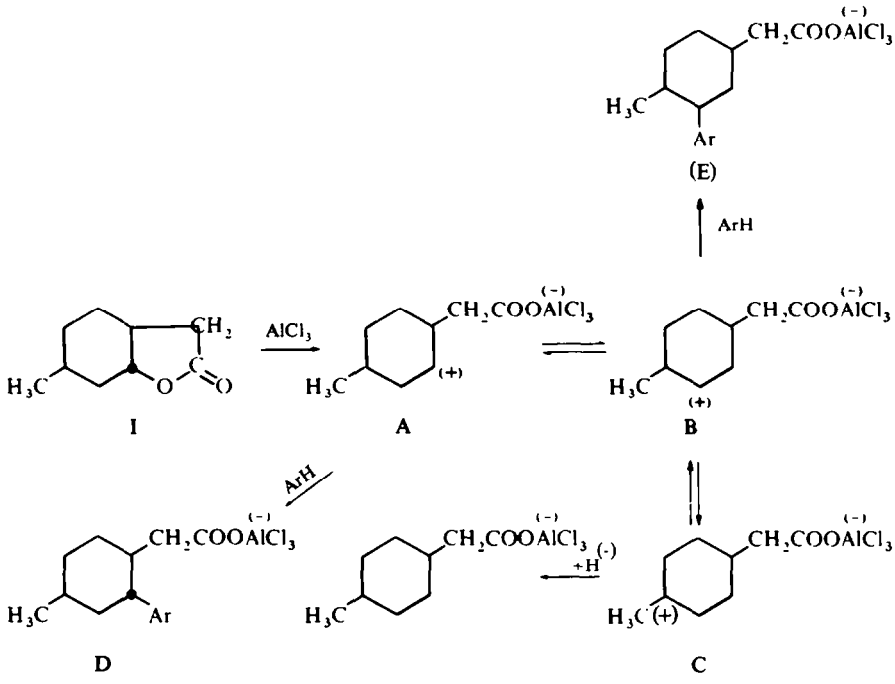
III: R = H
VII: R = CH_3



IV: R = R_1 = H
VIII: R = CH_3; R_1 = H
IX: R = H; R_1 = CH_3

The Friedel–Crafts alkylation of aromatics with lactones described above can be easily explained in terms of the classical carbonium ion mechanism. The interaction of the Lewis acid catalyst and the lactone of 4-methyl-2-hydroxy cyclohexane acetic acid leads to the formation of secondary carbonium ion (A) which then undergoes a series of

intramolecular 1,2-hydrogen shift giving secondary (**B**) and tertiary carbonium ion (**C**). The tertiary carbonium ion (**C**) which is formed at position 4 is apparently not stable in the system and reduced by intramolecular hydride abstraction to 4-methyl cyclohexane acetic acid. The hydride ion can be abstracted from either the olefin formed by the loss of proton from the ionic species (**A**) to give an allylic ion or form a C—H bond. In the absence of any



definite by-product, it is difficult to pinpoint the source. Considerable amount of the high boiling acid sludges always produced in the condensation using the lactone (I) could be produced from these allylic ions.

The *trans* stereochemistry observed in the *ortho* compound (**D**) may then be ascribed simply to thermodynamic control of the reaction in which the more stable product could be expected. It would be instructive to know the stereochemistry of the metaproduct (**E**), but we have not been able to determine it yet, as the 3-aryl isomers could not be isolated in stereochemically pure form.

The $AlCl_3$-catalysed alkylation of toluene with the lactone (I) was studied with a view to gain further insight into the scope and mechanism of the reaction, which was far more complicated than the benzene series. One interesting feature was that whereas the *para* condensation in the aromatic ring was attended with the formation of predominantly *cis* isomer, the *ortho* condensation resulted in the formation of a larger amount of the *trans* isomer.

The lactone (I) on Friedel–Crafts condensation with toluene afforded a complex mixture of isomeric acids (33%), purified through the ethyl ester, containing 4-methyl-2-*o*-tolyl-cyclohexyl acetic acid (V), 4-methyl-2-*p*-tolyl-cyclohexyl acetic acid (VI) and 4-methyl-3-*p*-tolylcyclohexyl acetic acid (VII), which, however, could not be isolated in

pure form. A considerable portion of the lactone was reduced, as in the alkylation of benzene, to 4-methylcyclohexyl acetic acid.

The expected *ortho* and *para* condensation observed by us is in agreement with the work of Buu-Hoi and Cagniant[9] who reported the formation of *ortho* and *para* alkylated products during the alkylation of toluene with ethyl cyclopent-2-ene-1-acetate. *p*-Orientation was also observed in alkylation reaction with simple acyclic lactones.[10] *m*-Alkylations have also been reported in some cases.[11, 12]

Polyphosphoric acid cyclization of the acidic mixture resulted in the cyclization of 33% of the material giving *trans*-3,5-dimethyl-9-keto-1,2,3,4,9,10,11,12-octahydrophenanthrene (25%) VIII, and a stereoisomeric mixture (75%) consisting predominantly of *cis*-2,6,-dimethyl-10-keto-5,6,7,8,9,10,13,14-octa-hydrophenanthrene (IX) as an oil.

