STEREOCHEMISTRY OF CAMPHORIC ACID

Part I.—Some Reactions of Inactive Cis and Trans Methyl Hydrogen Camphorate

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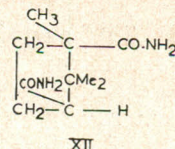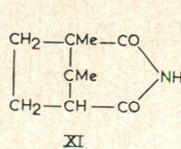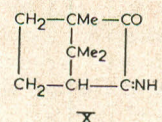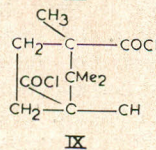
The so called *ortho* and *allo*-methyl hydrogen camphorate have been prepared from *dl*-camphoric acid, their configurations have been re-examined and they have been re-designated *cis* and *trans* methyl hydrogen camphorate respectively on the basis of the reactions of their acid chlorides with bromine, and zinc methyl iodide. The former reaction resulted in the production of bromo camphoric anhydride together with methyl camphanate and some bromo-esters, while the latter reaction gave one and the same ketonic ester. The ketonic ester underwent Dieckman condensation to give 1:1:5-trimethyl-2:5-*bicyclo*-hexane - 6:8-dione. On Clemmenson reduction this dione gave a mixture of three products one of which is 1:1:5-trimethyl -6- keto *bicyclo* hexane.

A large volume of work has already been published on the chemistry of camphoric acid, and yet the question of the constitution of the acid esters of camphoric acid does not appear to have been definitely decided. One 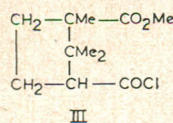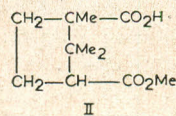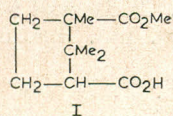of us reported in 1930,[1] that *ortho* methyl hydrogen camphorate (I) and *allo* methyl hydrogen camphorate (II) yielded one and the same keto methyl ester (IV), through their acid chlorides (III), with zinc methyl iodide; and there he pointed out that the isomerism of the acid esters (I) and (II), cannot be a structural one as hitherto assumed; on the other hand they are really stereoisomeric in nature, and must be represented by the configurations (V) and (VI), i.e., the hitherto called *ortho*-methyl hydrogen camphorate is in reality the *cis*-isomer (V), and *allo*-methyl hydrogen camphorate the *trans*-isomer (VI).

The formation of *iso*-camphoric acid from cam-

phoric acid is not an uncommon phenomenon. Bredt[2] showed that when camphoric acid is treated with phosphorus pentachloride, there results a mixture of acid chlorides of camphoric acid (VIII) and *iso*-camphoric acid (IX), which have been given the configurations (VIII) and (IX) respectively. Their configuration had been assumed from the resulting unsymmetrical imino anhydride (X) or the imide (XI) and the diamide (XII). The *cis* compound, due to its proneness to form the ring, changes into the imide (XI), while the *trans* isomer, because of its inability to undergo any ring formation, remains in the diamido form (XII). Camphoric acid also changes into a mixture


of camphoric acid and *iso* camphoric acid when fused with caustic potash.[3] The mixture is conveniently separated by taking advantage of the fact that *iso* camphoric acid does not form an anhydride. The fact, however, emerges from these

experiments that through these reactions camphoric acid, which has a *cis* configuration, changes to a *trans* compound.

The method of formation of the *ortho* ester from the anhydride appears to follow a similar line and gives mostly the *cis* acid ester, while the dimethyl ester, which probably shows a tendency to pass into the *trans* form under hydrolysing conditions gives rise to the *trans* or *allo* methyl hydrogen camphorate.

This simple explanation has not been accepted by Simonsen,[4] who said that there were quite a large number of facts against this finding. It has become necessary now to examine his statement and find out all the facts in respect of this very important question.

