CAMPHENANIC ACID, its ISOMERS & DERIVATIVES

T H E S I S

Presented by

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INTRODUCTORY

Much research has already been done on the constitution of Camphene and Bornylene for the purpose of gaining knowledge of the structure of these two substances and their relationship to one another. This inquiry into the nature of these hydrocarbons by means of oxidising agents was begun as far back as 1859 when camphor was obtained by the oxidation of terpene hydrocarbons. Since then the knowledge of these substances has gradually increased and at the present day there is a mass of literature and much diversity of opinion regarding the constitution of Camphene and Bornylene and their derivatives.

Much interest attaches to the acid oxidation products of Bornylene and Camphene and it is in order to try to correlate these various acids and through them to throw some light on the relationship between Bornylene and Camphene that this work was undertaken. The work here submitted is an account of four acids obtained by the oxidation of Bornylene and Camphene and some derivatives obtained from these acids.

THEORETICAL -

In 1900 Bredt and Jagelke (Annalen 1900 310 112) obtained by treatment of Camphene with Chromyl Chloride, an aldehyde - camphenilanaldehyde $C_9 H_{15} CHO$. This aldehyde they found was spontaneously oxidised in air giving camphenilanic acid $C_9H_{15}COOH$. Further they found that this acid can be easily transformed by the action of hot concentrated nitric acid into a stereoisomeric acid, iso camphenilanic acid.

Later in 1911 Henderson & Heilbron (Journal of the Chemical Society Vol. 99 1887) obtained from Bornylene by the action of chromyl chloride two compounds, a chloroketone $C_{10}H_{15}OCL$ and a smaller quantity of camphenilanaldehyde. This aldehyde was found to contain a small quantity of iso camphenilanaldehyde as, on spontaneous oxidation in air camphenilanic acid was obtained mixed with a small quantity of iso-camphenilanic acid. They observed also that the camphenilanic acid so obtained was gradually transformed into iso-camphenilanic acid on repeated crystallisation from water, alcohol, or light petroleum but remained as camphenilanic acid on crystallising from dilute acetic acid. Further, the acid remained unchanged on heating for some time above its melting point or on exposing to ultraviolet light. Finally they found that the acid was transformed into the iso-acid if camphenilanaldehyde semi-carbazone was prepared and was then decomposed and the aldehyde so liberated allowed to oxidise in air.

In 1911 Henderson & Sutherland (Journal of Chemical Society Vol. 99 1539) oxidised camphene with 30% perhydrol and

obtained various oxidation products of which about 50% were acid products. This mixture of acids consisted principally of a monobasic acid $C_9H_{15}COOH$, a crystalline solid of melting point 95°C and a smaller quantity of another crystalline acid of formula also $C_9H_{15}COOH$ which has melting point 70°C. The Acid of melting point 95° has been given the name camphenanic acid, the acid of melting point 70° was found to be identical with an acid obtained by Aschan of M.P. 74°C when pure. In 1911 Aschan ("Ofversigt af Finska Vetenskaps-Societetens Forhandlingar Bd LIII Afd. A.N:o 12) obtained, by means of oxidation of camphene with Potassium permanganate in acetic acid solution, two acids, one Camphenanic Acid of Melting point 95° the other iso-camphenanic acid of M.P. 74°- 76°C identical with those obtained by oxidation of camphene with Perhydrol. Finally in 1913 Henderson & Caw (Journal of Chemical Society Vol 103 1544) obtained, among other products, camphenanic and iso-camphenanic acids by the action of Perhydrol in an acetic acid solution of Bornylene.

These four acids, therefore, all obtained from both Bornylene and camphene have the formula $C_{10}H_{16}O_2$ and behave towards reagents in a very similar manner. Their behaviour towards reagents and their formation from Bornylene and Camphene point to the likelihood of there being a great similarity in constitution.

PREPARATION OF ACIDS

In order to investigate the nature of these four acids they

were prepared in comparatively large quantity using in each case the method which appeared to give the largest yield.

PREPARATION OF CAMPHENILANIC ACID

This acid was obtained by the action of chromyl chloride on camphene according to the method of Bredt & Jagelki (Annalen 310 121). Camphene was subjected to the action of chromyl chloride dissolved in Carbon disulphide whereby a solid additive product was obtained, $C_{10}H_{16}.2\ CrO_2Cl_2$. This was decomposed with water yielding camphenilanaldehyde which was then allowed to oxidise in air and the acid so obtained purified by crystallisation from dilute acetic acid. Iso-camphenilanic acid was obtained in small quantity along with the camphenilanic acid but was easily separated from it as iso-camphenilanic acid is much less soluble in acetic acid and separates out first on crystallisation. This, along with the iso-acid obtained from camphenanic acid constituted the source of iso-camphenelanic acid at first used. Further quantities were obtained by a method described later.

CAMPHENANIC ACID.

It was obtained from the oxidation of camphene with perhydrol in acetic acid solution. Camphene was dissolved in acetic acid, 2 molecules of perhydrol added and the mixture kept heated to 40° - 60° C for several weeks. When the oxidation was thought to be complete the acid products were separated from the neutral products by neutralising the mixture with sodium carbonate in this way a mixture of acids was obtained as the sodium salts

of the acids. These were separated from the neutral products and the acids obtained by acidifying the mixture with dilute sulphuric acid. The acids separated as a crystalline solid and proved to be a mixture of acids mainly camphenanic acid with samll quantities of an acid described by Aschan as iso-camphenanic acid. The mixture was subjected to fractional crystallisation and in this way camphenanic and iso-camphenanic acids were separated. The iso-acid appears to be much more soluble ~~than~~ in acetic acid than camphenanic acid.
These two acids were also obtained by the oxidation of Bornylene with Perhydrol in acetic acid solution. The acids in both cases were found to be identical.

