LXXXVII.—*The Reduction of isoPhthalic Acid.* *Part II.*

By WILLIAM GOODWIN and WILLIAM HENRY PERKIN, jun.

THE first part of this investigation (Perkin and Pickles, *Trans.*, 1905, 87, 293) dealt with the behaviour of *isophthalic acid* on reduction with sodium amalgam; from the product, the four possible tetrahydro-*isophthalic acids* were obtained, their properties described, and their relationship and constitutional formulæ discussed.

Attention was called to the fact that it had not been found possible to isolate, from the mixture of acids formed, even a trace of a dihydro-*isophthalic acid*, and it was mentioned that, in this respect, *isophthalic acid* behaves differently from *phthalic* and *terephthalic acids*, both of which, when treated with sodium amalgam, yield dihydro-derivatives as the first products of the reduction. A dihydro-*isophthalic acid* (m. p. 255°) was, however, obtained indirectly, namely, from 3:4-dibromohexahydro-*isophthalic acid* by the action of methyl-alcoholic potash, and to this acid the constitution $\Delta^{2,4}$,

was provisionally assigned (*loc. cit.*, p. 310).*

In the present communication we describe a series of experiments having for their starting point hexahydro-*isophthalic acid*, which, as is well known, exists in *cis*- and *trans*-modifications:

These acids were first obtained synthetically (Perkin, *Trans.*, 1891, 59, 808) from the product of the action of methylene di-iodide on the disodium derivative of ethyl pentanetetracarboxylate by hydrolysis and elimination of carbon dioxide. In the preparation of the considerable

* The scheme of numbering is that employed in the previous paper, that is:

quantity of material required for the present investigation, we preferred to employ a method of synthesis which was discovered shortly afterwards (Perkin and Prentice, *Trans.*, 1891, **59**, 990), as this appeared to be the more convenient.

In this synthesis, the disodium derivative of ethyl propanetetracarboxylate is digested with trimethylene dibromide,

and, after hydrolysing, the hexamethylene-1 : 1 : 3 : 3-tetracarboxylic acid is heated at 180°, when it is decomposed with elimination of two molecules of carbon dioxide and formation of a mixture of the *cis*- and *trans*-modifications of hexahydroisophthalic acid.

These acids cannot be separated by crystallisation, and separation has, so far, only been accomplished by taking advantage of the fact that the calcium salt of the *cis*-acid is much less soluble than that of the *trans*-acid (*Trans.*, 1891, **59**, 808). The melting point of the *cis*-acid was given as 161—163° and that of the *trans*-acid as 120—122°. Baeyer and Villiger (*Annalen*, 1893, **276**, 255) subsequently prepared the hexahydroisophthalic acids by combining the mixture of tetrahydroisophthalic acids, produced when isophthalic acid is reduced with sodium amalgam, with hydrogen bromide and then reducing the resulting bromohexahydroisophthalic acids with zinc dust and acetic acid. The two isomerides were separated, as before, by means of their calcium salts; the less soluble calcium salt yielded the pure *cis*-acid (m. p. 161—163°), whereas the *trans*-acid was obtained from the mother liquors, and after repeated crystallisation melted at 118—120°. During the course of our experiments, we repeatedly made observations which led us to suspect that the product melting at 120°, and which had, so far, been assumed to be pure *trans*-hexahydroisophthalic acid, was not a single substance.

Unlike the *cis*-modification, which crystallises in well-defined needles, the acid melting at 120° always separates in indefinite nodular masses, and the melting point is not so sharp as that which a pure substance of this nature might be expected to exhibit. The acid has, indeed, properties which are very similar to those of the curious mixture of *cis*- and *trans*-*αα*-dimethylglutaric acids (Auwers and Thorpe, *Ber.*, 1895, **28**, 623; Bone and Perkin, *Trans.*, 1896, **59**, 268) which melts at 105—106° and cannot be separated into its components by crystallisation. The latter mixture may, however, be resolved by taking advantage of the fact that the *cis*-modification is converted into the

anhydride by the action of acetyl chloride in the cold and dissolves, whereas the *trans*-modification is unchanged by this treatment and remains undissolved. When this method was applied to the acid melting at 120°, no such separation could be accomplished, because the whole dissolved in the acetyl chloride, and on treatment with water the acid melting at 120° was recovered unchanged.

