

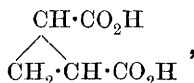
CXXXI.—*cycloButane-1 : 3-dicarboxylic Acid and Some of its Derivatives.*

By WILLIAM HENRY PERKIN, jun., and JOHN LIONEL SIMONSEN.

It has long been known that substances containing the *cyclopropane* ring exhibit very remarkable differences in stability, especially towards hydrobromic acid. In some cases, for example in the case of *cyclopropane-1 : 1-dicarboxylic acid*, the ring suffers disruption in contact with hydrobromic acid in the cold :

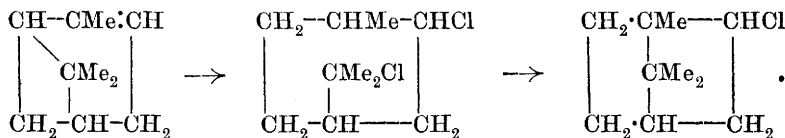


whereas *cyclopropane-1 : 2-dicarboxylic acid*,



is not affected even when boiled with concentrated aqueous hydrobromic acid. These important differences in stability in the *cyclopropane* series have already been discussed in some detail in previous papers (compare especially *Trans.*, 1894, **65**, 951 ; 1907, **91**, 816), and fresh examples of the instability of the *cyclopropane* ring, especially in such bridged-ring compounds belonging to the terpene series, as carone and sabinene, are constantly being observed.

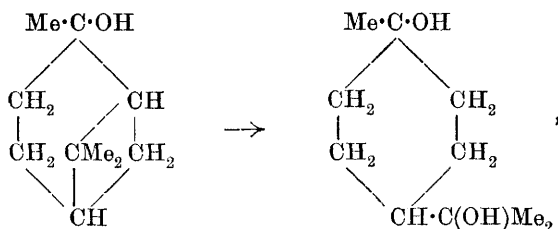
It is also well known that the *cyclobutane* ring, when it forms part of a bridged-ring complex, not infrequently exhibits marked instability. Thus, in the conversion of pinene into *isobornyl chloride* by the action of hydrogen chloride at 0°, it is assumed that the *dimethylcyclobutane* bridged-ring suffers disruption, and rearrangement subsequently takes place according to the scheme :



If this representation of the process should prove to be correct, the disruption of the *dimethylcyclobutane* ring which it involves, together with the subsequent rearrangement, must constitute one of the most remarkable changes in organic chemistry.

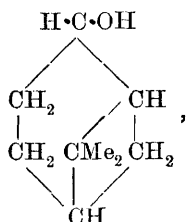
That the *dimethylcyclobutane* ring readily suffers disruption in bridged-ring compounds receives further confirmation from the recent

work of Wallach (*Annalen*, 1907, 356, 241), who has shown that methylnopinol is converted into terpene hydrate by shaking with 5 per



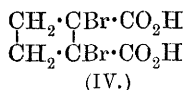
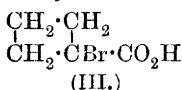
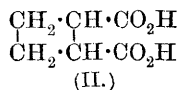
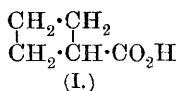
cent. sulphuric acid, or even with dilute oxalic acid, at the ordinary temperature, and further that, when treated with hydrochloric acid, it yields dipentene dihydrochloride.

In view of these facts, it is remarkable that nopinol itself is not



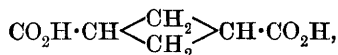
affected by contact with dilute sulphuric acid for four weeks (*loc. cit.*, p. 237). It is very difficult to understand why the substitution of hydrogen for methyl in nopinol should bring about such a marked change in the condition of stability.

If we turn from the consideration of bridged-rings to the study of the stability of the *cyclobutane* ring by itself, such evidence as there is seems to point to that ring being distinctly more stable than the *cyclopropane* ring. Thus *cyclobutanecarboxylic acid* (I) and *cyclobutane-1:2-dicarboxylic acid* (II) may be brominated at the temperature of the water-bath under the usual conditions, with formation of bromo*cyclobutanecarboxylic acid* (III) and dibromo*cyclobutane-1:2-dicarboxylic acid* (IV) :



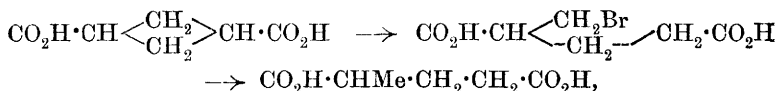
and there is no evidence that the hydrogen bromide produced during the bromination caused appreciable fission of the ring in either case.

