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STEREOCHEMISTRY OF SOME DERIVATIVES OF PHENYLCYCLOHEXANE

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Abstract—1-Phenylcyclohexene oxide (I) reacted with hydrogen chloride in chloroform to give only 2-phenyl-*cis*-2-chlorocyclohexanol (V), while in ethanol a mixture of V and its *trans* diastereoisomer (IV) were formed. The two diastereoisomeric 1-phenylcyclohexane-1,2-diols were transformed by hydrogen chloride in chloroform into IV and V, with entirely stereospecific reactions involving retention. IV and V were oxidized to 2-chloro-2-phenylcyclohexanone (VI); the compound described in the literature and reported to have the latter constitution was found to be instead *cis*-2-chloro-6-phenylcyclohexanone (XII). It was transformed, through *trans*-3-phenyl-1,2-epoxycyclohexane (XV) and the corresponding glycols, into 2-phenyladipic acid. The stereochemistry and the possible mechanisms of the reactions are discussed.

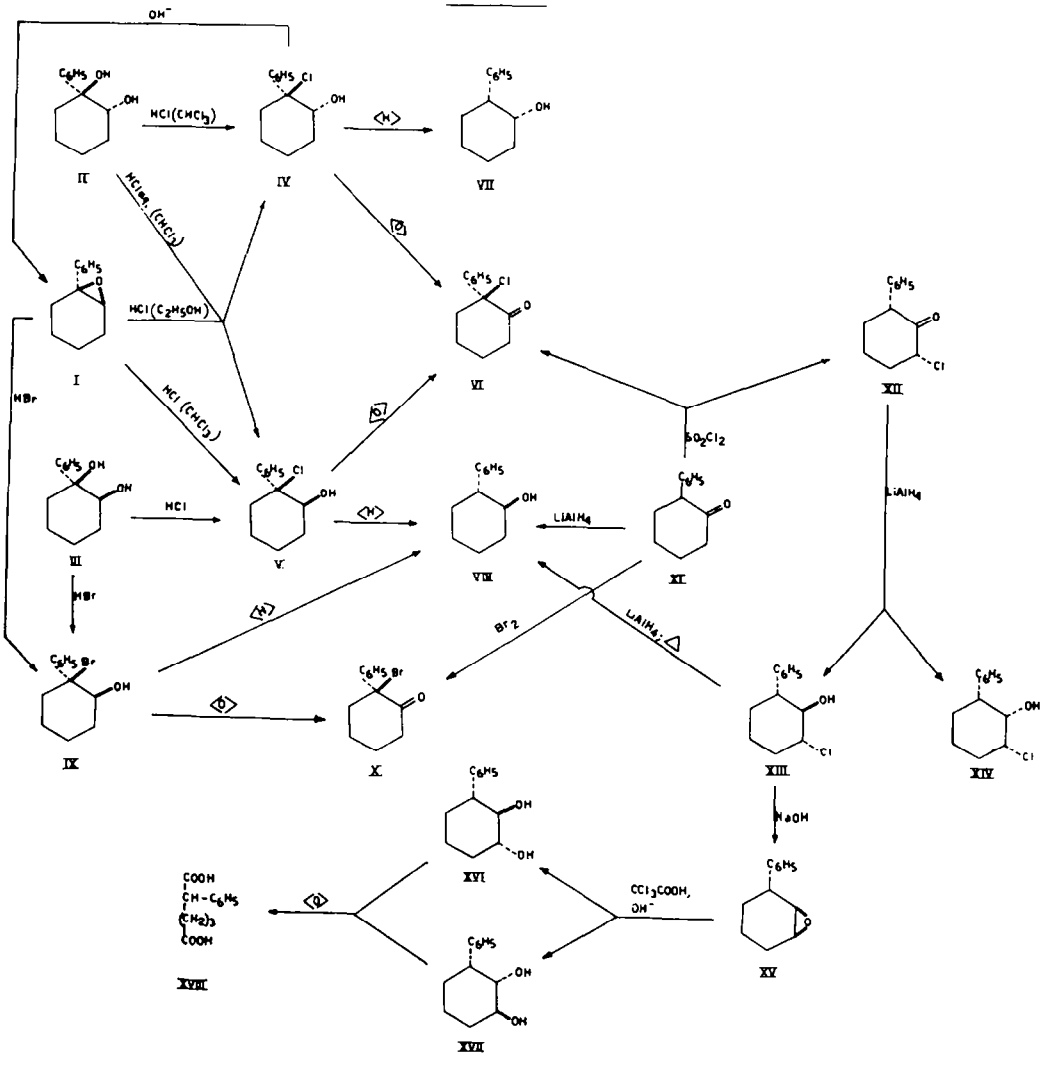
PREVIOUS work had shown that the steric course of additions of acids to aryl-substituted epoxides can depend on the type of solvent in which the reaction is carried out, on the constitution and configuration of the epoxide and on the type of acid.[1] In order to get some information about the influence of conformational factors, this work has been extended to 1-phenylcyclohexene oxide (I).