Simonsen's conjecture regarding the intermediate formation of a chloroanhydride (VII), before the bromination took place, does not appear to be tenable. The anhydride of camphoric acid does not brominate in the presence of phosphorus oxychloride, nor does the anhydride once formed, hydrolyse into the acid with water or to acid ester with alcohol, even on heating. The product of bromination of *ortho* acid ester (I) isolated after treating it with methanol gave methyl camphorate (XIII), bromocamphoric anhydride (XIV), and a little normal dimethyl camphorate (XV) from the unbrominated portion of the reaction mixture.

XIII

XIV

XV

XVI
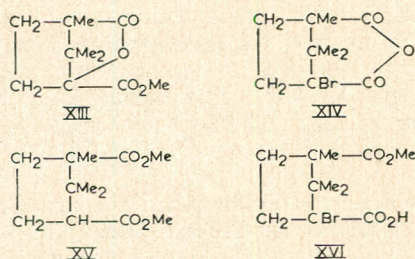
It should be further noted that to clarify these points the bromination experiment has now been repeated with the acid esters of inactive (*dl.*) camphoric acid with results as has been described above. The two acid esters obtained in this case were different from the acid esters prepared from *d*-camphoric acid. They were separately converted into the ester acid chlorides with phosphorus pentachloride as also with thionyl chloride and subsequently brominated. In one experiment, after bromination the products were separated with a nonhydroxylic solvent, when bromocamphoric anhydride separated out in crystalline condition. The solution yielded a crystalline

residue, when the solvent including phosphorus oxychloride was completely removed under reduced pressure. After isolation in pure condition the bromo-camphoric anhydride was boiled with dry methyl alcohol for several hours. It did not undergo any decompositon into the bromo methyl hydrogen camphorate (XVI). Nor could a sample of pure inactive camphoric anhydride in the presence of phosphorus oxychloride be brominated into the bromo anhydride.

It should, therefore, be concluded that the bromination of the acid ester takes place through its acid chloride (XVII) and after bromination had been effected, part of the acid chloride was converted into the bromocamphoric anhydride (XVIII). When this change had taken place,

XVII

XVIII
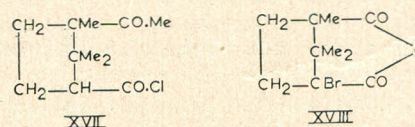
the anhydride ring could not open up to form either the acid ester (VI) or the diester (XV). It should, therefore, be understood that the acid chloride had a fair stability and when zinc methyl iodide reacted with it, there results the ketonic ester (IV).

In another experiment the product of bromination on being treated with methanol gave a mixture consisting of the bromo-camphoric anhydride (XVIII), methyl camphanate (XIII) as well as some bromo-camphoric ester (XIX).

XIX

XX
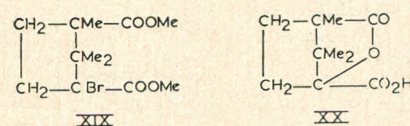
The bromo ester, obtained from either the *allo* or the *ortho* ester, pointed to the fact that the free carboxyl group in both the esters is attached to a -CH, group, leaving no doubt regarding the stereo-isomeric relationship between the acid esters of inactive camphoric acid. Although the bromo-camphoric ester could not be obtained in a very pure form, yet its identity is beyond any doubt. The formation of methyl camphanate and its hydrolysis to camphanic acid (XX), also points to the same fact that the bromination takes place at the α-carbon atom to the free carboxyl group, which later gives off its bromine with methyl radical of the ester at the second carboxyl group, to form the lactonic ring.

Simonsen[4] tried to explain the reaction, leading to the formation of the same ketonic ester (IV), from either the *allo* or the *ortho* methyl hydrogen camphorate, by stating that it was not the acid chloride that actually reacted, but the change took place through the intermediate conversion of the anhydride (XXI), which gave the same keto methyl ester (IV) from both the *allo* and the *ortho* acid esters. This would indeed be a very unusual course of reaction to take place between thionyl chloride and *ortho*-methyl hydrogen camphorate in so far as to suggest that thionyl chloride caused the intermediate formation of an anhydride (XXI) which subsequently changed into the structurally isomeric form. Haller and Blanc's[5] experiments do not support this view, nor do our experiments.