The four acids - camphenilanic, isocamphenilanic, camphenanic and isocamphenanic seem very closely related as has already been shown by the various investigators. Camphenilanic and iso-camphenilanic acids appear to be true isomers, the other two acids it is difficult to explain. It seemed possible that some indication of the constitution of these acids and their connection one with another might be obtained by using the method employed by Bouveau & Blanc (Comptes Rendus 1903 136 1676 137 60) i.e. of reducing the methyl ester of an acid and thereby obtaining from it the corresponding alcohol.

Bouveau & Blanc found that starting with an acid R.COOH and preparing from that an ester R.COO.Me and reducing this with alcohol and sodium they obtained the corresponding alcohol R.CH_2OH.

According to this it seemed probable that by preparing the methyl esters of these four acids and reducing them, alcohols could be obtained from them which might be the same or different and which might, on investigation, help to prove the relationship of these acids.

With this end in view the methyl esters of camphenilanic, iso-camphenilanic, camphenanic and isocamphenanic acids, respectively, were prepared.

These esters are all colourless, syrupy liquids of agreeable odour and they distil with little decomposition under diminished pressure The boiling points of the esters are either identical or so close together that no difference can be detected. For example: the methyl ester of camphenanic acid boils at $103^{\circ}/21$ mm.

The methyl ester of iso-camphenanic acid boils at $104^{\circ}/22$ mm The methyl ester of iso-camphenilanic acid boils at 103° - $105^{\circ}/22$ mm. and that of camphenilanic acid at 104/22mm.

Bredt found that the methyl ester of camphenilanic acid, which he obtained by a different method, boiled at 99°-$100^{\circ}/12$ mm.

That these esters are not identical substances is shown by the fact that on hydrolysis of each ester the original acid is liberated except in the case of the ester of iso-camphenanic acid. Whereas in the case of the esters of camphenanic, camphenilanic and iso-camphenilanic acids they yield, on hydrolysis the corresponding acids, camphenanic, camphenilanic and iso-camphenilanic

acids respectively, the ester of iso-camphenanic acid yields a mixture of acids. These were carefully fractionally crystallised from dilute acetic acid and it was found that, taking the crystals in small crops, the first crop yielded an acid of melting point 117°-118°C whilst the other crops yielded an acid of melting point 60°-65°C. This points to the probability that the so-called isocamphenanic acid obtained by Aschan (Finska Vetenskaps-Societetens) and by Henderson & Caw (Jounal of Chemical Society Vol 103 1546) is not a simple acid but a mixture of camphenilanic and iso-camphenilanic acids. These two acids it has been observed show a great tendency to form mixtures of constant melting point (Henderson & Heilbron J.C.S. 99 1893). It seems possible therefore that iso-camphenanic acid is not an individual acid but a eutectic, composed of a mixture of camphenilanic and iso-camphenilanic acids, which crystallises as a single substance. The calcium salt of iso-camphenanic acid was prepared to compare it with the ca salts of camphenilanic, iso-camphenilanic and camphenanic acids and it was found to have formula $(C_9H_{15}COO)_2$ Ca. $5H_2O$ when crystallised from cold water. From hot water it separates out as anhydrous calcium salt. Bredt & Jagelki found that the calcium salt of camphenilanic acid was obtained from hot water as an anhydrous salt. Aschan also found the calcium salt of iso-camphenanic acid to crystallise with $5H_2O$ as also camphenanic acid calcium salt. The calcium salt of iso-camphenilanic acid crystallises with $2H_2O$ (Annalen 310 130). So that the calcium salt of iso-camphenanic acid seems partly to uphold Aschan's view that the acid is a definite acid distinct from

camphenilanic and isocamphenilanic acids whilst its behaviour when crystallised from hot water seems to show a similarity with camphenilanic acid. Aschan, in fact, believes camphenanic acid and iso-camphenanic acid to be another pair of isomeric acids quite distinct from the camphenilanic and iso-camphenilanic acids first investigated by Bredt & Jagelki (Annalen 310 112).

The methyl esters of these four acids prepared by the method of Werner & Seybold (Berichte XXXVII 3658) is a method which excludes as far as possible the chance of intramolecular rearrangement, so that the methyl esters may be taken as the true methyl esters of the acids.

Turning to the reduction of the esters, the methyl esters of these acids were each in turn reduced according to the method used by Bouveau & Blanc (Comptes Rendus 1903 136 1676) on various monobasic acids. The ester was dissolved in four times its weight of absolute alcohol and added slowly to the calculated quantity of sodium. The reaction went smoothly and a fairly good yield of the new alcohols was obtained. These alcohols proved to be identical in every case so that from four different acids the same reduction alcohol is obtained. This alcohol is probably the alcohol corresponding to camphenilanaldehyde and is evidently the parent substance of all four acids.

Turning now to the bye-product, obtained during reduction, after reduction was complete the mixture was diluted and steam-distilled.

The liberated methyl and ethyl alcohol distilled over first and finally a solid substance, the reduction product. This was collected and laid aside for investigation. The residue in the flask after steam distillation was then acidified and the acid so obtained collected and recrystallised and melting point determined. It was found in each case, no matter which methyl ester formed the starting point, that the acid bye-product from the reduction is iso-camphenilanic acid. So that in some way during the reduction the larger part of the methyl ester is reduced whilst a small proportion undergoes hydrolysis and intramolecular rearrangement and forms the sodium salt of iso-camphenilanic acid. It is apparent that camphenilanic acid is the ultimate and stable form of all three acids, camphenanic, iso-camphenanic and camphenilanic acids.

This formation of iso-camphenilanic acid from the iomeric acids, though greatly reducing the quantity of these acids for further investigation, formed a convenient source of iso-camphenilanic acid during the research.

