

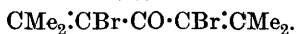
CCXXXIII.—*Some Derivatives of Phorone. Part I.*

By FRANCIS FRANCIS and FRANCIS GEORGE WILLSON.

THE great ease with which nitrosotriacetoneamine is catalytically decomposed into phorone, nitrogen, and water has been previously described (T., 1912, **101**, 2358), and the reaction has been utilised as a method for the determination of the concentration of hydroxyl ions (this vol., p. 1722).

There can be but little doubt that the formula used at present to represent the structure of phorone is correct, and that consequently this material affords an interesting basis for the study of chemical relations existing in a compound containing two adjacent pairs of conjugated double bonds—the so-called “cross-conjugated system.” We desired to commence this study by the investigation of some simple derivative of phorone, in which the magnitude of the residual affinities should be altered.

As phorone tetrabromide was found to be readily converted into a dibromo-derivative, we determined to investigate this first, since its method of preparation pointed to the conclusion that it was a dibromophorone of the constitution

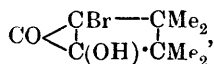


The replacement of two hydrogen atoms in phorone by bromine, however, results in the formation of a substance the properties of which differ more, from those of the parent material, than might have been expected.

The molecular refractivity of this dibromo-derivative showed an exaltation of 1.1, whereas phorone gives the abnormally high value of 3.0; further, the substance could not be directly brominated, did not combine with hydrogen bromide, and was curiously resistant towards oxidising agents.

The most characteristic reaction of this dibromo-derivative is the ease with which it is converted, by concentrated sulphuric acid, into a crystalline material of the molecular formula of a bromo-hydroxyphorone.

A study of the oxidation and reduction products of this derivative led us to formulate it as 1-bromo-2:2:3:3-tetramethylbicyclo-[0, 1, 2]pentan-4-ol-5-one :

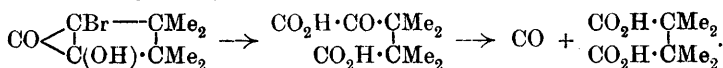


although the peculiar action of bromine on it cannot be said

to receive a very satisfactory explanation from such a conception of its constitution.

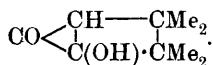
When this *bicyclopentanone* derivative is oxidised with alkaline permanganate it gives an excellent yield of a dibasic acid, $C_9H_{14}O_5$, and when this acid is warmed with concentrated sulphuric acid to 70–80° carbon monoxide is eliminated, and a quantitative yield of tetramethylsuccinic acid is obtained. The latter can also be obtained directly from the *bicyclopentanone* by oxidation with chromic and sulphuric acids.

These changes may be represented as follows:



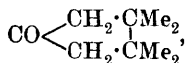
There can be little doubt that the oxidation of a derivative containing a five-membered ring had been carried out.

When the *bicyclopentanone* derivative is reduced with zinc dust and glacial acetic acid, the yield of reduction product obtained is very unsatisfactory; but it becomes quantitative if the acetyl derivative is employed. The reduced acetyl derivative which is formed is a liquid possessing a terpene-like odour, readily saponified by alkali, and the free hydroxyl derivative is a crystalline material which so closely resembles the parent substance in all its properties that we assign to it a similar constitution, namely, 2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one,



When the latter derivative, or the original *bicyclopentanone*, is reduced in alkaline solution by sodium amalgam, a substance of the formula $C_9H_{16}O$ results. This forms a semicarbazone, condenses with difficulty with aldehydes, and in appearance, odour, taste, and volatility shows a striking resemblance to camphor.

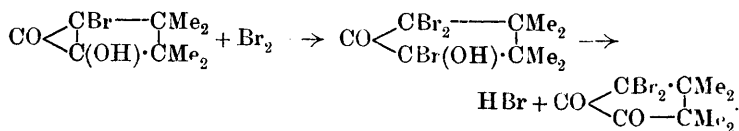
There is but little doubt that it is 1:1:2:2-tetramethylcyclopentan-4-one,



and we consider that the difficulty experienced in obtaining condensation products with aldehydes may be ascribed to the accumulation of methyl groups in the molecule.