In this explanation Simonsen has completely ignored the ordinary mechanism of the reaction, because by the change of the acid ester into the anhydride, there will be the resultant production of some methyl chloride, which by no stretch of imagination, could combine with the anhydride group to yield subsequently the acid ester. The experimental evidences with *dl-cis*-methyl hydrogen camphorate[1] and with *dl-trans*-methyl hydrogen camphorate now undertaken in these laboratories, were that after the reaction of zinc methyl iodide with the acid chloride (III), the ketonic ester (IV) and the anhydride (XXI) were the only products.

If it was possible for zinc methyl iodide to react with the anhydride, the course of the reaction would be as follows:—

$$
\begin{array}{c}
CH_2\text{---}CMe\text{---}CO \\
|\qquad\quad CMe_2\qquad O \\
CH_2\text{---}CH\text{---}CO \\
\underline{XXI}
\end{array}
\xrightarrow{ZnCH_3I}
$$

$$
\begin{array}{c}
CH_2\text{---}CMe\text{---}COOZnI \\
|\qquad\quad CMe_2 \\
CH_2\text{---}CH\text{---}COCH_3 \\
\underline{XXII}
\end{array}
\text{ or }
\begin{array}{c}
CH_2\text{---}CMe\text{---}CO.CH_3 \\
|\qquad\quad CMe_2 \\
CH_2\text{---}CH\text{---}COOZnI \\
\underline{XXIII}
\end{array}
\xrightarrow{H_2O}
$$

$$
\begin{array}{c}
CH_2\text{---}CMe\text{---}CO_2H \\
|\qquad\quad CMe_2 \\
CH_2\text{---}CH\text{---}CO.CH_3 \\
\underline{XXIV}
\end{array}
\text{ or }
\begin{array}{c}
CH_2\text{---}CMe\text{---}CO.CH_3 \\
|\qquad\quad CMe_2 \\
CH_2\text{---}CH\text{---}CO_2H \\
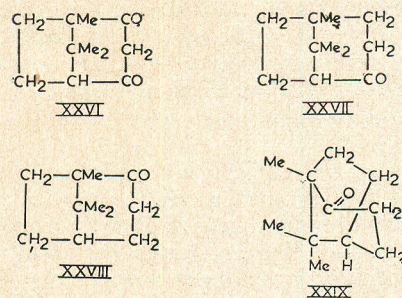\underline{XXV}
\end{array}
$$
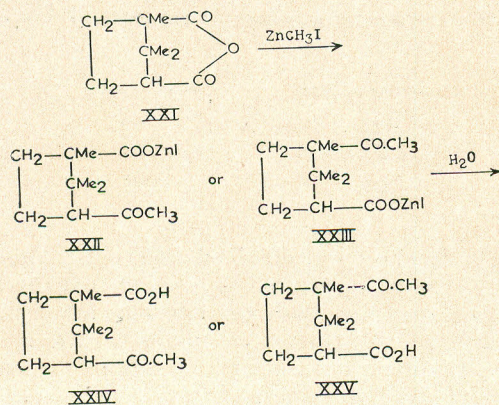
Zinc methyl iodide had no action on the *dl*-camphoric anhydride, which was recovered unchanged. The suggestion of Simonsen in this respect must, therefore, be considered as misleading, and his hypothesis about the interconversion of the two structurally different *ortho* and *allo* acid esters, to give the same keto ester is untenable.

The free carboxyl in the inactive *cis* or *trans*-methyl hydrogen camphorate could be easily converted into the acetyl group in the usual way and methyl 1:1:5-trimethyl cyclopentane -2-acetyl -5-carboxylate (IV) underwent Dieckman condensation to give the dione (XXVI). The reduction of the resultant dione gave rise to a mixture of ketones, an alcohol and another oxygen containing compound.

