239. *Fused Carbon Rings. Part XII. A Simple Synthesis of Derivatives of Decalin from* cyclo*Hexanone, and Observations on* cyclo*Hexane*spiro*butyrolactone and Allied Compounds.*

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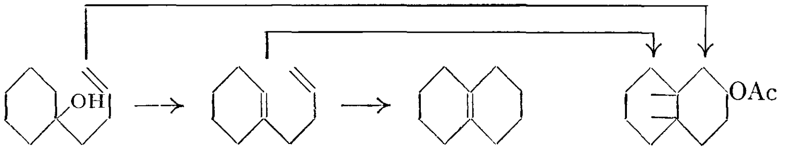
In recent communications (Hibbit and Linstead, J., 1936, 470; Hibbit, Linstead, and Millidge, *ibid.*, p. 476) it was shown that derivatives of decalin containing an angular methyl group could easily be obtained by the cyclisation of methyl-Δ^{γ}-butenyl*cyclo*hexanols, in which the alkyl groups were substituted on adjacent carbon atoms of the ring and the hydroxyl groups attached to either of these atoms. It was important to determine whether this method could be used for the synthesis of compounds not containing an angular methyl group, for it is known from the work of J. W. Cook and others that such a group facilitates cyclisation. Moreover, if unmethylated dicyclic compounds were obtainable by this process, it seemed probable that their configuration could be ascertained with certainty.

We have accordingly examined the action of a number of dehydrating agents on 1-Δ^{γ}-*butenyl*cyclo*hexanol* (I), which is easily prepared in one stage from *cyclo*hexanone. Oxalic acid at 130° yielded the monocyclic diene, probably 1-Δ^{γ}-*butenyl*cyclo*hexene* (II), which was unaffected by sodium and amyl alcohol. A mixture of phosphoric acid and phosphoric oxide dehydrated the alcohol to a mixture of diene and a dicyclic hydrocarbon. Cyclisation was completed by treatment of this mixture with phosphoric oxide at 140°. The dicyclic hydrocarbon obtained was an octalin, mainly the $\Delta^{9:10}$-isomeride, identical with that prepared from decalin by Nametkin and co-workers (*Ber.*, 1926, **59**, 370; 1929, **62**, 1570). The structure has been established with certainty by Hückel, Danneel, Schwartz, and Gercke (*Annalen*, 1929, **474**, 121). Our synthetic material yielded the same crystalline dibromide and blue nitrosochloride as obtained by the latter workers. On hydrogenation it gave the expected mixture of *cis*- and *trans*-decalins.

The position of the double bond is interesting. One would expect it in the Δ^1- or Δ^2-position, and in the corresponding 9-methyloctalin (in which the bridge position is impossible) the double bond is Δ^2 (Hibbit and Linstead; but see following paper). We find, however, that *trans*-Δ^2-octalin is readily isomerised to the $\Delta^{9:10}$-isomeride by heating with phosphoric oxide, and that *trans*-β-decalol yields the same substance when dehydrated under the conditions of cyclisation of butenyl*cyclo*hexanol. Hence the double bond is mobile and the $\Delta^{9:10}$-isomeride must be the final product, whatever the primary position taken by the double bond. It should be said that, although the hydrocarbons obtained in all these reactions give the solid derivatives of the $\Delta^{9:10}$-form and no acid oxidation products corresponding with other positions of the double bond, the physical constants vary to some extent and the presence of minor amounts of isomeric impurities is probable.

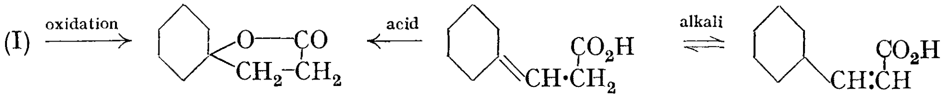
The next series of experiments was suggested by the work of Bertram and his collaborators on the cyclisation of geraniol to terpin hydrate and on the ready addition of acetic acid to terpenoid double bonds (*J. pr. Chem.*, 1894, **49**, 1, 194; 1900, **61**, 293). When 1-butenyl*cyclo*hexanol was treated with acetic acid containing a little acetic anhydride and sulphuric acid, it was partly converted into *cis*-β-decalyl acetate (IV), which on hydrolysis yielded the well-known form of *cis*-β-decalol of m. p. 104°. The diene (II) gave the same acetate and alcohol on treatment with a mixture of sulphuric and acetic acids.