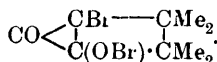
The action of bromine on the original *bicyclopentanone* derivative results in the formation of a red, crystalline dibromo-derivative, $C_9H_{12}O_2Br_2$. It was found that 1-bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one is not completely brominated in acetic acid solution unless one molecular proportion of

bromine was used for the purpose; this fact and the red colour of the derivative, suggesting an *o*-diketone structure, led us to formulate the bromination as follows:



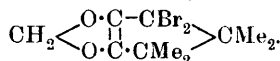
This explanation is based on K. Meyer's investigations of the action of bromine on substances of the nature of ethyl acetoacetate (*Annalen*, 1911, **380**, 212), and is supported by the fact that it was not found possible to brominate, in acetic acid solution, either the methyl or acetyl derivatives of 1-bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one, clearly indicating that the hydrogen of the hydroxyl group played a part in the reaction.

The dibromo-derivative is characterised by the great ease with which it is reconverted into 1-bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one, and this decomposition on the basis of the constitution we have assigned to the former, namely, 5:5-dibromo-1:1:2:2-tetramethylcyclopentan-3:4-dione, appears to indicate that under certain conditions it can functionate in the tautomeric form expressed by the formula



Although under one set of conditions one bromine atom is readily eliminated, yet such reagents as alkali hydroxides, or sodium acetate in alcoholic solution, yield bromine-free derivatives. The diacetate which results from the latter decomposition has been analysed, but the product from the action of alkalis is a syrup which, so far, we have been unable to investigate.

The only derivative of the red dibromo-derivative still containing two bromine atoms, which it has been found possible to isolate, is one resulting from the action of diazomethane on its ethereal solution. This is a colourless, crystalline material, differing only from the parent bromide by CH_2 , and to which, based on our previous conceptions, we provisionally assign the constitution:



The investigation is being continued, and it is hoped that further light will be thrown on these interesting substances.

EXPERIMENTAL.

Phorone tetrabromide has been described by Claisen, and is readily prepared by the action of bromine on phorone in carbon

disulphide or carbon tetrachloride solution. If the bromination is carried out in alcoholic solution an oil is obtained with properties altogether different from those of the tetrabromide, and it is proposed to investigate this substance at a later date.

Dibromophorone.

When the tetrabromide is dissolved in a little more than its own weight of cold pyridine, and the solution kept for twenty-four hours, the above is formed, and can be isolated by the addition of a large excess of water, when it is precipitated as an oil, which is obtained in quantitative yield and in a high state of purity by washing with water and then 30 per cent. sulphuric acid. The latter process must be thoroughly carried out, since the dibromo-derivative retains traces of pyridine with great tenacity, but when freed from this base the oil usually crystallises at once.

The compound crystallises in large, transparent, slightly yellow prisms, and melts at 32°. It may be distilled under greatly diminished pressure with but slight decomposition, it is extremely soluble in the usual organic solvents, possesses a faint odour resembling that of pine, and on exposure to the air rapidly becomes green:

0.4111 gave 0.5289 AgBr. Br=54.7.

$C_9H_{12}OBr_2$ requires Br=54.2 per cent.

The dibromo-derivative has a density of 1.552 at 37.4°, and the refractive index at this temperature for the *D*-line is 1.53941, and for the *C*-line 1.53460; this gives a molecular refractivity of 59.77 and 59.37 respectively, and an exaltation of 1.09 and 1.12, based on the formula we have assigned to this substance. The magnitude of this exaltation is what might have been expected in such a cross-conjugated system, but is very much less than that of phorone itself, which, according to Brühl, is 3.05.

The dibromo-derivative is either unacted on by reducing agents or else a very small yield of phorone is obtained. Oxidising agents have no action on it. When dissolved in carbon disulphide and treated with excess of bromine, it can be recovered unchanged; it is also unacted on when dissolved in a concentrated acetic acid solution of hydrogen bromide and allowed to remain for two weeks.

1-Bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one.

The best method for the preparation of this substance consists in acting on dibromophorone in the cold with about three molecular proportions of concentrated sulphuric acid and allowing the mixture to remain for twenty-four hours. Bromine and hydrogen bromide

are evolved, and the product is isolated by pouring the solution on to crushed ice.

By using not more than 50 grams of the dibromo-derivative at one operation, a yield of 82 per cent. of the *bicyclopentanone* derivative can be obtained.

The substance is best crystallised from dilute alcohol, from which solvent it separates in well-formed, colourless needles, melting at 116° . It is soluble in hot water, slightly volatile with steam, and its behaviour in this boiling solvent recalls that of benzoic acid. It is extremely stable towards concentrated sulphuric acid, and its solution in this medium may be heated to a temperature of 200° without showing any signs of decomposition:

0.1554 gave 0.2640 CO_2 and 0.0796 H_2O . $\text{C}=46.33$; $\text{H}=5.69$.

