XII.—*Synthesis of Pinacones. Part II.*

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IN Part I of this research (T., 1911, **99**, 1169) the preparation and properties were described of some unsymmetrical pinacones which were obtained by the interaction of Grignard's reagents and ethyl α -hydroxyisobutyrate.

In continuation of this work, the ester has been submitted to the action of magnesium *isoamyl* bromide in dry ethereal solution, and it has been found that $\beta\zeta$ -dimethyl- γ -isoamylheptane- $\beta\gamma$ -diol, $\text{OH}\cdot\text{CMe}_2\cdot\text{C}(\text{C}_5\text{H}_{11})_2\cdot\text{OH}$, is formed in good yield. Reaction also

takes place with magnesium *p*-tolyl bromide, but the pinacone has not been obtained pure.

Now it is well known that symmetrical pinacones of the type $\text{OH}\cdot\text{CR}_2\cdot\text{CR}_2\cdot\text{OH}$ or $\text{OH}\cdot\text{CRR}_1\cdot\text{CRR}_1\cdot\text{OH}$ lose the elements of water when heated with dilute sulphuric acid, and by the transference of the radicle R or R_1 from the one carbon atom to the other are converted into tertiary ketones or β -pinacolins, thus:

If, however, no "wandering" of the radicle R or R_1 takes place, the free valence of the oxygen atom will attach itself to that of the other carbon atom, and an α -pinacolin will be formed which is a derivative of ethylene oxide, thus:

Benzopinacone is capable of undergoing both transformations, for Thoerner and Zincke (*Ber.*, 1878, **11**, 1396) have shown that the two possible benzopinacolins are produced simultaneously when benzophenone is reduced by zinc and alcoholic hydrogen chloride.

It seemed, then, to be of interest to ascertain if unsymmetrical pinacones of the type $\text{OH}\cdot\text{CR}_2\cdot\text{CR}'_2\cdot\text{OH}$ or $\text{OH}\cdot\text{CR}_2\cdot\text{CR}/\text{R}''\cdot\text{OH}$ reacted in a similar way under the influence of sulphuric acid, and work in this direction was far advanced—and was, indeed, practically completed in respect of β -methyl- γ -ethylpentane- $\beta\gamma$ -diol, $\text{OH}\cdot\text{CMe}_2\cdot\text{CEt}_2\cdot\text{OH}$, and $\alpha\alpha$ -diphenyl- β -methylpropane- $\alpha\beta$ -diol, $\text{OH}\cdot\text{CMe}_2\cdot\text{CPh}_2\cdot\text{OH}$

—when Meerwein (*Annalen*, 1913, **396**, 255) published a paper, in the course of which he described these two pinacones and the action of sulphuric acid on them.*

* On communication with Professor Meerwein a division of the work was arranged. After reading Meerwein's paper the author was, for the first time, aware of a dissertation ("Beiträge zur Kenntniss der Pinakone und der Radikalwanderungen bei diesen," Rostock, 1910) by Erdmann, who prepared " $\alpha\alpha$ -diphenyl-dimethylpinacone" by the action of magnesium methyl iodide on methyl benzilate, and investigated the action of sulphuric acid on it.

The unsymmetrical pinacones which have so far been investigated are of the type $\text{OH} \cdot \text{CMe}_2 \cdot \text{CR}_2 \cdot \text{OH}$, where $\text{R} = \text{ethyl, } n\text{-propyl, isoamyl, and phenyl}$, and it has been found that: (1) they readily undergo the pinacolin rearrangement; (2) when $\text{R} = \text{alkyl}$, the pinacolin has the constitution $\text{CMe}_2\text{R} \cdot \text{COR}$, and is identical with that obtained from the corresponding symmetrical pinacone; (3) when $\text{R} = \text{phenyl}$, $\gamma\gamma$ -diphenylbutan- β -one, $\text{CMePh}_2 \cdot \text{COMe}$, is formed, and is the same pinacolin as that prepared by Thoerner and Zincke (*Ber.*, 1878, **11**, 1989) by reduction of acetophenone with alcoholic hydrogen chloride.