The reaction of I with hydrogen chloride in dry chloroform or of its chloroform solution with conc. aqueous hydrochloric acid gave only one chlorohydrin, 2-phenyl-*cis*-2-chlorocyclohexanol (V). Similarly, I and hydrogen bromide produced the corresponding *cis*-bromohydrin (IX). The products were contaminated with some of the rearrangement compound, 2-phenylcyclohexanone (XI), when the solvent was dry, but not when it was saturated with water. When I was reacted with hydrogen chloride in ethanol the product was a mixture of V with the *trans*-chlorohydrin IV and a little XI.

The reaction of 2-phenyl-*trans*-cyclohexane-1,2-diol (II) with hydrogen chloride in dry chloroform proceeded rapidly and in a completely *cis*-stereospecific way to yield the *trans*-chlorohydrin (IV) while the same reaction, carried out in water-saturated chloroform, led to a mixture of about 70% IV and 30% V. The *cis*-glycol (III) reacted much more slowly than II in dry chloroform to give only V; the more rapid reaction in humid chloroform had the same steric course. Similarly, III in chloroform gave with 48% aqueous hydrobromic acid only the bromohydrin (IX). In none of these reactions of II and III was any of the ketone XI formed. Compound III did not react at room temperature with hydrogen chloride at an appreciable rate in tetrahydrofuran, while on heating it gave only the rearranged product (XI).

[1a] G. Berti, F. Bottari and B. Macchia, *Chim. e ind. Milan* **45**, 1527 (1963); [b] G. Berti, F. Bottari and B. Macchia, *Ibid*, **46**, 827 (1964); [c] G. Berti, F. Bottari, B. Macchia and V. Nuti, *Ann. chim., Rome* **54**, 1253 (1964); [d] G. Berti, F. Bottari, P. L. Ferrarini and B. Macchia, *J. Org. Chem.* in press; [e] G. Berti, F. Bottari, B. Macchia and F. Macchia, *Tetrahedron* **21**, 3277 (1965); [f] C. C. Tung and A. J. Speziale, *J. Org. Chem.* **28**, 2009 (1963).

SCHEME 1



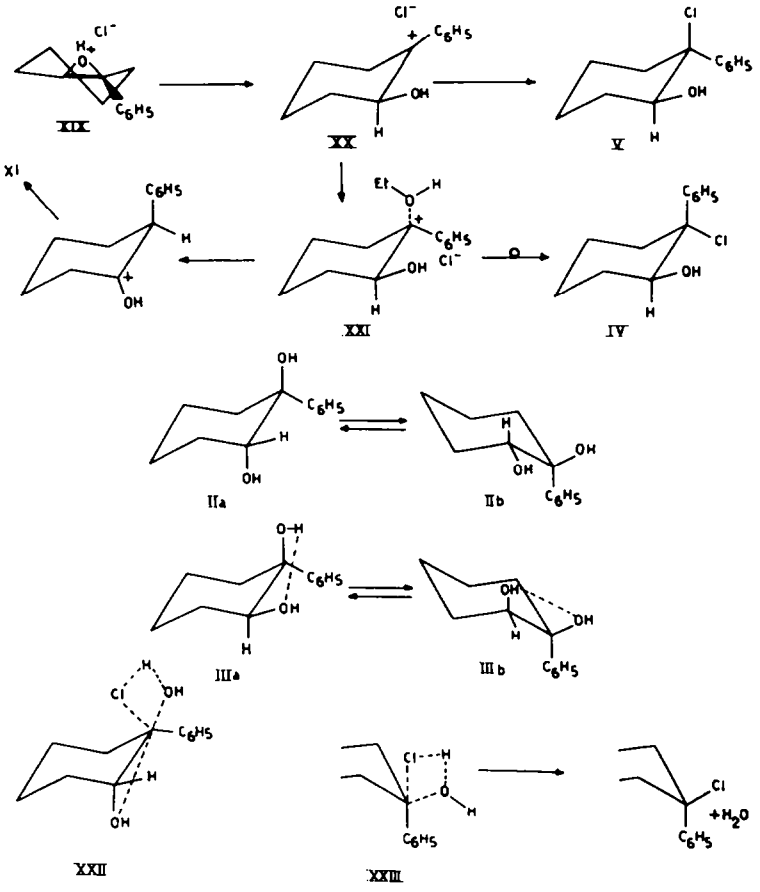
The constitutions of the halohydrins (IV, V and IX) were demonstrated by their oxidation to the haloketones (VI and X) and their configurations were deduced from their behaviour with alkali: while IV gave rapidly and quantitatively the epoxide (I), as expected for a diaxial *trans*-chlorohydrin, V and IX reacted much more slowly, to yield mixtures of the ketone (XI) and hydroxyl-containing products. Furthermore, V and IX were reduced catalytically to pure *trans*-2-phenylcyclohexanol (VIII), while the mixture of IV and V obtained from I and hydrogen chloride in ethanol was reduced to a mixture of VIII and its *cis*-isomer (VII): catalytic reductions of halides usually take place with retention of configuration.

