CXCv.—*Experiments on the Synthesis of 1-Methylcyclohexylidene-4-acetic Acid. Part II.*

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IN Part I of this investigation (Trans., 1908, 93, 1075) a series of experiments was described which was undertaken with the object of preparing the above acid, and of ascertaining whether it could be resolved into active modifications by the crystallisation of its salts with optically active bases. It was pointed out that, while these experiments were in progress, W. Marckwald and R. Meth (*Ber.*, 1906, 39, 1171) were engaged with the same problem, and had prepared an acid (m. p. 41°) by the elimination of water from 4-hydroxy-1-methylcyclohexylacetic acid,

which they pronounced to be 1-methylcyclohexylidene-4-acetic acid,

They also showed that the acid may be resolved into its *d*- and *l*-modifications by the fractional crystallisation of the cinchonine salts. In subsequent communications (*ibid.*, 2035 and 2404) they described further experiments, which, in their opinion, clearly demonstrated that their view of the constitution of this acid was the correct one. On the other hand, Perkin and Pope (*loc. cit.*) pointed out that the elimination of water from 4-hydroxy-1-methylcyclohexylacetic acid may take place in a different direction from that assumed by Marckwald and Meth, and may lead to the formation of 1-methyl- Δ^3 -cyclohexene-4-acetic acid,

and they expressed the opinion that this formula most probably represents the constitution of the acid of melting point 41° .

If this view should prove to be correct, the acid would contain an asymmetric carbon atom, and there would then be nothing remarkable in its resolution into active modifications in the manner described by Marckwald and Meth. During the last two years, we have been engaged in a detailed investigation of the difficult problem of the constitution of this acid, and have obtained experimental evidence which we think proves without doubt that the acid of melting point 41° is 1-methyl- Δ^3 -cyclohexene-4-acetic acid, and that the view of Marckwald and Meth that this acid is 1-methylcyclohexylidene-4-acetic acid cannot be accepted as correct.

The first indirect evidence of constitution was obtained during the course of a series of researches, which we hope shortly to publish, on the condensation of ketones with ethyl cyanoacetate in the presence of sodium ethoxide or piperidine. The reaction takes place in such a way that the enolic modification of the ketone condenses with the ethyl cyanoacetate (or cyanoacetic acid) with elimination of water, and the result is either the free condensation product or its sodium derivative, according as to whether piperidine or sodium ethoxide has been employed:

When this interesting reaction was investigated in the case of cyclohexanone, it was found that condensation took place readily, and that elimination of water proceeded almost entirely in the direction:

that is to say, with the production of *ethyl α-cyano-Δ¹-cyclohexeneacetate*.

This cyano-ester is readily hydrolysed with formation of *α-cyano-Δ¹-cyclohexeneacetic acid*, and this, on distillation, is decomposed with elimination of carbon dioxide and formation of *Δ¹-cyclohexeneacetoneitrile*,

When this nitrile is hydrolysed under the conditions described in detail in the experimental part (p. 1959), it yields *Δ¹-cyclohexeneacetic acid*,

which melts at 38°. Whilst then the condensation of *cyclohexanone* with *ethyl cyanoacetate* proceeds almost entirely in the direction described above, the product nevertheless contains small quantities of the isomeric *ethyl cyanocyclohexylideneacetate*,

and from this a small quantity of a nitrile is obtained which, on hydrolysis, yields *cyclohexylideneacetic acid*,

which melts at 91°.

These acids of melting points 38° and 91° are identical with the acids which Wallach (*Annalen*, 1907, 353, 292) obtained by the elimination of water from *cyclohexanolacetic acid*:

As in the cyanoacetic ester and *cyclohexanone* condensation just described, so also during the decomposition of *cyclohexanolacetic acid*, the unsaturated acid produced in by far the larger quantity is *Δ¹-cyclohexeneacetic acid* (m. p. 38°). The question of the constitution of these acids has been very carefully investigated by Wallach (*loc. cit.*). The acid of melting point 91° yields *cyclohexanone* when it is oxidised with permanganate, and it is therefore evidently

cyclohexylidene-4-acetic acid. The nature of the change which takes place when the acid of melting point 38° is oxidised by permanganate has proved to be much more difficult to understand. The product of oxidation contains a volatile oil, $C_7H_{10}O$, the semicarbazone of which has the formula $C_8H_{13}N_3O$ and the melting point $203-204^\circ$, and the oil, on oxidation with chromic acid, yields glutaric acid. Wallach at first expressed the opinion that the substance $C_7H_{10}O$ was either

1-Methyl- Δ^6 -cyclohexen-2-one.

Tetrahydrobenzaldehyde.

In a later paper (*Annalen*, 1908, 359, 310), he shows that this substance is neither 1-methyl- Δ^6 -cyclohexen-2-one nor tetrahydrobenzaldehyde, and suggests that its constitution is possibly represented by the formula $CH_2 \begin{array}{c} \text{CH}_2 \cdot \text{CH}_2 \\ \text{CH}_2 - \text{CO} \end{array} \text{C} \cdot \text{CH}_2$.

Experiments on the oxidation of the ester of the acid of melting point 38° , which are described below, clearly indicate, however, that the substance $C_7H_{10}O$ is Δ^1 -cyclopentene methyl ketone,

and this view is in harmony with the fact that this ketone yields glutaric acid when it is oxidised with chromic acid.

When ethyl Δ^1 -cyclohexeneacetate is oxidised by ozone in chloroform solution in the presence of water, it is converted into an ester, which gives in alcoholic solution with ferric chloride a violet coloration, and the formation of which may be doubtless expressed thus:

This ester is readily decomposed by boiling dilute sulphuric acid with elimination of alcohol and carbon dioxide and formation of a ketone, $C_7H_{10}O$, which yields a semicarbazone of melting point $203-204^\circ$, and is evidently identical with the ketone possessing these properties which Wallach prepared in the manner just described. We have no doubt that this ketone is Δ^1 -cyclopentene methyl ketone, and that its formation is due to the following series of changes.

Some years ago (*Trans.*, 1890, 57, 242), Marshall and Perkin prepared a methyl derivative of this ketone by a very similar

condensation, namely, from ethyl diacetyladipe by the action of alcoholic potash.

and this latter ketone has properties very similar to those of the ketone $\text{C}_7\text{H}_{10}\text{O}$.

When the method of formation and properties of the acid of melting point 38° , its behaviour on oxidation, and its isomerism with *cyclohexylideneacetic acid*, m. p. 91° , are taken into account, there can no longer be any doubt that Wallach's view that it is Δ^1 -*cyclohexeneacetic acid* must be accepted as correct. But this acid is practically the sole product of the hydrolysis of the ester which is produced when *cyclohexanone* is condensed with ethyl cyanoacetate (p. 1945), and it follows therefore that this ester must consist almost entirely of *ethyl α -cyano- Δ^1 -cyclohexeneacetate*,

This point is, however, so important that we confirmed it by investigating the action of sodium and methyl iodide on the cyano-ester, and obtained an almost quantitative yield of *ethyl α -cyano- α - Δ^1 -cyclohexene-propionate*,

The description of this substance and of its decomposition products, and also of the analogous derivative obtained with the aid of ω -bromoacetophenone, will be found on pp. 1958 and 1961. The formation of these substitution products can only be explained on the assumption that the original ester contains the grouping $-\text{CH}(\text{CN}) \cdot \text{CO}_2\text{Et}$; the isomeric ester,

which might, conceivably, result from the condensation of *cyclohexanone* with ethyl cyanoacetate, does not contain a hydrogen atom replaceable by sodium. We now investigated the action between 1-methyl*cyclohexan-4-one* and ethyl cyanoacetate in the presence of sodium ethoxide or piperidine, and found that the condensation evidently proceeded in a similar manner to that already described in the case of *cyclohexanone*, and there was no reason to doubt that the product was *ethyl α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetate*,

and not ethyl α -cyano-1-methyl*cyclohexylidene-4-acetate*,

This view was, however, controlled by investigating the behaviour of the ester with sodium and methyl iodide (p. 1972), when an almost quantitative yield of *ethyl- α -cyano- α -1-methyl- Δ^3 -cyclohexene-4-propionate*,

was obtained, and a similar substitution product resulted from the action of bromoacetophenone on the sodium derivative (p. 1966).