What the connection between these acids camphenanic, camphenilanic and iso-camphenilanic is it is difficult to understand but if iso-camphenanic acid can be disposed of as merely a constant melting mixture it seems possible that the suggestion of Aschan, which he afterwards tried to disprove, is the true one and that camphenanic acid forms what might be called the racemic form of camphenilanic and iso-camphenilanic acids. Camphenanic acid can be transformed into iso-camphenilanic acid by the action of acetic anhydride (J.C.S. vol 99 1544) and also as already mentioned by the action

of sodium and alcohol on the methyl ester.

The alcohol from the reduction of the methyl ester of these acids is a white waxy solid of melting point 77°C. It is volatile in steam slightly soluble in hot water and very soluble in all organic solvents. It is a saturated compound and is easily oxidised giving an aldehyde and a monobasic acid. From its oxidation products the alcohol is evidently a primary alcohol.

The alcohol yields characteristic derivatives and through these it is easy to obtain it in a state of purity. The acid phthalate of this alcohol is a white crystalline compound which, when crystallised from benzene is obtained in small colourless, glistening plates. It is easily hydrolysed yielding the alcohol as a white crystalline solid of melting point 77°C.

The nitrobenzoate crystallises in very faintly yellow needles of melting point 90°C. This ester is difficult to hydrolyse but on hydrolysis again yields the original alcohol of melting point 77°C.

The alcohol is easily oxidised and yields an oxidation with chromic mixture camphenilanaldehyde and iso-camphenilanic acid. The identity of the aldehyde was proved by preparing the semicarbazone and comparing it with the semicarbazone of camphenilanaldehyde.

From the nature of the alcohol and its oxidation to camphenilanaldehyde and iso-camphenilanic acid it is evident that the alcohol is the corresponding alcohol to camphenilanaldehyde. Thus starting with

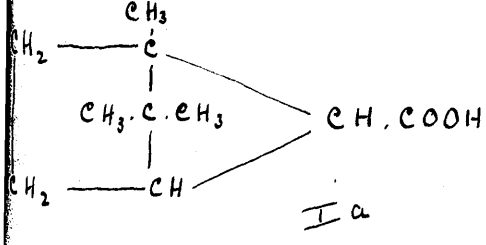
camphenanic acid. $C_9H_{15}COOH \longrightarrow C_9H_{15}COOCH_3 \longrightarrow$
Methyl Camphenanate

$C_9H_{15}CH_2OH \longrightarrow C_9H_{15}CHO \longrightarrow C_9H_{15}COOH$

Camphenilanol Camphenilan aldehyde. iso camphenilanic acid

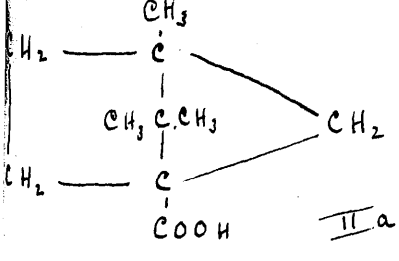
The alcohol may be termed camphenilanol to denote its relationship with camphenilanal(dehyde) and camphenilanic acid. So far the work has been successful in that it has shown that the four acids of formula $C_{10}H_{16}O_2$, oxidation products of bornylene and camphene, all yield the same alcohol thus strengthening the assumption that these acids have much the same constitution.

It is probable that, taking iso-camphenilanic and camphenilanic acids as having the formula suggested by Bredt (annalen 310 112)



I a

Camphenanic acid may have formula II a

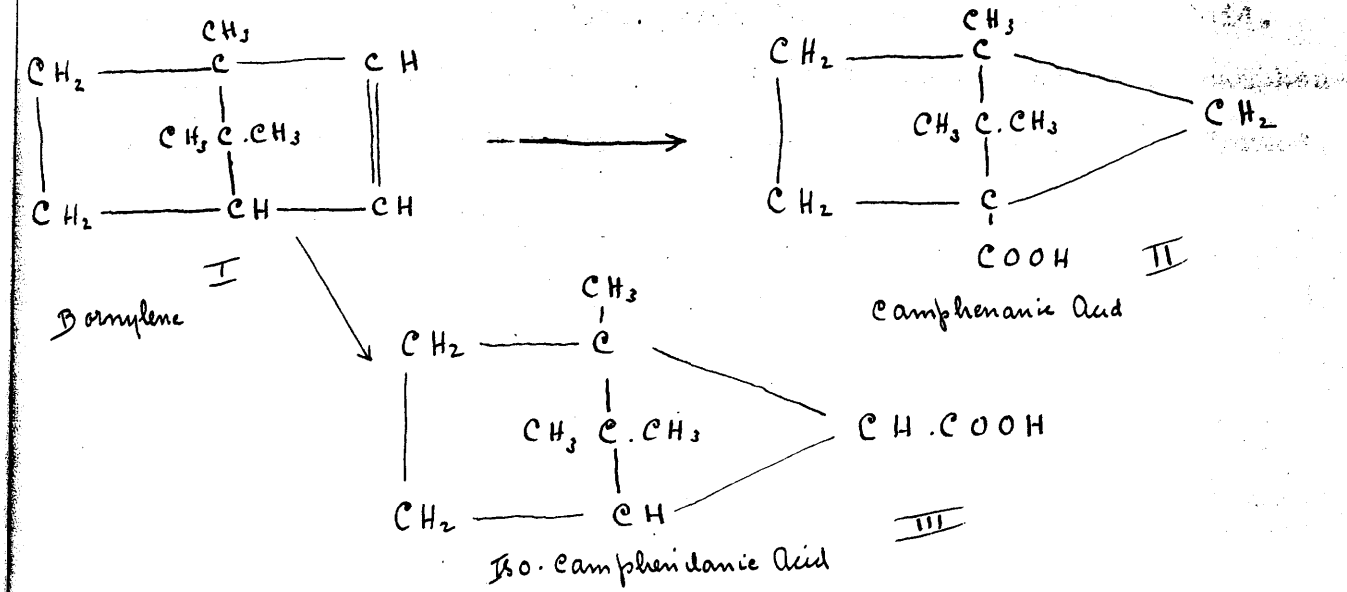


II a.