We subsequently found that this acid, when dissolved in a considerable excess of ammonia and heated for some hours with calcium chloride, yields a quantity of the calcium salt of the *cis*-acid, and, after repeating this treatment several times, the mother liquor deposits, on acidifying, pure *trans*-hexahydroisophthalic acid, which crystallises from water in well-defined prismatic needles and melts at 148°.

We were now able to prepare the acid melting at 120° by mixing about equal quantities of the pure *cis*- and *trans*-modifications and crystallising the mixture from a little water; the nodular masses thus obtained melted at 120–122° and had all the properties of the substance which had previously been assumed to be pure *trans*-hexahydroisophthalic acid. In the earlier experiments by Perkin and by Baeyer and Villiger (*loc. cit.*), the acid (m. p. 120°) was naturally subjected to treatment with ammonia and calcium chloride in order to show that it did not contain any of the *cis*-modification.

Perkin (*loc. cit.*, p. 814) employed a strong *neutral* solution for this purpose, and Baeyer and Villiger (*loc. cit.*, p. 261) state that they used "möglichst wenig Ammoniak," but we now find that it is necessary to have a considerable *excess* of ammonia present, otherwise no separation of the calcium salt of the *cis*-acid takes place.

In possession of this means of separation, we have prepared large quantities of the *cis*- and *trans*-modifications of hexahydroisophthalic acid, and submitted these to a detailed investigation, the results of which may be briefly summarised as follows:

The *trans*-acid (m. p. 148°) is partially converted into the *cis*-acid (m. p. 163°) by heating with hydrochloric acid at 170°, and the reverse change is also true. It is clear, therefore, that if either isomeride is subjected to this treatment a condition of equilibrium is established, but the mixture, the composition of which seems to vary with the temperature and the concentration of the hydrochloric acid, has not been quantitatively investigated.

When the *trans*-acid is treated first with phosphorus pentachloride and then with bromine (1 mol.), and the product decomposed by formic acid, it yields 1-bromo-*trans*-hexahydroisophthalic acid, which melts at 210°, and the constitution of which is proved by the fact that on reduction with zinc dust and acetic acid it is again converted into the *trans*-acid. This 1-bromo-*trans*-acid is readily decomposed by boiling

caustic potash with elimination of hydrogen bromide and formation of Δ^3 -tetrahydroisophthalic acid (Trans., 1905, 87, 307),

but whether this acid is the direct product of the elimination of hydrogen bromide, or whether one of the other tetrahydroisophthalic acids is first produced and then converted into the Δ^3 -acid by the action of the caustic potash, it is impossible to say.

It is, however, interesting to note that the 1-bromo-*trans*-acid yields Δ^3 -tetrahydroisophthalic acid in small quantities when it is digested with dilute sodium carbonate, and since it is unlikely that this treatment would convert one modification of tetrahydroisophthalic acid into another, this fact may be taken as some evidence that the Δ^3 -tetrahydro-acid is the direct product of the elimination of hydrogen bromide from the bromo-*trans*-acid.*

Very little Δ^3 -tetrahydroisophthalic acid is, however, produced from the *trans*-bromo-acid by the action of sodium carbonate, and if the reagent is very dilute, a mere trace only is formed. The principal product of the reaction is 1-hydroxy-*trans*-hexahydroisophthalic acid,

* By direct elimination of hydrogen bromide (without molecular change), 1-bromo-*trans*-hexahydroisophthalic acid might yield either Δ^2 - or Δ^3 -tetrahydroisophthalic acid :

and, in order to obtain evidence as to the direction in which this change takes place, the following experiment was made after the present paper had been written and was in the press. A very pure specimen of Δ^2 -tetrahydroisophthalic acid was prepared and boiled for half an hour with a solution of sodium carbonate (saturated at the ordinary temperature). The product was acidified and allowed to stand for 24 hours, but no trace of the very sparingly soluble Δ^3 -tetrahydroisophthalic acid separated, and, on extracting with ether, the whole of the Δ^2 -acid was recovered unchanged. It is clear, therefore, that the latter acid does not undergo molecular change when boiled with sodium carbonate, and the obvious deduction from this experiment is, that no molecular change takes place when Δ^3 -tetrahydroisophthalic acid is formed from 1-bromo-*trans*-hexahydroisophthalic acid by the action of alkalis.