The structure of the *trans* ketone was established by its reduction and dehydrogenation with 10% Pd-C catalyst to hitherto unknown 3,5-dimethyl phenanthrene and from its unequivocal synthesis from ethyl 4-methyl cyclohexane-2-one-1-acetate and *o*-tolyl magnesium bromide through Clemmensen reduction of the resulting lactone followed by cyclization of the acidic material. The *trans*-configuration of the synthetic ketone was assumed by analogy with the observation of Buchta and Ziener.[8] An interesting *ortho*-migration of the alkyl group was noticed during selenium dehydrogenation of the hydroaromatic compound derived from the *trans* ketone when 3,6-dimethyl phenanthrene was isolated instead of the expected 3,5-dimethyl derivative.

The oily ketone obtained from the cyclization experiment was found to be predominantly *cis*-2,6-dimethyl-10-keto-5,6,7,8,9,10,13,14-octahydrophenanthrene (IX). Its structure was established by its reduction and dehydrogenation with 10% Pd—C to 2,6-dimethyl phenanthrene as well as by unequivocal synthesis from ethyl 4-methyl cyclohexane-2-one-1-acetate and *p*-tolyl magnesium bromide. The condensation afforded the lactone of 4-methyl-2-hydroxy-2-*p*-tolyl-cyclohexyl acetic acid in 50% yield which on Clemmensen reduction gave 4-methyl-2-*p*-tolyl-cyclohexyl acetic acid in 70% yield in stereoisomeric forms as a semisolid mass from which no homogeneous solid could be isolated. Cyclization of this acidic mixture with polyphosphoric acid gave a stereoisomeric mixture of 2,6-dimethyl-10-keto-5,6,7,8,9,10,13,14-octahydrophenanthrene (IX) in 96% yield from which pure *trans* ketone, m.p. 136° was isolated by fractional crystallization from petroleum ether. Although no pure *cis*-ketone was obtained from the mother liquor, we were able to get a pure sample of 2 : 4-D.N.P. derivative of the *cis* form from the mother liquor of the 2 : 4-D.N.P. derivative of the *trans*-ketone. This was identical with the 2 : 4-D.N.P. derivative of the oily ketone obtained from the acidic mixture resulting from the alkylation of toluene with the lactone (I). Both the synthetic *trans* ketone, m.p. 136° and the oily ketone on reduction and dehydrogenation yielded the same 2,6-dimethyl phenanthrene, thus establishing they were stereoisomers. Selenium dehydrogenation of the above *trans* ketone after reduction gave no abnormal dehydrogenation product.

The relative proportion of the 3-aryl isomer (VII) in the condensation product was ascertained as in the case of benzene series by a cyclization. The acidic product recovered from the cyclization of the Friedel–Crafts condensation product (58%) consisted of 4-methyl-3-*p*-tolyl-cyclohexyl acetic acid (VII) in stereoisomeric forms, for the identity of which no direct evidence could be put forward. The structure of the acid was, however, confirmed by its dehydrogenation with 10% Pd—C catalyst to 2,4′,5-

trimethyl biphenyl and its subsequent oxidation to biphenyl-2,4′,5-tricarboxylic acid. The hydrocarbon showed no characteristic UV spectra of the *o*-disubstituted biphenyl. The absence of any peak corresponding to 2,2′-disubstituted biphenyl as well as failure to isolate any acidic product other than biphenyl-2,4′,5-tricarboxylic acid was indicative of the fact that the *para* condensation in the aromatic ring was the major product here although the possibility of formation of a small amount of the *ortho*-condensation product which might have escaped detection could not be ruled out.

EXPERIMENTAL

All the m.ps and b.ps are uncorrected. Neutral Brockman alumina (E.M.) was used for chromatography. The petroleum ether refers to 40°–60° fraction. IR spectra were measured on Perkin–Elmer Infra Cord Model 137 and UV spectra on a Unicam S.P.500 Spectrophotometer.

4-Methyl cyclohexane-2-one-1-acetic acid. This compound was prepared from ethyl 4-methyl cyclohexane-2-one-1-carboxylate by the condensation with ethyl bromo acetate followed by acidic hydrolysis according to Kotz and Kayser,[5] m.p. 93–94°, semicarbazone, m.p. 195°, ethyl ester, b.p. 120°/1 mm, semicarbazone of the ethyl ester, m.p. 116°.

For synthesis of the lactone (I) the ethyl ester (39·6 g, 0·2 mole) was reduced by aluminium isopropoxide, prepared from Al granules (13·5 g), isopropyl alcohol (250 ml), $HgCl_2$ (0·5 g) and CCl_4 (2 ml) by refluxing for 1 hr. The acetone formed was slowly distilled. This process was continued till the separation of acetone was complete (4 hr). The residue was then cooled and decomposed with ice-cold dil. HCl. The liberated oil, recovered by ether extraction, was hydrolysed by boiling with alcoholic KOH (20 g). After removal of alcohol, the resulting product was acidified with 1 : 1 H_2SO_4 and gently boiled for 1 hr to effect lactonization. After cooling, the whole mass was extracted with three 100 ml portions of ether, washed with Na_2CO_3 aq (5%), water and dried ($CaCl_2$). Removal of the solvent followed by distillation gave the desired lactone as a colourless oil, b.p. 135–140°/8–9 mm, n_D^{35} 1·5590; IR 5·65 μ (C=O str. in γ-lactone). (Found: C, 63·52; H, 9·03. $C_9H_{14}O_2$ requires C, 63·63; H, 9·09%).