Ethyl α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetate is readily hydrolysed, and the free acid is decomposed on distillation with elimination of carbon dioxide and formation of 1-methyl- Δ^3 -cyclohexene-4-acetonitrile. When this nitrile is digested with alcohol and sulphuric acid and the resulting ester hydrolysed, it yields 1-methyl- Δ^3 -cyclohexene-4-acetic acid,

The acid obtained in this way melted at 41° , and was found by direct comparison to be identical with the acid described by Marckwald and Meth (*Ber.*, 1906, **39**, 1171) as 1-methylcyclohexylidene-4-acetic acid. During the investigation of the condensation of cyclohexanone and ethyl cyanoacetate (p. 1945), we were able to isolate from the product, not only Δ^1 -cyclohexeneacetic acid (m. p. 38°), but also very small quantities of cyclohexylideneacetic acid (m. p. 91°):

In the present case, however, 1-methyl- Δ^3 -cyclohexene-4-acetic acid appears to be the only acid formed, since, in spite of careful search, we were unable to isolate even traces of 1-methylcyclohexylidene-4-acetic acid,

Whilst, then, the experiments described above seem to us to be very strong evidence that the acid of Marckwald and Meth (m. p. 41°) is 1-methyl- Δ^3 -cyclohexene-4-acetic acid, we have carried out a further investigation of this acid with the view, not only to emphasise this point, but also clearly to establish the fact that this acid is in all respects the counterpart of Wallach's Δ^1 -cyclohexeneacetic acid (m. p. 38°). Probably the most characteristic property of Δ^1 -cyclohexeneacetic acid is the behaviour of its ester with ozone (p. 1946), and we have found that, under the same conditions, 1-methyl- Δ^3 -cyclohexene-4-acetic acid (m. p. 41°) behaves in an exactly similar manner. When the ester of this acid is oxidised with ozone in chloroform solution and in the presence of water, it is converted into an ester which

yields an intense violet coloration when ferric chloride is added to its alcoholic solution.

There can be little doubt that this ester is *ethyl ζ-aldehydo-β-keto-isooctate*, and that its formation is due to the following change :

When this ester is digested with dilute sulphuric acid, it is decomposed with elimination of alcohol and carbon dioxide and formation of a ketone, $\text{C}_8\text{H}_{12}\text{O}$, which yields a semicarbazone (m. p. 207—209°), and is obviously a simple homologue of the ketone, $\text{C}_7\text{H}_{10}\text{O}$, obtained under similar conditions from *cyclohexeneacetic acid* (m. p. 38°: compare p. 1946). The formation of this ketone is readily understood from the following scheme :

and the ketone, $\text{C}_8\text{H}_{12}\text{O}$, is therefore *1-methyl-Δ³-4-cyclopentene methyl ketone*.

While these experiments were in progress, we were struck with the similarity in structure between *ββ*-dimethylacrylic acid and *1-methyl-cyclohexylidene-4-acetic acid* :

Now it is well known that ethyl *ββ*-dimethylacrylate, like all esters containing the group $\text{>C} \cdot \text{CH} \cdot \text{CO}_2\text{Et}$, readily condenses with ethyl sodiocyanoacetate with formation of the sodium derivative of ethyl cyanodimethylglutarate, $\text{CO}_2\text{Et} \cdot \text{C}(\text{CN})\text{Na} \cdot \text{CMe}_2 \cdot \text{CH}_2 \cdot \text{CO}_2\text{Et}$ (Perkin and Thorpe, *Trans.*, 1899, **75**, 901). Since this reaction is not shown by acids like *1-methyl-Δ³-cyclohexene-4-acetic acid*, which contain the double linking in the *βγ*-position, it was thought that valuable evidence of structure might be obtained by employing it in connexion with the present investigation. We therefore digested the ester of the acid of melting point 41° with ethyl sodiocyanoacetate for several hours, but no additive compound was produced, and practically the whole of the acid was recovered unchanged. When the same experiment was made with ethyl *Δ¹-cyclohexeneacetate*,

which admittedly contains the double linking in the *βγ*-position, an exactly similar result was obtained, and no trace of an additive com-

pound was produced. This experiment is not only strong evidence that the acid of melting point 41° cannot be 1-methylcyclohexylidene-4-acetic acid, but it is also a further example of the striking similarity in properties between this acid and Δ^1 -cyclohexeneacetic acid.

We next examined in detail the evidence brought forward by Marckwald and Meth in support of their contention that the acid (m. p. 41°) is 1-methylcyclohexylidene-4-acetic acid. In the first place these investigators (*Ber.*, 1906, 39, 1175) state that the acid yields methylcyclohexanone and potassium acetate when it is heated with potassium hydroxide and a little water, a change which they obviously assume to be due to disruption at the double linking by hydrolysis:

We have repeated the experiment and can confirm the result, but we find that, in order to bring about this change, the acid has practically to be fused with potassium hydroxide. The acid may be heated at 210° with 90 per cent. aqueous potassium hydroxide without any apparent change, but, when distilled with potassium hydroxide and a trace of water, it is ultimately decomposed with formation of methylcyclohexanone and potassium acetate. Perkin and Pope (*Proc.*, 1906, 22, 108) have already pointed out that it is well known that $\beta\gamma$ -unsaturated acids, like 1-methyl- Δ^3 -cyclohexene-4-acetic acid are, not infrequently, converted by treatment with strong alkali into $\alpha\beta$ -unsaturated acids, and that this isomeric change may have taken place in the case of Marckwald and Meth's acid prior to the decomposition into methylcyclohexanone and acetic acid; in a later paper (*Ber.*, 1906, 39, 2036), Marckwald and Meth acknowledge the justice of this criticism. This behaviour with potassium hydroxide is, in fact, strong evidence in support of our view that the acid is 1-methyl- Δ^3 -cyclohexene-4-acetic acid, since, if it were 1-methylcyclohexylidene-4-acetic acid, it might be expected to yield methylcyclohexanone when boiled with strong aqueous potassium hydroxide much more readily than is actually the case.

In their second communication (*Ber.*, 1906, 39, 2036), Marckwald and Meth show that the acid of melting point 41° is decomposed on distillation with elimination of carbon dioxide and formation of a hydrocarbon, which, as they suggest, is doubtless 1-methyl-4-methylene-cyclohexane,

and they regard this as evidence that the double linking in the acid

must be in the side-chain, and that therefore the acid must be 1-methylcyclohexylidene-4-acetic acid. But Wallach (*Annalen*, 1908, **360**, 27) has shown that Δ^1 -cyclohexeneacetic acid is decomposed by dry distillation into carbon dioxide and methylenecyclohexane;

and he makes the general statement that, when acids of this type are distilled, there is a tendency for the double linking to change from the ring to the side-chain. It follows therefore that the behaviour of 1-methyl- Δ^3 -cyclohexene-4-acetic acid in this respect is quite normal, and that the formation of 1-methyl-4-methylenecyclohexane by distillation cannot be used as an argument in favour of the view of Marckwald and Meth that this acid is 1-methylcyclohexylidene-4-acetic acid. Very strong evidence against this view is the behaviour of this acid (m. p. 41°) on oxidation with permanganate. If this acid has the constitution

it should behave, on oxidation, like other acids containing the group $>\text{C} : \text{CH} \cdot \text{CO}_2\text{H}$, that is to say, it should yield the corresponding aldehyde (or ketone) and oxalic acid. In agreement with this view is the observation of Wallach (*Annalen*, 1907, **353**, 289), that cyclohexylideneacetic acid (m. p. 91°) readily yields cyclohexanone when it is oxidised with permanganate:

But Marckwald and Meth (*Ber.*, 1906, **39**, 2037) specially mention that they were unable to obtain 1-methylcyclohexan-4-one from the acid of melting point 41° by oxidation, and, although we have investigated the behaviour of this acid towards permanganate under a variety of conditions, we have never succeeded in demonstrating the formation even of a trace of methylcyclohexanone. We cannot therefore confirm the statement of Wallach and Evans (*Annalen*, 1907, **353**, 311), that methylcyclohexanone is produced when the acid (m. p. 41°) is oxidised by permanganate, and are of opinion that the ketone which these investigators obtained was 1-methyl- Δ^3 -4-cyclopentene methyl ketone, the formation of which may well be assumed to take place according to the following scheme:

This process is, in fact, very similar to that which is known to take place when Δ^1 -cyclohexeneacetic acid is oxidised by permanganate (p. 1946), or when its ester or the ester of 1-methyl- Δ^3 -cyclohexene-4-acetic acid is treated with ozone (compare p. 1946).

In their last communication on 1-methylcyclohexylidene-4-acetic acid (*Ber.*, 1906, **39**, 2405), Marckwald and Meth deduce fresh evidence which they state removes any possible remaining doubt that the acid of melting point 41° is 1-methylcyclohexylidene-4-acetic acid. They point out quite correctly * that cinnamic acid,

is decomposed when it is treated with sodium carbonate and bromine water with separation of ω -bromostyrene, $\text{C}_6\text{H}_5\cdot\text{CH}:\text{CHBr}$, and state that their acid of melting point 41° under the same conditions and in the cold yields in an exactly analogous manner the bromohydrocarbon,

If this were correct, this experimental evidence would no doubt strongly support their view that the acid of melting point 41° is 1-methylcyclohexylidene-4-acetic acid. But Marckwald and Meth have been deceived by appearances. It is true that the addition of bromine water to the cold solution of the acid in sodium carbonate causes the immediate separation of a heavy oil, just as in the case of cinnamic acid; *but this oil is not a bromohydrocarbon.*

If the product is left in a cool place, or, better, extracted with ether, the oil soon solidifies, and, after crystallisation, melts at 103° .

Analysis shows that this beautiful substance has the formula $\text{C}_9\text{H}_{13}\text{O}_2\text{Br}$, and is a bromo-lactone.