The completely stereospecific *cis* addition of hydrogen chloride and bromide to the epoxide (I) in dry or humid chloroform is in contrast with the rule of diaxial opening of epoxides[2] and with the 83% inversion obtained when styrene oxide was

[2] D. H. R. Barton, *J. Chem. Soc.* 1027 (1953).

subjected to the same reaction.[1d] Some conformational effects must favour this course in the more rigid cyclohexane system. The hypothetical carbonium ion (XX) which would be formed by the breaking of the weaker C–O bond of the protonated epoxide (XIX) should give more easily the *cis*-chlorohydrin (V) as this would involve the passage of the bulky phenyl group to the less hindered equatorial position. Solvation may account for the lower stereospecificity observed for the addition of

SCHEME 2



hydrogen chloride in ethanol solution; such solvation should be favoured from the axial side and would relieve some of the strain due to the eclipsing of the phenyl group with the equatorial atoms in 2 and 6. Attack by the anion on the solvated cation (XXI) should be more hindered from the axial side and may therefore take place in part from the equatorial one, leading to appreciable amounts of the less stable *trans*-chlorohydrin (IV). The longer life of the cation caused by solvation can account for the concomitant formation of the rearrangement product (XI) by 1,2 hydrogen shift. It is remarkable that according to Cookson and Hudec[3] 2α, 3α-epoxy-3β-phenylcholestane, which is closely related to, but more rigid than I, gives only the

[3] R. C. Cookson and J. Hudec, *Proc. Chem. Soc.* 24 (1957).

rearranged ketone, 3α-phenylcholestan-2-one, with hydrogen bromide in chloroform: apparently, this points to an influence of the rigidity of the system on the alternative formation of addition and rearrangement products, which should be investigated further.

The fact that the *trans*-glycol (II) reacted with hydrogen chloride in dry chloroform much more rapidly than the *cis*-form (III) and that both reactions gave complete retention of configuration was somewhat unexpected. If one assumes that the two glycols react in their more stable conformations (IIa and IIIa)[4] the higher reaction rate of IIa could be explained with an intramolecular assistance by the *trans* axial hydroxyl group in an "S_Ni-type" reaction, as shown in XXII; such an assistance would be much less effective in the case of the *cis*-equatorial hydroxyl group of IIIa, which would also exert an unfavourable steric effect. The complete stereospecificity, on the other hand, appears in contrast with the fact that, while equatorial groups can be displaced with complete retention by "S_Ni-type" mechanisms, axial ones usually give more easily rearranged or inverted products:[5] as said above, no trace of rearrangement products were observed in our cases. These results may perhaps be explained better by assuming that the reactions take place preferentially on the less stable conformations (IIb and IIIb) in which the equatorial 1-hydroxyl groups are more easily available for a frontal attack in a cage of solvent, such as shown in XXIII. The higher reaction rate of II could therefore be due to a smaller difference in energy between IIa and IIb, than between IIIa and IIIb. Furthermore, the ion derived from conformer IIIb would not be likely to give 2-phenylcyclohexanone. The higher reaction rate of III in humid than in dry chloroform may be caused by solvation which should interfere with intramolecular hydrogen-bonding and increase the effective bulks of the two hydroxyl groups, thus decreasing the energy difference between IIIa and IIIb. Such a solvation would also interfere with the ion-pair process (XXIII), and explain the lower stereospecificity of the reaction of II, because of formation of some of the more stable, inverted *cis*-chlorohydrin (V).