(I.) (II.) (III.) (IV.)

The highest overall yield of decalol obtained from such cyclisations was only 25%, but the process represents a simple three-stage synthesis from *cyclo*hexanone and gives a product which is stereochemically nearly homogeneous.

Finally it was necessary to establish the fact that the double bond in the parent alcohol (I) was in the position shown and had not migrated during the preparation. This was proved by oxidation with permanganate, the alcohol yielding cyclo*hexane*spiro-*butyrolactone* (V), the structure of which was established by its synthesis from β-cyclo*hexylidenepropionic acid* (VI).



(V.) (VI.) (VII.)

Examination of the literature on these substances and on the corresponding Δ^{α}-acid (β-*cyclo*hexylacrylic acid, VII) revealed a number of apparent abnormalities. Sircar (J., 1928, 54) prepared the Δ^{β}-acid (VI) by oxidising the corresponding unsaturated ketone, and the lactone (V) by condensing *cyclo*hexanealdehyde with malonic acid in the presence of alcoholic diethylamine. Both products were described as liquids, the lactone boiling at 152—155°/15 mm., and the Δ^{β}-acid as having an odour resembling that of the lactone. It was also stated that long boiling of the lactone with alkali yielded the Δ^{α}-acid, but that the latter yielded no Δ^{β}-acid under the same conditions.

In the light of previous experience on the preparation and properties of unsaturated acids, many of these statements were open to question. We should expect : (i) The aldehyde to condense with malonic acid in the presence of a molar amount of diethylamine to yield the Δ^{β}-acid. (ii) The lactone to give with alkali the sodium salt of the γ-hydroxy-acid, which would not be dehydrated under the experimental conditions. (iii) A Δ^{α}-acid such as (VII) with a disubstituted γ-carbon atom to yield a considerable quantity of Δ^{β}-acid on boiling with alkali (compare J., 1932, 115). These substances have accordingly been reinvestigated with the following results.

The Δ^{α}-acid (VII), m. p. 59—60°, is readily prepared by condensing *cyclo*hexane-aldehyde with malonic acid in pyridine. If triethanolamine is used as condensing agent, the product is the Δ^{β}-acid (VI), m. p. 47—48°. This result falls into line with other similar condensations (Boxer and Linstead, J., 1931, 740; Linstead, Noble, and Boorman, J., 1933, 557). When the Δ^{α}-acid is boiled with alkali, it yields an equilibrium mixture of Δ^{α}- and Δ^{β}-acids containing 54% of the Δ^{β}-isomeride. The Δ^{β}-acid separated from this mixture by means of partial esterification (Eccott and Linstead, J., 1929, 2153) is identical with that prepared directly from the aldehyde. The Δ^{β}-acid is readily lactonised by cold 50% sulphuric acid to the *spiro*-lactone (V), m. p. 20°, identical with that prepared by the oxidation of butenyl*cyclo*hexanol. Like other lactones of similar structure (Boorman and Linstead, J., 1933, 580), the *spiro*-lactone is very little hydrolysed by boiling water. The pure lactone boils some 20° below the temperature recorded by Sircar and its odour is quite distinct from that of the Δ^{β}-acid. Sircar's " Δ^{β}-acid " and " lactone " therefore appear to have been mixtures of these substances, which would explain the abnormal reactions reported by him. It is difficult to avoid the lactonisation of Δ^{β}-acids of this type during their isolation, unless special precautions are taken.

These cyclic substances are therefore normal in their methods of preparation and properties, and closely resemble their acyclic analogues, such as Δ^{α}- and Δ^{β}-*iso*hexenoic acids and *iso*hexolactone, which contain two methyl groups in place of the ring.

EXPERIMENTAL.