That it is a lactone is shown by the fact that, whilst insoluble in cold sodium carbonate, it dissolves in warm dilute potassium hydroxide, and, when digested with excess of alkali hydroxide, it is converted into

* Except that the conversion of an unsaturated acid into the bromohydrocarbon, by treatment in sodium carbonate solution with bromine water, surely does not take place in the way they represent, namely,

The probable course of this important change seems to be the addition, in the first place, of hypobromous acid to the double linking, followed by the formation of the bromo- β -lactone, which then decomposes with elimination of carbon dioxide and separation of the bromohydrocarbon:

the corresponding dihydroxy-acid, $C_8H_{13}(OH)_2 \cdot CO_2H$. [View Online](#)
 of the bromo-lactone is readily understood from the scheme: *

and is in strict accordance with the view that the acid of melting point 41° is 1-methyl- Δ^3 -cyclohexene-4-acetic acid.

The dihydroxy-acid obtained by hydrolysis with potassium hydroxide is doubtless 3:4-dihydroxy-1-methylcyclohexane-4-acetic acid,

Marckwald and Meth (*loc. cit.*) claim to have proved that the product of the action of bromine water and sodium carbonate on the acid of melting point 41° is 4-bromo-1-methylmethylenecyclohexane (compare p. 1952) by studying its behaviour with water at $140-150^\circ$.

* This bromo-lactone may, of course, be a β -lactone of the formula

and, when the similarity in structure between this substance and the β -lactone of β -hydroxyisopropylmalonic acid,

(Meldrum, *Trans.*, 1908, **93**, 598), is taken into account, this view, although improbable, is not at all impossible.

Wallach (*Annalen*, 1907, **353**, 289) has, however, shown that both Δ^1 -cyclohexene-acetic acid and cyclohexylideneacetic acid yield the same bromo-acid on treatment with hydrogen bromide:

It is therefore probable that the addition of hypobromous acid to 1-methyl- Δ^3 -cyclohexene-4-acetic acid takes place in the direction

in which case a bromo- γ -lactone would result.

They obtained in this way a substance, the semicarbazone of which corresponded with that of hexahydro-*p*-tolualdehyde,

and they therefore concluded that this substance had been produced.

Wallach (*Annalen*, 1906, **347**, 346), who first prepared this aldehyde in small quantities, states that the melting point of a specimen of the semicarbazone after crystallisation from water was 154—156°.

As the formation of this aldehyde was not in accord with the constitution ascribed by us to the bromo-lactone, which is the actual product of the action of bromine and sodium carbonate on the acid of melting point 41°, we heated this lactone with water at 140—150°, and found that it was converted almost quantitatively into a *ketone*, which yielded a semicarbazone of melting point 167°. We were ultimately able to prove that this ketone is 1:4-dimethylcyclohexan-2-one,

This ketone has recently been described by Sabatier and Mailhe (*Compt. rend.*, 1906, **142**, 553), who obtained it from *p*-xylenol by reduction with hydrogen in the presence of nickel and subsequent oxidation of the resulting 1:4-dimethylcyclohexan-2-ol:

We have prepared a pure specimen of the ketone (b. p. 176°) by this method, and converted it into the semicarbazone, which melted at 155°, but, after several crystallisations from methyl alcohol, the melting point rose to 167°. On comparing this ketone with the ketone which we had obtained from the bromo-lactone by the action of water at 140—150°, it was at once clear that the two specimens were identical. Thus, for example, when the semicarbazones were mixed, there was no alteration in melting point. There can be little doubt that the substance which Marckwald and Meth described as hexahydro-*p*-tolualdehyde was, in reality, 1:4-dimethylcyclohexan-2-one, and the low melting point which they appear to have observed for the semicarbazone was due to that derivative not being quite pure.

In order to be still more certain on this point, we have prepared hexahydro-*p*-tolualdehyde by a new method, namely, from 4-bromo-1-methylcyclohexane,

by treatment with magnesium and orthoformic ester (p. 1974).

The semicarbazone melted, after crystallisation from dilute methyl alcohol, at 154° , as stated by Wallach (*Annalen*, 1906, **347**, 346), and, when this was mixed with the semicarbazone of the substance produced from the bromo-lactone by the action of water at 140 – 150° , the mixture melted at about 138° .

The formation of 1:4-dimethylcyclohexan-2-one from the bromo-lactone by the action of water at 140 – 150° is readily explained by the following series of changes :

and the production of 1:4-dimethylcyclohexan-2-one in this way is again strong evidence in favour of the view that the acid of melting point 41° is 1-methyl- Δ^3 -cyclohexene-4-acetic acid.

In order to demonstrate, in this respect also, the complete analogy between this acid and Δ^1 -cyclohexeneacetic acid (m. p. 38°), we have submitted the latter to the action of sodium carbonate and bromine under exactly the same conditions and with a precisely similar result.

The addition of bromine water to the solution of this acid in sodium carbonate causes the immediate separation of an oil, which crystallises with difficulty, melts at about 70° , and is a bromo-lactone of the formula $\text{C}_8\text{H}_{11}\text{O}_2\text{Br}$. When this bromo-lactone is heated with water at 140 – 150° , it is decomposed with formation of 1-methylcyclohexan-2-one :

a behaviour which is exactly analogous to the conversion of the bromo-lactone, $\text{C}_9\text{H}_{13}\text{O}_2\text{Br}$, from the acid of melting point 41° into 1:4-dimethylcyclohexan-2-one.

It appears to us that the above experimental evidence proves conclusively that the acid of melting point 41° is 1-methyl- Δ^3 -cyclohexene-4-acetic acid, and that the view of Marckwald and Meth that it is 1-methylcyclohexylidene-4-acetic acid must be abandoned.

It follows therefore that, in spite of the interesting and valuable work of these investigators, the problem of the resolution of a substance of the type

(compare *Trans.*, 1908, **93**, 1075) still awaits solution.

EXPERIMENTAL.

α-Cyano-Δ¹-cyclohexeneacetic Acid,

In preparing ethyl *α*-cyano-*Δ*¹-cyclohexeneacetate, ethyl cyanoacetate (56 grams) was added to a solution of sodium (12 grams) in alcohol, and, after heating to boiling, *cyclohexanone* (54 grams) was added; as soon as the sodium derivative had passed into solution, the product was rapidly cooled, diluted with water, acidified with hydrochloric acid, and extracted with ether. The ethereal solution was washed with dilute sodium carbonate (*A*), dried and evaporated, and the residue distilled under reduced pressure, when, after some unchanged *cyclohexanone* had passed over, *ethyl α-cyano-Δ¹-cyclohexeneacetate* (15 grams) distilled constantly at 174°/25 mm. as a viscid oil possessing the odour of a nitrile:

0.1698 gave 10.8 c.c. N₂ at 18° and 774 mm. N = 7.5.

C₁₁H₁₆O₂N requires N = 7.2 per cent.

When the mixture of the sodium derivative of ethyl cyanoacetate and *cyclohexanone* (prepared as described above) is boiled on the water-bath for an hour, it becomes reddish-brown, and a sodium salt separates.

If the product is decomposed with acid and the ethereal extract treated with sodium carbonate, it yields a neutral oil and an acid. The neutral oil contains *cyclohexanone*, *Δ¹-cyclohexeneacetoneitrile* (p. 1959), and a small quantity of ethyl *α*-cyano-*Δ¹-cyclohexeneacetate*.

The sodium carbonate extract yields, on acidifying, a viscid syrup, which, when cooled in ice and salt and stirred, soon solidifies, and, in contact with porous porcelain, the oily impurity is gradually absorbed, leaving a solid residue of crude *α*-cyano-*Δ¹-cyclohexeneacetic acid*, which is best purified by recrystallisation from benzene:

0.1302 gave 0.3096 CO₂ and 0.0760 H₂O. C = 65.6; H = 6.4.

0.1502 „ 11.4 c.c. N₂ at 21° and 775 mm. N = 8.5.

C₉H₁₁O₂N requires C = 65.5; H = 6.6; N = 8.5 per cent.

α-Cyano-Δ¹-cyclohexeneacetic acid separates from benzene in short needles, and melts at 109–110°. It is almost insoluble in cold,

but more readily so in hot, water, and crystallises, on cooling, in irregular groups of needles. It does not react with hydrobromic acid in the cold, but its solution in sodium carbonate instantly decolorises permanganate. Its solution in strong potassium hydroxide gradually decomposes with separation of *cyclohexanone*.

When the sodium carbonate extract (A) (p. 1956) is acidified and extracted with ether, a yellow syrupy acid is obtained in quantity, which, on long standing, partly crystallises. This was left in contact with porous porcelain until free from oil, and recrystallised either from water or by adding light petroleum to its solution in ether :

- I. 0.1143 gave 0.2376 CO₂ and 0.0691 H₂O. C = 56.6 ; H = 6.7.
 II. 0.1125 „ 0.2330 CO₂ „ 0.0706 H₂O. C = 56.5 ; H = 6.9.
 III. 0.1199 „ 10.2 c.c. N₂ at 12° and 753 mm. N = 9.5.
 IV. 0.1575 „ 13.2 c.c. N₂ „ 17° „ 752 mm. N = 9.6.
 C₁₄H₂₀O₅N₂ requires C = 56.8 ; H = 6.8 ; N = 9.4 per cent.