Condensation of lactone (I) *with benzene.* A solution of I (15·4 g, 0·1 mole) in dry C_6H_6 (40 ml) was slowly added to a stirred suspension of anhydrous $AlCl_3$ (14·7 g, 0·11 mole) in dry C_6H_6 (100 ml) cooled in a freezing mixture. After addition, it was stirred at 0° for 2 hr, at room temp. for 4 hr and left overnight. The product was decomposed with ice and HCl and steam distilled. The residue was cooled and the semisolid mass purified through Na_2CO_3 aq to give an acidic mixture (22 g) which was converted to the ethyl ester by refluxing with EtOH (50 ml), C_6H_6 (100 ml) and conc. H_2SO_4 (1 ml) for 12 hr. Usual work up gave a forerun of ethyl 4-methyl cyclohexylacetate (5 g), b.p. 100°/1 mm furnishing 4-methyl cyclohexyl acetic acid, m.p. 71°, on hydrolysis, followed by a stereoisomeric mixture of ethyl 4-methyl-2-phenyl cyclohexylacetate and ethyl 4-methyl-3-phenyl cyclohexyl acetate (13 g, 50%) obtained as a colourless oil, b.p. 140–45°/0·5 mm. (Found: C, 78·12; H, 9·61. $C_{17}H_{24}O_2$ requires C, 78·46; H, 9·23%). Saponification of the above ethyl ester (13 g) gave the stereoisomeric mixture of II and III (11·5 g, 50%) as a colourless viscous liquid, b.p. 180°/1 mm, which did not solidify. (Found: C, 77·42; H, 8·64. $C_{15}H_{20}O_2$ requires C, 77·58; H, 8·62%).

Polyphosphoric acid cyclization of the acidic mixture; isolation of trans-3-*methyl*-9-*keto*-1,2,3,4,9,10,11,12-*octahydrophenanthrene* (IV). To polyphosphoric acid[14] (60 g) was added the foregoing acid mixture (11·5 g; 0·05 mole) and stirred at 100° for 30 min. The viscous brown product was hydrolysed with ice and extracted with three 100 ml portions of ether, washed with water, Na_2CO_3 aq (5%) and finally with water and dried (Na_2SO_4). The residue, after removal of ether, was distilled to give the methylketohydrophenanthrene (4 g, 37·4%) as a thick yellow oil, b.p. 165–70°/1 mm, which readily solidified in the receiver. Chromatography over a column of alumina (120 g) followed by elution with C_6H_6–petrol mixture (1 : 1) gave the pure ketone which crystallized from hexane to give colourless needles of IV, m.p. 144–45° undepressed on admixture with a synthetic specimen of the above compound.

Reduction of IV *to* 3-*methyl*-1,2,3,4,9,10,11,12-*octahydrophenanthrene and its dehydrogenation to* 3-*methylphenanthrene.* The foregoing ketone IV (4·3 g, 0·02 mole) was gently boiled with amalgamated zinc (20 g), conc. HCl (50 ml) and toluene (5 ml) for 30 hr with the addition of conc. HCl (5 ml) after 6 hr. After cooling, the toluene layer was separated and the aqueous layer extracted with two 50 ml portions of C_6H_6. The combined C_6H_6–toluene layer was washed with water and dried (Na_2SO_4). After careful fractionation of solvent under reduced pressure, the residue was chromatographed over alumina (120 g). Elution with

hexane (100 ml) removal of solvent and distillation gave 3-methyl-1,2,3,4,9,10,11,12-octahydrophenanthrene (2·6 g, 65%) as a colourless fluorescent oil, b.p. 155°/1 mm. (Found: C, 89·65; H, 10·12. $C_{15}H_{20}$ requires C, 90·00; H, 10·00%). The above hydrocarbon (1 g) was heated with sulphur (0·75 g) at 180–200° for 8 hr. The temp. was allowed to rise to 230° over 4 hr when evolution of H_2S became less. The product was taken up in C_6H_6 filtered and boiled with freshly precipitated Cu powder. It was filtered, solvent removed and the residue chromatographed over alumina (20 g). Elution with petroleum ether (100 ml) and removal of solvent gave a semisolid mass which was converted to the picrate in methanolic solution. The picrate from yellow needles, (methanol) m.p. 138° (lit. value[15], 137–38°).

The hydrocarbon regenerated from the picrate by passing the solution in C_6H_6 through alumina was an oil which slowly solidified. It crystallized from CH_3OH as colourless plates, m.p. 66° (lit. value[15], 62–63°). The m.m.p. with an authentic sample of 3-methylphenanthrene was not depressed.