which melts at about 160° , and when warmed with sulphuric acid at 40° is decomposed with elimination of carbon monoxide and formation of γ -keto-hexahydrobenzoic acid :

Both of these acids had already been prepared by Baeyer and Tutein (*Ber.*, 1889, 22, 2182—2187). γ -Keto-hexahydrobenzoic acid was obtained from tetrahydrohydroxyterephthalic acid (keto-hexahydro-terephthalic acid) by the elimination of carbon dioxide :

The keto-acid was found to combine readily with hydrogen cyanide with formation of the nitrile of 1-hydroxyhexahydroisophthalic acid, from which the acid itself was obtained by hydrolysis with hydrochloric acid. Baeyer and Tutein do not give the melting point of the hydroxy-acid which they prepared in this way, but, from its method of formation, it seems probable that it consisted of a mixture of the *cis*- and *trans*-modifications.

A series of experiments was next made with the object of preparing 1 : 3-dibromo-*trans*-hexahydroisophthalic acid,

and it was found that this acid may be very readily obtained by treating *trans*-hexahydroisophthalic acid first with phosphorus pentachloride and then with bromine (2 mols.), and then decomposing the product with formic acid. This acid melts at about 181° , and when digested with methyl-alcoholic potash yields a dihydroisophthalic acid which is isomeric with that previously obtained from 3 : 4-dibromo-hexahydroisophthalic acid by similar treatment (compare p. 841 ; also

Trans., 1905, **87**, 293), and the constitution of which is probably represented by the formula

We have also investigated the action of bromine on *cis*-hexahydroisophthalic acid and find that, when this acid is heated with phosphorus pentachloride and bromine at a temperature not exceeding 100°, it is converted into 1-bromo-*trans*-hexahydroisophthalic acid. This conversion of a *cis*- into a *trans*-modification, under the above conditions, did not appear to have been observed until Buchner and Wedemann (*Ber.*, 1905, **38**, 1599) quite recently showed that the *cis*-modification of trimethylene-1 : 2-dicarboxylic acid, $\text{CH}_2 \begin{matrix} \text{CH} \cdot \text{CO}_2\text{H} \\ \text{CH} \cdot \text{CO}_2\text{H} \end{matrix}$, after being successively converted into the acid-chloride and then heated with bromine at 150—160°, yields bromo-derivatives of the *trans*-acid.

There is, however, this difference in the two series of experiments, namely, that the temperature employed by Buchner and Wedemann is much higher than that which we used in our experiments on the bromination of *cis*-hexahydroisophthalic acid.

*Preparation of Hexamethylene-1 : 1 : 3 : 3-tetracarboxylic Acid
and of cis-Hexahydroisophthalic Acid.*

In the preparation of considerable quantities of these substances, the process which was found to give the best results was the following modification of the method previously employed by Perkin and Prentice (*Trans.*, 1891, **59**, 990). Sodium (23 grams) is dissolved in alcohol (350 grams), the solution mixed with ethyl propanetetracarboxylate (166 grams) and trimethylene dibromide (101 grams), and heated in a reflux apparatus for one hour on the water-bath; and, as the action is a rather vigorous one, it is advisable, in order to avoid loss, to use a large flask and very long condenser in this operation.

The product is diluted with water, extracted with ether, and, after the ethereal solution has been well washed and dried over calcium chloride, the ether is evaporated and the residue fractionated under 25 mm. pressure. The fractions collected were :

(a) B. p. 120—200°. This oil evidently contained much ethyl methylenemalonate, $(\text{CO}_2\text{Et})_2\text{C}:\text{CH}_2$, since it deposited a quantity of the horn-like polymeride of this substance on standing (compare Haworth and Perkin, *Trans.*, 1898, **73**, 342; Bottomley and Perkin, *Trans.*, 1900, **77**, 307).

(b) B. p. 220—240°. This fraction was a viscid, pale yellow oil and consisted largely of ethyl hexamethylenetetracarboxylate.