0.5768 „ 0.4636 AgBr . $\text{Br}=34.14$.

$\text{C}_9\text{H}_{13}\text{O}_2\text{Br}$ requires $\text{C}=46.34$; $\text{H}=5.58$; $\text{Br}=34.34$ per cent.

A determination of the molecular weight by the ebullioscopic method, using acetone as solvent, gave the following result:

1.0221 in 19.8 gave Δt 0.360. $\text{M.W.}=244$.

$\text{C}_9\text{H}_{13}\text{O}_2\text{Br}$ requires $\text{M.W.}=233$.

This compound possesses well-marked acidic properties, a hot aqueous solution reddens litmus paper, it is easily soluble in solutions of the alkalis and in alkaline carbonates, and the sodium salt separates from concentrated solutions in characteristic silky needles.

We were unable to obtain either an oxime or semicarbazide, probably due to the presence of substituents on either side of the carbonyl group.

The presence of one hydroxyl group was confirmed by the formation of the following derivatives:

The *acetyl* derivative, prepared by boiling the *bicyclopentanone* for one hour with excess of acetic anhydride, recrystallises from dilute acetic acid in long, colourless needles, melting at 74° :

0.1562 gave 0.2782 CO_2 and 0.0807 H_2O . $\text{C}=48.57$; $\text{H}=5.74$.

0.605 „ 0.4172 AgBr . $\text{Br}=29.34$.

$\text{C}_{11}\text{H}_{15}\text{O}_3\text{Br}$ requires $\text{C}=48.01$; $\text{H}=5.45$; $\text{Br}=29.09$ per cent.

The *benzoyl* derivative was obtained in the usual way, using pyridine as solvent. After crystallisation from dilute alcohol it melts at 92° :

0.184 gave 0.3825 CO_2 and 0.0892 H_2O . $\text{C}=56.7$; $\text{H}=5.38$.

$\text{C}_{19}\text{H}_{17}\text{O}_3\text{Br}$ requires $\text{C}=56.98$; $\text{H}=5.04$ per cent.

The *carbomethoxy*-derivative, after crystallisation from dilute alcohol and ether, melts at $75-77^{\circ}$:

0.205 gave 0.3396 CO₂ and 0.0954 H₂O. C=45.18; H=5.17.

C₁₁H₁₅O₄Br requires C=45.36; H=5.15 per cent.

Oxidation of 1-Bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one.

Ten grams of this derivative were dissolved in an excess of potassium hydroxide and oxidised with a solution of 15 grams of potassium permanganate, care being taken not to allow the temperature to rise. On acidification and repeated extraction with ether, 8 grams of an oil were obtained, which set to a very hard, crystalline mass on keeping. After solidification it could be recrystallised from toluene, and melted at 139°:

0.2416 gave 0.4732 CO₂ and 0.1492 H₂O. C=53.42; H=6.86.

C₉H₁₄O₅ requires C=53.46; H=6.93 per cent.

A determination of the molecular weight by the ebullioscopic method, using acetone as solvent, gave the following result:

0.1612 in 12.70 gave Δt 0.120°. M.W.=180.

C₉H₁₄O₅ requires M.W.=202.

This substance was readily soluble in water, gave a strongly acid solution, and was shown to be dibasic by an analysis of its *silver* salt:

0.4410 gave 0.2325 Ag. Ag=52.60.

C₉H₁₂O₅Ag₂ requires Ag=51.93 per cent.

In order to determine the number of hydroxyl groups, a specimen of the pure acid was treated with excess of diazomethane in ethereal solution. The resulting oil was fractionated in a vacuum, and the main bulk of the methyl derivative boiled at 160°/50 mm. On keeping for a long period this oil set to a crystalline mass, which melted at 93—97° on recrystallisation from benzene and light petroleum. The analysis showed that a dimethyl derivative only had been formed, and hence that there were only two hydroxyl groups present:

0.2133 gave 0.4436 CO₂ and 0.1479 H₂O. C=56.71; H=7.71.

C₁₁H₁₈O₅ requires C=57.39; H=7.82 per cent.

Since this acid can be quantitatively converted into dimethylsuccinic acid, there can be no doubt that it is α -keto- β -*γ*-tetramethylglutaric acid, CO₂H·CO·CMe₂·CMe₂·CO₂H.