Isolation of 4-*methyl*-3-*phenylcyclohexyl acetic acid* III *and its dehydrogenation to* 2,5-*dimethylbiphenyl.* The alkaline extract from the cyclization experiment was acidified with HCl (6N) and extracted with two 100 ml portions of C_6H_6, and washed with water. Removal of solvent followed by vacuum distillation gave a stereoisomeric mixture of III (6·9 g; 60%) as a thick viscous liquid, b.p. 180–85°/1 mm, which did not solidify. (Found: C, 77·32; H, 8·38. $C_{15}H_{20}O_2$ requires C, 77·58; H, 8·62%). The foregoing acid (III) (1 g) was heated with 10% Pd—C catalyst (0·1 g) at 300–320° for 2 hr. The product was dissolved in hot C_6H_6 and filtered through alumina. After removal of solvent the hydrocarbon was distilled to give 0·5 g of 2,5-dimethyl biphenyl (50%) as a colourless mobile liquid, b.p. 104–105°/1 mm, n_D^{25} 1·5775. UV (C_2H_5OH) λ_{max} 238 mμ (ε 9120).

The hydrocarbon (1 g) was oxidized by refluxing for 48 hr with a mixture of 5% NaOH (100 ml) and excess $KMnO_4$ solution (5%). Excess of the oxidant was decomposed with C_2H_5OH. Filtration from the sludge of MnO_2 followed by concentration, acidification and ether extraction gave a semisolid acid which was esterified with CH_2N_2. The methyl ester was chromatographed over Al_2O_3 (20 g) with C_6H_6 when it was obtained as a solid which crystallized from hexane as soft silky needles, m.p. 68°, undepressed on admixture with an authentic specimen prepared according to Weisburger and Weisburger.[16] No other biphenyl derivative could be isolated from the mother liquor.

A part of the ester was hydrolysed with alcoholic KOH (1 g). Acidification followed by crystallization from MeOH (aq) gave colourless granules of biphenyl-2,5-dicarboxylic acid, m.p. 278–80°, undepressed on admixture with an authentic specimen.

Synthesis of trans-3-*methyl*-9-*keto*-1,2,3,4,9,10,11,12-*octahydrophenanthrene* (IV). A Grignard reagent prepared from 1·2 g (0·05 gm atom) of Mg, 7·9 g (0·05 gm mole) of C_6H_5Br and dry ether (40 ml), was added dropwise with continuous stirring to a solution of 9·9 (0·05 mole) of ethyl 4-methylcyclohexane-2-one-1-acetate in dry ether (40 ml) cooled below 0°, during 1 hr. The mixture was stirred for 2 hr at 0° and left overnight. The yellowish white ppt. of the complex was cooled and decomposed with ice-cold dil. H_2SO_4. The ether layer was separated and the aqueous layer extracted with two 100 ml portions of ether, washed with water and dried (Na_2SO_4). After removal of solvent, the residue (1 g) was hydrolysed with alcoholic KOH (10 g) by refluxing for 1 hr. After removal of alcohol under reduced pressure, the mixture was diluted, cooled and the unhydrolysed portion separated by ether extraction. The clear alkaline solution was acidified with 6N H_2SO_4 and boiled gently under reflux for 1 hr. After cooling, the whole mass was extracted with two 100 ml portions of ether. The combined ether layer was washed with water, 5% Na_2CO_3 (100 ml) and finally with water and dried (Na_2SO_4). Removal of the solvent followed by vacuum distillation of the residue gave two fractions: (1) 1 g (16%) of the lactone of 4-methyl-2-hydroxycyclohexane-1-acetic acid (I), b.p. 120–25°/1 mm evidently formed by the reduction of the keto-ester with the Grignard reagent. (2) 5 g (58·2%) of the lactone of 4-methyl-2-hydroxy-2-phenyl-cyclohexane-1-acetic acid as a colourless viscous liquid, b.p. 180–85°/ mm, IR 5·65 μ (C=O str. in γ-lactone). (Found: C, 78·12; H, 7·45. $C_{15}H_{18}O_2$ requires C, 78·26; H, 7·62%). The alkaline extract was acidified with 6N HCl and the liberated acid filtered, dried and purified by crystallization from petroleum ether to give 2·5 g of the acid, m.p. 88–90°, identified to be 4-methyl-cyclohexane-2-one-1-acetic acid derived from the unreacted keto-ester.