(c) B. p. 240—260°. On standing, this fraction became semi-solid owing to the separation of crystals of ethyl pentanehexacarboxylate (Bottomley and Perkin, *loc. cit.*, p. 298).*

The crude ethyl hexamethylenetetracarboxylate (which is obtained in a yield of about 35 per cent. of that theoretically possible) is hydrolysed by boiling with methyl-alcoholic potash (6 mols.) for four hours; water is then added and the solution evaporated on the water-bath with the repeated addition of small quantities of water, until the methyl alcohol has been completely removed. The concentrated solution is then acidified with hydrochloric acid and extracted at least 20 times with ether, the extracted liquor (a) being then treated as described below. After drying over calcium chloride, the ethereal solution is evaporated, when a pale yellow oil is obtained which gradually crystallises. The mass is left in contact with porous porcelain until free from oil, washed with a little ether, and recrystallised from warm water, when colourless, glistening crystals of hexamethylenetetracarboxylic acid separate, which melt at 217—219° and are rather sparingly soluble in cold water. The liquor (a) is evaporated to dryness, the residue mixed with the broken-up porous porcelain employed in the above purification and extracted with ether in a Soxhlet apparatus; the extract is mixed with the crude hexamethylenetetracarboxylic acid, obtained by the evaporation of the mother liquors from the purification of this acid and heated at 180° until carbon dioxide ceases to be evolved. The brown syrup thus obtained is digested with alcohol and sulphuric acid for 6 hours, water is then added, the ester extracted with ether in the usual way and fractionated under reduced pressure, when the greater portion distils at 160—190° (25 mm.). This is hydrolysed with methyl-alcoholic potash and, after completely removing the alcohol by evaporation with water, the acidified product is extracted 10 times with ether. The ethereal solution is carefully dried over calcium chloride and evaporated, and the residue digested for 6 hours with twice its volume of acetic anhydride and fractionated, the fraction 200—210° (30 mm.) being collected separately. The oil, which consists largely of the anhydride of *cis*-hexahydroisophthalic acid and solidifies partially on cooling, is boiled with water in a reflux apparatus until dissolved, the solution

* The formation of the fractions (a and c) shows that, in the course of the above reaction, much of the ethyl propanetetracarboxylate employed must have been decomposed into formaldehyde and ethyl malonate, which then condensed to form ethyl methylenemalonate and ethyl pentanehexacarboxylate. A similar behaviour has been observed in other synthetical experiments in which the sodium derivative of ethyl propanetetracarboxylate has been employed.

is then made strongly alkaline with ammonia and heated on the water-bath with an excess of strong calcium chloride solution for some hours and until the separation of the crystalline calcium salt of the *cis*-acid appears to be complete. After collecting at the pump and washing with a little hot water, the salt is dissolved in boiling dilute hydrochloric acid, from which solution the pure *cis*-acid separates as a colourless, glistening, crystalline mass which melts at 162—163°.

Action of Heat on Hexamethylenetetracarboxylic Acid. Separation of the cis- and trans-Modifications of Hexahydroisophthalic Acid.

During this investigation, about 100 grams of pure hexamethylenetetracarboxylic acid were heated at 208—210° until decomposition commenced, the temperature was then allowed to fall to 185°, and the heating continued until the evolution of carbon dioxide had completely ceased. The residue, which crystallised on cooling, was dissolved in water, made strongly alkaline with ammonia, and heated for some hours on the water-bath with strong calcium chloride solution. The crystalline calcium salt of the *cis*-acid, which separated in quantity, was collected at the pump, washed with water, and the mother liquors evaporated to a small bulk and again filtered from a further crop of crystals of the calcium salt, this operation being repeated several times in order to separate as much of this salt as possible.

From the calcium salt, the *cis*-acid is readily obtained by decomposition with hydrochloric acid and recrystallisation from water. The mother liquor of the calcium salt of the *cis*-acid is acidified, when a large quantity of a crystalline acid separates, which is collected at the pump and recrystallised from water, and in this way hard, nearly colourless, crystalline masses may be obtained which consist of pure *trans*-hexahydroisophthalic acid.

0.1479 gave 0.3021 CO₂ and 0.0951 H₂O. C = 55.7; H = 7.2.

0.1345 „ 0.2751 CO₂ „ 0.0867 H₂O. C = 55.8; H = 7.1.

C₈H₁₂O₄ requires C = 55.8; H = 7.0 per cent.

trans-Hexahydroisophthalic acid melts at 148°, is readily soluble in hot water and separates, on slowly cooling, in small, striated, prismatic needles.