*cyclo*Butane-1 : 3 :dicarboxylic acid,

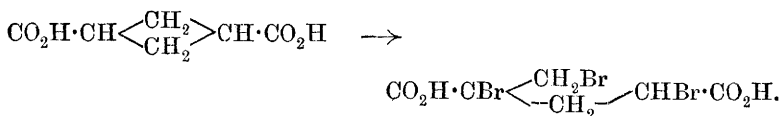


has been synthesised in several ways (compare Haworth and Perkin, *Trans.*, 1898, **73**, 330), but the yields obtained have always been so small that a complete investigation of its properties has, so far, not been attempted. Recently, however, Simonsen (*Trans.*, 1908, **93**, 1778) has worked out a process by which the *cis*-modification may be prepared in quantity, and since it is clear that this acid is more closely allied to the bridged-ring compounds, pinene, nopinol, and methylnopinol, than either of the *cyclobutanecarboxylic* acids just mentioned, we determined to investigate its behaviour with sulphuric acid, hydrobromic acid, and also with bromine.

We found, in the first place, that this acid is not affected by boiling with 10 per cent. sulphuric acid, and, even if heated with concentrated sulphuric acid for three hours on the water-bath, very little change takes place, and almost the whole of the acid may be recovered. When, however, the acid is heated in a sealed tube at 100° with fuming hydrobromic acid, the ring suffers disruption, and an almost quantitative yield of a monobromo-acid is obtained, which, since it yields α -methylglutaric acid on reduction, is probably α -bromobutane- $\beta\delta$ -dicarboxylic acid :



but it is, of course, also possible that the bromo-acid has the constitution $\text{CO}_2\text{H}\cdot\text{CHMe}\cdot\text{CH}_2\cdot\text{CHBr}\cdot\text{CO}_2\text{H}$. The readiness with which this disruption of the *cyclobutane* ring takes place led us to investigate the behaviour of *cis-cyclobutane*-1 : 2-dicarboxylic acid with hydrogen bromide under the same conditions, but, even after heating at 100° for three hours, no appreciable change could be observed, and almost the whole of the acid was recovered unchanged. Obviously we have here again a case of the remarkable effect on the stability of a closed ring exercised by mere change in position of the substituting groups. We next investigated the action of bromine (2 mols.) on the acid chloride of *cyclobutane*-1 : 3-dicarboxylic acid (1 mol.) at the temperature of the water-bath, and found that the product of the action, after decomposing with water, is a *tribromo-acid*, $\text{C}_6\text{H}_7\text{O}_4\text{Br}_3$. This acid has therefore been produced by the substitution of two atoms of hydrogen by bromine in the usual positions, and at the same time the *cyclobutane* ring has suffered disruption owing to the addition of hydrogen bromide produced during the reaction ;

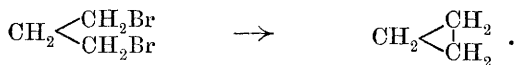


The tribromo-acid is therefore *αβδ-tribromobutane-βδ-dicarboxylic acid*. The most striking property of this acid is the fact that its methyl ester is quantitatively converted into *cyclobutane-1:3-dicarboxylic acid* when it is treated with zinc and acetic acid and subsequently hydrolysed, reduction and closing of the ring taking place simultaneously.

It is well known that some *αβ*-dibromo-acids are readily converted into the corresponding unsaturated acids by the action of zinc; thus, for example, *αβ*-dibromobutyric ester yields crotonic ester when its ethereal solution is treated with zinc filings (Michael and Schulthess, *J. pr. Chem.*, 1891, [ii], 43, 590). Assuming Baeyer's "Spannungs Theorie" to be correct, a change of this kind should take place with greater ease in the case of the formation of a *cyclobutane* ring from an *αδ*-dibromide,

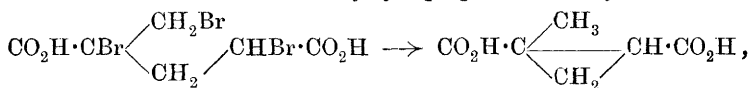


than in the formation of the ethenoid linking, because the "Spannung" in the closed four-carbon ring is much less than that in the ethenoid linking. And the same appears to be true in the *cyclopropane* series, since Gustavson (*Compt. rend.*, 1899, 128, 437; *J. pr. Chem.*, 1891, [ii], 59, 302) has shown that *cyclopropane* is almost quantitatively produced when an alcoholic solution of trimethylene bromide is digested with zinc:



It is therefore to be expected that ring formation will often be found to result from the action of zinc and other metals on *αγ*-, *αδ*-, *αε*-, and possible other more extended dibromo-compounds.