Analyses I and III were made with substance which had been recrystallised from water ; II and IV from ether and light petroleum.

The basicity of this acid was determined by titration with decinormal sodium hydroxide, when 0.2441 neutralised 0.0330 NaOH, whereas this amount of a monobasic acid, C₁₄H₂₀O₅N₂, should neutralise 0.0340 NaOH. This curious acid has the composition cyano-Δ¹-*cyclohexeneacetic acid* + *cyanoacetic ester* + water :

and was obtained on several occasions and always with the same properties, so that it is doubtless a definite substance.

When it is boiled with sodium carbonate, it is decomposed into α-cyano-Δ¹-*cyclohexeneacetic acid* and an oil, which is evidently cyanoacetic ester. It is difficult to assign a satisfactory constitutional formula to this acid.

During the course of an experiment in which *cyclohexanone* and ethyl cyanoacetate were condensed in methyl-alcoholic solution, the resulting crude methyl α-cyano-Δ¹-*cyclohexeneacetate* gradually deposited a small quantity of a crystalline substance. This was collected and crystallised from benzene, from which it separated in short prisms melting at 170—171° :

- 0.1366 gave 0.3724 CO₂ and 0.0971 H₂O. C = 74.4 ; H = 7.9.
 0.1395 „ 7.0 c.c. N₂ at 16° and 755 mm. N = 5.8.

C₁₆H₂₁O₂N requires C = 74.1 ; H = 8.1 ; N = 5.4 per cent.

This substance is evidently *methyl α-cyanodi-Δ¹-cyclohexeneacetate*, and doubtless has the constitution

It was not further investigated.

The Condensation of cycloHexanone with Ethyl Cyanoacetate and with Cyanoacetic Acid in the Presence of Piperidine.

When equimolecular proportions of *cyclohexanone* and *ethyl cyanoacetate* are mixed with a few drops of *piperidine* and allowed to stand, condensation takes place readily with separation of water.

The product is heated for two hours on the water-bath, diluted with water, and extracted with ether, the ethereal solution well washed with dilute hydrochloric acid, dried and evaporated, and the pale yellow oil distilled under reduced pressure, when a good yield of *ethyl α-cyano-Δ¹-cyclohexeneacetate* (p. 1956), distilling at 165—167°/15 mm., is obtained :

0·1393 gave 0·3463 CO₂ and 0·0947 H₂O. C = 67·9 ; H = 7·7.

0·1836 „ 12·2 c.c. N₂ at 15° and 754 mm. N = 7·7.

C₁₁H₁₅O₂N requires C = 68·4 ; H = 7·8 ; N = 7·2 per cent.

α-Cyano-Δ¹-cyclohexeneacetic acid is readily obtained directly when *cyclohexanone* (7 grams) is added to a mixture of *cyanoacetic acid* (6 grams) and *piperidine* (8 grams). The mixture is allowed to stand for two hours, and then heated on the water-bath for one hour.

After diluting with water, the product acidified, is extracted with ether, the ethereal solution well shaken with sodium carbonate, the alkaline solution acidified, and again extracted with ether. The ethereal extract deposits, on evaporation, a good yield of crude *α-cyano-Δ¹-cyclohexeneacetic acid*, which, after crystallisation from benzene, melts at 109—110°.

Ethyl α-Cyano-β-benzoyl-α-Δ¹-cyclohexenepropionate,

This crystalline substance was prepared with the object of proving the identity of the oily esters (*ethyl α-cyano-Δ¹-cyclohexeneacetate*) obtained by the condensation of *cyclohexanone* with *ethyl cyanoacetate* in the presence of sodium and *piperidine* respectively (compare p. 1956 and the last section). In each case, the ester (10 grams) was mixed with sodium (1·2 grams), dissolved in alcohol, and then *ω*-bromoacetophenone (10 grams) gradually added to the yellow solution.

Decomposition commences in the cold, and is completed by heating on the water-bath for fifteen minutes. The product is diluted with water, extracted with ether, the ethereal solution washed well, and evaporated, when a syrup remains, which, if rubbed under water with a sharp glass rod, gradually crystallises. The mass was left in contact with porous porcelain until quite hard, and then crystallised twice

from light petroleum, from which it separated in crusts melting at 83°: [View Online](#)

0.1560 gave 6.4 c.c. N₂ at 24° and 760 mm. N = 4.6.

C₁₉H₂₁O₃N requires N = 4.5.

Experiments showed that the derivatives which resulted in the above manner from the cyano-esters, obtained by the sodium and piperidine condensations, were identical in all respects.

Δ¹-cycloHexeneacetonitrile and Δ¹-cycloHexeneacetic Acid,

α-Cyano-Δ¹-cyclohexeneacetic acid is readily decomposed on slow distillation under a pressure of 90 mm., with elimination of carbon dioxide and formation of Δ¹-cyclohexeneacetonitrile, which distils at about 120—160° in the first instance. The temperature then rises rapidly, and, if the distillation is continued under 15 mm. pressure, a small quantity of a viscid oil is obtained, which crystallises, and the examination of which is not yet complete. The nitrile was purified by repeated distillation, and then analysed:

0.0985 gave 10.2 c.c. N₂ at 11° and 748 mm. N = 12.1.

C₈H₁₁N requires N = 11.6 per cent.

Δ¹-cycloHexeneacetonitrile is a colourless liquid, which distils at 144°/90 mm., and has the pungent odour characteristic of nitriles; it combines with hydrobromic acid, with formation of an oily hydrobromide.

Hydrolysis.—The conversion of the nitrile into the corresponding acid appears to take place best under the following conditions.

The nitrile (20 grams) is digested with twice its volume of alcohol, containing 20 per cent. of sulphuric acid, for thirty-six hours, the product is diluted with water, extracted with ether, the ethereal solution washed well, dried, evaporated, and the residue distilled under 90 mm. pressure. The distillate, which consists of ethyl Δ¹-cyclohexeneacetate and some unchanged nitrile, is digested with alcoholic potash for twenty minutes, diluted with water, and the unchanged nitrile and amide removed by extraction with ether.* The aqueous solution was evaporated until free from alcohol, cooled with ice, and acidified, when a viscid, syrupy acid separated, which, especially if rubbed with a glass rod, soon solidified. It was collected, washed well, drained on porous porcelain, and distilled under diminished pressure:

* This oil gradually deposited crystals of Δ¹-cyclohexeneacetamide, which separated from aqueous alcohol in glistening leaflets and melted at 152° (compare Wallach, *Annalen*, 1907, **353**, 292).

0.1282 gave 0.3228 CO₂ and 0.0960 H₂O. C = 68.5; H = 8.4.

C₈H₁₂O₂ requires C = 68.6; H = 8.6 per cent.

Δ¹-cycloHexeneacetic acid melts at about 38°, distils at 145° (17 mm.), and is identical with the acid of this constitution described by Wallach (*Annalen*, 1907, 353, 290), and which he obtained by an entirely different process. In order to be certain of the identity, the acid, prepared as described above, was left in contact with fuming aqueous hydrobromic acid, when it was converted into β-bromocyclohexylacetic acid, which, after crystallisation from light petroleum, melted at 89—91°:

0.1512 gave 0.1270 AgBr. Br = 35.7.

C₈H₁₂O₂Br requires Br = 36.1 per cent.

Wallach (*loc. cit.*) gives 89—90° as the melting point of this bromo-acid. We were also able to confirm Wallach's observation that Δ¹-cyclohexeneacetic acid does not undergo isomeric change when boiled with strong alkalis, since, even after digesting for sixty hours with concentrated aqueous barium hydroxide, more than 75 per cent. of the acid was recovered unchanged.

Oxidation of Ethyl Δ¹-cycloHexeneacetate by Means of Ozone.

Wallach (*Annalen*, 1905, 343, 53; 1907, 353, 294; 1908, 359, 287) has shown that Δ¹-cyclohexeneacetic acid is converted by oxidation with permanganate into δ-acetylvaleric acid,

a decomposition which clearly proves its constitution, but, as it was important to demonstrate the complete analogy between this acid and 1-methyl-Δ³-cyclohexene-4-acetic acid (p. 1948), we carried out a series of experiments on the oxidation of its ester by ozone.

For this purpose, the ester (5 grams) was dissolved in twice its volume of chloroform in a wide test-tube, a little water was added, and then ozone passed for several days and until it escaped freely.

The chloroform solution was diluted with ether, washed with sodium carbonate, dried, and the chloroform and ether removed by distillation under reduced pressure, when a neutral oil was obtained, which, in alcoholic solution, gave an intense blood-red coloration with ferric chloride, and there can be little doubt that this consisted essentially of the compound

(compare p. 1946). No attempt was made to purify and analyse this substance, and it was at once digested with dilute sulphuric acid and distilled in steam, when a volatile oil passed over, having the pungent odour characteristic of unsaturated ketones, and yielding a semicarbazone

which, after two recrystallisations from alcohol, melted with decomposition at 203—205°:

0.1439 gave 0.3021 CO₂ and 0.1073 H₂O. C = 57.3; H = 8.2.