On reduction with sodium amalgam in alkaline solution this acid passes quantitatively into the lactone of α -hydroxy- β -*γ*-tetramethylglutaric acid, an oil which slowly solidifies to a crystalline mass; this may then be purified by recrystallisation from benzene and light petroleum, and melts at 68°:

0.2168 gave 0.4578 CO_2 and 0.1503 H_2O . $\text{C}=57.58$; $\text{H}=7.65$.

$\text{C}_9\text{H}_{14}\text{O}_4$ requires $\text{C}=58.06$; $\text{H}=7.52$.

An analysis of the *silver* salt of this lactonic acid showed that it was monobasic:

0.4880 gave 0.1798 Ag. $\text{Ag}=36.85$.

$\text{C}_9\text{H}_{13}\text{O}_4\text{Ag}$ requires $\text{Ag}=36.85$ per cent.

When α -keto- β -tetramethylglutaric acid was warmed to 80° with concentrated sulphuric acid, carbon monoxide was evolved, and a quantitative yield of tetramethylsuccinic acid obtained. This acid (m. p. 180 — 190°) gave correct data on analysis, and was characterised by conversion into its anhydride, which melted at 147° , and also gave correct analytical data.

Tetramethylsuccinic acid was also obtained by the direct oxidation of the *bicyclopentanone* derivative with chromic acid.

Reduction of 1-Bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one.

This derivative gives only a very poor yield of reduction product when treated with zinc dust and glacial acetic acid, but when the acetyl derivative is used an excellent yield of the acetyl derivative of 2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one is obtained. This derivative is an oil, which is easily saponified by warming with dilute alkalis; when this solution is acidified and extracted with ether, the parent substance is obtained, which fuses at 86° on recrystallisation from boiling water.

In appearance and solubility it closely resembles the bromo-derivative; it also possesses a very similar, but somewhat more pungent, odour, and shows the same acid properties:

0.2190 gave 0.5618 CO_2 and 0.1788 H_2O . $\text{C}=69.96$; $\text{H}=9.07$.

$\text{C}_9\text{H}_{14}\text{O}_2$ requires $\text{C}=70.13$; $\text{H}=9.09$ per cent.

The *benzoyl* derivative, prepared by the ordinary method, melts at 69° on crystallisation from dilute alcohol:

0.2324 gave 0.6330 CO_2 and 0.1470 H_2O . $\text{C}=74.29$; $\text{H}=7.03$.

$\text{C}_{16}\text{H}_{18}\text{O}_3$ requires $\text{C}=74.42$; $\text{H}=6.98$ per cent.

When 1-bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one is reduced in alkaline solution by 2 per cent. sodium amalgam, a strong odour of camphor soon becomes apparent, and the reduction product separates in flakes which can be extracted with ether.

The derivative is purified with difficulty by crystallisation from dilute alcohol and ether; it melts at 130° , and sublimes so readily that it cannot be dried in a vacuum. The same substance can also

be obtained by the reduction, under similar conditions, of 2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one.

The material is only sparingly soluble in water, but dissolves in the ordinary organic solvents, and has an appearance, odour, and taste curiously similar to that of camphor, and, like that substance, feels the same when pressed or cut with a spatula:

0.2086 gave 0.5884 CO₂ and 0.2152 H₂O. C=76.91; H=11.47.

C₉H₁₆O requires C=77.14; H=11.43 per cent.

A determination of the molecular weight by the ebullioscopic method, using acetone as solvent, gave the following result:

1.4367 in 16.36 gave Δt 1.008. M.W.=148.

C₉H₁₆O requires M.W.=140.

The semicarbazone obtained in the usual manner melted at 223° on recrystallisation from dilute alcohol:

0.144 gave 26.6 c.c. N₂ at 13.5° and 759.7. N=21.78.

C₁₀H₁₈ON₃ requires N=21.32 per cent.

There can be but little doubt that the substance described is 1:1:2:2-tetramethylcyclopentan-4-one, but, unlike cyclic ketones of this class, it does not condense at all readily with aldehydes. Both with benzaldehyde and with *o*- and *m*-nitrobenzaldehyde, under the influence of sodium ethoxide, small quantities of yellow condensation products were obtained, but analysis showed that these were mixtures of mono- and di-benzylidene derivatives, which, with the small amount at our command, we were unable to separate.