Reduction of the two different carbonyl groups in the dione (XXVI), can give rise to two isomeric ketones (XXVII) and (XXVIII), which are structurally different.

$$
\begin{array}{c}
CH_2\text{---}CMe\text{---}CO \\
|\qquad\quad CMe_2\quad CH_2 \\
CH_2\text{---}CH\text{---}CO \\
\underline{XXVI}
\end{array}
\qquad
\begin{array}{c}
CH_2\text{---}CMe\text{---}CH_2 \\
|\qquad\quad CMe_2\quad CH_2 \\
CH_2\text{---}CH\text{---}CO \\
\underline{XXVII}
\end{array}
$$

$$
\begin{array}{c}
CH_2\text{---}CMe\text{---}CO \\
|\qquad\quad CMe_2\quad CH_2 \\
CH_2\text{---}CH\text{---}CH_2 \\
\underline{XXVIII}
\end{array}
\qquad
\begin{array}{c}
Me\text{---}C\text{---}CH_2 \\
|\qquad O\quad CH_2 \\
Me\text{---}C\text{---}C\text{---}CH_2 \\
\quad Me\ H \\
\underline{XXIX}
\end{array}
$$

Reduction of this diketone resulted in the production of a mixture. One of its components is a mono-ketone and the other an unsaturated alcohol, which is probably the enolic form of this mono ketone or that of its isomeride. A third compound containing some oxygen function was also isolated but could not be characterized due to paucity of this material.

Considering the steric influence of molecule it seems likely that the mono-ketone obtained as the major product from the reduction is (XXVIII) rather than (XXVII). The thermodynamic considerations of this reduction also makes it likely that it would have the structure (XXIX).

On the same consideration it seems that the "enolic" form of this ketone (XXVIII) will be more likely to be produced than the enolic form of (XXVII).

It will be seen that reduction of this diketone can result in the production of several different structural and stereo-isomerides, considering that ring contraction also takes place during such reduction.[6,7] It is proposed to make a more detailed study of this reduction at a later date.

Experimental

The analyses recorded here were done by A. Barnhardt, Microanalytical Laboratories, Mulheim, West Germany. Unless otherwise stated the infra-red absorption spectra were taken in KBr pellets.

dl-Camphoric Acid.—The acid was prepared by Bredt's method from synthetic camphor (150 g.), on oxidation with concentrated nitric acid (sp.gr. 1.41, 1250 ml.) and water (800 ml.), by heating on the water bath for sixty-five hours. Two such lots of experiments yielded 180 g. of *dl*-camphoric acid when cooled in ice and filtered. The acid thus separated crystallised from hot water and melted at 203°C. (Found: C, 59.8; H, 8.1; O, 32.3% Calc. for $C_{10}H_{16}O_4$; C, 60.0; H, 8.05; O, 32.0%). This had infra-red bands at 1690 and 1710 cm-¹ (– COOH).

dl-Cis-Methyl Hydrogen Camphorate, previously known as *orth* acid ester of camphoric acid, could be separated from the product of esterification of *dl*-camphoric acid (93 g.) by heating with methanol (470 ml.) and concentrated sulphuric acid (23.5 ml.) under reflux (10 hrs.). The alcohol was distilled off and the residue diluted with water and was taken up in petroleum ether. The petroleum extract was washed with sufficient sodium carbonate solution and water. It was then dried (Na_2SO_4) and distilled, when *dl*-dimethyl camphorate was obtained in 17.5% yield and boiled at 134°/12 mm. It had $d_4^{30}1.0668$ [n]$^{30}_D$ 1.4576 (whence R=58.339, Calc. 58.298) (Found: C.63.0; H, 8.2; $C_{12}H_{20}O_4$ requires C, 63.1; H, 8.7%).