The ketone (VI) obtained by oxidation of the chlorohydrins (IV and V) had a m.p. which was considerably different from that of a compound obtained by Woods and Scotti[6] from 2-phenylcyclohexanone with sulphuryl chloride and reported as 2-chloro-2-phenylcyclohexanone. As there could not be any doubt about the constitution of our product, we repeated the preparation of Woods and Scotti and found, on careful fractionation of the product, that it contained, beside the chloroketone described by these authors, an isomer which was identical with our compound, and a third compound which was present in too small a quantity for purification and characterization.

It was found that the compound described by Woods and Scotti as VI was actually the isomer XII. Reduction with LAH in the cold gave two epimeric chlorohydrins (XIII and XIV); one of these (XIII) was further reduced by an excess of hydride at reflux temperature to *trans*-2-phenylcyclohexanol (VIII) and slowly transformed by

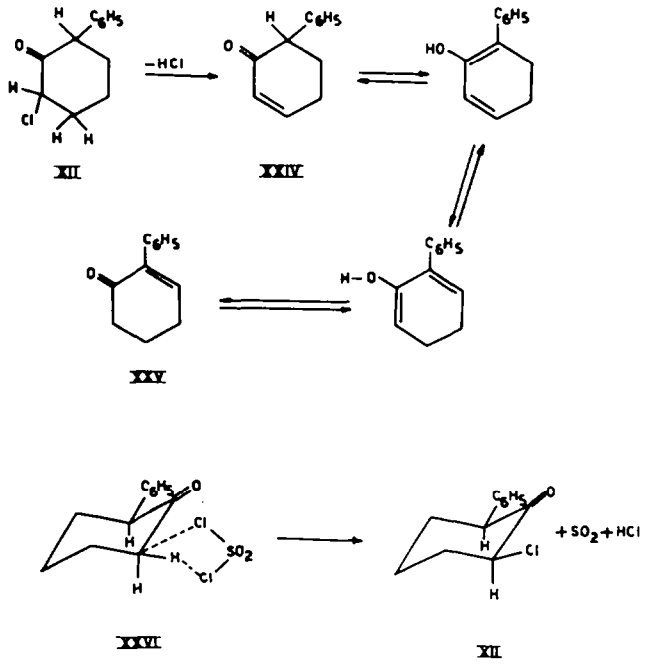
[4] E. Galantay, *Tetrahedron* **19**, 319 (1963).

[5a] E. L. Eliel, *Steric Effects in Organic Chemistry* (Edited by M. S. Newman) p. 128. J. Wiley, New York (1956); [b] W. Hückel and K. Heyder, *Chem. Ber.* **96**, 220 (1963); [c] T. Cohen and E. Jankowsky, *J. Amer. Chem. Soc.* **86**, 4217 (1964).

[6] G. F. Woods and F. Scotti, *J. Org. Chem.* **26**, 312 (1961).

sodium hydroxide into an epoxide which was isomeric with I. The second chlorohydrin (XIV) did not form an epoxide. The epoxide obtained from XIII was shown to be XV by addition of trichloroacetic acid, followed by hydrolysis to the diastereoisomeric glycols XVI and XVII, which, on oxidation, were transformed into 2-phenyladipic acid (XVIII). The configuration of XIII follows from its reduction to

SCHEME 3



XII XXIV XXV XXVI XII

VIII, which indicates the relative position of the phenyl and hydroxyl group, and from its transformation into XV which requires a *trans* disposition of hydroxyl and chlorine: the slow rate of this reaction is in accordance with the fact that the molecule is certainly much more stable in the triequatorial than in the triaxial conformation, which is necessary for a *trans* elimination. As the second chlorohydrin is epimeric with XIII in the 2-position, it must have configuration XIV. The glycols obtained from XV are very likely to be the two *trans* forms, as cyclohexene oxides without aryl substituents on the oxirane ring generally open in a *trans* fashion.[7]

The constitution VI had been attributed to the chloroketone isolated by Woods and Scotti on the basis of the fact that it could be dehydrohalogenated to 2-phenyl-2-cyclohexen-1-one (XXV); however, XII could give the same product by dehydrohalogenation to XXIV, followed by a series of tautomeric shifts as shown in Scheme 3. It must be observed that according to the authors the chloroketone was isolated in only 23% yield, while the crude reaction mixture of XI with sulphuryl chloride, containing also VI and the third isomer (probably the diastereoisomer of XII), gave XXV in 85% yield.