The foregoing lactone (11·5 g, 0·05 mole) was refluxed with Zn/Hg (60 g), $C_6H_5CH_3$ (20 ml) and conc. HCl (250 ml) for 60 hr with the addition of conc. HCl (10 ml) after 6 hr. It was cooled, the organic layer separated and the aqueous layer extracted with two 50 ml portions of C_6H_6, washed with water, Na_2CO_3 aq (5%) and finally with water. The Na_2CO_3 extract was acidified with HCl and the product extracted with two 100 ml portions of C_6H_6. Removal of solvent followed by distillation of the residue gave 7 g (60·4%) of 4-methyl-2-phenylcyclohexyl acetic acid (II) as a thick viscous liquid, b.p. 180–85°/ 1 mm. Attempted crystallizations from C_6H_6. AcOH and MeOH were unsuccessful. (Found: C, 77·32; H, 8·85. $C_{15}H_{20}O_2$

requires C, 77·58; H, 8·62%). The foregoing acid (II) (4·64 g, 0·02 mole) was heated with polyphosphoric acid (30 g) at 100° for ½ hr. The viscous brown product was hydrolysed with ice. Usual work up gave 3·5 g (82%) of *trans* ketone (IV) as a colourless solid which after two crystallizations from EtOH gave colourless plates, m.p. 144–45°. UV (EtOH) λ_{max} 252, 257, 296 mμ (ε 14130, 20420, 1995). IR 5·95 μ (C=O str. in aryl ketone). (Found: C, 83·90; H, 8·22. $C_{15}H_{18}O$ requires C, 84·11; H, 8·41%). The semicarbazone crystallized from MeOH as colourless needles, m.p. 170–71°. (Found: C, 70·51; H, 7·63. $C_{16}H_{21}N_3O$ requires C, 70·85; H, 7·75%).

Condensation of lactone (I) *with toluene.* The condensation of 15·4 g (0·1 mole) of the lactone (1) with dry toluene (40 ml) in the presence of 14·7 g (0·11 mole) of anhydrous $AlCl_3$ as described in the condensation of the lactone (I) with C_6H_6, gave 16 g of a semisolid acidic mass which was esterified by refluxing with EtOH (50 ml), C_6H_6 (100 ml) and conc. H_2SO_4 (1 ml) for 10 hr. Usual work up gave a forerun of ethyl 4-methylcyclohexylacetate (3·5 g), b.p. 100°/1 mm followed by a stereoisomeric mixture of ethyl 4-methyl-2-*o*-tolyl cyclohexylacetate, ethyl 4-methyl-2-*p*-tolylcyclohexylacetate and ethyl 4-methyl-3-*p*-tolylcyclohexylacetate (9 g, 32·9%) obtained as a colourless oil with blue fluorescence, b.p. 160–165°/1 mm. (Found: C, 78·51; H, 9·38. $C_{18}H_{26}O_2$ requires C, 78·83; H, 9·49%). Saponification of the foregoing ethyl ester (9 g) gave 8·2 g of a stereoisomeric mixture of 4-methyl-2-*o*-tolylcyclohexylacetic acid (V), 4-methyl-2-*p*-tolylcyclohexylacetic acid (VI) and 4-methyl-3-*p*-tolylcyclohexylacetic acid (VII) as a colourless viscous liquid, b.p. 190–195°/1 mm, which did not solidify even on prolonged standing. (Found: C, 77·72; H, 8·72. $C_{16}H_{22}O_2$ requires C, 78·05; H, 8·94).

Polyphosphoric acid cyclization of the acidic mixture. A mixture of polyphosphoric acid (50 g) and the foregoing acid mixture (6 g, 0·025 mole) was stirred at 100° for 20 min, heating was stopped and stirring continued for a further 15 min. The brown viscous fluid was decomposed with ice. Usual work up followed by distillation gave 2 g (33·3%) of dimethyl keto-hydrophenanthrenes as a light yellow oil, b.p. 165–68°/1 mm, a part of which solidified on trituration with petroleum ether and recrystallized from petroleum ether. It was further purified through chromatography over a column of Al_2O_3 (30 g) followed by elution with C_6H_6-petroleum ether mixture (1 : 1). After crystallization from hexane, 0·5 g (25%) of trans-3,5-*dimethyl*-9-*keto*-1,2,3,4,9,10,11,12-*octahydrophenanthrene* (VIII) was obtained as colourless plates, m.p. 136°, undepressed on admixture with an authentic synthetic specimen.

The oily ketone obtained from the petroleum mother liquor was purified by sublimation under reduced pressure to give 1·5 g (75%) of the liquid ketone which was chromatographed over Al_2O_3 (60 g) using 25% C_6H_6-hexane mixture as eluent when cis-2,6-*dimethyl*-10-*keto*-5,6,7,8,9,10,13,14-*octahydrophenanthrene* (IX) was obtained as a light yellow oil, b.p. 168°/1 mm. UV (EtOH) λ_{max} 255, 282, 306 mμ (ε 13800, 1000, 2399). IR 5·95 μ (C=O str. in aryl ketone). (Found: C, 83·66; H, 8·36. $C_{16}H_{20}O$ requires C, 84·20; H,8·77%). The 2,4-*dinitrophenylhydrazone* crystallized from EtOAc as red needles, m.p. 205°, not depressed on admixture with the 2:4-D.N.P. derivative of the synthetic specimen.