When its solution in excess of ammonia is boiled with calcium chloride, no separation of a calcium salt takes place even after many hours.

The mother liquors of the *trans*-acid were extracted with ether and the ethereal solution evaporated, when a considerable quantity of a crystalline substance was obtained which separated from hydrochloric acid in nodular masses; this melted at 118—121° and had all the

properties of the substance previously obtained and described as *trans*-hexahydroisophthalic acid (Perkin, *Trans.*, 1891, 59, 814. Compare Baeyer and Villiger, *Annalen*, 1893, 276, 262). It is stated by the first-named author that a strong neutral solution of this acid, on the addition of calcium chloride, gives no precipitate even on continued boiling, and this is quite true. If, however, the acid is dissolved in a little water made strongly alkaline with ammonia, and heated for two hours on the water-bath with an excess of calcium chloride, a quantity of the calcium salt of the *cis*-acid gradually separates, and the mother-liquor from this deposits, on acidifying, crystals which melt at about 145° and consist of the almost pure *trans*-acid.

Equal quantities of the *cis*- and *trans*-acids were then weighed out, mixed, dissolved in a little hot water, and then allowed to crystallise slowly, when nodular masses separated which melted at 120–122° and had all the properties of the substance which was formerly supposed to be the pure *trans*-acid.

Partial Conversion of the trans-Acid into cis-Hexahydroisophthalic Acid by means of Hydrochloric Acid.—*trans*-Hexahydroisophthalic acid (1 gram) was heated in a sealed tube with hydrochloric acid (5 c.c.) at 170° for 1 hour, the product was extracted with ether, the ethereal solution evaporated, and the colourless, crystalline residue dissolved in excess of dilute ammonia and digested with calcium chloride. The sparingly soluble calcium salt, which soon separated, was collected, washed with warm water, and dissolved in a small quantity of boiling hydrochloric acid, from which solution the pure *cis*-acid separated in colourless needles melting at 161–162°.

0.1205 gave 0.2462 CO₂ and 0.0772 H₂O. C = 55.7; H = 7.1.

C₈H₁₂O₄ requires C = 55.8; H = 7.0 per cent.

From the mother liquors of the calcium salt, a small quantity of impure *trans*-acid was isolated, so that it seems probable that the conversion of this into the *cis*-acid by heating with hydrochloric acid is only partial, a result which is in harmony with previous observations on the subject.

Complete Conversion of trans-Hexahydroisophthalic Acid into the cis-Modification by means of Acetyl Chloride.—*trans*-Hexahydroisophthalic acid is sparingly soluble in acetyl chloride, but dissolves on warming, and, if the solution is heated at 100° for one hour and then at 150° for two hours and evaporated on the water-bath, a crystalline residue is obtained. This was left in contact with porous porcelain until quite dry and then crystallised from a mixture of benzene and light petroleum, when a satiny mass of crystals was obtained which melted at 188–189°.

0.1255 gave 0.2867 CO_2 and 0.0748 H_2O . $\text{C} = 62.2$; $\text{H} = 6.6$.

$\text{C}_8\text{H}_{10}\text{O}_3$ requires $\text{C} = 62.3$; $\text{H} = 6.5$ per cent.

That this substance was the *anhydride* of *cis-hexahydroisophthalic acid* was proved by dissolving it in boiling water and concentrating the solution, when the pure *cis*-acid (m. p. $162-163^\circ$) separated on cooling. This transformation of the *trans*-modification into the *cis*-form is evidently a complete one, since no trace of *trans*-acid could be detected in the mother liquors of the *cis*-anhydride.

1-Bromo-trans-hexahydroisophthalic Acid.

In preparing this acid, *trans*-hexahydroisophthalic acid (3.5 grams) was heated in a tube with phosphorus pentachloride (6 grams) in the water-bath until the decomposition was complete, bromine (3.3 grams) was then added and the tube sealed and heated at 100° for two hours.

The product was mixed with twice its volume of formic acid (sp. gr. 1.22°) and allowed to remain for two days; the crystalline crust which had formed was then collected and recrystallised from formic acid.

0.1628 gave 0.2280 CO_2 and 0.0633 H_2O . $\text{C} = 38.2$; $\text{H} = 4.3$.