A solution of 125 g. of Δ^{γ}-butenyl bromide (Linstead and Rydon, J., 1934, 1998) in 300 c.c. of dry ether was added during 4½ hours to 24 g. of magnesium, and after a further 2 hours' refluxing, a solution of 100 g. of *cyclo*hexanone in 200 c.c. of dry ether was added slowly. The mixture was refluxed overnight and decomposed with ammonium chloride solution, and the alcohol isolated by means of ether. After two distillations 58 g. (40%) of 1-Δ^{γ}-*butenyl*cyclo*hexanol* (I) were obtained, b. p. 95—96°/10 mm., $d_{4^{\circ}}^{14^{\circ}}$ 0·9333, $n_{\mathrm{D}}^{14^{\circ}}$ 1·4814, $[R_L]_{\mathrm{D}}$ 46·95 (calc., 47·24) (Found : C, 77·7; H, 11·4. $C_{10}H_{18}O$ requires C, 77·9; H, 11·7%).

Dehydration. 10 G. of the alcohol were refluxed with 10 g. of hydrated oxalic acid at 125—135° for 2 hours, and the residue distilled under reduced pressure. The distillate was dried with calcium chloride, refluxed for a further 2 hours with the residual anhydrous oxalic acid in the original flask, and again distilled. The distillate was washed with alkali, dried, and fractionally distilled, finally over sodium. 1-Δ^{γ}-*Butenyl*-Δ^{1}-cyclo*hexene* (II) was a mobile liquid with the strong smell of a diene, b. p. 60—62°/10 mm., $d_{4^{\circ}}^{18^{\circ}}$ 0·8445, $n_{\mathrm{D}}^{18^{\circ}}$ 1·4745, $[R_L]_{\mathrm{D}}$ 45·42 (calc., $|\overline{=}_2$ 45·25). Yield, 6·2 g. (Found : C, 87·9; H, 11·4. $C_{10}H_{16}$ requires C, 88·2; H, 11·8%).

A mixture of 10 g. of the alcohol, 10 g. of phosphoric oxide, and 50 c.c. of syrupy phosphoric acid was refluxed at 160° for 3 hours. The cooled product was poured into water and neutralised, and the hydrocarbon extracted with ether. 7·5 G. of a liquid were obtained, b. p. 69—72°/10 mm., $d_{4^{\circ}}^{16\cdot8^{\circ}}$ 0·8677, $n_{\mathrm{D}}^{16\cdot8^{\circ}}$ 1·4813, $[R_L]_{\mathrm{D}}$ 44·56. Titration with percamphoric acid in chloroform solution (Masson, *J. Amer. Chem. Soc.*, 1933, **55**, 347) gave a value of 1·31 double bonds per molecule. The mixture of hydrocarbons (7 g.) was accordingly refluxed for 3 hours at 140° with 3 g. of phosphoric oxide and worked up as before. The smell had then changed from that of the diene to a faint pleasant odour. The octalin (mainly III) had b. p. 71—72°/10 mm., and the other physical properties shown in the table below. Titration with percamphoric acid showed 0·96 double bond (Found: C, 87·6; H, 11·8. Calc. for $C_{10}H_{16}$: C, 88·2; H, 11·8%). The dibromide formed small plates from light petroleum (charcoal), m. p. 161—162°; and the nitrosochloride, obtained in good yield, separated from ether in massive blue prisms, m. p. 90° (decomp.). No white nitrosochloride could be isolated. Pure $\Delta^{9:10}$-octalin gives a dibromide, m. p. 163—164°, and a blue nitrosochloride, m. p. 91° (Hückel, Danneel, Schwartz, and Gercke, *loc. cit.*).

The octalin was reduced over Adams's catalyst in absolute alcohol. The product, distilled over sodium, had b. p. 74—76°/12 mm., $d_{4^\circ}^{16\cdot2^\circ}$ 0·8809, $n_D^{16\cdot2^\circ}$ 1·4813, corresponding to a mixture of decalins, mainly the *trans*-isomeride (compare Hückel *et al.*) (Found: C, 86·5; H, 13·0. Calc. for $C_{10}H_{18}$: C, 87·0; H, 13·0%). Oxidation of the octalin with aqueous permanganate gave no isolable quantity of solid acid.