[7] A. Rosowsky, *Heterocyclic compounds with three- and four-membered rings* (Edited by A. Weissberger) Part I; p. 377. Interscience, New York (1964).

When the reaction of XI with sulphuryl chloride was carried out in more dilute solution the yield of VI increased considerably. Compound VI would be expected to be the product of the normal acid-catalysed halogenation, proceeding through the more stable conjugated enolic form, in which the enolization step is rate-determining[8] and its rate is independent of the concentration of the halogenating agent. Wyman and Kaufmann[9] have investigated several cases of chlorination of ketones with sulphuryl chloride and have found, for instance, that phenylacetone, which is the open-chain analogue of XI, gives 95% 1-phenyl-1-chloropropanone-2 and only traces of the 3-chloro isomer. The formation of substantial amounts of XII in the chlorination of XI may be due to the fact that the situation is less favourable for enolization in the cyclohexane derivative, thus allowing for an alternative mechanism of chlorination which leads to XII: as a larger amount of this compound is formed in more concentrated solution, such a mechanism probably involves the chlorinating agent in the rate-determining step and may proceed through a cyclic transition state, such as the one discussed by Wyman and Kaufmann[9] (XXVI) in which the sulphuryl chloride attacks the ketonic form on the less hindered α position, with introduction of the halogen atom from the equatorial side.

EXPERIMENTAL

M.ps were determined on a Kofler block. IR spectra were taken on paraffin oil mulls, unless stated otherwise, with a Perkin–Elmer Infracord 137. All comparisons between compounds were based on mixed m.ps and IR spectra. Pet ether is the fraction, b.p. 30–50°, unless stated otherwise. "Usual treatment" stands for washing with sat. $NaHCO_3$ aq, water, drying with $MgSO_4$ and evaporation. Thin layer chromatographies (TLC) were carried out over alumina containing fluorescent indicator, dried 4 hr at 200° and using benzene as eluent; spots were detected with UV light at 254 mμ.

2-Phenyl-trans-2-*chlorocyclohexanol* (IV)

(a) To 0·100 g 1-phenylcyclohexane-*trans*-1,2-diol (II) were added 15 ml 0·1 N HCl in $CHCl_3$; after 80 min the usual treatment gave 0·105 g IV, which crystallized from pet ether in prisms, m.p. 89–91°. (Found: C, 68·06; H, 6·99. $C_{12}H_{15}ClO$ requires: C, 68·40; H, 7·17%.) The IR spectrum of the crude product showed that V and carbonyl compounds were completely absent.

(b) A solution of 0·40 g II in 15 ml $CHCl_3$ was shaken 20 min with 3 ml 36% HCl aq. Usual treatment gave a residue (0·42 g), which was found by IR analysis (bands at 11·37 and 12·8 μ) to be composed of about 70% IV and 30% V; the CO band was absent. Fractional crystallization from pet ether achieved the separation of 0·22 g IV, m.p. 88–91° and 0·10 g V, m.p. 60–62°.

2-Phenyl-cis-2-*chlorocyclohexanol* (V)

(a) Dry HCl was bubbled to saturation through a solution of 2·0 g 1-phenylcyclohexene oxide[10] (I) in 50 ml dry $CHCl_3$. Usual treatment gave 1·9 g of a solid residue of V exhibiting a small CO band at 5·85 μ in the IR. Crystallization from pet ether gave the pure compound, m.p. 60–62°. (Found: C, 68·21; H, 7·07. $C_{12}H_{15}ClO$ requires: C, 68·40; H, 7·17%.)

(b) A solution of 0·20 g I in 8 ml $CHCl_3$ was shaken 20 min with 3 ml 36% HCl aq; usual treatment gave 0·20 g V, m.p. 60–62°; no trace of CO band was detected in the IR.

(c) A solution of 1·9 g 1-phenylcyclohexane-*cis*-1,2-diol (III) in 20 ml $CHCl_3$ was shaken 20 min with 10 ml 36% HCl aq. Usual treatment gave 1·7 g V, m.p. 60–62°. No carbonyl impurity was present in the crude product.