The alkaline extract on acidification gave an oil which was taken up in ether, dried (Na_2SO_4) and the solvent distilled off. The residue on cooling gave *dl-cis*-methyl hydrogen camphorate (81 g)., m.p. 43-55°C. which on being crystallised from 25% acetic acid solution gave the pure *acid ester* m.p. 87°C. (Found: C, 61.25; H, 8.6; $C_{11}H_{18}O_4$ requires C, 61.6; H. 8.5%). The same acid ester was obtained from *dl*-camphoride and sodium methoxide in the usual way. The *cis*-acid ester also crystallises well from petroleum ether (50-60°) as beautiful rhombs) and melts at 87°C. (Found: C, 61.55; H, 8.6%. This had infra-r d absorption b nds at 1680 cm^{-1} (– COOH) and 1740 cm^{-1} (–COO Me).

In another experiment the mixture of camphoric acid (75 g.), dry methanol (375 ml.) and concentrated sulphuric acid (19 ml.) was continuously distilled into a receiver containing anhydrous potassium carbonate. The receiver was also heated simultaneously so as to distil back the dried methanol into the reaction flask through a tube dipped into the mixture. The yield of *dl*-dimethyl camphorate was th s improved to 37% and methyl hydrogen comphorate obtained was 62% of the theoretical.

dl-Trans-Methyl Hydrogen Camphorate.—The neutral *dl*-dimethyl camphorate, described above (17 g.) was refluxed with methanol (50 ml.) containing caustic potash (4.0 g.) for twenty minutes. Methanol was then distilled off and the residue diluted with water. The mixure was extracted with ether, the alkaline aqueous solution was acidified and the precipitated oil was taken up in ether, it was dried (Na_2SO_4) and the solvent removed, when *dl-trans* methyl hydrogen camphorate, crystallised out. This was recrystallised from 25% acetic acid when it came out as fine rhombs m.p. 77°C. (Found: C, 61.70; H, 8.75%). This had infrared absorption bands at 1700 cm^{-1} (– COOH) and 1740 cm^{-1} (– COOMe).

dl-Camphoric Anhydride.—*dl*-Camphoric acid (50 g.) was refluxed with excess of acetic anhydride, which was then distilled off and the r.sidu treated with water. The crystals that separated were filtered and recrystallised from ethanol, when a mass of needles separated, which melted at 225°C. The purified product was 90% of the theoretical. (Found: C, 66.1; H, 7.85; O, 26.0% Eq. Wt., 270. Calc. for $C_{10}H_{14}O_3$; C, 65.9; H, 7.75; O, 26.35% Eq. Wt. 270). This had infra-red absorption bands at 1750 and 1800 cm.$^{-1}$ (Anhydride).

Action of Bromine on Camphoric Anhydride.—The purpose of this experiment was to see if bromination could be effected to *dl*-camphoric anhydride itself. *dl*-Camphoric anhydride (3.5 g.) was dissolved in warm phosphorus oxychloride (5 ml.) and dry bromine (0.5 ml.) was added to it, while the solution was heated at 100°C. After four-hour heating, excess of free bromine was removed, there being no evidence of any hydrogen bromide being evolved. The mixture in the flask was treated with excess of methanol, which was removed completely on the water bath. On trituration with petroleum ether, crystals of unchanged anhydride melting at 220° were isolated. The petroleum ether extract was washed with sodium carbonate solution, which gave a little precipitate of *dl*-camphoric acid m.p. 197-200°C., while the neutral portion from petroleum ether yielded an oil reminiscent of *dl*-dimethyl camphorate in odour and did not contain any bromine (sodium fusion test). Prolonged refluxing of the anhydride with either water or ethanol (upto 4 hours) resulted in 100% recovery of the unchanged *dl*-camphoric anhydride.