$\Delta^{9:10}$-Octalin was obtained for comparison following Hückel by dehydrating *trans*-decalol with zinc chloride, and by the following methods. *trans*-β-Decalol was heated with phosphoric acid and anhydride exactly as described above for butenyl*cyclo*hexanol. Yield, 94% of octalin. *trans*-β-Decalol was dehydrated to *trans*-Δ^2-octalin by means of potassium hydrogen sulphate (Leroux, Hückel) and this was refluxed with phosphoric oxide as described above for the complete cyclisation of the diene. Yield, 65%. The physical properties of these three octalins are tabulated below together with those of pure regenerated $\Delta^{9:10}$-octalin (Hückel) and of the cyclisation product of butenyl*cyclo*hexanol.

Preparation.	$d_{4^\circ}^{t^\circ}$.	$n_D^{t^\circ}$.	*t*.	$[R_L]_D$.
(1) $ZnCl_2$	0·9165	1·4930	17·8°	43·12
(2) P_2O_5	0·9160	1·4970	16·0	43·46
(3) Isomerised Δ^2-	0·9206	1·4943	17·8	43·01
(4) Pure $\Delta^{9:10}$-	0·9170	1·4996	20·0	43·64
(5) Cyclisation product	0·9060	1·4955	16·0	43·82

$[R_L]_D$, calc. for $C_{10}H_{16}|\!\overline{=}_1$, 43·51.

The dibromides of samples (1), (2), and (3) melted after crystallisation at 162—163°, and the nitrosochlorides at 91—93°. The derivatives of the isomerised Δ^2-octalin (sample 3) were the least pure and a trace of a white nitrosochloride was isolated. Mixed m. p. determinations of the derivatives of (2), (3) and of the cyclisation product (5) with the corresponding derivatives of authentic $\Delta^{9:10}$-octalin (1) showed no depression.

Dehydration of butenyl*cyclo*hexanol with potassium hydrogen sulphate gave a poor yield of unsaturated hydrocarbon.

Synthesis of cis-*β-Decalol* [with K. D. ERRINGTON].—200 C.c. of glacial acetic acid were mixed with 20 c.c. of acetic anhydride and 20 c.c. of concentrated sulphuric acid. To 150 c.c. of this mixture at 0° were added, during ½ hour, 20 g. of butenyl*cyclo*hexanol. The mixture was kept at room temperature for 5 days, poured into water, and extracted with ether. The extract was washed with 5% aqueous potassium hydroxide until the washings were alkaline, and then with water. The residue after removal of the solvent had a strong odour of an ester. It was refluxed with 20% methyl-alcoholic potassium hydroxide for 3 hours and kept overnight. The bulk of the methyl alcohol was removed through a column, and the residue poured into water. The decalol, isolated by means of ether, boiled at 120—126°/11 mm. and rapidly solidified. 5 G., m. p. 94—97°, were obtained, which, after pressing on a porous tile and one crystallisation from light petroleum, melted at 104°, alone or admixed with authentic *cis*-β-decalol (Found: C, 77·3; H, 11·75. Calc. for $C_{10}H_{18}O$: C, 77·9; H, 11·75%).

10 C.c. of the diene (II) were shaken with 30 c.c. of a 5% solution of sulphuric acid in acetic acid for 24 hours and finally warmed at 70—80° for ½ hour. The product was worked up in the manner described above, but was distilled before hydrolysis. 3·5 G. of an unsaturated hydrocarbon, b. p. 66—68°/10 mm., were obtained and a fragmentary residue of ester remained. This was hydrolysed as described above and yielded 1·2 g. of *cis*-β-decalol, m. p. and mixed m. p. 104°.

cyclo*Hexane*spiro*butyrolactone and Allied Substances.*—7·2 G. of Δ^γ-butenyl*cyclo*hexanol were shaken for 6 hours at room temperature with 800 c.c. of 3% potassium permanganate solution. Sulphur dioxide was passed to clear the solution, which was then acidified and thoroughly extracted with ether. The extract yielded 3·8 g. of a colourless oil with a characteristic lactonic odour, b. p. 131—133°/10 mm. This slowly solidified; the pure material was obtained by pouring off liquid impurities. cyclo*Hexane*spiro*butyrolactone* melts at 20—20·5° and dissolves very slowly in caustic alkali (Found: C, 69·8; H, 9·2. $C_9H_{14}O_2$ requires C, 70·1; H, 9·1%).