C₈H₁₄ON₃ requires C = 57.5; H = 7.8 per cent.

It is explained in the introduction (p. 1946) that there can be little doubt that this volatile ketone has the formula

and is therefore Δ^1 -cyclopentene methyl ketone. It is most probably identical with the ketone which Wallach (*Annalen*, 1907, 353, 293) obtained by the oxidation of Δ^1 -cyclohexeneacetic acid with permanganate, and which also yielded a semicarbazone of melting point 203—204°. Wallach made the important observation that this ketone yields glutaric acid when oxidised by chromic acid, a fact which strongly supports the above view of its constitution.

When the crude, semi-solid cyano-acid, obtained by the condensation of ethyl sodiocyanoacetate and cyclohexanone under the conditions given on p. 1956, is distilled without further purification, and the nitrile obtained treated with sulphuric acid and alcohol and afterwards with alcoholic potassium hydroxide (p. 1959), a relatively large amount escapes hydrolysis, which is not the case when pure Δ^1 -cyclohexeneacetonitrile is employed. The unchanged nitrile was again subjected to the action of alcoholic sulphuric acid until it was completely esterified, and the product yielded, on hydrolysis with alcoholic potash, a small quantity of an acid which melted at 89—90°:

0.1331 gave 0.3339 CO₂ and 0.1024 H₂O. C = 68.5; H = 8.5.

C₈H₁₂O₂ requires C = 68.6; H = 8.6 per cent.

There can be no doubt that this acid is cyclohexylideneacetic acid, and is identical with the acid (m. p. 91°) which Wallach (*Annalen*, 1907, 353, 288) obtained from cyclohexanolacetic ester by elimination of water and subsequent hydrolysis.

α - Δ^1 -cycloHexenepropionitrile and α - Δ^1 -cycloHexenepropionic Acid,

These substances are readily obtained from α -cyano- Δ^1 -cyclohexeneacetic ester by the following process.

The cyano-ester (30 grams) is added to sodium (3.5 grams), dissolved in methyl alcohol, and the intense yellow solution gradually mixed

with a considerable excess of methyl iodide, when rise of temperature takes place and the yellow colour disappears. After heating on the water-bath for forty-five minutes, the product is diluted with water, extracted with ether, the ethereal solution washed well, dried, evaporated, and the oil fractionated, when a considerable quantity distils at 140—142° (10 mm.) and consists of nearly pure *methyl α-cyano-α-Δ¹-cyclohexenepropionate*,

0·1818 gave 11·9 c.c. N₂ at 13° and 762 mm. N = 7·7.

C₁₁H₁₅O₂N requires N = 7·2 per cent.

This oil was digested with excess of alcoholic potassium hydroxide for ten minutes, water was then added, the alcohol removed by evaporation, the alkaline solution acidified, and repeatedly extracted with ether.

The ethereal solution was dried, evaporated, and the residue distilled under 90 mm. pressure, when carbon dioxide was eliminated and *α-Δ¹-cyclohexenepropionitrile* was obtained as a colourless oil (12 grams), which, after repeated fractionation, distilled at about 150°/90 mm. :

0·1348 gave 0·3960 CO₂ and 0·1204 H₂O. C = 80·1 ; H 9·9.

0·1727 „ 16·1 c.c. N₂ at 18° and 751 mm. N = 10·5.

0·1129 „ 10·0 c.c. N₂ at 17° „ 764 mm. N = 10·3.

C₉H₁₃N requires C = 80·0 ; H = 9·6 ; N = 10·4 per cent.

On attempting to hydrolyse this nitrile, it was found that it exhibited remarkable stability towards the usual acid and alkaline hydrolytic agents, but, after boiling with alcoholic sulphuric acid for many hours, it was converted into ethyl *α-Δ¹-cyclohexenepropionate*, and this, on hydrolysis with alcoholic potash, yielded the free acid. Prepared in this manner, *α-Δ¹-cyclohexenepropionic acid* is a viscid oil, which distils at about 145°/18 mm. :

0·1379 gave 0·3495 CO₂ and 0·1069 H₂O. C = 69·1 ; H = 8·6.

C₉H₁₄O₂ requires C = 70·1 ; H = 8·6 per cent.

The *silver* salt was obtained, on the addition of silver nitrate to the slightly alkaline solution of the ammonium salt, as a curdy, white precipitate :

0·3862 gave 0·1596 Ag. Ag = 41·3.

C₉H₁₃O₂Ag requires Ag = 41·3 per cent.

α-Δ¹-cyclohexenepropionic acid has quite recently been prepared by Wallach (*Annalen*, 1903, 360, 44) from the product of the condensation of *cyclohexanone* with ethyl *α*-bromopropionate, and he describes it as an oil distilling at 148—150°/13 mm.

The Action of Bromine and Sodium Carbonate on Δ^1 -cycloHexeneacetic Acid. Formation of the Lactone of 2-Bromo-1-hydroxycyclohexyl-2-acetic Acid,

In this experiment, pure Δ^1 -cyclohexeneacetic acid (m. p. 38° ; 4.7 grams) was dissolved in dilute sodium carbonate (3.5 grams), and, after mixing with powdered ice, bromine (5.3 grams), dissolved in water, was gradually added. The cloudy liquid was extracted with ether, the ethereal solution washed well, dried, evaporated, and the syrup left over sulphuric acid in an evacuated desiccator, when it deposited a quantity of crystals, but much oil remained. The mass was left in contact with porous porcelain until quite dry, and then washed with light petroleum (b. p. $35-40^\circ$):

0.1585 gave 0.2530 CO_2 and 0.0710 H_2O . C = 43.5; H = 5.0.

$\text{C}_8\text{H}_{11}\text{O}_2\text{Br}$ requires C = 43.8; H = 5.0 per cent.

Purified in this manner, the lactone of 2-bromo-1-hydroxycyclohexyl-2-acetic acid is a colourless, crystalline substance, which melts at about 70° , and is insoluble in cold sodium carbonate, but dissolves readily in hot dilute potassium hydroxide. Some of the lactone was heated with water at $140-150^\circ$ for three hours, when a ketone was obtained, which, after distillation in steam, was converted into the semicarbazone in the usual manner. This separated from methyl alcohol as a colourless, crystalline mass, and melted at 192° :

0.1141 gave 0.2365 CO_2 and 0.0929 H_2O . C = 56.6; H = 9.0.

0.1074 „ 24 c.c. N_2 at 24° and 760 mm. N = 25.0.

$\text{C}_8\text{H}_{15}\text{ON}_3$ requires C = 56.8; H = 8.9; N = 24.8 per cent.

That this substance was the semicarbazone of 1-methylcyclohexan-2-one, $\text{CH}_2 \begin{array}{l} \diagup \text{CH}_2 - \text{CO} \diagdown \\ \diagdown \text{CH}_2 \cdot \text{CH}_2 \diagup \end{array} \text{CHMe}$, was proved by mixing it with a specimen of the semicarbazone prepared from 1-methylcyclohexan-2-one from *o*-cresol, when there was no alteration in melting point.

The Condensation of 1-Methylcyclohexan-4-one with Ethyl Cyanoacetate. α -Cyano-1-methyl- Δ^3 -cyclohexene-4-acetic Acid,

The condensation of 1-methylcyclohexan-4-one with ethyl sodiocyanoacetate was carried out under the following conditions.

Sodium (11.5 grams), dissolved in alcohol, was mixed with ethyl cyanoacetate (56 grams) and methylcyclohexanone (56 grams), when

the white sodium derivative soon dissolved, and a yellow solution was obtained. The whole was heated for half an hour on the water-bath, the bulky, yellow sodium derivative which separated decomposed by water and dilute hydrochloric acid, extracted with ether, the ethereal solution washed with water and dilute sodium carbonate, dried, and evaporated. On fractionating the residual oil, a small quantity of methylcyclohexanone was recovered, and ethyl α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetate then distilled at 175°/20 mm. or 167°/14 mm. as a viscid, colourless oil :

0.1745 gave 0.4460 CO₂ and 0.1300 H₂O. C = 69.7 ; H = 8.3.

0.2477 „ 14 c.c. N₂ at 20° and 775 mm. N = 6.6.

C₁₂H₁₇O₂N requires C = 69.6 ; H = 8.2 ; N = 6.8 per cent.

The sodium carbonate extract of the product of condensation (see above) yielded, on acidifying with hydrochloric acid, a considerable quantity of a viscid syrup, which was extracted with ether.

After the ethereal solution had been dried and evaporated, the pale yellow residue was poured into a basin, when it rapidly crystallised, and, in contact with porous porcelain, the oily impurity was rapidly absorbed, leaving a colourless, crystalline mass, which was purified by solution in benzene and addition of light petroleum until a cloudiness appeared. On vigorously stirring, the acid separated in prisms :

0.1693 gave 12 c.c. N₂ at 19° and 760 mm. N = 8.1.

C₁₀H₁₃O₂N requires N = 7.8 per cent.