Reduction of the trans *ketone* (VIII) *and its dehydrogenation to* 3,5-*dimethylphenanthrene.* A mixture of 0·2 g of the *trans*-ketone (VIII), N_2H_4,H_2O (1·5 ml), KOH (0·2 g) and diethylene glycol (10 ml) was heated for 1 hr and refluxed for 3 hr. Excess glycol was removed under reduced pressure and the mixture diluted with water. The separated oil was extracted with two 50 ml portions of ether, washed with water and dried (Na_2SO_4). After removal of solvent, the residue was purified by chromatography on Al_2O_3 (20 g) using petroleum ether as eluent when 0·1 g (52%) of 3,5-*dimethyl*-1,2,3,4,9,10,11,12-*octahydrophenanthrene* was obtained as a colourless fluorescent oil, b.p. 160–170°/1 mm. (Found: C, 89·24; H, 9·83. $C_{16}H_{22}$ requires: C, 89·72; H, 10·28%). Dehydrogenation of the foregoing dimethyl hydrophenanthrene derivative by heating with 10% Pd—C catalyst at 300–320° for 2 hr gave hitherto unknown 3,5-dimethylphenanthrene, m.p. 28°, picrate, m.p. 136° undepressed on admixture with an authentic synthetic specimen.

Dehydrogenation with selenium by heating at 300–320° for 8 hr and then at 320–340° for 4 hr, however, gave 3,6-dimethylphenanthrene, m.p. 138° (lit.[17b, 18] m.p. 141–142°), picrate, m.p. 172° (lit.[17a] m.p. 174°).

Reduction of the cis *ketone* (IX) *and its dehydrogenation to* 2,6-*dimethylphenanthrene.* The oily ketone (IX) (1·5 g) was reduced with $LiAlH_4$ (0·5 g) in dry ether (50 ml) by refluxing for 4 hr. The complex was decomposed with ice-cold water and acidified with dil. HCl. Usual work up and distillation gave 1 g of the distillate as a light yellow oil, b.p. 165–170°/1 mm, which was heated with 10% Pd—C (0·1 g) at 300–320° for 2 hr. After cooling, the whole mass was taken in ether, filtered and solvent removed. The residue on distillation over Na gave 0·5 g (50%) of 2,6-dimethylphenanthrene as an oil which slowly solidified on cooling. The picrate prepared with this sublimate in hot methanolic solution crystallized from MeOH as orange needles, m.p. 135°. M.m.p. with the picrate prepared from synthetic specimen of 2,6-dimethylphenanthrene was not depressed.

The hydrocarbon regenerated from the picrate was obtained in the form of an oil which slowly solidified. After crystallization from MeOH, it had m.p. 33°. The m.m.p. with a synthetic specimen of 2,6-dimethylphenanthrene was not depressed.

Isolation of the stereoisomeric mixture of 4-methyl-3-p-tolylcyclohexyl acetic acid (VII) *from the condensation product and its dehydrogenation.* The alkaline extract from the cyclization experiment was acidified with 6N HCl and the liberated oil extracted with two 100 ml portions of C_6H_6 and washed with water. The solvent was removed and the residue distilled to give 3·4 g of a stereoisomeric mixture of VII as a thick fluorescent liquid, b.p. 185°/1 mm, which did not solidify. (Found: C, 78·48; H, 9·22. $C_{16}H_{22}O_2$ requires C, 78·05; H, 8·94).

The foregoing acid (VII) was heated with 10% Pd—C (0·2 g) at 300–320° for 2 hr. The product was dissolved in hot C_6H_6 and filtered through a column of alumina. Removal of the solvent followed by vacuum distillation over Na gave 0·5 g (34%) of 2,4′,5-trimethylbiphenyl as a colourless mobile liquid, b.p. 120–22°/1 mm, n_D^{25} 1·5735, UV (EtOH) 237 mμ (ε 13800).

Oxidation of the foregoing biphenyl derivative by alkaline $KMnO_4$ solution as described by Phillips and Chatterjee[2b] followed by esterification by CH_2N_2 gave trimethyl 2,4′,5-biphenyl tricarboxylate, m.p. 103–104°, undepressed on admixture with an authentic sample prepared according to Phillips and Chatterjee.[2b]

Synthesis of trans-3,5-*dimethyl*-9-*keto*-1,2,3,4,9,10,11,12-*octahydrophenanthrene* (VIII). *Lactone of 4-methyl-2-hydroxy-2-o-tolylcyclohexylacetic acid.* This was prepared in 35% yield by the action of *o*-tolyl magnesium bromide on ethyl 4-methylcyclohexan-2-one-1-acetate by following the conditions as described in connection with the preparation of the lactone of 4-methyl-2-hydroxy-2-phenyl-cyclohexane acetic acid. It was a colourless oil, b.p. 160°/1 mm, IR 5·65 μ (C=O str. in γ-lactone). (Found: C, 78·21; H, 8·31. $C_{16}H_{20}O_2$ requires C, 78·68; H, 8·19%).