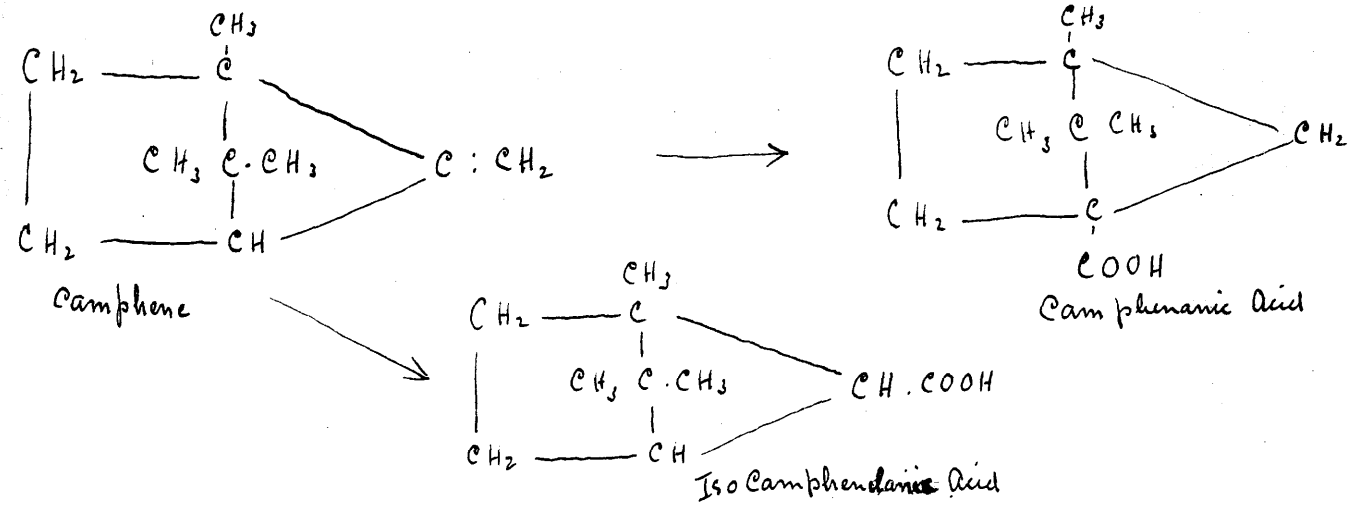
This on treatment with any active reagent at once rearranges itself to the more stable form I a.

Taking Bornylene as having the formula I we have on oxidation 2 acids formed, formula II camphenanic, and formula III camphenilanic and iso-camphenilanic.

and iso-camphenilanic.



In the case of oxidation of camphene a little more rearrangement would be necessary. If the formula used for camphene be that proposed by Semmler and adopted by Henderson & Heilbron (J.C.S. 99 1905) the formation of the two acids by the oxidation of camphene may be represented by formulae given below



On treatment with acetic anhydride or by the action of sodium and

alcohol on the methyl ester of the acid, the acid would seem to rearrange itself to the form given for iso-camphenilanic acid. So that instead of obtaining the alcohol corresponding to camphenanic acid that corresponding to iso-camphenilanic acid is formed.

EXPERIMENTAL.

I.

CAMPHENANIC ACID

This acid was obtained from camphene by oxidation with perhydrol. 100 grms camphene was dissolved in 500 grms glacial acetic acid and two molecular proportions, 100 CCS of 30% aqueous perhydrol, were added. The mixture was kept heated for several weeks at a temperature of 50°-60°C. At the end of about 3 weeks the oxidation was taken as complete and the oxidation products worked up. The solution was diluted considerably with water and the acetic acid just neutralised by adding the calculated quantity of sodium carbonate. The mixture of oxidation products which separated out as a thick oil was then extracted several times with ether. The ethereal extract was then distilled from a water-bath and the residue, after removal of the ether, was heated with sodium carbonate solution in order to separate the acid products from the neutral products. The solution was allowed to cool and extracted with ether whereby the neutral products were removed. The residue was then acidified with dilute sulphuric acid when the acid products separated out as a thick brown oil which gradually solidified. The solid acid was filtered off, the filtrate extracted repeatedly with ether, the ethereal solution dried over calcium chloride and finally the ether distilled off, when a brown oily residue was obtained which gradually solidified. This further quantity of acid was added to the main bulk and the whole fractionally crystallised, when it was found to be a mixture of acids.

The crystallisation was very troublesome as the acids are very soluble in the usual organic solvents. It was found that the acids crystallised fairly well from petroleum spirit also from cold dilute acetic acid. The first acid to separate, that is the portion least soluble in acetic acid, was an acid of melting point 90°-93°C. This constituted the bulk of the acid products. The second fraction was found to be an acid of melting point 70°-73°C and the most easily soluble acid was an oily acid which boiled at 153/20mm.

After repeated fractional crystallisation an acid of melting point 95°C, camphenanic acid, was obtained and a small quantity of acid of melting point 74°C. and a still smaller quantity of an oily unsaturated acid. This latter was troublesome as it prevented the acid of M.P. 74°C from crystallising.

Camphenanic acid $C_9H_{15}COOH$, the principal acid formed by the oxidation of camphene with perhydrol, is a white crystalline solid of M.P. 95°C. It crystallises from dilute acetic acid in shining prisms and from dilute alcohol in colourless needles. (J.C.S. 1911 99 1542; 1913 103 1546).