One other point in connexion with the formation of *cyclobutane-1:3-dicarboxylic acid* by the elimination of bromine from *αβδ*-tribromobutane-*βδ*-tricarboxylic acid is of interest. This elimination might result in the formation of a methyl*cyclopropanedicarboxylic acid*:

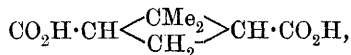


especially as the two *α*-bromo-atoms are probably the most reactive,

and the fact that the reaction actually proceeds quantitatively with formation of the *cyclobutane* ring is additional evidence that this ring is more readily formed than the *cyclopropane* ring.

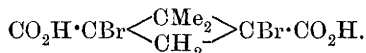
During the course of this investigation we have prepared large quantities of pinonic acid, and have made several new observations in connexion with this acid and its derivatives. The results of these experiments are described on p. 1174, and it will be only necessary, in this introduction, to discuss the experiments which illustrate the extraordinary stability of norpinic acid.

Norpinic acid,



is the *gem*-dimethyl derivative of *cyclobutane*-1:3-dicarboxylic acid, and, like this acid, it exists in *cis*- and *trans*-modifications.

Its investigation was thought to be interesting because this acid is a simple derivative of that dimethyl*cyclobutane* ring which, as has already been pointed out (p. 1166), so readily undergoes disruption when it is a constituent of the bridged-ring characteristic of pinene, nopinone, etc. Our experiments have, however, shown that this ring, in norpinic acid, exhibits quite unusual stability, and it is quite clear, therefore, that the closing of the bridged-ring in compounds such as pinene entirely alters the character of the dimethyl*cyclobutane* ring, possibly by producing a "strain" which is not present in the ring itself. Although *cis-cyclobutane*-1:3-dicarboxylic acid readily undergoes fission when it is treated with hydrobromic acid at 100°, this reagent has no action on *cis*-norpinic acid at 120°. Again, it is pointed out on p. 1168 that *cis-cyclobutane*-1:3-dicarboxylic acid is readily attacked by bromine at 100° with disruption of the ring and formation of $\alpha\beta$ -tribromobutane- $\beta\delta$ -dicarboxylic acid. Baeyer (*Ber.*, 1896, 29, 1911) states that the *cis*-norpinic acid yields a bromo-acid when it is treated with bromine by the Volhard method, and we can confirm this, but our experiments show that the acid chloride is attacked only with great difficulty by bromine at 100°, and that at 120° a bromo-acid is produced which, although not obtained pure, is doubtless 1:3-dibromo-*cis*-norpinic acid,

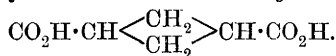


In this case, also, there is no evidence of any fission of the closed ring. It has already been pointed out (p. 1167) that the dimethyl*cyclobutane* ring in certain derivatives of pinene readily suffers disruption under the influence of weak acids, but norpinic acid, on the other hand, may be boiled with 10 per cent. sulphuric acid or heated on the water-bath with concentrated sulphuric acid without change.

Results such as the above clearly show (a) that comparatively slight changes, such as the introduction of methyl groups or the rearrangement of carboxyl groups, exercise a great influence on the stability of the *cyclobutane* ring, and (b) that this ring undergoes a remarkable reduction in stability when it becomes part of a bridged-ring system.

EXPERIMENTAL.

cis-cyclobutane-1 : 3-dicarboxylic Acid,



We have succeeded in devising two new methods for the preparation of this acid.