4-Methyl-2-o-tolylcyclohexylacetic acid (V). The foregoing lactone (6 g, 0·025 mole) was refluxed with 30 gm of Zn/Hg, toluene (10 ml) and conc. HCl (150 ml) for 48 hr with addition of 10 ml portion of conc. HCl after 6 hr. Usual work up as described in the synthesis of the acid II gave 4·2 g (70%) of V as a thick viscous liquid, b.p. 190°/1 mm, which did not solidify even on prolonged standing. (Found: C, 78·52; H, 8·80. $C_{16}H_{22}O_2$ requires C, 78·05; H, 8·94%).

trans-3,5-*Dimethyl*-9-*keto*-1,2,3,4,9,10,11,12-octahydrophenanthrene VIII. The foregoing acid (V) (3·7 g, 0·015 mole) was heated with polyphosphoric acid (25 g) at 100° for 20 min. The viscous brown product was hydrolysed with ice. Usual work up followed by vacuum distillation gave 2·5 g (70%) of VIII as a thick oil, b.p. 165–68°/1 mm, which immediately solidified. It crystallized from aqueous MeOH as colourless plates, m.p. 142°. UV (EtOH) 253 mμ (ε 13800), IR 5·96 μ (C=O str. in aryl ketone). (Found: C, 83·84; H, 8·65. $C_{16}H_{20}O$ requires C, 84·20; H, 8·77%).

The 2:4-*dinitrophenylhydrazone* crystallized from pyridine as orange-red needles, m.p. 252°. (Found: N,13·65. $C_{22}H_{24}N_4O_4$ requires N,13·72%).

3,5-*Dimethylphenanthrene.* The foregoing *trans*-ketone (VIII), m.p. 142° (0·7 g) was reduced with LAH (0·2 g) in dry ether (25 ml) by refluxing for 2 hr. After cooling, the product was decomposed with water and acidified with dil. HCl. Usual work up and distillation gave a residue which was heated with 10% Pd—C (0·1 g) at 300–320° for 2 hr. The product was dissolved in hot C_6H_6 and filtered through a column of Al_2O_3. Removal of solvent followed by distillation gave 0·5 g (80%) of 3,5-dimethylphenanthrene as a colourless liquid, b.p. 154–55°/1·5 mm. The picrate of this hydrocarbon prepared in MeOH was obtained as orange needles, m.p. 136°. (Found; C, 60·81; H, 3·69; N, 9·59. $C_{22}H_{17}N_3O_7$ requires C, 60·69; H, 3·90; N, 9·65%). The *hydrocarbon* regenerated from the picrate by passing its C_6H_6 solution through a column of Al_2O_3 and eluting the column with petroleum ether was obtained in the form of an oil which slowly solidified on keeping in the refrigerator. It crystallized from cold MeOH in colourless plates, m.p. 30°.

UV (EtOH 254, 279, 293, 302, 324 mμ (ε 79430, 12590, 14130, 12590, 316·2). (Found: C, 92·82; H, 6·64. $C_{16}H_{14}$ requires C, 93·20; H, 6·79%). The *TNB complex* of 3,5-dimethylphenanthrene crystallized from MeOH as soft silky needles, m.p. 158–59°. (Found: N,10·24. $C_{22}H_{17}N_3O_6$ requires N,10·02%).

Synthesis of 2,6-*dimethyl*-10-*keto*-5,6,7,8,9,10,13,14-*octahydrophenanthrene* (IX). *Lactone of 4-methyl-2-hydroxy-2-p-tolylcyclohexyl acetic acid.* It was prepared in 50% yield by the action of *p*-tolyl magnesium bromide prepared from Mg (1·2 g), *p*-bromotoluene (8·6 g) on ethyl 4-methylcyclohexane-2-one-1-acetate (9·9 g) as described in the preparation of the lactone of 4-methyl-2-hydroxy-2-*o*-tolylcyclohexyl acetic acid. It was a colourless liquid, b.p. 165°/1 mm. IR 5·65 μ (C=O str. in γ-lactone). (Found: C, 78·97; H, 7·95. $C_{16}H_{20}O_2$ requires C, 78·68; H, 8·19%).

4-Methyl-2-p-tolylcyclohexyl acetic acid (VI). The foregoing lactone (6 g, 0·025 mole) was boiled gently with Zn/Hg (30 g), toluene (10 ml) and conc. HCl (150 ml) for 48 hr. Usual work up gave 4·2 g (70%) of 4-

methyl-2-*p*-tolylcyclohexyl acetic acid (VI) as a colourless thick viscous oil, b.p. 180°/1 mm, which did not solidify. (Found: C, 77·78; H, 9·21. $C_{16}H_{22}O_2$ requires C, 78·05; H, 8·94%).

