CCII.—*The Constitution of the Benzenetetracarboxylic Acids.*

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DURING the course of an investigation which is described in the succeeding paper (p. 1910), it became necessary definitely to determine the constitution of two of the benzenetetracarboxylic acids, namely, prehnitic and mellophanic acids. The three isomeric benzenetetracarboxylic acids were first obtained by Baeyer (*Annalen*, 1873, **166**, 325) during the course of his classical researches on mellitic acid. It is unnecessary here to enter into the reasoning by which he deduced the formulæ to be ascribed to these acids, and it will suffice to point out that whilst he proved conclusively (*loc. cit.*, p. 344) pyromellitic acid to be benzene-1:2:4:5-tetracarboxylic acid, he was unable to decide whether prehnitic acid was benzene-1:2:3:4- or -1:2:3:5-tetracarboxylic acid. He inclined to the latter view, however (*loc. cit.*, p. 344), because he found that this acid only yields a monoanhydride, whilst if it had possessed four adjacent carboxyl groups it should give a dianhydride.

The question remained undecided until O. Jacobsen (*Ber.*, 1884, **17**, 2517) by the oxidation of *isodurene* obtained an acid which was shown by direct comparison to be identical with Baeyer's mellophanic acid. Now, since *isodurene* was obtained from bromomesitylene, it followed that mellophanic acid must be benzene-1:2:3:5-tetracarboxylic acid, and hence prehnitic acid would be the 1:2:3:4-isomeride. Further evidence in support of this view was obtained by Töhl (*Ber.*, 1888, **21**, 907), who oxidised prehnitene and isolated an acid which showed all the properties of prehnitic acid.

As the present authors had obtained results which seemed to throw some doubt on these experiments, it was decided to endeavour to devise methods for preparing prehnitic and mellophanic acids which would leave no doubt as to their constitution.

A ready means of carrying this out appeared to be to prepare mesitylenecarboxylic acid and to oxidise this to the corresponding tetrabasic acid.

Mesitylenecarboxylic acid (II) was found to be most conveniently obtained by the action of magnesium and carbon dioxide on bromomesitylene (I), and on oxidation with nitric acid under the conditions described in the experimental part of this paper (p. 1907), it was found to be converted quantitatively into benzene-1:2:3:5-tetracarboxylic acid (III).

The substance obtained in this way showed all the properties ascribed by Baeyer to the acid called by him prehnitic acid, and there can therefore be little doubt that this acid is really benzene-1:2:3:5-tetracarboxylic acid. This view also receives support from the following stereochemical considerations: (a) The acid yields only a monoanhydride (Baeyer, *loc. cit.*); (b) when esterified in the cold with methyl alcohol and hydrochloric acid it gives a dimethyl ester (compare Meyer and Sudborough, *Ber.*, 1894, **27**, 1591), which probably has the constitution (IV); (c) when, however, the acid is esterified by means of alcohol and sulphuric acid by heating on the water-bath in the usual manner, it yields a triethyl ester which undoubtedly has the constitution (V).

Having shown conclusively that prehnitic acid is benzene-1:2:3:5-tetracarboxylic acid, it seemed that mellophanic acid must be benzene-1:2:3:4-tetracarboxylic acid, but in order to be certain it was decided to synthesise this acid.

For this purpose a large amount of 1:4-dimethylnaphthalene was prepared, and this, on oxidation with nitric acid, gave a mixture of acids, from which a tetrabasic acid was separated; this possessed all the properties of Baeyer's mellophanic acid.

When the silver salt of the acid was heated with methyl iodide, a neutral tetramethyl mellophanate (m. p. 133°) was obtained.

Since mellophanic acid is 1:2:3:4-benzenetetracarboxylic acid, it should, in accordance with the usual views on steric hindrance, yield only a diacid ester by the direct process of esterification. This is probably the case, since no trace of neutral tetraethyl mellophanate was produced on heating the acid with alcohol and sulphuric acid. A barium salt was isolated by treatment of the reaction product with baryta and subsequent evaporation, and this gave on titration results which indicated it to be a barium salt of the diacid ester with two or three molecules of water of crystallisation. The direct determination of the water of crystallisation gave entirely anomalous results, and this important point will therefore be re-investigated. It is clear, however, that the acid cannot be completely esterified by the usual process.

As the result of these experiments there can therefore be little doubt that prehnitic acid and mellophanic acid are respectively benzene-1: 2: 3: 5- and -1: 2: 3: 4-tetracarboxylic acids.