The constitution of these tertiary ketones was determined by oxidation, either with chromic acid mixture or with chromic acid in glacial acetic acid. Some difficulty was experienced in the cases where $\text{R} = n\text{-propyl}$ and *isoamyl*. When the former oxidising agent was employed, the alkyl radicle of the group $\cdot \text{COR}$ was alone oxidised; but with the latter agent, the acid $\text{CMe}_2\text{R} \cdot \text{CO}_2\text{H}$ was isolated, although the quantity obtained was insufficient for purification for analysis.

Experiments are now being conducted with the pinacones prepared from ethyl α -hydroxy- α -methylbutyrate with the object of gaining further insight into the mechanism of the "pinacolin transformation."

EXPERIMENTAL.

Action of Sulphuric Acid on β -Methyl- γ -ethylpentane- $\beta\gamma$ -diol, $\text{OH} \cdot \text{CMe}_2 \cdot \text{CEt}_2 \cdot \text{OH}$: $\delta\delta$ -Dimethylhexan- γ -one, $\text{CMe}_2\text{Et} \cdot \text{COEt}$.

This reaction has been studied by Meerwein (*loc. cit.*), who employed ice-cold, concentrated sulphuric acid, and purified the product by way of the semicarbazone.

The pinacolin can also be obtained by heating the pinacone for several hours on the boiling-water bath with an excess of sulphuric acid diluted with its own volume of water. After distillation in a current of steam, the oil is fractionated once under diminished pressure and twice under atmospheric pressure. (Found, $\text{C} = 74.8$; $\text{H} = 12.45$. Calc., $\text{C} = 75$; $\text{H} = 12.5$ per cent.)

Oxidation of the oil to $\alpha\alpha$ -dimethylbutyric acid proved that this pinacolin is identical with that obtained by Lawrinowitsch (*Annalen*, 1877, **185**, 124) by heating the corresponding symmetrical pinacone with dilute sulphuric acid.

Meerwein (*loc. cit.*) carried out the oxidation with sodium hypobromite, and obtained a good yield of $\alpha\alpha$ -dimethylbutyric acid.

* The action of sulphuric acid on *s*-dimethyldi*isoamylethylene* glycol does not appear to have been investigated; but, judging from analogy to the diethyl- and dipropyl-pinacones, it should yield the same pinacolin as the unsymmetrical compound.

In the author's experiments chromic acid mixture was employed, when, in addition to the above-mentioned acid, there were formed: (1) carbon dioxide; (2) acetic acid, which was identified by analysis of the silver salt (Found, $\text{Ag}=64.8$. Calc., $\text{Ag}=64.7$ per cent.); and (3) a small quantity of a dark green chromium compound, which was found to be soluble in ether and to separate, on spontaneous evaporation of the solvent, in green crystals. This compound was distilled with 30 per cent. sulphuric acid, and the distillate neutralised with sodium hydroxide, evaporated, and acidified. After extraction with ether and removal of the solvent, a small amount of an oily acid was left, which was converted into the *silver* salt:

0.2103 gave 0.1019 Ag. $\text{Ag}=48.4$.

$\text{C}_6\text{H}_{11}\text{O}_2\text{Ag}$ requires $\text{Ag}=48.4$ per cent.

It is thus seen that the green substance is a compound of chromic oxide with $\alpha\alpha$ -dimethylbutyric acid.

Action of Sulphuric Acid on β -Methyl- γ -propylhexane- $\beta\gamma$ -diol, $\text{OH}\cdot\text{CMe}_2\cdot\text{CPr}^a_2\cdot\text{OH}$: $\epsilon\epsilon$ -Dimethyloctan- δ -one, $\text{CMe}_2\text{Pr}^a\cdot\text{COPr}^a$.