I. *By Condensation of Monochloromethyl Ether with the Sodium Derivative of Ethyl Methylenedimalonate.*

Ethyl methylenedimalonate (35 grams) was added to finely divided sodium (2.5 grams) suspended in dry ether, when a vigorous reaction ensued, and, after remaining overnight, the sodium had completely dissolved and a yellow sodium derivative separated. Monochloromethyl ether (10 grams), dissolved in an equal volume of dry ether, was then added all at once, and in two hours the reaction, which proceeds without the evolution of much heat, was complete and much sodium chloride had separated. The product was mixed with water, the ethereal solution separated, dried, and evaporated, when a colourless oil remained which, after several fractionations, distilled fairly constantly at 215—220°/24 mm. :

0.1226 gave 0.2413 CO₂ and 0.08 H₂O. C = 53.7 ; H = 7.2.

C₁₇H₂₈O₉ requires C = 54.2 ; H = 7.4 per cent.

This oil undoubtedly consists of ethyl δ -methoxybutane- α,γ,γ -tetracarboxylate, a substance which had already been obtained by a quite different process (Trans., 1908, **93**, 1784). This ester (3 grams) was mixed with 50 per cent. hydrochloric acid (25 c.c.) and digested on the sand-bath in a reflux apparatus for twelve hours, when hydrolysis was complete. On removing the excess of hydrochloric acid by evaporation, an oil was obtained which rapidly solidified, and after two crystallisations from dry ether, the acid melted at 129° and was found on examination to consist of *cis-cyclobutane-1 : 3-dicarboxylic acid*.

II. *By the Condensation of Ethyl Methylenedimalonate with Methylal.*

In carrying out this interesting condensation, the following method was, after several comparative experiments, found to give the best

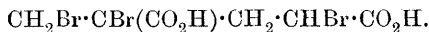
results. Ethyl methylenedimalonate (20 grams) was mixed with methylal (30 grams) and zinc chloride (0.5 gram) and heated in a sealed tube for two hours at 150—160° and then for one hour at 170°, and during the operation the tube was occasionally agitated in order to keep the contents well mixed. After cooling, the pale brown solution was poured into water, the oil which separated dissolved in ether, the ether was then evaporated, and the residual oil fractionated under diminished pressure, when a considerable quantity (9 grams) distilled at 200—220°/20 mm., a small, high boiling residue remaining in the flask. This crude oil, without further purification, was hydrolysed by boiling with 50 per cent. hydrochloric acid, when, after removing the hydrochloric acid by evaporation, a brown oil was obtained which soon almost completely solidified. After draining on porous porcelain, the acid was crystallised from ether, and found to melt at 128—130° and consist of pure *cis-cyclobutane-1 : 3-dicarboxylic acid* :

0.1346 gave 0.2456 CO₂ and 0.0642 H₂O. C = 49.8 ; H = 5.3.

C₆H₈O₄ requires C = 50.0 ; H = 5.6 per cent.

The *anhydride* of *cis-cyclobutane-1 : 3-dicarboxylic acid*.—As we were desirous, in our further experiments, to employ the pure *cis*-acid quite free from even traces of the *trans*-isomeride, we decided to purify it by conversion into the anhydride. The anhydride was obtained by digesting the acid with acetyl chloride in the manner previously described (Trans., 1898, **73**, 338), but, on the present occasion, it was purified by distillation under diminished pressure, when it was found to boil at 175—177°/20 mm. as a colourless oil which soon solidified, and, after remaining in contact with porous porcelain, the crystalline mass melted at 50—51°. The pure *cis*-acid, obtained from the anhydride by hydrolysis, melted sharply at 135—136°.

Bromination of cis-cyclobutane-1 : 3-dicarboxylic Acid. Formation of αβδ-Tribromobutane-βδ-dicarboxylic Acid,



The pure acid (2 grams) was digested with phosphorus pentachloride (5.8 grams) until decomposition was complete, and then heated with bromine (4.6 grams) in a sealed tube in a boiling-water bath for fifteen hours. The bromo-acid chloride was left in contact with powdered ice for two days, the heavy, viscid syrup extracted with ether, the ethereal solution well washed, dried, and evaporated, when an almost colourless syrup remained which rapidly crystallised. After remaining in contact with porous porcelain until quite dry, the solid residue was several times recrystallised from ether :

0.1184 gave 0.1726 AgBr. Br = 62.0.

$C_6H_7O_4Br_3$ requires Br = 62.7 per cent.

αβδ-Tribromobutane-βδ-dicarboxylic acid separates from ether in crusts of small plates, and melts with decomposition at 172°.