Bromination of dl-cis-Methyl Hydrogen Camphorate.—*dl-cis* Methyl hydrogen camphorate (42 g.) was mixed with phosphorus pentachloride (41 g.), when a reaction started, which was allowed to proceed with external cooling. When the reaction

abated, it was heated on a water bath for about an hour and then in course of another hour dry bromine (12 ml.) was added and the heating was continued for four hours, during which most of the bromine had reacted and evolution of hydrogen bromide ceased. Traces of bromine were removed at the pump and the crystalline residue was treated with methanol (150 ml.), under cooling. Excess of methanol was removed from a water bath and the residue was diluted with water, cooled and extracted with ether. The ethereal solution was washed with sodium carbonate solution and then with water and dried (Na_2SO_4). Ether was removed and the residue on cooling deposited a viscous mass which on trituration with warm petroleum ether (40-60°) gave crystals of dl-bromocamphoric anhydride, which were recrystallised from chloroform and melted at 220°C. (Found: C, 45.95; H, 5.35; Br, 30.2 $C_{10}H_{13}O_3$ Br requires C, 45.0; H, 5.05; Br., 30.6%). This had infra-red absorption bands at 1770 and 1800 cm.$^{-1}$ (anhydride). The petroleum ether solution, on evaporation of the solvent, gave a viscous oil. This deposited crystals after leaving at room temperature for some time. Thrice crystallised from petroleum ether (b.p. 50-75°C.), it gave colourless rohmbs m.p. 81° of dl-methyl camphanate (Found: C, 62.45; H, 7.75; O, 30.0. $C_{11}H_{16}O_4$ required: C, 62.25; H, 7.60: O, 30.15%) which on titrating at 100° gave its equivalent weight as 216.5 (required for methyl camphanate 212.2). This had infra-red absorption bands at 1735 cm.$^{-1}$ (-COOMe) and 1780 cm.$^{-1}$ (lactone). From the mother liquor of the petroleum ether (b.p. 40-60°C.), a viscous oil was obtained, which decomposed on distillation. The crude product consisted of bromo esters (Found: Br, 38.05. $C_{12}H_{19}O_4Br$; requires Br. 26.02% and $C_{12}H_{18}O_4Br_2$ requires 41.4%). A small quantity of a crystalline compound was obtained from the sodium carbonate washing of the product of bromination which was indentified as dl-camphoric acid m.p. and mixed m.p. 203°C.

Bromination of dl-trans-Methyl Hydrogen Camphorate.—The reaction was carried out as in the case of the *cis* compound. dl-trans methyl hydrogen camphorate (7.2 g.), with phosphorus pentachloride (7 g.) and dry bromine (1.9 ml.) gave dl-bromo camphoric anhydride m.p. and mixed m.p. with that obtained from previous experiment 222°C., colourless rhombic crystals of dl-methyl camphanate m.p. 81°C. and mixed m.p. with that as obtained in the previous experiment 81°C. (Found: C, 62.4: H, 7.3%). It had identical infra-red spectrum with the lactone obtained from the previous experiment, and a neutral viscous bromo-ester which decomposed when distilled *in vacuo* (Found: Br., 30.9%).

Prolonged refluxing of dl-bromo camphoric anhydride with ethanol resulted in 100% recovery of the unchanged product.