0.2192 „ 0.1662 AgBr. $\text{Br} = 32.2$.

$\text{C}_8\text{H}_{11}\text{O}_4\text{Br}$ requires $\text{C} = 38.2$; $\text{H} = 4.4$; $\text{Br} = 31.9$ per cent.

1-Bromo-trans-hexahydroisophthalic acid melts at about 210° and separates from formic acid as a heavy powder which, under the microscope, is seen to consist of leafy masses. It is rather sparingly soluble in dry ether or cold formic acid, very sparingly so in hot benzene, toluene, light petroleum, or chloroform, but readily so in alcohol or boiling formic acid. When boiled with water, it dissolves and, if the solution is rapidly cooled, a large amount of the acid crystallises out unchanged; if, however, the solution is boiled for a few minutes, the acid is completely decomposed with elimination of hydrogen bromide and formation of a solid acid which appears to be 1-hydroxy-trans-hexahydroisophthalic acid (p. 851).

Reduction.—In order to be sure that no molecular change had taken place during bromination, the above bromo-acid was dissolved in glacial acetic acid and reduced, first at the ordinary temperature and then at 100° , with a large excess of zinc dust.

The product was mixed with hydrochloric acid and distilled in steam until the acetic acid had been removed; the residue in the steam distillation flask was then extracted several times with ether, when, on evaporating the ethereal solution, a solid acid remained,

which, after crystallisation from water, melted at 143—145° and consisted of almost pure *trans*-hexahydroisophthalic acid.

This result proves conclusively that the acid obtained by the bromination of this *trans*-acid under the conditions described above is 1-bromo-*trans*-hexahydroisophthalic acid.

Action of Alkalis on 1-Bromo-trans-hexahydroisophthalic Acid.

Formation of Δ^3 -Tetrahydroisophthalic Acid, 1-Hydroxy-trans-hexahydroisophthalic Acid, and γ -Keto-hexahydrobenzoic Acid.

I. *Action of Caustic Potash.*—1-Bromo-*trans*-hexahydroisophthalic acid dissolves readily in caustic potash, and, if the solution is boiled for a few minutes and then acidified, a sandy crystalline precipitate separates; this melts, after recrystallisation, at 242—244° and crystallises from much water in the stars with jagged edges which are so characteristic of Δ^3 -tetrahydroisophthalic acid (Trans., 1905, 87, 307).

0.1618 gave 0.3360 CO₂ and 0.0880 H₂O. C = 56.6; H = 6.0.

C₈H₁₀O₄ requires C = 56.4; H = 5.9 per cent.

II. *Action of Sodium Carbonate.*—In studying this action, the pure bromo-acid was dissolved in an excess of dilute sodium carbonate and heated on the water-bath for 5 hours, the solution was then boiled in a reflux apparatus for half an hour, cooled, acidified, and allowed to stand for a week. A small quantity of a very sparingly soluble substance gradually separated in long, slender needles; this was collected at the pump, recrystallised from much water, and found to consist of Δ^3 -tetrahydroisophthalic acid.

The filtrate was saturated with ammonium sulphate, extracted five times with ether, and the ethereal solution dried over calcium chloride and evaporated, when a syrupy residue was obtained which soon completely solidified. In order to separate any trace of Δ^3 -tetrahydroisophthalic acid which might still be present, the whole was dissolved in a little water, boiled with animal charcoal, and evaporated to a small bulk, but, even after standing for several days, only a trace of a crystalline substance separated. The solution was now allowed to concentrate over sulphuric acid in an exhausted desiccator, when a hard, crystalline mass gradually formed; this was collected, dried at 100°, and analysed.

0.2451 gave 0.4623 CO₂ and 0.1380 H₂O. C = 51.3; H = 6.3.

C₈H₁₂O₅ requires C = 51.1; H = 6.4 per cent.

1-Hydroxy-*trans*-hexahydroisophthalic acid, when purified in the manner described above, melts at about 160° with previous softening, but owing to the difficulty which was experienced in satisfactorily

recrystallising the acid, this melting point must be taken as only approximately correct. The hydroxy-acid is very soluble in water, and its solution, after neutralising with sodium carbonate, does not decolorise permanganate. The composition of this acid was further confirmed by titration with *N*/10 caustic soda, when it was found that 0.105 gram neutralised 0.044 gram NaOH, whereas this amount of a dibasic acid, $C_8H_{12}O_5$, should neutralise 0.045 gram NaOH. The *silver* salt, $C_8H_{10}Ag_2O_5$, was obtained by adding a solution of silver nitrate to a neutral solution of the ammonium salt in the form of a sparingly soluble white precipitate.