II. ISO-CAMPHENANIC ACID.

This acid was accumulated by repeated recrystallisation of the acid products of the oxidation of camphene and bornylene with perhydrol. After repeated crystallisation from dilute acetic acid an acid was obtained of M.P. 73°-74°. This acid was obtained from the oxidation of both camphene and bornylene and the two acids proved to be identical.

Iso-camphenanic acid crystallises in small glistening prisms resembling camphenanic acid in appearance. The acid appears to be more soluble in petroleum spirit and in glacial acetic acid than its isomer camphenanic acid so that a fairly good separation is effected by fractional crystallisation from acetic acid, adding water in small quantity, freezing the solution, and collecting the various crops of crystals. The process is slow and the last crops of acid are difficult to purify some specimens having a melting point as low as 40°C. An acid of fairly definite melting point is finally obtained and in order to compare this with camphenanic acid, the calcium salt of which was prepared by Aschan who obtained camphenanic acid by the oxidation of camphene with acid potassium permanganate, a calcium salt of iso-camphenanic acid was prepared.

PREPARATION OF CALCIUM SALT.

Acid of melting point 73°-74° was mixed with a slight excess of calcium carbonate and a large proportion of water. The whole was heated on a water-bath for some time. The solution was then filtered from unchanged $CaCo_3$ and the filtrate evaporated to small bulk on the water-bath. The salt which separated was collected and again dissolved in a small quantity of cold water and the solution then concentrated at ordinary temperature under diminished pressure. The calcium salt which separated from the cold solution crystallised in small colourless needles and on analysis was found to have composition $(C_{10}H_{15}O_2)_2Ca.\ 5\ H_2O$. The salt is readily soluble in cold water. It was further found that if a cold saturated solution of the salt is heated a crystalline deposit of the anhydrous salt separates out.

Determination of Water of Crystallisation in Calcium Salt.

The crystals were dried by pressure between filter paper and a weighed quantity heated in an air oven at 110°C. The results were as follows:-

1.0346 grms Ca salt lost 0.2105 grms H_2O = 20.3% of H_2O

$(C_{10}H_{15}O_2)_2$ Ca.$5H_2O$ requires H_2O = 19.47%

Determination of Calcium in Salt.

0.2910 grms anhydrous salt i.e. salt dried at 110°C

gave 0.0420 " CaO Ca = 10.3%

for $(C_{10}H_{15}O_2)_2Ca$ Ca = 10.7%

The calcium salt of iso-camphenanic acid therefore crystallises with $5H_2O$ just as calcium salt of camphenanic acid.

1. CAMPHENILANIC ACID

This was prepared by the method of Bredt (Annalen 1900 310) by the action of chromyl chloride on camphene. Chromyl chloride dissolved in carbon disulphide was added slowly to a solution of camphene in carbon disulphide, the whole being kept well cooled.

The additive product at first obtained, $C_{10}H_{16}Cr.O\ Cl_2$, was decomposed by water and the sole product camphenilanal(dehyde) collected by distilling in steam when an oily viscid substance distilled over. This was extracted with ether, the ethereal solution dried over calcium chloride, the ether distilled off and the residue left exposed to the air for some time, when the aldehyde

gradually oxidised to camphenilanic acid. The aldehyde oxidises very rapidly at first but the last traces are somewhat slow to oxidise. The acid was then taken up with aqueous sodium carbonate extracted with ether to separate any neutral impurity, and the residue after extraction acidified with dilute sulphuric acid. The acid was obtained as a thick oily substance which gradually solidified. The solid was filtered off and the filtrate extracted with ether when a small additional quantity of acid was obtained. Finally the acid was crystallised from dilute acetic acid from which it crystallises in small colourless needle-shaped crystals of melting point 65°C.

Petroleum spirit or methyl alcohol could not be used as these have been found to transform the acid into its isomer iso-camphenilanic acid. The first crops of crystals proved to be a small quantity of iso-camphenilanic acid. This was easily separated owing to its being less soluble in acetic acid.

ISO-CAMPHENILANIC ACID.

This acid was prepared in various ways and the accumulated quantity thus obtained used for investigation of the acid. It had been previously found (Henderson & Sutherland J.C.S. 1911) that when camphenanic acid is heated with acetic anhydride the acid is transformed completely into iso-camphenilanic acid. This was repeated in order to make sure of the statement and also to obtain some of the acid. A small quantity of the acid was also obtained from the preparation of camphenilanic acid and a further small quantity from the decomposition of camphenil-

analdehyde semicarbazone. This semicarbazone on decomposition has beem found to yield iso-camphenilanaldehyde and not camphenilanaldehyde as would be expected and the iso-aldehyde on oxidation yields iso-camphenilanic acid. The largest proportion of iso-camphenilanic acid was obtained as a bye-product in the reduction of the methyl esters of the acids, camphenanic, iso-camphenanic and camphenilanic. These esters on reduction with sodium and absolute alcohol, gave alcohols and sodium salt of acid. The residue after steam distilling off the volatile alcohol was acidified with dilute sulphuric acid when solid acid separated out and was filtered off. A further quantity of acid was extracted from the filtrate. This acid was crystallised from glacial acetic acid when the first crops of crystals separated from the concentrated solution in colourless prisms of melting point 115°-117°C. These were purified by recrystallisation and found to melt sharply at 118°C. Further crops of crystals after recrystallisation also melted at 118°C. The last crops of crystals were troublesome to purify as there was a little of an oily impurity present which coloured the crystals yellow and lowered the melting point.

V. PREPARATION OF METHYL ESTERS OF THE ACIDS

The Methyl ester of camphenanic acid.