α -Cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid melts at 116°, and is sparingly soluble in water or light petroleum, but readily so in ether, alcohol, or benzene. It dissolves in aqueous potassium hydroxide (30 per cent.), yielding a clear solution, which soon clouds, owing to separation of 1-methylcyclohexan-4-one.

When the condensation of ethyl sodiocyanoacetate with methylcyclohexanone is carried out under the above conditions, the principal product obtained is the cyano-acid just described. If, however, the methylcyclohexanone is added to the ethyl sodiocyanoacetate suspended in hot alcohol, the sodium derivative dissolves immediately, and on cooling rapidly, extracting at once as before, and treating with sodium carbonate, the principal product is ethyl α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetate. The sodium carbonate extract yields, on acidifying and extracting with ether, a solid mass, which, by crystallisation from benzene, may be separated into two substances, melting at 105° and 186° respectively. The substance of melting point 105° crystallised in colourless needles, and possibly consisted of α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid, crystallising with $\frac{1}{2}$ H₂O :

0.1160 gave 0.2730 CO₂ and 0.0780 H₂O. C = 64.2; H = 7.5.

0.1486 „ 10 c.c. N₂ at 26° and 760 mm. N = 7.5.

C₁₀H₁₃O₂N, $\frac{1}{2}$ H₂O requires C = 63.8; H = 7.4; N = 7.4 per cent.

The substance of melting point 186° separated from benzene in feathery needles:

0.1300 gave 0.2930 CO₂ and 0.0830 H₂O. C = 61.4; H = 7.0.

0.1100 „ 9.4 c.c. N₂ at 26° and 764 mm. N = 9.5.

C₁₅H₂₀O₄N₂ requires C = 61.6; H = 6.8; N = 9.6 per cent.

The formula of this substance corresponds with that obtained by adding the formulæ of α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid and cyanoacetic ester:

and there can be no doubt that it is a definite compound, and obviously somewhat similarly constituted to the substance obtained under similar conditions from cyclohexanone (p. 1957). When it is boiled with sodium carbonate, it is decomposed, with formation of α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid.

Condensation of 1-Methylcyclohexan-4-one with Ethyl Cyanoacetate and with Cyanoacetic Acid in the Presence of Piperidine.

When ethyl cyanoacetate (28 grams) is mixed with methylcyclohexanone (28 grams) and a few drops of piperidine, the solution gradually clouds, owing to the separation of water. After heating on the water-bath for half an hour, the product was dissolved in ether, washed with dilute hydrochloric acid, the ethereal solution dried and evaporated, and the residue fractionated under diminished pressure, when an almost quantitative yield of ethyl α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetate was obtained, boiling at 165–168°/14 mm.:

0.2066 gave 0.5274 CO₂ and 0.1560 H₂O. C = 69.6; H = 8.3.

C₁₂H₁₇O₂N requires C = 69.6; H = 8.2 per cent.

This ester is readily hydrolysed by boiling in alcoholic solution with a slight excess of sodium methoxide, diluting with water, and evaporating until free from alcohol. After removing any unchanged ester by extraction with ether, the alkaline solution is acidified, and extracted in the usual way, when a colourless, crystalline mass of α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid is obtained, which, after crystallisation from benzene and light petroleum, melts at 116° (compare p. 1964). It was subsequently found that this acid may be obtained directly from methylcyclohexanone and cyanoacetic acid in the following way. Methylcyclohexanone (6 grams) is mixed with finely-powdered cyanoacetic acid (5 grams), piperidine (4.5 grams) is added, and the whole allowed to remain overnight and then heated on the

water-bath for two hours. The product is extracted with ether, the ethereal solution washed with dilute hydrochloric acid, and shaken with sodium carbonate. The alkaline extract is acidified, again extracted with ether, and the solid product crystallised from benzene, when a good yield of α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid is obtained, melting at 116° .

Proof of the Identity of the Condensation Products obtained from 1-Methylcyclohexan-4-one and Ethyl Cyanoacetate with Sodium Ethoxide and Piperidine respectively.

This important point was established by converting each condensation product into the same solid derivative with the aid of ω -bromoacetophenone. The conditions employed were exactly the same in both comparative experiments.

The condensation product (11 grams) was added to sodium (1.15 grams), dissolved in alcohol, and the clear yellow solution mixed with ω -bromoacetophenone (10 grams), when, in a few minutes, the yellow colour disappeared and sodium bromide separated. After remaining overnight, water was added, the product extracted with ether, the ethereal solution washed, dried, and evaporated, when a syrup was obtained, which, in contact with light petroleum, soon solidified. The mass was drained on porous porcelain and recrystallised from light petroleum, from which it separated in colourless needles:

0.1230 gave 0.3308 CO_2 and 0.0780 H_2O . $\text{C} = 73.4$; $\text{H} = 7.0$.

0.1233 „ 0.3340 CO_2 „ 0.0770 H_2O . $\text{C} = 73.9$; $\text{H} = 7.0$.

$\text{C}_{20}\text{H}_{23}\text{O}_3\text{N}$ requires $\text{C} = 73.8$; $\text{H} = 7.1$ per cent.

Ethyl α -Cyano- β -benzoyl- α -1-methyl- Δ^3 -4-cyclohexenepropionate,

melts at 74° , and is hydrolysed by cold aqueous potassium hydroxide with the formation of a solid acid, which, when boiled with alkalis, is decomposed with separation of acetophenone. Careful comparison showed that the esters obtained from methylcyclohexanone and ethyl cyanoacetate with the aid of sodium or piperidine, both yielded the same condensation product (m. p. 74°) with ω -bromoacetophenone.

1-Methyl- Δ^3 -cyclohexene-4-acetonitrile and 1-Methyl- Δ^3 -cyclohexene-

α -Cyano-1-methyl- Δ^3 -cyclohexene-4-acetic acid is readily decomposed when it is distilled under 13 mm., with elimination of carbon dioxide and formation of 1-methyl- Δ^3 -cyclohexene-4-acetonitrile, the process being nearly quantitative. On refractionating the distillate under 100 mm. pressure, the nitrile was readily obtained pure as a colourless oil, distilling at 155—156°, and having a pungent odour resembling that of tolunitrile:

0.1112 gave 10 c.c. N_2 at 18° and 758 mm. $\text{N} = 10.4$.

$\text{C}_9\text{H}_{13}\text{N}$ requires $\text{N} = 10.4$ per cent.

The hydrolysis of this nitrile is best carried out by digesting it for twenty-four hours with 20 per cent. alcoholic sulphuric acid, when, on cooling, crystals of ammonium sulphate separate. After the addition of water, the product is extracted with ether, the ethereal solution well washed with water and dilute sodium carbonate, dried, and distilled, when almost the whole quantity passes over at 175—185°/200 mm., and consists of a mixture of *ethyl 1-methyl- Δ^3 -cyclohexene-4-acetate* with some unchanged nitrile. The distillate was divided into two portions, one of which was hydrolysed by leaving it in contact with an excess of methyl-alcoholic potash for twenty-four hours. The product was diluted with water, unchanged nitrile removed by extraction with ether, the aqueous solution saturated with carbon dioxide, and evaporated until quite free from methyl alcohol. When the well-cooled solution was acidified with hydrochloric acid, an oily acid separated, which rapidly crystallised, and, after remaining in contact with porous porcelain over sulphuric acid, the colourless, crystalline mass melted at 39—41° and gave the following results on analysis:

0.1160 gave 0.2972 CO_2 and 0.0960 H_2O . $\text{C} = 69.9$; $\text{H} = 9.2$.

$\text{C}_9\text{H}_{14}\text{O}_2$ requires $\text{C} = 70.1$; $\text{H} = 9.1$ per cent.

It is explained in the introduction (p. 1948) that 1-methyl- Δ^3 -cyclohexene-4-acetic acid, obtained in this way, is identical with the acid which Marckwald has described as 1-methyl-cyclohexylidene-4-acetic acid. The second portion of the ester was digested for three hours with hydrochloric acid (1 vol. of concentrated acid, and 1 vol. of water), the oil extracted with ether, and the ethereal solution, after washing with water, well shaken with sodium carbonate.

The alkaline solution was freed from ether by evaporation, cooled with ice, and acidified, when a mass of crystals separated, which, after drying on porous porcelain, melted at 40—41° and consisted of pure 1-methyl- Δ^3 -cyclohexene-4-acetic acid. In another experiment, in which

the ester was digested with strong aqueous barium hydroxide containing a little potassium hydroxide, the same acid of melting point 41° was obtained, and, in addition, a considerable quantity of another acid melting at 138° . This latter acid is 4-hydroxy-1-methylcyclohexyl-4-acetic acid,

since, when mixed with a specimen of this acid which had been obtained by the condensation of methylcyclohexanone with ethyl bromoacetate (Marckwald and Meth, *Ber.*, 1906, **39**, 1173), the mixture melted at $139\text{--}140^{\circ}$. Obviously therefore, under the conditions employed in this experiment, addition of water to the double linking in methyl- Δ^3 -cyclohexene-4-acetic acid had taken place to a considerable extent.