The pinacone, β -methyl- γ -propylhexane- $\beta\gamma$ -diol, has now been obtained in colourless needles arranged in rosettes, which melt at 30° . It was added gradually, in quantities of 25 grams, to concentrated sulphuric acid (100 c.c.) cooled to -5° . After keeping for two hours at the ordinary temperature, the yellowish-red solution was poured on ice (500 grams) and extracted with ether. The ethereal solution was dried, the solvent removed, and the residual oil fractionated under diminished pressure, when the bulk of it distilled at $80-86^\circ/20$ mm. (Yield, 36 grams from 50 grams of the pinacone.) This was then distilled in a current of steam, and the yellow oil extracted and fractionated, when it boiled at $182-186^\circ/765$ mm.:

0.1350 gave 0.3796 CO_2 and 0.1556 H_2O . $\text{C}=76.69$; $\text{H}=12.8$.

$\text{C}_{10}\text{H}_{20}\text{O}$ requires $\text{C}=76.85$; $\text{H}=12.9$ per cent.

$\epsilon\epsilon$ -Dimethyloctan- δ -one is a colourless oil with a faint odour of peppermint. It is obtained as a yellow oil when the pinacone is heated on the boiling-water bath with an excess of 75 per cent. sulphuric acid, and is, in all probability, identical with the pinacolin prepared by Szymanski (*Ber.*, 1886, **19**, 1532) by heating "*s*-dimethyldipropylglycol" with dilute sulphuric acid (20 per cent.). He described it as a yellow oil of camphoraceous odour, boiling at $182-187^\circ$, and concluded that it was not a methyl ketone, since it did not combine with sodium hydrogen sulphite.

The *semicarbazone* is formed with difficulty, and in poor yield, when a mixture of the pinacolin (2 grams), semicarbazide hydro-

chloride (2 grams), and fused sodium acetate (2.5 grams) in aqueous alcoholic solution is heated on the water-bath for two hours and kept for several days, with frequent shaking. It separates from dilute alcohol, in which it is readily soluble, in white needles, which melt at 145° :

0.1353 gave 0.3068 CO_2 and 0.1374 H_2O . $\text{C}=61.84$; $\text{H}=11.28$.

$\text{C}_{11}\text{H}_{23}\text{ON}_3$ requires $\text{C}=61.91$; $\text{H}=10.88$ per cent.

The constitution of the pinacolin was proved by oxidation (1) with chromic acid mixture, (2) with chromic acid in glacial acetic acid.

The oil (5 grams) was heated on the boiling-water bath with potassium dichromate (15 grams) dissolved in 250 c.c. of dilute sulphuric acid (15 per cent.), when carbon dioxide was evolved in quantity. After four days' heating water was added, and the liquid distilled until the distillate had no longer an acid reaction. On filtering the contents of the flask, a very small amount of a green chromium salt was obtained. The distillate was neutralised with sodium hydroxide and evaporated to dryness on the water-bath, when about 10 grams of sodium salt were left (from 15 grams of ketone).

On decomposition of the sodium salt with sulphuric acid, an acid separated, which was extracted with ether, the solvent removed after drying, and the oil fractionated. Two fractions were collected, (A) from 100° to 130° , and (B) from 135° to 145° . The latter, which formed the bulk of the product, was analysed:

0.1688 gave 0.2943 CO_2 and 0.1211 H_2O . $\text{C}=47.55$; $\text{H}=7.9$.

0.3531 Ag salt gave 0.2102 Ag. $\text{Ag}=59.5$.

$\text{C}_3\text{H}_6\text{O}_2$ requires $\text{C}=48.65$; $\text{H}=8.1$ per cent.

$\text{C}_3\text{H}_5\text{O}_2\text{Ag}$ requires $\text{Ag}=59.6$ per cent.

The oil (B) was evidently propionic acid contaminated with a very little acetic acid.

The only evidence of the formation of $\alpha\alpha$ -dimethylvaleric acid was the presence of the above-mentioned green chromium compound, which weighed less than half a gram.

The pinacolin (6 grams) was next dissolved in glacial acetic acid (50 c.c.), heated to 70° on a water-bath, and a solution of chromium trioxide (6 grams) in glacial acetic acid (60 c.c.) slowly run in from a dropping-funnel. After heating for a day, water was added, the solution extracted with ether, the extracts well washed, and dried over anhydrous magnesium sulphate. The ether was distilled, and the product neutralised with sodium hydroxide, when a quantity of unoxidised oil remained, which was removed by means of ether. The alkaline solution was evaporated, acidified, extracted, and the ether expelled. The residual oil was heated on

the boiling-water bath for several hours under 50 mm. pressure to remove acetic acid, when about 1 gram was left, which was insufficient for purification by distillation. It was converted into the *silver salt*:

0.3729 gave 0.1724 Ag. $\text{Ag} = 46.2$.