The ester was prepared according to the method of Werner & Seybold (Berichte XXXVII 3658) The ester was prepared in 10 gramme quantities. 10 grams of acid were dissolved in a strong solution of K.O.H. in a conical flask

i.e. a concentrated solution of the sodium salt of the acid was prepared, to this was added 20 grms of methyl sulphate i.e. excess of methyl sulphate. The mixture was shaken vigorously for some time and the reaction completed by slightly warming the mixture on a water-bath to 40°-60°C. The excess of methyl sulphate was destroyed by heating the mixture to a higher temperature for half an hour on the water-bath.

After the solution had cooled excess of K.O.H. solution was added to take up any free acid and then the solution was extracted several times with ether. The ethereal solution was dried over anhydrous calcium chloride, ether distilled off and the residue, the crude methyl ester, laid aside until more was collected. The residue after extraction was acidified with dilute sulphuric acid when some unchamged acid was liberated. This acid was collected and again esterified. When about 40 grms of acid had been converted into ester the impure ester was placed in a distilling flask and fractionally distilled under diminished pressure. The ester passes over as a colourless viscid substance of boiling point.

129° - 130°C/56mm

or 103°C/21mm

or 104°C/22mm

PROPERTIES -

Methyl camphenanate is a colourless syrupy liquid with a pleasant ethereal odour and distils with little

decomposition under diminished pressure. A small quantity of the ester splits up giving acid which remains in the flask.

The ester is insoluble in water, readily soluble in alcohol, ether and the usual organic solvents.

HYDROLYSIS OF METHYL CAMPHENANATE -

In order to prove that 95°C was the correct melting point of camphenanic acid and also that the acid had undergone no change in esterification a quantity of the ester was hydrolysed. 5 grms of the ester were heated under a reflux with the calculated quantity of potassium hydroxide in methyl alcoholic solution. The hydrolysis took several hours to complete and at the end of the time the excess of methyl alcohol was distilled off and the residual solution extracted with ether to remove any unchanged ester and the last of the methyl alcohol. The residue after extraction was then acidified when the acid separated out at first oily and finally as a white crystalline substance. The crystals were collected and drained at the filter pump and crystallised from acetic acid. The acid separated from acetic acid solution in colourless prisms similar to those of camphenanic acid and the melting point was found to be 95°C. The acid thus obtained from the ester was camphenanic acid so that the ester must be the true methyl ester of camphenanic acid.

VI. METHYL ESTER OF ISO-CAMPHENANIC ACID -

Various quantities of 73°-74° melting acid, the so-called iso-camphenanic acid of Aschan were esterified using the method

already described. In this way a good yield of methyl ester was obtained and this was purified as in the case of methyl camphenanate by distillation under diminished pressure.

The ester gave boiling points as follows -

109° - 110°C	at	25/mm
104° C	at	22/mm
99° C	at	19/mm

The ester is a colourless syrupy liquid having a pleasant odour indistinguishable from that of methyl camphenanate. It is insoluble in water, soluble in alcohol ether and the usual organic solvents.

HYDROLYSIS OF ESTER -

The ester was hydrolysed by heating it for some time under a reflux with methyl alcoholic potash. When the hydrolysis was judged to be complete the alcohol was distilled off, unchanged ester and residual methyl alcohol removed and the alkaline residue acidified. The acid separated out as a white crystalline solid. This was collected and drained at the pump and finally recrystallised from dilute acetic acid. The melting point of the first crop which separated was determined and it was found that although the substance began to melt at 70°C the whole of the substance was not melted until about 110°C. This pointed to the chance that the acid was a mixture and not a simple substance. Accordingly the acid was very carefully crystallised fractionally. The acid was dissolved in a small quantity of glacial acetic acid, the solution very slightly

diluted and then placed in the ice-chest. A small crop of crystals was obtained these were collected and the mother liquor further diluted, again placed in ice, and a further quantity of crystals obtained. This was repeated until all the acid had been collected. In all about five crops of crystals were collected. The melting points were then determined. The first crystals were found to melt at 117°-118°. The other crops melted at 60°-65°. The first crystals obtained were short prisms closely resembling in appearance iso-camphenilanic acid. The other crops were obtained in fine needles. So that by the preparation of the methyl ester of the acid of melting point 74° and hydrolysis of this ester the acid obtained seems to be not iso-camphenanic acid but a mixture of acids one of melting point 118°C and the other M.P. 65° i.e. a mixture of camphenilanic and iso-camphenilanic acids.

METHYL ESTER OF CAMPHENILANIC ACID -

The ester was prepared as already described for camphenanic acid a good yield of ester was obtained and the ester purified by distillation under diminished pressure. The ester distilled over as a colourless syrupy liquid at 116°C under 36/mm or 104°/22mm

PROPERTIES -

Methyl camphenilanate is a colourless syrupy liquid with a pleasant odour closely resembling that of methyl camphenanate. Like the other esters described is insoluble in water but soluble in organic solvents.

HYDROLYSIS OF THE ESTER -

The ester was hydrolysed in the same manner as the other esters and

the liberated acid obtained from hydrolysis crystallised from dilute acetic acid. The acid crystallised in colourless needles of melting point 63° - 65°C.

METHYL ESTER OF ISO-CAMPHENILANIC ACID -

This was also prepared in exactly similar manner to the ester of camphenanic acid. The ester was purified by distillation under diminished pressure when the liquid distilled over at 103° - 104°/22mm.

PROPERTIES -

It is a colourless syrupy liquid of pleasant odour, insoluble in water and soluble in the usual organic solvents.

The four esters prepared resemble one another very closely both in appearance, odour, and in boiling point.

HYDROLYSIS OF ESTER OF ISO-CAMPHENILANIC ACID.

Methyl ester hydrolysed with methyl alcoholic potash iso-camphenilanic acid was obtained.