[8a] E. E. Royals, *Advanced Organic Chemistry* p. 740, Prentice-Hall, Englewood Cliffs, N.J. (1956);
[b] R. F. W. Cieciuch and F. H. Westheimer, *J. Amer. Chem. Soc.* **85**, 2591 (1963).
[9] D. P. Wyman and P. R. Kaufmann, *J. Org. Chem.* **29**, 1956 (1964).

(d) A solution of 0·19 g III in 30 ml 0·1 N HCl in $CHCl_3$, left 80 min at room temp and treated as usual, gave a product consisting mostly of unreacted III; when the reaction mixture was left 16 hr at room temp before work-up, the product was pure V, m.p. 60–62°, completely free of III and of carbonyl rearrangement products.

IR analysis of the products of all four reactions showed that the isomeric chlorohydrin (IV) was completely absent.

Compound III (0·210 g) was recovered unchanged after 1 hr at room temp in 5 ml tetrahydrofuran and 4 ml 36% HCl aq. When the same solution was refluxed 2 hr it was transformed into a liquid, the IR spectrum of which showed that it consisted mostly of 2-phenylcyclohexanone (XI).

Reaction of I *with hydrogen chloride in ethanol*

A solution of 5·0 g I in 50 ml 95% EtOH was cooled at 0° and treated with 300 ml EtOH saturated with HCl, kept 15 min at 0°, diluted with water and worked up as usual. The residue was an oil, whose IR spectrum (neat) showed a strong OH band at 2·93 μ and a CO band at 5·85 μ. It consisted of a mixture of the chlorohydrins (IV and V) and 2-phenylcyclohexanone (XI). Treatment of a portion with 2,4-dinitrophenylhydrazine (DNP) reagent[10] gave 2-phenylcyclohexanone-2,4-DNP, m.p. 135–136°,[11] identical with a sample prepared from XI.[12] A solution of 2·1 g of the residue in 70 ml EtOH was shaken with H_2 in the presence of 0·5 g 5% PdO_2 on $CaCO_3$.[13] When the gas absorption stopped the solution was filtered, evaporated and the residue distilled to give 1·3 g of a liquid, b.p. 130–140°/3 mm. TLC showed that it consisted of a mixture of the two diastereoisomeric 2-phenylcyclohexanols and 2-phenylcyclohexanone.

Dehydrohalogenation of IV *and* V

A solution of 0·0475 g of the chlorohydrin (IV) in 5 ml MeOH was titrated with 0·1 N NaOH aq (phenolphthalein). The reaction was complete after 15 min with the theoretical consumption of base. Dilution with water and extraction with $CHCl_3$ yielded 0·033 g of the pure epoxide I (IR).

The chlorohydrin (V) was recovered unchanged from a similar treatment. Only when the treatment with NaOH was carried out at 50–60° a slow reaction took place and the product was an oil that did not contain any I, but showed an OH band at 2·92 μ and a CO band at 5·85 μ.

2-*Chloro*-2-*phenylcyclohexanone* (VI)

A solution of 2·1 g V in 40 ml acetone was treated drop-wise with 2·4 ml 8 N chromic acid in H_2SO_4 aq,[14] diluted with water and extracted with ether. Usual treatment gave 1·5 g VI, an oil which crystallized from hexane in two polymorphic forms, m.p. 52–54° or 64–66°. The IR spectra of the two forms showed same differences in the solid state, but were identical in CCl_4 solution. (Found: C, 68·87; H, 6·21. $C_{12}H_{13}ClO$ requires: C, 69·06; H, 6·28%.)

The chlorohydrin (IV) was similarly transformed into VI.

cis-2-*Chloro*-6-*phenylcyclohexanone* (XII)

The reaction was carried out according to Woods and Scotti:[6] a solution of 7·0 g (0·04 mole) XI[12] in 7 ml CCl_4 was cooled at 0° and treated drop-wise with 6·0 g (0·044 mole) sulphuryl chloride, shaken 2 hr at room temp and stored overnight. The solution was diluted with enough $CHCl_3$ to dissolve the precipitate, washed with sat. $NaHCO_3$ aq and concentrated *in vacuo* to give 1·7 g XII, which, after crystallization from hexane, had m.p. 121–123°. (Woods and Scotti[6] give m.p. 122–123° for their product, which they thought to be VI.) Evaporation of the mother liquor under red. press. gave an oil, which on fractional crystallization from pet ether yielded 0·33 g VI, m.p. 64–66°, and a mixture, m.p. 55–59°, containing a third chloroketone, possibly the diastereoisomer of XII (λ_{CO} 5·80 μ), which was, however, not obtained pure.