2,6-*Dimethyl*-10-*keto*-5,6,7,8,9,10,13,14-*octahydrophenanthrene* (IX). A mixture of 6 g (0·025 mole) of the foregoing acid (VI) and polyphosphoric acid (50 g) was heated at 100° for 5 min. The viscous brown complex was decomposed with ice. The oily product was extracted with two 100 ml portions of ether, washed with water, Na_2CO_3 aq (5%), water and dried (Na_2SO_4). No unreacted acidic matter was recovered from the alkaline extract. Removal of solvent followed by distillation under reduced pressure gave 5·3 g (96·4%) of IX as a thick viscous oil, b.p. 170°/1 mm, which readily solidified. Crystallization from EtOH yielded trans-2,6-*dimethyl*-10-*keto*-5,6,7,8,9,10,13,14-*octahydrophenanthrene* as colourless plates, m.p. 136°. UV (EtOH) 255, 282, 307 mμ (ε 13800, 1259, 2399). IR 5·95 μ (C=O str. in aryl ketone). (Found: C, 83·94; H, 8·81. $C_{16}H_{20}O$ requires C, 84·20; H, 8·77%). The 2,4-*dinitrophenylhydrazone* of the *trans* ketone crystallized from ETOAc as reddish orange needles, m.p. 265°. (Found: N,13·81. $C_{22}H_{24}N_4O_4$ requires N, 13·72%). The distilled ketone from the cyclization experiment was converted to the 2:4-D.N.P. derivative. The mother liquor after separation of the 2:4-D.N.P. derivative of the *trans*-ketone, m.p. 265° was concentrated when another crop of crystals separated. Two crystallizations from EtOAc–EtoH gave the pure 2,4-dinitrophenylhydrazone of *cis*-2,6-*dimethyl*-10-*keto*-5,6,7,8,9,10,13,14-*octahydrophenanthrene* as fine orange needles, m.p. 205°. (Found: N, 13·43. $C_{22}H_{24}N_4O_4$ requires N, 13·72%).

2,6-*Dimethylphenanthrene*. The foregoing *trans*-ketone IX (1 g) was reduced by refluxing with LAH (0·5 g) in dry ether (40 ml) for 4 hr. The complex was decomposed with ice-cold dil. HCl. Ether layer was separated and the aqueous layer extracted with two 50 ml portions of ether, washed with water and dried (Na_2SO_4). Ether was evaporated and the residue crystallized from petroleum ether to give 1 g of *trans*-2,6-*dimethyl*-10-*hydroxy*-5,6,7,8,9,10,13,14-*octahydrophenanthrene*, m.p. 138°. This hydroxy compound (1 g) was heated with 10% Pd—C (0·1 g) at 300–320° for 4 hr. After cooling, the whole mass was taken in ether, filtered, and solvent removed. The residue on distillation over Na gave 0·6 g (66·6%) of 2,6-*dimethylphenanthrene* crystallized from MeOH, m.p. 33°. The picrate crystallized from MeOH as orange needles, m.p. 136° (Lit.[19] m.p. of the hydrocarbon 33–34° and that of its picrate, m.p. 135–36°). Identical result was obtained when dehydrogenation of the *trans*-ketone was carried out with selenium at 350° for 12 hr.

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REFERENCES

[1] [a] Preliminary communication: D. N. Chatterjee and S. P. Bhattacharyya, *Curr. Sci.* **38**, 39 (1969); [b] D. D. Phillips, *Chem. & Ind.* **54** (1956)

[2] [a] D. D. Phillips and D. N. Chatterjee, *J. Am. Chem. Soc.* **80**, 1360 (1956); [b] D. D. Phillips and D. N. Chatterjee, *Ibid.* **80**, 1911 (1956)

[3] B. S. Friedman, F. L. Morritz, C. J. Morrisey, *J. Am. Chem. Soc.* **79**, 1465 (1957)

[4] B. S. Friedmann, F. L. Morritz, C. J. Morrisey and R. Koncos, *Ibid.* **80**, 5867 (1958)

[5] A. Kotz and V. G. Kayser, *Biebigs Ann.* **250**, 243 (1906)

[6] J. Linsk, *J. Am. Chem. Soc.* **72**, 4257 (1950)

[7] H. Pines, D. R. Strehlau and V. N. Ipatieff, *Ibid.* **72**, 5521 (1950)

[8] E. Buchta and H. Ziener, *Liebigs Ann.* **601**, 155 (1956)

[9] N. P. Buu-Hoi, and P. Cagniant, *C. R. Acad. Sci., Paris* **220**, 744 (1945)

[10] C. D. Nenitzescu and A. Isasescu, *Chem. Ber.* **66**, 110 (1953)

[11] N. K. Chowdhury, *Science and Culture* **18**, 442 (1953)

[12] S. M. Mukherjee, O. P. Vig, S. Singh and N. K. Bhattacharyya, *J. Org. Chem.* **18**, 1499 (1953)

[13] C. Black, G. L. Buchanan and Miss A. W. Jarvie, *J. Chem. Soc.* 2971 (1956)

[14] F. Uhlig and H. R. Snyder, *Advances in Organic Chemistry, Methods and Results* (Ed. by R. A. Raphael, E. C. Taylor and H. Wynberg) Vol. I, p. 35. Interscience, New York (1960)

[15] D. S. Noyce and H. I. Wingarten, *J. Am. Chem. Soc.* **79**, 3098 (1957)

[16] E. K. Weisburger and John H. Weisburger, *J. Org. Chem.* **23**, 1193–8 (1958)
[17] [a]S. C. Sengupta and D. N. Chatterjee, *J. Ind. Chem. Soc.* **30**, 27–9 (1953); [b]S. C. Sengupta and A. Mitra, *Ibid.* **40**, 615–22 (1963)
[18] O. Krubber and Armin Raeithel, *Chem. Ber.* **87**, 1469–78 (1954)