$\text{C}_7\text{H}_{13}\text{O}_2\text{Ag}$ requires $\text{Ag} = 46$ per cent.

It thus appears that $\alpha\alpha$ -dimethylvaleric acid is formed by the oxidation of this pinacolin, which, therefore, has the constitution $\text{CMe}_2\text{Pr}^\alpha\cdot\text{COPr}^\alpha$.

$\beta\zeta$ -Dimethyl- γ -isoamylheptane- $\beta\gamma$ -diol, $\text{OH}\cdot\text{CMe}_2\cdot\text{C}(\text{C}_5\text{H}_{11})_2\cdot\text{OH}$.

For the preparation of this pinacone, magnesium turnings (24 grams) were covered with dry ether (300 c.c.), and a little *isoamyl* bromide was added. The flask was warmed on the water-bath until reaction commenced, when a solution of *isoamyl* bromide (150 grams) and ethyl α -hydroxyisobutyrate (33 grams) in dry ether (100 c.c.) was dropped in at such a rate that the mixture boiled gently (Davies and Kipping, T., 1911, **99**, 296). When all had been added, the flask was heated for two hours, and left overnight.

After decomposition with ice and dilute sulphuric acid, and the separation of the ethereal solution, the aqueous liquid was extracted twice, the combined extracts washed with water and dilute sodium sulphite solution, and dried over anhydrous magnesium sulphate. The ether was then removed, and the yellow oil which was left was twice fractionated under diminished pressure, when a colourless liquid passed over, and solidified in the receiver to a white solid resembling wax. After a day's contact with porous porcelain, which absorbed a little adhering oil, the yield of pure material was 30 grams (52 per cent. of the theoretical):

0.1782 gave 0.4733 CO_2 and 0.2132 H_2O . $\text{C} = 72.44$; $\text{H} = 13.29$.

0.354 in 18.53 benzene gave $\Delta t = -0.388$. $\text{M.W.} = 246$.

0.797 „ 18.53 „ „ $\Delta t = -0.781$. $\text{M.W.} = 275$.

$\text{C}_{14}\text{H}_{30}\text{O}_2$ requires $\text{C} = 72.9$; $\text{H} = 13.1$ per cent. $\text{M.W.} = 230$.

$\beta\zeta$ -Dimethyl- γ -isoamylheptane- $\beta\gamma$ -diol boils at $150^\circ/20$ mm., and solidifies, on cooling, in clusters of white, waxy needles, radiating from a point. It melts at 34 – 35° , and is very readily soluble in all the common organic media. It has the distinctive odour characteristic of *isoamyl* compounds. Its symmetrical isomeride has already been prepared by Rohn (*Annalen*, 1878, **190**, 311) by reduction of methyl *isoamyl* ketone, and melts at 30° .

Action of Sulphuric Acid on $\beta\zeta$ -Dimethyl- γ -isoamylheptane- $\beta\gamma$ -diol,
 $\text{OH}\cdot\text{CMe}_2\cdot\text{C}(\text{C}_5\text{H}_{11})_2\cdot\text{OH}$: $\beta\zeta\zeta$ -Tetramethyldecan- ϵ -one,
 $\text{C}_5\text{H}_{11}\cdot\text{CMe}_2\cdot\text{CO}\cdot\text{C}_5\text{H}_{11}$.

The pinacone (25 grams) was added gradually to concentrated sulphuric acid (100 c.c.) cooled to -5° , the flask being shaken vigorously at intervals. It dissolved slowly, with evolution of heat, and the yellowish-red solution was left for one hour at the ordinary temperature. It was then poured on powdered ice, and distilled in a current of steam.