A similar chlorination, carried out by adding 6·0 g sulphuryl chloride in 8 ml CCl_4 to 7·0 g XI in 25 ml CCl_4 gave 1·7 g XII, 2·1 g VI and 0·8 g of the mixture, m.p. 55–59°.

[10] R. L. Shriner, R. C. Fuson and D. Y. Curtin, *The Systematic Identification of Organic Compounds* (4th Edition) p. 219. J. Wiley, New York, N.Y. (1956).

[11] A. S. Hussey and R. R. Herr, *J. Org. Chem.* **24**, 843 (1959).

[12] P. Tomboulian, *J. Org. Chem.* **26**, 2652 (1961).

[13] M. Busch and H. Stöve, *Ber. Dtsch. Chem. Ges.* **49**, 1063 (1916).

[14] R. G. Curtis, I. Heilbron, E. R. H. Jones and G. F. Woods, *J. Chem. Soc.* 461 (1953).

trans-2-*Chloro*-trans-6-*phenylcyclohexanol* (XIII) *and* cis-2-*chloro*-cis-6-*phenylcyclohexanol* (XIV)

A solution of 1·0 g XII in 100 ml ether was added slowly with stirring to 0·2 g LAH in 10 ml ether, stirred 30 min at room temp, treated with 15 ml water and 2 ml 2 N HCl, the ether layer was dried and evaporated. The residue was crystallized twice from pet ether to yield 0·38 g XIII, needles, m.p. 124–125°. (Found: C, 68·59; H, 7·37. $C_{12}H_{15}ClO$ requires: C, 68·40; H, 7·17%.) Concentration of the mother liquor gave 0·42 g XIV, prisms, m.p. 36–38°. (Found: C, 68·56; H, 7·14. $C_{12}H_{15}ClO$ requires: C, 68·40; H, 7·17%.)

cis-2-*Bromo*-2-*phenylcyclohexanol* (IX)

(a) Dry HBr[15] was bubbled through a solution of 1·0 g I in 20 ml anhydrous $CHCl_3$ until it was saturated. After 5 min it was washed with water and evaporated *in vacuo*. The residual oil, which showed the CO band of XI at 5·85 μ, solidified at 0° and was crystallized from pet ether to give IX, m.p. 54–56°. (Found: Br, 31·44. $C_{12}H_{15}BrO$ requires: Br, 31·32%.) Left at room temp IX decomposed slowly with evolution of HBr and was transformed completely into the ketone XI.

(b) A solution of 1·9 g III in 20 ml $CHCl_3$ was shaken 25 min with 14 ml 48% HBr aq. Vacuum evaporation of the organic layer and crystallization from pet ether produced 1·8 g IX, m.p. 54–56°.

Treatment of IX with methanolic KOH gave an oil which had an IR spectrum identical with that of the oil obtained in the same reaction of V (see above).

2-*Bromo*-2-*phenylcyclohexanone* (X)

A solution of 0·90 g (3·5 mole) IX in 20 ml acetone was treated drop-wise with 0·82 ml 8 N solution of CrO_3 in H_2SO_4 aq,[14] left 15 min at room temp and diluted with water to produce 0·70 g X, which crystallized from pet ether in a metastable form, large prisms, m.p. 74–77°. Recrystallization from pet ether or from MeOH gave the stable form, as plates, m.p. 98–101°, which were identical with the product obtained by bromination of XI.[16] The two forms gave identical IR spectra in $CHCl_3$ solution. (Found: Br, 31·41. $C_{12}H_{13}BrO$ requires: Br, 31·57%.)

trans-2-*Phenylcyclohexanol* (VIII)

(a) A solution of 0·21 g V in 40 ml EtOH was shaken with H_2 in the presence of 0·2 g 5% PdO_2 on $CaCO_3$.[18] When the absorption stopped, the solution was filtered and evaporated to give 0·15 g VIII, m.p. 55–58°, after crystallization from pet ether at 0°. It was identical with a sample prepared by LAH reduction of XI.[17]

(b) Similar reduction of 0·25 g IX gave 0·14 g VIII.