REDUCTION OF ESTERS

REDUCTION OF METHYL CAMPHENANATE

The reduction was carried out according to the method of Bouveau & Blanc (Comptes Rendus 1903, 136 1676; 137 60)

The ester was reduced in quantities of 10 grms each. Ten grms of methyl ester were dissolved in 40 grms of absolute alcohol. 8 grms of sodium, cut in small pieces were placed in a round bottomed flask attached to a reflux condenser. The alcoholic

solution of ester was added slowly through the condenser, the amount added being regulated in such a way that the solution in the flask was kept hot enought to melt the sodium and keep the mixture boiling. When the whole of the mixture had been added the last of the ester was rinsed down by a small additional quantity of absolute alcohol. The mixture was then kept heated on a metal bath at about 110°-115° for 6 or 7 hours. At the end of that time the mixture was allowed to cool and water added until all the solid had gone into solution. The solution was then steam distilled. Ethyl alcohol, methyl alcohol and a very little unchanged ester distilled over first then an oily mixture of water, a little ethyl alcohol and a small quantity of the reduction alcohol. Ultimately a white waxy substance distilled over and solidified in the receiver and in the condenser. Distillation was continued until all the reduction alcohol had distilled over. The aqueous distillate containing the solid alcohol was filtered at the pump and the white waxy solid finally dried on a porous tile. Further quantities of the alcohol were recovered from the distillate by saturating with salt and extracting with ether. Ethereal solution dried over anhydrous sodium sulphate, ether distilled off and the reisdue dried on porous tile as before. The first of the steam distillate was pure ethyl and methyl alcohol and then alcohol mixed with a small quantity of unchanged ester. This was reduced again along with other quantities of methyl ester. The yield of reduction alcohol is fairly good.

PROPERTIES -

The alcohol from the reduction of methyl camphenanate is

a white waxy substance with a faintly camphoric odour and as collected at first it melts at 65°-70°C. It is extremely soluble in all organic solvents and very sparingly soluble in hot water. It was partially purified by recrystallisation from ether or benzene althoughit is much too soluble in either of these solvents to obtain it quite pure. After several crystallisations the melting point was found to be 74°-76°C. It crystallises in long colourless flat prisms of wazy appearance when pressed on porous tile. When pure it melts at 77°C. In order to obtain the alcohol in a pure state derivatives of the alcohol were prepared.

PREPARATION OF ACID PHTHALATE OF ALCOHOL -

This was prepared by the method used by Henderson & Heilbron (J.C.S. Vol 93 293). Equal weights of the alcohol and phthalic anhydride dissolved in the least possible quantity of benzene were heated together on a water bath under a reflux condenser for 6 to 7 hours. The mixture was then poured on to crushed ice, dilute sodium carbonate solution added and the mixture kept stirred for some time. The mixture was then filtered to get rid of any unchanged anhydride. The filtrate was extracted with ether to remove unchanged alcohol and benzene and the residue acidified with dilute sulphuric acid. The acid phthalate of the alcohol along with some phthalic acid ~~were~~ was precipitated at first as an oil which gradually solidified. The solid portion was collected and drained at the filter pump. The filtrate was extracted with ether, the ethereal solution dried over anhydrous calcium chloride, the ether distilled off and a further yield of acid phthalate thus obtained.

The crude acid phthalate was treated with small quantities of chloroform in which the acid phthalate is soluble but the phthalic acid practically insoluble. The solution was then filtered to remove phthalic acid and the chloroform distilled off.

The acid phthalate which is practically insoluble in petroleum spirit was first crystallised from a mixture of ether and petroleum spirit and finally from benzene.

ROPERTIES - The substance crystallises from methyl alcohol and from benzene in small colourless plates of melting point 153°C. It is very soluble in chloroform, and ether, less so in alcohol and benzene and almost insoluble in petroleum spirit. It is readily hydrolysed on heating with aqueous sodium carbonate or hydroxide.

Analysis showed it to have the composition $C_{18}H_{22}O_4$.

0.1834 grms substance

gave H_2O - 0.1198 = 7.25% H_2.

CO_2 = 0. 482 = 71.67% C

Calculated for $C_{18}H_{22}O_4$

H = 7.28 %

C = 71.57 %

The acid phthalate is easily hydrolysed by heating with Na_2CO_3 and Na OH solution when the alcohol separates out as a white solid of melting point 76°-77°C.

XI PREPARATION OF NITROBENZOATE OF ALCOHOL

1 grm of alcohol was mixed with 30 grms Pyridine and 1 grm of p-nitrobenzoyl chloride was added. The substances were mixed and

allowed to stand for some time at room temperature. After about 3 days a few crystals appeared in the solution and the reaction was considered complete. The mixture was cooled in ice and dilute sulphuric acid gradually added, care being taken that the temperature did not rise. When the smell of pyridine had disappeared a solid separated out and was collected at the filter pump, washed first with small quantities of cold dilute sulphuric acid and then with water. The solid thus obtained was then mixed with sodium carbonate solution to remove any nitrobenzoic acid, which might have been formed, the solid was filtered off, thoroughly washed and drained at the pump. The nitrobenzoate was then dried on a porous tile and recrystallised several times from alcohol. In this way it was obtained in very fine long silky needles of melting point 89^{o}-90^{o}

PROPERTIES The substance is very sparingly soluble in cold alcohol readily soluble in hot alcohol, and readily soluble in ether and benzene. It is an almost white crystalline substance and crystallises in long silky needles on crystallising slowly. On crystallation from concentrated solution it crystallises in very small needles which felt together and when dry has the appearance of an amorphous powder.

ANALYSIS OF NITROBENZOATE - The nitrogen in the compound was estimated.