Reaction of Zinc Methyl Iodide with the Acid Chloride of dl-cis-Methyl Hydrogen Camphorate.—dl-cis-Methyl hydrogen camphorate (107 g.) was reacted with thionyl chloride (60 ml.) for one hour at 100°. The excess of thionyl chloride was removed by the pump and the acid chloride dissolved in dry benzene (200 ml.). A Grignard reagent was prepared from methyl iodide (78 g.) and magnesium (13 g.) in dry ether (100 ml.) in the usual way. A solution of freshly prepared anhydrous zinc chloride (77 g.) in dry ether (200 ml.) was added to the Grignard reagent slowly with stirring and cooling. The solution of zinc methyl iodide thus prepared was diluted with dry benzene (300 ml.) and stirred for about 40 mins. The acid chloride solution was then added slowly (90 mins.) to the stirred mass. During the later part of the addition, lumps of inorganic salts separating out made stirring difficult and it was manually shaken. It was left at room temp. for 40 mins., cooled in ice bath and then decomposed with 5% sulphuric acid (200 ml.) and the organic layer separated, washed with water and extracted with 5% caustic soda (200 ml × 2). The ether layer was dried (Na_2SO_4) and solvent removed. The neutral oil deposited crystals of dl-camphoric anhydride, (15.5 g.), m.p. and mixed m.p. 223°, on dilution with petroleum ether (b.p. 50-75°). Petroleum ether was removed *in vacuo* to give the keto-ester (58 g.) b.p. 125-6°C./16 mm. This gave a crystalline semicarbazone, as shining prismatic rods, m.p. 205° (Found: C, 57.65; H, 8.45; N, 15.75; O, 18.35. $C_{13}H_{23}O_3N_3$ requires C, 58.0; H, 8.6; N, 15.65; O, 17.85%).

Zinc methyl iodide when reacted with dl-camphoric anhydride in ether - benzene solution as above, resulted in the recovery of the unchanged dl- camphoric anhydride.

Reaction of Zinc Methyl Iodide with the Acid Chloride of dl-trans-Methyl Hydrogen Camphorate. - dl-trans-Methyl hydrogen camphorate (20 g.) was reacted with thionyl chloride as above and the acid chloride added to a solution of methyl zinc iodide prepared from 15 g. of zinc chloride in benzene-ether solution. On working up as above it gave only the oily keto-ester (12 g.) which gave a semicarbazone m.p. and mixed m.p. with that from the above experiment 205°C.

Zinc methyl iodide prepared from zinc-copper couple (43 g.), freshly distilled ethyl acetate (10 ml.) and methyl iodide (25 ml.) in dry benzene (75 ml.), when reacted with the acid chloride of

dl-trans-methyl hydrogen camphorate gave similar result.

dl- 1:1:5-*Trimethyl*-6:8-*diketobicyclohexane*.—The keto ester (70 g.) described above was added slowly to a solution of sodium ethoxide prepared from sodium (8.5 g.) and dry ethanol (180 ml.). It was then refluxed for 45 hours and the solvent distilled off. The residue was dissolved in water and extracted with ether (evaporation gave 3 g. of an oil). The aqueous layer was acidified with hydrochloric acid and the oil taken up in ether and dried (Na_2SO_4). The solvent was then removed to give an oil (61 g.) which gave a semi-solid mass on leaving overnight. This was dissolved in hot petroleum ether (b.p. 60-80°C.) and cooled. The deposited solid (16.8 g.) on repeated crystallisations gave the diketone, as long rhombic needles, m.p. 220°C. (Found: C, 72.85; H, 8.65. $C_{11}H_{16}O_2$ requires C, 73.35; H, 8.9%). The diketone sublimed at 180°C./0.5 mm. to give a solid m.p. 221-2°C. (Found: C, 73.05; H, 8.75%). This had infra-red absorption bands ($CHCl_3$ soln.) at 1700 and 1725 cm.$^{-1}$ (diketone) as compared to the bands at 1700 and 1725 cm.$^{-1}$ (diketone) of dimedone. The ultraviolet absorption maxima was at 281.5 mμ (log ε 4.4) in 0.0004% alcoholic solution. The maxima was shifted to 282.5 mμ (log ε 4.5) in alkaline solution. The semicarbazone had m.p. 232-3°C. (Found: C, 60.25; H, 8.35; N, 17.5; O, 13.6. $C_{12}H_{19}N_3O_2$ requires C, 60.75; H, 8.05; N, 17.7; O, 13.5%).