It is readily soluble in ether, formic acid, or hot water, but only sparingly so in benzene, chloroform, or light petroleum.

Methyl αβδ-Tribromobutane-βδ-dicarboxylate.—This substance was obtained by pouring the bromo-acid chloride, prepared as described above, into well cooled methyl alcohol. After remaining overnight, the methyl ester was precipitated by water, the heavy oil extracted with ether, the ethereal solution washed well with water and sodium carbonate, dried, evaporated, and the pale yellow oil left for some days in a vacuum desiccator over sulphuric acid. Two different preparations gave the following results on analysis :

0.1453 gave 0.1939 AgBr. Br = 56.8.

0.1681 „ 0.2261 AgBr. Br = 57.3.

$C_8H_{11}O_4Br_3$ requires Br = 58.4 per cent.

As it seemed possible that the remarkable course of the bromination of *cis-cyclobutane-1 : 3-dicarboxylic acid* was due to the pressure of the hydrogen bromide in the sealed tube, an experiment was made with the same quantities as before, but in an open flask fitted with a ground-in tube. The bromination proceeded on the water-bath very slowly, and, as soon as it was complete, the product was poured into methyl alcohol as described above. On analysis, the methyl ester was found to have practically the same composition as before :

0.2089 gave 0.2720 AgBr. Br = 55.4.

$C_8H_{11}O_4Br_3$ requires Br = 58.4 per cent.

Reduction of Methyl αβδ-Tribromobutane-βδ-tricarboxylate to cis cycloButane-1 : 3-dicarboxylic acid.—The bromo-methyl ester (4 grams), dissolved in acetic acid and a little water, was treated with zinc dust (20 grams), at first in the cold and afterwards on the water-bath. After filtering from undissolved zinc, water was added, the oil extracted with ether, and the ethereal solution well washed and evaporated.

The residual oil, which was quite free from bromine, was then hydrolysed with alcoholic potash, the solution mixed with water, evaporated until free from alcohol, acidified, and extracted several times with ether. After removing the ether by evaporation, a solid was obtained which separated from water in prisms melting at 131—133°, and consisted of *cis-cyclobutane-1 : 3-dicarboxylic acid*, the yield being nearly quantitative :

0.1682 gave 0.3081 CO_2 and 0.0831 H_2O . C = 49.9 ; H = 5.5

$C_6H_8O_4$ requires C = 50.0 ; H = 5.6 per cent

*Action of Hydrogen Bromide on cis-cyclobutane-1:3-dicarboxylic Acid.
Formation of α -Bromobutane- $\beta\delta$ -dicarboxylic Acid.*

In order to determine whether fission of the ring took place when *cis-cyclobutane-1:3-dicarboxylic acid* was heated with hydrobromic acid alone, the pure acid (1 gram) was mixed with aqueous hydrobromic acid (saturated at 0°, 10 c.c.) and heated in a sealed tube at 100° for three hours. The hydrobromic acid was then removed on the water-bath, when an oil remained which completely solidified, and, after crystallisation from benzene, the following results were obtained on analysis :

0.1113 gave 0.0922 AgBr. Br = 35.2.

$C_6H_9O_4Br$ requires Br = 35.5 per cent.

α -Bromobutane- $\beta\delta$ -dicarboxylic acid, which does not appear to have been previously described, separates from benzene, in which it is fairly readily soluble, in hard, nodular clusters of needles and melts at 106—107°. It is readily soluble in ether, water, or formic acid, but sparingly so in chloroform or light petroleum.

Reduction to α -Methylglutaric Acid.—This reduction, which proves the constitution of the bromo-acid, was carried out by treating the acid, dissolved in dilute sodium carbonate, with a large excess of sodium amalgam in the cold. The solution was acidified, extracted several times with pure ether, the ether evaporated, and the solid residue left in contact with porous porcelain until quite dry and then crystallised from ether :

0.1135 gave 0.2045 CO_2 and 0.0731 H_2O . C = 49.1 ; H = 7.1.

$C_6H_{10}O_4$ requires C = 49.3 ; H = 6.9 per cent.

Pinonic Acid, $CH_3 \cdot CO \cdot CH < \begin{smallmatrix} CMe_2 \\ -CH_2- \end{smallmatrix} > CH \cdot CH_2 \cdot CO_2H$, and its
Derivatives.