0.12 grms nitrobenzoate

gave 5.2 ccs N_2 at 12^{o}C and 764mm

% of N_2 = 5.15%.

calculated for $C_6H_4NO_2COO\ C_{10}H_{17}$ N_2 = 4.63%

Hydrolysis of Nitrobenzoate The ester was difficult to hydrolyse and required several hours boiling with the calculated quantity of potash solution. Finally the alcohol was liberated and the melting point again determined and found to be 76°-77° as before. 76°-77° therefore can be taken as the correct melting point of the reduction alcohol.

An attempt to prepare a urethane of the alcohol proved unsuccessful.

II OXIDATION OF ALCOHOL - In order to determine the nature of the alcohol a portion of it was oxidised with Beckmann's chromic mixture. The oxidising mixture was made as follows:
60 grms $K_2Cr_2O_7$ mixed with 80 grms H_2SO_4 (conc) and 270 grms H_2O. This mixture = 9 grms oxygen. 2 grms of alcohol were placed in a small flask and 66 grms of the mixture added gradually to the alcohol dissolved in glacial acetic acid. The mixture was allowed to stand for several hours and then the acid was neutralised with solid sodium carbonate, the mixture diluted and steam distilled. An oily substance distilled over with the strong characteristic odour of camphenilanaldehyde. This oil was collected by extracting the distillate with ether drying the ethereal extract over anhydrous $CaCl_2$ and distilling off the ether. The oil obtained was slightly yellow in colour and was semi-solid in appearance and had the characteristic aldehydic smell. It was dissolved in a small quantity of alcohol and mixed with the necessary quantity of semicarbazide hydrochloride and potassium acetate and allowed to stand for several days. At the end of that time the mixture

was diluted and a white crystalline substance separated out and was filtered off. This was recrystallised several times from methyl alcohol and obtained finally in lustrous leaflets of melting point 191°C, the melting point which has been found for camphenilanaldehyde semicarbazone. A small quantity of the semicarbazone was mixed with the semicarbazone of camphenilanaldehyde and the melting point determined and found to be as before 191°C. The two substances were taken as identical, that is the aldehyde from the oxidation of the reduction alcohol is camphenilanaldehyde.

The residue after steam distillation was acidified and a white substance was precipitated. This was filtered off and taken up with a little sodium carbonate solution to free it from chromium salts. The sodium carbonate solution was filtered and acidified and the acid so obtained collected, washed, dried and recrystallised from acetic acid. A crystalline acid separated out of melting point 118°C. This was mixed with iso-camphenilanic acid and the melting point again determined when it was found to be as before 118°C.

Thus from oxidation of the alcohol obtained by reduction of methyl camphenanate camphenilanaldehyde and iso-camphenilanic acid are produced.

It was found on reduction of methyl camphenanate that after all the alcohol was removed on acidifying the ~~alcohol~~ alkaline residue with dilute sulphuric acid an acid was precipitated from the solution as a brown oily liquid which, after some time, solidified to a

brown crystalline mass. This acid was filtered off, washed, dried and recrystallised from acetic acid and was obtained as a colourless crystalline substance melting at 115°-117°C. The acid was then carefully crystallised fractionally and was found to consist entirely of iso-camphenilanic acid. A small quantity was mixed with iso-camphenilanic acid and the melting point of the mixture determined. No depression of the melting point was observed the melting point remaining constant at 118°. So that during the reduction of the ester of camphenanic acid a portion of the ester is transformed into the isomeric 118°acid.

III REDUCTION OF METHYL ESTER OF ISO-CAMPHENILANIC ACID

This was reduced in the same manner and under the same conditions as the ester of camphenanic acid. The product was steam-distilled and as before ethyl and methyl alcohols volatised over first mixed with a little unchanged ester. Then a little of reduction product mixed with alcohol and finally solid reduction product. This was collected, dried, and the melting point determined. The melting point suggested that it was the same substance as that obtained from methyl camphenanate. The substance is a white waxy substance resembling in appearance the alcohol already obtained.

The substance is converted into the acid phthalate in the manner used for the preparation of the acid phthalate of the reduction alcohol from methyl camphenanate. In this way the acid phthalate was obtained in shining plates in appearance closely resembling the acid phthalate of the alcohol from camphenanic acid. After

crystallisation from benzene the melting point was determined and found to be 153°C the same melting point as the acid phthalate of alcohol of camphenanic acid. A mixed melting point showed no depression. The alcohol from iso-camphenilanic acid is therefore the same as that from the reduction of camphenanic acid. On acidifying the residue after the alcohol had distilled over an acid was precipitated which was collected and recrystallised and found to be iso-camphenilanic acid.

REDUCTION OF METHYL ESTER OF ISO-CAMPHENANIC ACID

This was reduced in the way already described and on steam distilling a solid alcohol was again collected. It resembled the alcohol already obtained both in melting point, properties, and appearance. Its identity was confirmed by preparing the nitrobenzoate and the acid phthalate. Both of these had the melting point of these derivatives prepared from alcohol of camphenanic acid and mixed melting points showed no depression whatever. The residue after distilling off the alcohol was acidified as before and again the acid formed was found to be entirely iso-camphenilanic acid. The yield of acid in this case seemed somewhat greater than in the case of reduction of camphenanic and iso-camphenilanic acids.

V. REDUCTION OF METHYL ESTER OF CAMPHENILANIC ACID

This was reduced in the same manner and the alcohol collected and dried. It also has same appearance and properties as the alcohol already described.

A nitrobenzoate was prepared to compare with that prepared from the other alcohols. The nitrobenzoate was crystallised from alcohol and melts sharply at 89°-90° and determination of the melting point of this substance when mixed with nitrobenzoate already prepared showed no depression, the mixture melting sharply at 89° to 90°C.

The acidified residue again yielded entirely iso-camphenilanic acid.

The alcohol therefore formed from these four acids of bornylene and camphene is the same in all four cases and is apparently the corresponding alcohol to camphenilanaldehyde.

This alcohol has not so far been described I would therefore propose for the substance the name camphenilanol.