0.1351 gave 0.0722 Ag. $Ag = 53.5$.

$C_8H_{10}O_5Ag_2$ requires $Ag = 53.7$ per cent.

Baeyer and Tutein (*Ber.*, 1889, **22**, 2186), who first obtained 1-hydroxyhexahydroisophthalic acid, state that it crystallises from alcohol in warty masses, but, as they do not give the melting point, it is impossible to decide whether the acid which they prepared is identical with that described above; it seems more probable from the method of formation that it was a mixture of the *cis*- and *trans*-modifications.

γ-Ketohexahydrobenzoic Acid.

When finely powdered 1-hydroxy-*trans*-hexahydroisophthalic acid is warmed with concentrated sulphuric acid at 40°, it dissolves with evolution of carbon monoxide and without any charring. After a few minutes, and as soon as the evolution of gas had ceased, the solution was poured on to powdered ice and extracted several times with ether.

After drying over calcium chloride, the ethereal solution deposited an oily acid, which was very soluble in water and yielded precipitates with phenylhydrazine and semicarbazide. In order to characterise the acid, it was dissolved in a little water and mixed with a strong solution of hydroxylamine hydrochloride, when the oxime gradually separated as a sparingly soluble crystalline powder.

0.1817 gave 14.2 c.c. nitrogen at 17° and 762 mm. $N = 9.1$.

$C_7H_{11}O_3N$ requires $N = 8.9$ per cent.

The *oxime* of *γ-ketohexahydrobenzoic acid* prepared in this way melted at about 167–168° with decomposition, whereas Baeyer and Tutein (*loc. cit.*, p. 2183) give 170° as the melting point of the specimen of this oxime, which they prepared from hydroxytetrahydroterephthalic acid by the action of hydroxylamine hydrochloride.

1 : 3-Dibromo-trans-hexahydroisophthalic Acid and Dihydroisophthalic Acid.

The above-mentioned dibromo-acid is readily prepared by heating *trans*-hexahydroisophthalic acid (1·7 grams) with phosphorus pentachloride (2·5 grams) and then with bromine (3·5 grams) in a sealed tube at 100° for 2 hours. The oily product is poured into three times its volume of formic acid (sp. gr. 1·22), warmed at 50° until decomposition is complete, and allowed to stand for several days, when a crystalline crust will have separated. The mother liquor is decanted and left exposed to the air until no more crystals separate, the combined crops of crystals are then purified by recrystallisation from formic acid.

0·2590 gave 0·2949 AgBr. Br = 48·4.

$C_8H_{10}O_4Br_2$ requires Br = 48·5 per cent.

1 : 3-Dibromo-trans-hexahydroisophthalic acid melts at about 181° and is readily soluble in ether, alcohol, or hot formic acid, but sparingly so in benzene or light petroleum. It is best crystallised from glacial formic acid, from which it separates in crusts which, under the microscope, are seen to be composed of curious oval leaflets; the separation is, however, very slow, and sometimes takes days before it is complete. The dibromo-acid is sparingly soluble in cold water, but dissolves readily on warming with decomposition and elimination of hydrogen bromide, and if the solution is boiled for a few minutes and then evaporated a viscid, syrupy acid remains which gradually crystallises. This acid, which is quite stable to permanganate, is probably 1 : 3-dihydroxy-*trans*-hexahydroisophthalic acid, but it was not obtained in sufficient quantity for purification and analysis.

Action of Caustic Potash.—When the pure dibromo-acid is added to a large excess of a strong solution of pure caustic potash in methyl alcohol, a vigorous action takes place, and potassium bromide separates at once in quantity. After heating for 10 minutes on the water-bath, the product was mixed with water and boiled, out of contact with air,* until quite free from methyl alcohol; it was then cooled and acidified, when a white, crystalline precipitate separated, which closely resembled barium sulphate. This was collected, washed with water, dried at 100°, and analysed.