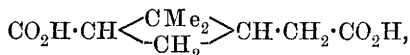
The large quantities of pinonic acid which have been prepared for the present investigation and during the course of our experiments on nopinone (Trans., 1907, 91, 1736) were obtained by the oxidation of pinene under the conditions recommended by Baeyer (*Ber.*, 1896, 29, 22). In purifying crude pinonic acid, we have found it advantageous, instead of distilling the acid itself as recommended by Baeyer, to convert it into its ester by digesting with alcohol and sulphuric acid, and then to fractionate this carefully under diminished pressure. The fraction distilling at 147—148°/16 mm. is pure *ethyl pinonate*, as the following analysis shows :

0.1141 gave 0.2858 CO_2 and 0.0975 H_2O . C = 68.2 ; H = 9.5.

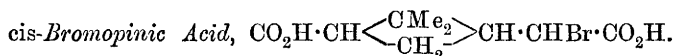
$C_{12}H_{20}O_3$ requires C = 68.0 ; H = 9.4 per cent.

When this ester is hydrolysed, it yields a syrup which soon becomes semi-solid, and doubtless consists of the *cis*- and *trans*-modifications of pinonic acid. In contact with porous porcelain, the syrup is absorbed, and the crystalline residue separates from water in colourless prisms melting at 103—105°.

In preparing *cis*-pinic acid,



by the method described by Baeyer (*loc. cit.*, p. 25), we have also found that it is best purified by conversion into the ester, which distils at 156°/20 mm., and, on hydrolysis, at once yields the pure acid.



Baeyer (*loc. cit.*, p. 1908) prepared this acid in a crude condition by the action of phosphorus tribromide and bromine on *cis*-pinic acid, but did not purify it. We have found that the pure bromo-acid is readily obtained by the following modification of Baeyer's process.

Pure *cis*-pinic acid (43 grams) is mixed with phosphorus pentachloride (100 grams), and, as soon as the vigorous action has subsided, the mixture is heated on the water-bath for half an hour. Bromine (13 grams) is then added to the well-cooled acid chloride, and the whole heated on the water-bath for three hours, care being taken so to regulate the process that there is no loss of bromine.

The product is poured in a thin stream into excess of anhydrous formic acid, and the solution heated on the water-bath until decomposition is complete, when, on keeping in the ice-chest, a quantity of a crystalline acid separates, which is collected and recrystallised from formic acid:

0.124 gave 0.0900 AgBr. Br = 30.9.

$\text{C}_9\text{H}_{13}\text{O}_4\text{Br}$ requires Br = 30.2 per cent.

cis-Bromopinic acid melts at about 154°, and separates from formic acid, in which it is sparingly soluble in the cold, in nodular masses composed of stout plates.

cis-Hydroxypinic acid, $\text{CO}_2\text{H}\cdot\text{CH}\begin{array}{c} \text{CMe}_2 \\ \text{CH}_2 \end{array}\text{CH}\cdot\text{CH}(\text{OH})\cdot\text{CO}_2\text{H}$, is conveniently prepared in the following way (compare Baeyer, *loc. cit.*, p. 1908). The bromo-acid chloride, obtained as explained above, is left in contact with ice until decomposed, and the syrup extracted with ether. After removing the ether by evaporation, the residue is digested with excess of barium hydroxide for one hour, the alkaline liquid filtered from tarry matter, concentrated, acidified, and extracted five times with ether. The ethereal solution yields, on con-

centration, a crystalline mass of pure *cis*-hydroxypinic acid, melting at 191—193°.

Ethyl cis-hydroxypinate is readily obtained by treating the acid with alcoholic sulphuric acid in the usual manner. It distils at 179°/16 mm. as a colourless oil, which rapidly crystallises, and separates from light petroleum in colourless needles melting at 58—60°:

0.1729 gave 0.3821 CO₂ and 0.1335 H₂O. C = 60.3; H = 8.6.

C₁₃H₂₂O₅ requires C = 60.5; H = 8.5 per cent.

cis-Norpinic acid, CO₂H·CH< $\begin{smallmatrix} \text{CMe}_2 \\ \text{CH}_2 \end{smallmatrix}$ >CH·CO₂H, is obtained, as Baeyer (*loc. cit.*, p. 1910) has shown, by the oxidation of hydroxypinic acid with chromic acid. We have prepared large quantities of this acid, and, during the course of our experiments, have obtained several derivatives which do not appear to have been previously described.