The distillate was extracted with ether, the solution dried over anhydrous magnesium sulphate, and fractionated, when a quantity (15 grams) boiled at $239\text{--}244^\circ/771$ mm. On keeping for a few days, the oil became rather dark coloured, from which it appeared that some decomposition had taken place during the distillation under atmospheric pressure. It was therefore fractionated twice under diminished pressure and analysed:

0.1696 gave 0.4888 CO_2 and 0.2048 H_2O . $\text{C}=78.6$; $\text{H}=13.42$.

$\text{C}_{14}\text{H}_{28}\text{O}$ requires $\text{C}=79.16$; $\text{H}=13.3$ per cent.

$\beta\zeta\zeta$ -Tetramethyldecan- ϵ -one is a yellow oil, which has not been obtained colourless. It boils at $132\text{--}134^\circ/25$ mm., and has no odour. Attempts to prepare a semicarbazone were unsuccessful, and this fact indicates that the pinacolin is not a methyl ketone. When it was oxidised with chromic acid mixture, no solid chromium compound was formed, but carbon dioxide was evolved, and, after treatment as previously described, a small amount of an oily acid was obtained, which boiled at $190\text{--}195^\circ$ under atmospheric pressure.

Analysis of the silver salt of this acid (Found, $\text{Ag}=51.7$; $\text{C}_5\text{H}_9\text{O}_2\text{Ag}$ requires $\text{Ag}=51.7$ per cent.) proved that *isovaleric* acid had been formed by oxidation of the terminal $\cdot\text{C}_5\text{H}_{11}$ group.

When, however, the pinacolin was oxidised by chromic acid in glacial acetic acid, an oil was eventually obtained which did not distil from a boiling-water bath when the pressure was diminished to 50 mm. It was pale yellow, very viscid, and had an odour resembling that of *isovaleric* acid. It was insufficient in quantity for further purification, and on analysis gave numbers which indicated that it was still contaminated with acetic acid. (Found, $\text{C}=63.4$, 63.7 ; $\text{H}=9.24$, 9.03 . $\text{C}_9\text{H}_{18}\text{O}_2$ requires $\text{C}=68.3$; $\text{H}=11.4$ per cent.)

It was converted into the *silver* salt:

0.1947 gave 0.0818 Ag. $\text{Ag}=41.1$.

$\text{C}_9\text{H}_{17}\text{O}_2\text{Ag}$ requires $\text{Ag}=40.8$ per cent.

The formation of $\alpha\alpha\delta$ -trimethylhexoic acid proves that the constitution of the pinacolin is $\text{C}_5\text{H}_{11}\cdot\text{CMe}_2\cdot\text{CO}\cdot\text{C}_5\text{H}_{11}$.

Action of Sulphuric Acid on $\alpha\alpha$ -Diphenyl- β -methylpropane- $\alpha\beta$ -diol, $\text{OH}\cdot\text{CMe}_2\cdot\text{CPh}_2\cdot\text{OH}$: $\gamma\gamma$ -Diphenylbutan- β -one, $\text{CMePh}_2\cdot\text{COMe}$.

Erdmann (*loc. cit.*) and Meerwein (*loc. cit.*) effected this transformation by the aid of cold, concentrated sulphuric acid.

In the author's experiments, the pinacone was heated for several hours on the boiling-water bath with excess of sulphuric acid diluted with its own volume of water, and the contents of the flask were then distilled in a current of steam. The product was a pale yellow oil, boiling constantly at $180^\circ/18$ mm. (Found, $\text{C}=85.8$; $\text{H}=7.2$. Calc., $\text{C}=85.66$; $\text{H}=7.2$ per cent.) It solidified when seeded with a crystal of "acetophenone pinacolin," prepared by Thoerner and Zincke's method (*loc. cit.*), and, after pressure on porous porcelain and crystallisation from dilute alcohol, formed snow-white needles, melting at 41° . The semicarbazone was readily formed from the yellow oil (4.7 grams from 5 grams of oil), and crystallised from alcohol in white needles, melting at 175° (Erdmann gives 179°).

Oxidation by chromic acid mixture yielded the $\alpha\alpha$ -diphenylpropionic acid described by Thoerner and Zincke (*Ber.*, 1878, **11**, 1993), thus confirming the identity of the two pinacolins.

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