0·1309 gave 0·2712 CO_2 and 0·0592 H_2O . C = 56·5; H = 5·0.

0·1441 „ 0·3003 CO_2 „ 0·0643 H_2O . C = 56·8; H = 4·9.

$C_8H_8O_4$ requires C = 57·1; H = 4·8 per cent.

* If this precaution is not taken, oxidation seems to take place and *isophthalic* acid is formed.

This *dihydroisophthalic acid* separates from acetic acid, in which it is almost insoluble in the cold and not readily so on boiling, as a crystalline powder which, under the microscope, has no characteristic appearance. It softens somewhat at 255° , but does not melt at 270° ; it therefore appears to be different from the *dihydroisophthalic acid* which was obtained from 3:4-dibromohexahydroisophthalic acid by the action of methyl-alcoholic potash (Trans., 1905, 87, 310), since this latter acid crystallised in stars and melted completely at 255° .

A small quantity of the *dihydroisophthalic acid* described in the present paper was exposed over dry bromine for 3 days and then placed in an exhausted desiccator over powdered potash for 3 days. The product contained bromine, but, after crystallising from much glacial formic acid, an acid was obtained which was free from bromine and exhibited all the properties of *dihydroisophthalic acid*, the identity with which was confirmed by analysis.

0.1212 gave 0.2506 CO_2 and 0.055 H_2O . C = 56.5; H = 5.1.

$\text{C}_8\text{H}_8\text{O}_4$ requires C = 57.1; H = 4.8 per cent.

This result seems to show that this *dihydroisophthalic acid* is not capable of yielding an additive product when it is exposed to dry bromine vapour.

Action of Bromine on cis-Hexahydroisophthalic Acid.

During the course of these experiments, we experienced unexpected difficulties in obtaining a definite product of bromination, although we employed the conditions which had given such good results in the case of the *trans*-acid. When the quantities taken were exactly those required for the formation of the monobromo-acid and the product was purified by repeated crystallisation from formic acid, we obtained crystalline acids melting in different experiments from 197° to 204° , and which yielded, on analysis, percentages of bromine varying from 33.2 to 35.1, whereas the formula $\text{C}_8\text{H}_{11}\text{O}_4\text{Br}$ requires 31.9 per cent. of bromine. A satisfactory result was, however, at last obtained in an experiment in which we employed a method exactly similar to that recommended by Baeyer (*Annalen*, 1888, 245, 179) for the preparation of (I) bromohexahydroterephthalic acid.

cis-Hexahydroisophthalic acid (6 grams) was digested with phosphorus pentachloride (17 grams) and then heated with bromine (6 grams) in a sealed tube at 100° for 4 hours. The product was mixed with powdered ice and left for 2 days; the sandy precipitate which had separated was collected and dissolved in 750 c.c. of cold, very dilute sodium carbonate. The solution was filtered and acidified, but, as after standing for 2 days nothing had separated, the whole

was acidified, saturated with ammonium sulphate, and extracted several times with ether. The ethereal solution was dried over calcium chloride and evaporated, when a gummy mass was obtained which gradually became semi-solid; on warming with a little water, the gummy impurity was dissolved, leaving a white, crystalline mass.

This was collected and rapidly recrystallised from hot water, in which it is sparingly soluble, but from which it separated as a sandy, crystalline powder melting at 210° .

0.1679 gave 0.2352 CO_2 and 0.0688 H_2O . $\text{C} = 38.2$; $\text{H} = 4.5$.

0.1257 „ 0.0940 AgBr. $\text{Br} = 31.8$.

$\text{C}_8\text{H}_{11}\text{O}_4\text{Br}$ requires $\text{C} = 38.2$; $\text{H} = 4.3$; $\text{Br} = 31.8$ per cent.

That this substance is *bromo-trans-hexahydroisophthalic acid* was proved by the fact that, when carefully reduced by zinc dust and acetic acid under the conditions described on p. 850, it was quantitatively converted into *trans-hexahydroisophthalic acid*.

It follows, therefore, that, at some stage during the treatment with phosphorus pentachloride and bromine at 100° , transformation of the *cis-* into the *trans-*modification must have taken place.

THE SCHUNCK LABORATORY,

THE VICTORIA UNIVERSITY OF MANCHESTER.