The petroleum ether mother liquor from the above crystallization on evaporation *in vacuo* gave an oil which refused to crystallise. This was converted into its semicarbazone which on fractional crystallisation gave a small crop of the above semicarbazone (m.p. 232 C.), whereas bulk of it gave the semicarbazone of hydrolysed keto ester, 1 : 1 : 5-trimethyl-2-acetyl-5-carboxyl semicarbazone m.p. 210°C. (Found C, 56.6; H, 8.3; N, 16.15; O, 18.85. $C_{12}H_{21}N_3O_3$ requires C, 56.45; H, 8.3; N, 16.45; O, 18.8%). This on hydrolysis with 2N hydrochloric acid gave an oil, b.p. 110 C/0.5 mm., as the free acid. (Found: C, 66.05; H, 9.0; O, 25.25; active H$^+$, 0.8. $C_{11}H_{18}O_3$ requires C, 66.65; H, 9.15; O, 24.15; Active H$^+$ for enolic form 1.0%). The keto acid absorbed bromine avidly in chloroform solution thus proving it exists preponderously in the enolic form which is also confirmed from the analysis.

Clemmenson Reduction of dl- 1:1:5-*Trimethyl*-6:8-*diketo*-2:5 *bicyclohexane*-6:8-*dione*.—The diketone (8.5 g.) was reduced with hot conc. hydrochloric acid (200 ml.) and water (100 ml.) with amalgamated zinc (50 g.) for 2 hours. It was cooled and extracted with ether. The ethereal extract was washed with 5% caustic soda solution. The dried (Na_2SO_4) organic layer was freed from the solvent giving an oil with strong comphoraceous odour (7.2 g.). Part of it was lost through glass stopper due to its very strong tendency to sublime off. It did not crystallise from any solvent. It was chromatographed on a column of neutral alumina (250 g.) and eluted with petroleum ether, benzene, ether and chloroform. The 50% benzene in petroleum ether (b.p. 50-75°C.(elute gave an oil, b.p. 100°C. (bath temp.) 1.0 mm. which readily absorbed bromine but did not form a semicarbazone and probably is *dl-* 1:1:5-trimethyl-6:7-en-6-ol (Found: C, 79.3; H, 10.5. $C_{11}H_{18}O$ requires C, 78.85; H, 10.9%). The benzene elute gave a low melting solid, b.p. 60° (bath temp.) /0.5 mm. with intense camphoraceous odour but did not give a semicarbazone and was extremely volatile due to which no satisfactory analysis could be obtained. The bulk of the substrate came as the 20% ether in benzene elute. The oil left on removal of solvents sublimed at 100°C./1 mm. to give a glassy solid, m.p. 109-10°C. (sealed tube), which had an odour reminiscent of camphor and slowly sublimed at atmospheric pressure. This mono-ketone is probably dl. 1:1:5-trimethyl-6-ketobicylohexane (Found: C, 48.25; 48.2; H, 5.25, 5.5; O, 46.05. $C_{14}H_{10}O_{10}$ requires C, 48.55; H, 5.25; O, 46.20%). It gave a crystalline semicarbazone. m.p. 235°C. (Found: C, 64.55; H, 9.45; N, 18.7; O, 7.3. $C_{12}H_{21}N_3O$ requires C, 64.55; H, 9.45; N, 18.8; O, 7.15%). The ketone had infra-red absorption band ($CHCl_3$ soln.) at 1730 cm.$^{-1}$.

The higher elutes gave only traces of the unchanged diketone.

References

1. Qudrat-i-Khuda, J. Chem. Soc. , 206 (1930).
2. Bredt., Ber., **45**, 1419 (1912).
3. Mahla, Tiemann, **B, 28**, 2153.
4. Simonsen, *Terpenes*, Cambridge University Press, Vol. III, p. 486.
5. Haller and Blanc., Compt. rend., **141**, 697 (1905).
6. Qudrat-i-Khuda, Nature, **132**, 210 (1933).
7. Dey & Linsted, J. Chem. Soc., 1063 (1935).