Ethyl 1-Methyl- Δ^3 -cyclohexene-4-acetate.—In order to prepare this ester in a pure state, the pure acid was digested with 10 per cent. alcoholic sulphuric acid for six hours, the product diluted with water, and extracted with ether. The ethereal solution was well washed with dilute sodium carbonate, dried, evaporated, and the residual ester fractionated, when it distilled constantly at $111^{\circ}/14$ mm. :

0.1290 gave 0.3420 CO_2 and 0.1136 H_2O . C = 72.3 ; H = 9.8.

$\text{C}_{11}\text{H}_{18}\text{O}_2$ requires C = 72.5 ; H = 9.9 per cent.

Oxidation of Ethyl 1-Methyl- Δ^3 -cyclohexene-4-acetate by Means of Ozone.

In carrying out this experiment, the pure ester was dissolved in chloroform, covered with water, and ozonised oxygen passed for several hours and until it escaped freely. The product was mixed with ether, the ethereal solution extracted with sodium hydrogen carbonate, dried, and evaporated, when a colourless oil remained which possessed the pungent odour of an aldehyde, and distilled, with the exception of a small quantity of resin, at $150\text{--}160^{\circ}/20$ mm. :

0.1280 gave 0.2840 CO_2 and 0.0976 H_2O . C = 60.5 ; H = 8.4.

$\text{C}_{11}\text{H}_{18}\text{O}_4$ requires C = 61.7 ; H = 8.4 per cent.

It is explained in the introduction (p. 1949) that this oily ester, which, in alcoholic solution, gives on the addition of ferric chloride a deep purple coloration, is doubtless *ethyl ζ -aldehydo- β -keto-isooctate*,

In order to hydrolyse this ester, it was mixed with dilute sulphuric acid and submitted to distillation in steam, when a mobile oil volatilised, which had an odour resembling that of the cyclic unsaturated ketones. The oil was extracted with ether, and, although only small in amount, it was distilled and found to consist essentially of a substance distilling at about $110\text{--}115^{\circ}/100$ mm. Small quantities of higher

fractions were also obtained, and, as these yielded the same results on analysis as the lower boiling substance, they apparently consisted of polymerides of this (compare Wallach, *Annalen*, 1907, **353**, 294). The fraction 110—115°/100 mm. yielded, on analysis, the following approximate figures, the difference being due to a trace of moisture, which, owing to the small amount of material at our disposal, we were unable to remove completely:

0.1220 gave 0.3360 CO₂ and 0.1110 H₂O. C = 75.2; H = 10.1.

C₈H₁₂O requires C = 77.4; H = 9.7 per cent.

That this is the formula for the ketone was proved by the preparation of the *semicarbazone*, which separates gradually when the ketone is shaken with strong aqueous semicarbazide hydrochloride and sodium acetate, and which crystallises from dilute methyl alcohol in short needles melting at 207—209°:

0.1096 gave 0.2400 CO₂ and 0.0860 H₂O. C = 59.7; H = 8.5.

0.0716 „ 0.1570 CO₂ „ 0.0550 H₂O. C = 59.8; H = 8.5.

0.0790 „ 16 c.c. N₂ at 20° and 758 mm. N = 23.0

C₉H₁₅O₃N requires C = 59.7; H = 8.3; N = 23.2 per cent.

It is explained in the introduction (p. 1949) that the ketone C₈H₁₂O is doubtless 1-methyl-Δ³-4-cyclopentene methyl ketone,

3 : 4-Dibromo-1-methylcyclohexyl-4-acetic Acid,

1-Methyl-Δ³-cyclohexene-4-acetic acid readily absorbs bromine when the halogen is added to its solution in glacial acetic acid at 0°, and the addition is complete when the liquid has acquired a permanent yellow colour. On diluting with water, a viscid oil separates, which gradually crystallises, especially if vigorously stirred, and, after remaining in contact with porous porcelain until free from oil and then crystallising from formic acid, the dibromide is readily obtained pure:

0.2050 gave 0.2440 AgBr. Br = 50.6.

C₉H₁₄O₂Br₂ requires Br = 50.9 per cent.

3 : 4-Dibromo-1-methylcyclohexyl-4-acetic acid melts at 104°, and has already been prepared by Wallach (*Annalen*, 1907, **353**, 312), who obtained it by the addition of bromine to the solution of the unsaturated acid in light petroleum, and states that it melts at 97—99°.

When this dibromo-acid is ground to a paste with water and shaken with sodium carbonate, it dissolves, and, in a short time, the solution

clouds and a heavy oil separates. This oil appears to be a mixture, and its investigation is not yet complete.

We have, however, found that, when heated with water at 140—150° (compare p. 1972), it is converted into 1:4-dimethylcyclohexan-2-one.

The ketone was extracted with ether, the ethereal solution dried, evaporated, and the oily residue fractionated, when a considerable quantity distilled at 174—177° and consisted of nearly pure 1:4-dimethylcyclohexan-2-one:

0.1674 gave 0.4640 CO₂ and 0.1740 H₂O. C = 75.6; H = 11.5.

C₈H₁₄O requires C = 76.2; H = 11.1 per cent.

When this ketone was shaken with excess of semicarbazide hydrochloride and sodium acetate, it was gradually converted into the solid semicarbazone, which, after crystallisation from methyl alcohol, melted at 167°, and was identical with the semicarbazone of 1:4-dimethylcyclohexan-2-one:

0.0923 gave 0.1985 CO₂ and 0.0810 H₂O. C = 58.7; H = 9.7.

C₉H₁₇ON₃ requires C = 59.0; H = 9.3.

The Action of Bromine and Sodium Carbonate on 1-Methyl-Δ³-cyclohexene-4-acetic Acid. Formation of the Lactone of 4-Bromo-3-hydroxy-1-methylcyclohexyl-4-acetic Acid,

In this experiment, pure 1-methylcyclohexene-4-acetic acid (5 grams) was dissolved in dilute sodium carbonate (3.5 grams), and then bromine (5.3 grams), dissolved in water, gradually added, care being taken that the temperature did not rise above 10°.

The addition of the bromine water caused an immediate cloudiness, and, on standing, a heavy oil separated, which gradually crystallised.

The whole was extracted with ether, the ethereal solution washed well, dried, and evaporated, when a pale yellow syrup (7.5 grams) remained, which soon crystallised. The mass was left in contact with porous porcelain until quite free from oil, and then crystallised from light petroleum:

0.1756 gave 0.3000 CO₂ and 0.0920 H₂O. C = 46.5; H = 5.8.

0.1880 „ 0.1530 AgBr. Br = 34.5.

C₉H₁₃O₂Br requires C = 46.4; H = 5.6; Br = 34.3 per cent.

The lactone of 4-bromo-3-hydroxy-1-methylcyclohexyl-4-acetic acid melts at 102—103°, and, when heated at 125—130°, decomposes with elimination of carbon dioxide and hydrogen bromide. It is readily soluble in ether, alcohol, benzene, or chloroform, but sparingly so in cold light petroleum, and separates as a woolly mass of slender needles

when the hot solution in light petroleum (b. p. 70—80°) is allowed to cool slowly. The lactone is very slowly attacked by boiling water, and is insoluble in warm dilute sodium carbonate, but it dissolves gradually in hot dilute potassium hydroxide. In order to investigate its behaviour with alkali, a considerable quantity of the lactone was dissolved in dilute potassium hydroxide at 80°, and, after standing for two days, excess of potassium hydroxide was added and the whole heated on the water-bath for two hours. The product was acidified, extracted, and the ethereal solution dried and evaporated, when a viscid, yellow syrup remained, which was free from bromine, but showed no signs of crystallising. It was dissolved in boiling water, made distinctly alkaline by the addition of barium hydroxide, and the excess removed by passing carbon dioxide. After filtering, the almost colourless filtrate was acidified and extracted with ether, the ethereal solution was then very carefully dried, evaporated, and the syrup left over sulphuric acid in an evacuated desiccator until quite free from ether. The analysis shows that the syrup consists of the free acid and not of the lactone:

0.1452 gave 0.3150 CO₂ and 0.1140 H₂O. C = 57.2; H = 8.7.

C₉H₁₆O₄ requires C = 57.4; H = 8.5 per cent.

The basicity of this acid was determined by titration with decinormal sodium hydroxide, when 0.306 neutralised 0.0652 NaOH, whereas this amount of a monobasic acid, C₉H₁₆O₄, requires 0.0651 NaOH for neutralisation. There can be little doubt that this acid is 3:4-dihydroxy-1-methylcyclohexyl-4-acetic acid,

This acid dissolves readily in hot water, but strong solutions cloud on cooling.

The slightly alkaline solution of the ammonium salt gives no precipitate with barium or calcium chlorides. Copper sulphate gives a pale blue, amorphous precipitate, and lead acetate a caseous precipitate. If silver nitrate is added to a not too dilute solution of the ammonium salt, a gelatinous *silver* salt separates, which dissolves in hot water and crystallises, on cooling, in microscopic balls of needles. When the syrupy hydroxy-acid is heated under 13 mm. pressure, water is eliminated, and a viscid oil distils remarkably constantly at 186—188°/13 mm., which is sparingly soluble in cold water and in dilute sodium carbonate, but dissolves readily on warming. The analysis gave the following results:

0.1590 gave 0.3670 CO₂ and 0.1185 H₂O. C = 63.0; H = 8.2.