*cyclo*Hexanealdehyde diethylacetal, obtained in 65% yield from *cyclo*hexylmagnesium chloride, gave 52% of the free aldehyde, b. p. 155—160°. A mixture of 10 g. of the aldehyde, 10 g. of malonic acid, and 13 g. of pyridine was kept for 5 days at room temperature and then heated on the steam-bath overnight. β-*cyclo*Hexylacrylic acid (VII) (compare Sircar, *loc. cit.*) was isolated in the usual manner, purified through sodium bicarbonate, and crystallised from light petroleum. Yield, 12 g.; m. p. 59—60° (Found : C, 70·0; H, 9·1; equiv., 153. Calc. for $C_9H_{14}O_2$: C, 70·1; H, 9·1%; equiv., 154).

A mixture of 10 g. of the aldehyde, 10 g. of malonic acid, and 20 g. of triethanolamine was kept for 5 days at room temperature and overnight on the steam-bath. The product was cooled to 0°, covered with a layer of ether, and cautiously acidified with ice-cold dilute sulphuric acid. These precautions were necessary to prevent lactonisation. The aqueous layer was further extracted with ether, and the organic acid extracted from the combined ethereal layer with aqueous sodium bicarbonate. Finally, the acid was again liberated with ice-cold sulphuric acid, and isolated by extraction with ether and distillation. B. p. 156—159°/16 mm.; yield, 5 g. β-cyclo*Hexylidenepropionic acid* slowly solidified and crystallised from a little light petroleum in large overlapping plates, resembling in its crystalline form and unpleasant smell other Δ^{β}-acids. M. p. 47—48° (Found : C, 69·9; H, 9·2; equiv., 152. $C_9H_{14}O_2$ requires C, 70·1; H, 9·1%; equiv., 154).

7·7 G. of the Δ^{α}-acid were boiled for 12 hours with 40% aqueous potassium hydroxide (30 c.c.), and the mixed acids isolated in the usual manner. The bulk of the product (6·1 g.) was partly esterified by standing with 12 c.c. of *N*-hydrochloric acid and 20 c.c. of alcohol. The mixture was separated into Δ^{α}-acid and Δ^{β}-ester in the usual way. The former (2·9 g.) melted at 57—59° without crystallisation. The latter (3·5 g.) boiled at 116—118°/18 mm. and on hydrolysis yielded 2·5 g. of Δ^{β}-acid. A reserved portion of the mixed acids (1·0 g.) had an equivalent of 152, showing that it was practically free from lactone. The iodine additions of this material (Linstead and May, J., 1927, 2565; time 12 minutes), of the two pure acids, and of known mixtures are shown below :

Δ^{α}-Acid, %	100	48	39	0 (Δ^{β}-)	Equilibrated product
Iodine addition, %	5·2	39·5	44·1	61·5	39·9

By interpolation, the equilibrium mixture of acids contains 46% of Δ^{α}-acid, which agrees well with the amount isolated by means of partial esterification.

The Δ^{β}-acid (2·3 g.) was kept for 2 days with 50% sulphuric acid (10 c.c.). The homogeneous liquid was diluted and extracted with ether, and the extract washed with aqueous sodium bicarbonate and dried over sodium sulphate. Removal of the ether and distillation yielded 1·2 g. of *cyclo*hexane*spiro*butyrolactone, b. p. 130—133°/12 mm., m. p. 20°, alone or admixed with lactone prepared by oxidation of butenyl*cyclo*hexanol. The lactone (1·80 g.) was boiled for 6 hours with 50 c.c. of water, and the free hydroxy-acid titrated. The degree of hydrolysis was 1·96%.

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