Ethyl cis-norpinate is readily obtained by treating the acid with alcohol and sulphuric acid in the usual manner, and is a colourless, mobile oil with a pleasant ethereal odour, which distils at 140°/20 mm.:

0.1223 gave 0.2826 CO₂ and 0.0951 H₂O. C = 63.0; H = 8.6.

C₁₂H₂₀O₄ requires C = 63.2; H = 8.8 per cent.

cis-Norpinic anhydride was prepared by heating the acid with excess of acetic anhydride in a sealed tube at 220°. The excess of acetic anhydride was removed under the ordinary pressure, and the residue rapidly distilled under 10 mm. pressure, when a syrup was obtained which soon crystallised. After remaining in contact with porous porcelain until quite dry, the anhydride was recrystallised from ether:

0.1539 gave 0.3474 CO₂ and 0.0898 H₂O. C = 62.2; H = 6.5.

C₈H₁₀O₃ requires C = 62.3; H = 6.5 per cent.

cis-Norpinic anhydride separates from ether in slender plates, melts at 135°, and, when warmed with water, is slowly converted into the crystalline acid, which melts at 173—175°, and is identical with the acid which is directly obtained by the oxidation of hydroxypinic acid.

It is clear, therefore, that norpinic acid and hydroxypinic acid, and probably also pinic acid and pinonic acid, belong to the *cis*-series.

trans-Norpinic Acid.—This acid, which does not appear to have been previously described, is obtained when the *cis*-acid is heated either with hydrochloric or with hydrobromic acid. The pure *cis*-acid (5 grams) is heated with hydrochloric acid (15 c.c.) and water (5 c.c.) in a sealed tube at 180° for two hours. The product is heated on the

water-bath until free from hydrochloric acid, and the solid residue, which consists of a mixture of the *cis*- and *trans*-acids, is fractionally crystallised from ether until nearly all of the less soluble *cis*-acid has been removed, and then from hydrochloric acid; from this solvent the pure *trans*-acid is ultimately obtained in hard nodules, which, under the microscope, are seen to be composed of slender prisms:

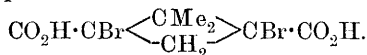
0.1106 gave 0.2265 CO₂ and 0.0725 H₂O. C = 55.8; H = 7.3.

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

trans-Norpinic acid softens at 137°, melts at 144°, and is more soluble in the usual solvents than the *cis*-modification.

Bromination of cis-Norpinic Acid.

cis-Norpinic acid is brominated with much greater difficulty than *cis*-cyclobutane-1:3-dicarboxylic acid, and evidently with the formation of 1:3-dibromonorpinic acid,



Norpinic acid (2 grams) was mixed with phosphorus pentachloride (5 grams), and, after the reaction had subsided, the mixture was heated on the water-bath for half an hour. Bromine (3.7 grams) was then added, and the whole heated in a sealed tube for forty-eight hours in a boiling-water bath, but, as the action was then not nearly complete, the heating was continued for three hours at 120°, when almost the whole of the bromine had disappeared. The bromo-acid chloride was decomposed by ice, the viscid, brown syrup dissolved in ether, and the ethereal solution dried and evaporated. The syrup, which showed no tendency to crystallise, was placed in a vacuum desiccator over sulphuric acid for some days and then analysed:

0.2515 gave 0.2500 AgBr. Br = 42.3.

C₈H₁₀O₄Br₂ requires Br = 48.5 per cent.

Although this result, as was to be expected, is only approximate, it clearly indicated that the product of the action of bromine on norpinic acid, under the conditions employed, is 1:3-dibromonorpinic acid, and this receives support from the fact that the bromo-acid yields norpinic acid when it is reduced by sodium amalgam in sodium carbonate solution. In confirmation of the above result, a second experiment was made in which the bromo-acid chloride was poured into methyl alcohol, when the methyl ester, extracted in the usual manner, was found to be a pale yellow oil, possessing a pungent odour, and having an unpleasant effect on the eyes:

0.1659 gave 0.1524 AgBr. Br = 39.1.

C₁₀H₁₄O₄Br₂ requires Br = 44.7 per cent.

This result again emphasises the difference in behaviour of *cyclo*-butane-1:3-dicarboxylic acid and norpinic acid on bromination (p. 1172).

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