C₉H₁₄O₃ requires C = 63.5; H = 8.2.

This substance is therefore the lactone of 3:4-dihydroxy-1-methyl-cyclohexyl-4-acetic acid.

In investigating the action of water on the lactone, $C_9H_{13}O_2Br$, it was heated, in quantities of one gram, with water (7 c.c.) in a sealed tube at 140–150° for three hours, when a volatile ketone was formed which, after extraction with ether, distilled at 170–180°. It was well shaken with a strong solution of semicarbazide hydrochloride and sodium acetate for several days, the crystalline mass was then collected, and recrystallised from methyl alcohol, from which the pure semicarbazone separated in colourless plates melting at 167°.

The ketone obtained in this way proved to be identical with that described on p. 1970, where analyses both of the ketone and its semicarbazone are given. As a series of experiments seemed to indicate that the above ketone was identical with 1:4-dimethylcyclohexan-2-one, recently described by Sabatier and Mailhe (*Compt. rend.*, 1906, 142, 553), we prepared some of the ketone, for the sake of comparison, by the method recommended by these investigators.

Pure *p*-xylolol was slowly distilled over reduced nickel in a stream of hydrogen, and, after it had been twice subjected to this treatment, the 1:4-dimethylcyclohexan-2-ol obtained was oxidised by chromic acid and the resulting 1:4-dimethylcyclohexan-2-one distilled in a current of steam.* The ketone was extracted from the distillate and fractionated, when almost the whole quantity distilled at 176°, and yielded a semicarbazone, which, when first prepared, melted at 155°, but, after repeated crystallisation from methyl alcohol, the melting point rose to 167°. That 1:4-dimethylcyclohexan-2-one is identical with the ketone produced by the action of water on the lactone, $C_9H_{13}O_2Br$, in the manner just described, was proved by careful comparison, and especially by the fact that the semicarbazones from both specimens, not only melted at 167°, but also that, when mixed, there was no alteration in the melting point.

α -1-Methyl- Δ^3 -cyclohexene-4-propionic Acid,

In order, in the first place, to prepare methyl α -cyano- α -1-methyl- Δ^3 -cyclohexene-4-propionate, sodium (2.3 grams) was dissolved in methyl alcohol, mixed with ethyl α -cyano-1-methyl- Δ^3 -cyclohexene-4-acetate (21 grams),† and then methyl iodide (20 grams) added, when

* We are indebted to Mr. H. D. Gardner for carrying out this preparation.

† Two condensations were made in one of which the cyano-ester had been prepared by the sodium ethoxide condensation (p. 1963), and in the other with the aid of piperidine (p. 1965), and the results in both cases were identical.

a considerable rise of temperature took place. After one hour, the product was heated for half an hour on the water-bath, mixed with water, and the oil extracted with ether.

The ethereal solution was washed well, dried, evaporated, and the residue distilled under diminished pressure :

0.1608 gave 9.6 c.c. N_2 at 19° and 756 mm. $N = 6.8$.

0.1406 „ 8.5 c.c. N_2 „ 18° „ 760 mm. $N = 6.9$.

$C_{12}H_{17}O_2N$ requires $N = 6.8$ per cent.

Methyl α -1-methyl- Δ^3 -cyclohexene-4-propionate is a colourless oil, which distils at $158-160^\circ/20$ mm. When the pure cyano-ester (17 grams) was digested on the water-bath with potassium hydroxide (9 grams) for three hours, and then water added, it was found that a portion only of the oil had passed into solution. The product was acidified, extracted with ether, the ethereal solution well washed with dilute sodium carbonate, dried, and evaporated, when a considerable quantity of oil remained, which distilled at $162^\circ/100$ mm., and consisted of *α -1-methyl- Δ^3 -cyclohexene-4-propionitrile*,

0.1480 gave 12.4 c.c. N_2 at 20° and 752 mm. $N = 9.5$.

0.0965 „ 8.0 c.c. N_2 „ 18° „ 765 mm. $N = 9.6$.

$C_{10}H_{15}N$ requires $N = 9.4$ per cent.

The sodium carbonate solution was acidified and extracted with ether, when a viscid, syrupy acid was obtained, which evidently contained *α -cyano- α -1-methyl- Δ^3 -cyclohexene-4-propionic acid*,*

since, when distilled under reduced pressure, it was decomposed with elimination of carbon dioxide and formation of *α -1-methyl- Δ^3 -cyclohexene-4-propionitrile*. A quantity of the nitrile prepared in this way was again found to distil at $162^\circ/100$ mm. :

0.2130 gave 17.5 c.c. N_2 at 19° and 760 mm. $N = 9.5$.

$C_{10}H_{15}N$ requires $N = 9.4$ per cent.

This nitrile is hydrolysed with considerable difficulty, and even after boiling in a reflux apparatus with 20 per cent. alcoholic sulphuric acid for thirty-six hours, it was only partly converted into ethyl *α -1-methyl- Δ^3 -cyclohexene-4-propionate*. The product was mixed with ether and water, the ethereal solution separated, washed well, evaporated, and the residual oil digested with excess of methyl-alcoholic potash for fifteen minutes. After diluting, acidifying, and extracting with ether,

* This acid is produced almost quantitatively when the cyano-ester is hydrolysed by potassium hydroxide in the cold.

the acid was separated from much unchanged nitrile by shaking the ethereal solution with sodium carbonate.

The aqueous solution was acidified, when an oil was precipitated, which was again extracted with ether, and, after drying, the ether was evaporated and the residue distilled :

0.2427 gave 0.6280 CO₂ and 0.2035 H₂O. C = 70.6 ; H = 9.3.

C₁₀H₁₆O₂ requires C = 71.4 ; H = 9.5 per cent.

α-1-Methyl-Δ³-cyclohexene-4-propionic acid, obtained in this way, distilled at 154—155°/20 mm. The silver salt was prepared by precipitating a slightly alkaline solution of the ammonium salt with silver nitrate :

0.5030 gave 0.1990 Ag. Ag = 39.5.

C₁₀H₁₅O₂Ag requires Ag = 39.3 per cent.

During their experiments on the condensation of 1-methylcyclohexan-4-one with ethyl *α*-bromopropionate (*Annalen*, 1908, **360**, 52), Wallach and Evans obtained an unsaturated acid distilling at 152—154°/13 mm., which partly solidified and melted at 103—104°, and this is possibly identical with our acid. The syrupy acid which we obtained showed no signs of crystallisation, even when well cooled and vigorously stirred with a glass rod, but this behaviour may be due to the syrup being a mixture of *cis*- and *trans*-isomerides.

The method employed in the preparation of this aldehyde was similar to that used with success in analogous cases by Tschitschibabin (*Ber.*, 1904, **37**, 850). The 4-bromo-1-methylcyclohexane required for the synthesis was obtained by dissolving 1-methylcyclohexan-4-ol in fuming hydrobromic acid (saturated at 0°), and heating the solution on the water-bath, when it separated into two layers. Water was added, the heavy oil extracted with ether, the ethereal solution washed, dried, and evaporated, and the crude bromide distilled, when almost the whole quantity passed over at 130°/200 mm. 4-Bromo-1-methylcyclohexane (88 grams) was dissolved in dry ether (3 vols.), magnesium (12 grams) was then added, when, on warming, reaction set in, at first slowly, but then proceeded vigorously. The product was mixed with toluene (75 grams), the ether distilled off, and then orthoformic ester (74 grams) added, when a solid magnesium compound separated immediately (compare Bodroux, *Compt. rend.*, 1904, **138**, 700).

After heating on the water-bath for an hour and a-half, the product was decomposed by water and dilute hydrochloric acid, and extracted with ether in the usual manner. The ethereal solution was dried

and evaporated, the toluene removed by heating on the water-bath under reduced pressure, and the residual acetal digested for three hours with dilute hydrochloric acid (5 per cent.). The oily layer was then separated, and well shaken with concentrated sodium hydrogen sulphite, the solid additive compound was collected, dissolved in water, and decomposed by sodium carbonate. After extracting with ether, the ethereal solution was washed rapidly, dried, evaporated, and the residual aldehyde distilled :

0.2372 gave 0.6550 CO_2 and 0.2330 H_2O . $\text{C} = 75.4$; $\text{H} = 10.9$.

$\text{C}_8\text{H}_{14}\text{O}$ requires $\text{C} = 76.2$; $\text{H} = 11.1$ per cent.

Hexahydro-p-tolualdehyde distils at about 180° , and has the pungent odour characteristic of aldehydes of this class ; it readily undergoes change, doubtless owing to condensation. The semicarbazone, prepared in the usual manner, separated from dilute methyl alcohol as a colourless, crystalline mass, which melted at about 154° . It has been mentioned (p. 1955) that Wallach (*Annalen*, 1906, **347**, 346) had already prepared this aldehyde from 1-methyl-4-methylenecyclohexane by oxidation to the glycol and subsequent treatment with dilute acids :

Wallach gives $154\text{--}156^\circ$ as the melting point of the semicarbazone.

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