When 1:1:2:2-tetramethylcyclopentan-4-one is oxidised with hydrogen peroxide in alkaline solution an acid results, which may be crystallised from a small quantity of water, or from benzene, and melts at 131°. The analysis indicated that this substance was $\alpha\beta$ -tetramethylglutaric acid, CO₂H·CH₂·CMe₂·CMe₂·CO₂H:

0.2272 gave 0.4794 CO₂ and 0.1662 H₂O. C=57.53; H=8.14.

C₉H₁₆O₄ requires C=57.45; H=8.51 per cent.

Action of Bromine on 1-Bromo-2:2:3:3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one.

Bromine does not act on the above compound in carbon disulphide solution, but one molecular proportion gives a quantitative yield of a dibromo-derivative when the operation is carried out in glacial acetic acid. The compound is insoluble in water, and may be purified by rapid crystallisation from alcohol. It is an orange, crystalline substance, melting at 182°.

From the analysis and molecular-weight determination we consider that this substance is 5:5-dibromo-1:1:2:2-tetramethylcyclopentane-3:4-dione:

0.1457 gave 0.185 CO_2 and 0.0507 H_2O . $\text{C}=34.63$; $\text{H}=3.87$.

0.4587 „ 0.5602 AgBr . $\text{Br}=51.96$.

$\text{C}_9\text{H}_{12}\text{O}_2\text{Br}_2$ requires $\text{C}=34.61$; $\text{H}=3.85$; $\text{Br}=51.28$ per cent.

The molecular weight was determined by the ebullioscopic method, using acetone as solvent:

0.3466 in 14.79 gave Δt 0.178. $\text{M.W.}=288$.

$\text{C}_9\text{H}_{12}\text{O}_2\text{Br}_2$ requires $\text{M.W.}=312$.

Neither the acetyl nor the methyl derivatives of 1-bromo-2 : 2 : 3 : 3-tetramethylbicyclo[0, 1, 2]pentan-4-ol-5-one could be brominated in acetic acid solution.

By far the most characteristic reaction of this dibromo-derivative was the ease with which it was reconverted into the substance from which it was obtained; a decomposition brought about quantitatively by concentrated sulphuric acid or by reduction with zinc dust and glacial acetic acid, and partly by boiling with water, alcohol, or acetone.

This decomposition clearly points to the fact that one bromine atom is situated differently from the other.

Although under the above conditions one bromine atom alone is eliminated, yet when the dibromo-derivative is acted on by alkalis in aqueous suspension a substance is obtained free from bromine. The yield of the latter, however, is small, and the substance is a syrup, which we have been unable to obtain in quantity in the crystalline form. A small specimen recrystallised from benzene in light petroleum melted at 68° .

When the dibromo-derivative is boiled with an excess of alcoholic sodium acetate a crystalline *diacetate* is obtained, which melts at 100 — 102° on recrystallisation from dilute acetic acid:

0.1468 gave 0.3118 CO_2 and 0.0898 H_2O . $\text{C}=57.91$; $\text{H}=6.79$.

$\text{C}_{13}\text{H}_{18}\text{O}_6$ requires $\text{C}=57.77$; $\text{H}=6.66$ per cent.

This diacetate is readily decomposed by dilute alkalis, and the resulting substance is a syrup which we believe to be identical with that mentioned in the last paragraph. A small quantity of this was also obtained in the crystalline form and melted at 67° , and this melting point remained unchanged when the substance was mixed with some of the product obtained by the action of alkalis on the dibromo-derivative.

The only derivative of the latter compound that we have been able to obtain, which still contains two bromine atoms, is that which results when its ethereal solution is treated with diazomethane. This derivative, which is colourless, crystallises indifferently, and the crystals feel sticky, although showing a definite melting point of 190° after repeated recrystallisations from dilute acetic acid:

0.2274 gave 0.3066 CO_2 and 0.0904 H_2O . $\text{C}=36.77$; $\text{H}=4.42$.

0.4578 „ 0.5299 AgBr . $\text{Br}=49.25$.

$\text{C}_{10}\text{H}_{12}\text{O}_2\text{Br}_2$ requires $\text{C}=36.81$; $\text{H}=4.29$; $\text{Br}=49.08$ per cent.

Our thanks are due to Mr. D. A. Clibbens for the great assistance he gave one of us in the preliminary investigation of the *bicyclopentanone* and its dibromo-derivative.

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