(c) A solution of 0·105 g XIII in 40 ml ether was refluxed 2 hr with 0·2 g LAH, treated with dil. H_2SO_4 and extracted with ether to yield pure VIII. Several attempts to carry out the reduction of XIII catalitically were unsuccessful.

The purity of the *trans*-2-phenylcyclohexanol obtained according to (a), (b) and (c) was established by TLC: in no case there was formed any of the *cis*-isomer VII.

cis- *and* trans-3-*Phenylcyclohexane*-trans-1,2-*diols* (XVI *and* XVII)

A solution of 0·60 g XIII in 30 ml MeOH, treated with 0·5 ml 0·1 N NaOH, had not reacted after 1 hr at room temp, nor after 30 min at 50°. Therefore it was treated with 1·8 g solid NaOH and refluxed 1 hr. Dilution with water and extraction with ether yielded 0·50 g of an oil, which did not contain any Cl_2, and showed only traces of OH and CO bands in the IR: it was crude *trans*-3-phenyl-1 2-epoxycyclohexane (XV), which was not purified further. (The same reaction, carried out with the chlorohydrin (XIV) gave a completely different product, with a strong OH and CO bands at 2·90 and 5·85 μ.) The crude XV was dissolved in 10 ml benzene, treated with 6·3 ml of a 0·56 M solution of trichloroacetic acid in benzene and stored overnight. Usual treatment gave an oily mixture (0·75 g) of mono(trichloroacetates) of XVI and XVII, λ_{OH} 2·95 μ, λ_{CO} 5·69 μ (neat), which was refluxed 15 min with 6 ml 2 M KOH in EtOH. Dilution with water and extraction with $CHCl_3$ produced 0·41 g of an oily mixture of the diols XVI and XVII.

[15] A. I. Vogel, *Practical Organic Chemistry* (3rd Edition) p. 182. Longmans Green, London (1956).
[16] W. E. Bachmann and L. B. Wick, *J. Amer. Chem. Soc.* **72**, 3388 (1950).
[17] G. Berti, *J. Amer. Chem. Soc.* **76**, 1213 (1954).

A solution of 0·195 g (1 mmole) of this mixture and 0·465 g (2·5 mmole) *p*-nitrobenzoyl chloride was shaken 5 min at room temp, heated 15 min on a steam-bath, poured into 30 ml water, acidified with dil. HCl and extracted with ether. The ether was evaporated, the residue refluxed with 30 ml 10% Na_2CO_3 aq, to decompose some *p*-nitrobenzoic anhydride, and filtered. Fractional crystallization of the precipitate (0·44 g) from EtOH gave 0·091 g of a bis-(*p*-nitrobenzoate), which crystallized from acetone–EtOH in plates, m.p. 208–209°. (Found: C, 63·68; H, 4·60. $C_{26}H_{22}N_2O_8$ requires: C, 63·67; H, 4·52%.)

Concentration of the EtOH mother liquor, filtration and recrystallization from EtOH gave a second bis-(*p*-nitrobenzoate) (0·20 g), small prisms, m.p. 148–152°. (Found: C, 63·96; H, 4·57. $C_{26}H_{22}N_2O_8$ requires: C, 63·67; H, 4·52%.)

The two esters were saponified by 1-hr reflux with 5% ethanolic KOH to the corresponding glycols: the higher-melting ester gave a glycol m.p. 90–91°. (Found: C, 75·03; H, 8·36. $C_{12}H_{16}O_2$ requires: C, 74·97; H, 8·39%.) The ester m.p. 148–152° gave a glycol, m.p. 117·5–119°. (Found: C, 74·81; H, 8·52. $C_{12}H_{16}O_2$ requires: C, 74·97; H, 8·39%.)

A solution of 0·05 g of the crude mixture of the two glycols (XVI and XVII) in 5 ml acetone was treated with 0·2 ml 8 N solution of chromic acid in H_2SO_4 aq,[14] diluted with water, saturated with NaCl and extracted with ether. Evaporation of the ether and crystallization from benzene gave 0·021 g 2-phenyladipic acid, m.p. 138–139°; lit.[18] m.p. 137–138°.

Acknowledgement—This work was supported by a grant from the Consiglio Nazionale delle Ricerche (Rome).

[18] W. Baker and P. G. Jones, *J. Chem. Soc.* 787 (1951).