It is somewhat difficult to see how Jacobsen (*loc. cit.*) obtained from *isodurene* the acid which he showed to be identical with Baeyer's mellophanic acid, since he prepared his hydrocarbon by the action of methyl iodide and sodium on bromomesitylene. It is hardly likely that any rearrangement of groups would take place during this reaction, as such rearrangement only appears to take place in the presence of aluminium chloride. We are therefore driven to the conclusion that the hydrocarbon used by Jacobsen in his experiments cannot have been mesitylene, and must have consisted mainly of ψ -cumene.

It has already been mentioned that Töhl (*loc. cit.*) obtained prehnitic acid by the oxidation of prehnitene, which hydrocarbon is prepared by the degradation of pentamethylbenzene by means of sulphuric acid. He, however, offers no proof of the constitution of his hydrocarbon apart from the fact that it was identical with that previously obtained by Jacobsen (*Ber.*, 1886, **19**, 1213; 1887, **20**, 901). Jacobsen isolated this hydrocarbon by the action of hydrochloric acid on a sulphonamide prepared from durene and by the degradation of pentamethylbenzene, two reactions which offer no proof of constitution, and the only grounds for considering that prehnitene is 1: 2: 3: 4-tetramethylbenzene is because it is isomeric with the hydrocarbon he obtained by the action of methyl iodide and sodium on bromomesitylene, and that it does not give pyromellitic acid on oxidation. If, then, the hydrocarbon obtained by Jacobsen from bromomesitylene is 1: 2: 3: 4-tetramethylbenzene, then prehnitene must be 1: 2: 3: 5-tetramethylbenzene.

Further experiments on this interesting subject are in progress. Unfortunately, the wrong conception of the nature of prehnitic acid and of prehnitene, which has so long prevailed, has led to much confusion in assigning constitutional formulæ on the basis of these substances being 1: 2: 3: 4-substitution derivatives of benzene.

EXPERIMENTAL.

Prehnitic Acid (Benzene-1: 2: 3: 5-tetracarboxylic Acid).

Mesitylenecarboxylic Acid.—Bromomesitylene (20 grams) was added to magnesium (2.4 grams) suspended in dry ether, the magnesium having first been treated with a small amount of methyl iodide in order to render it reactive. A vigorous reaction ensued, and when this had ceased, the mixture was heated on the water-bath until all the magnesium had passed into solution. After being kept cold overnight, a slow stream of dry carbon dioxide was

passed into the ethereal solution of the magnesium compound, when a heavy oil slowly separated. Ice and dilute hydrochloric acid were then added, and the ethereal layer was separated and washed with sodium carbonate solution.

On acidifying the latter solution, a colourless, crystalline precipitate (7.5 grams) separated, which was collected and dried. The mesitylenecarboxylic acid obtained in this way was purified by crystallisation from light petroleum, from which it separated in glistening prisms, possessing the correct melting point, 151—152°. (Found, C=72.9; H=7.4. Calc., C=73.4; H=7.3 per cent.)

Oxidation of Mesitylenecarboxylic Acid to Prehnitic Acid.—Mesitylenecarboxylic acid (1 gram) was mixed with 10 c.c. of dilute nitric acid (D 1.15), and heated in a sealed tube for eight hours at 170—180°. After removing the nitric acid by evaporation on the water-bath, the prehnitic acid was purified by repeated crystallisation from hydrochloric acid, from which it separated in small prisms. After drying at 100° to remove water of crystallisation, it was analysed. (Found, C=46.8; H=2.3. Calc., C=47.2; H=2.3 per cent.)

Prehnitic acid melts at 252°, previously softening at about 240°, and is converted into the anhydride, melting at 238°, whereas Baeyer (*Annalen*, 1873, **166**, 328) states that it begins to melt at 237°, becoming completely liquid at 250°, whilst the anhydride melts at 238°. That it was a tetrabasic acid was shown by titration with standard sodium hydroxide, when it was found that 0.096 neutralised 0.058NaOH, whereas a tetrabasic acid, $C_{10}H_6O_8$, should neutralise 0.06008NaOH. When barium chloride was added to an aqueous solution of prehnitic acid and the solution warmed, an immediate precipitate of the barium salt of the acid was obtained. After drying at the temperature of the laboratory for two days, it was analysed, when it was found to have the composition given to the barium salt of prehnitic acid by Baeyer (*Annalen*, 1873, **166**, 332):

0.2354 lost 0.0122 H_2O at 100°. $H_2O=5.2$.

0.1514 gave 0.0502 $BaSO_4$. $Ba=19.4$.

$(C_{10}H_5O_8)_2Ba \cdot 3H_2O$ requires $Ba=19.6$; $2H_2O=5.4$ per cent.

The barium salt, when dried at 100°, gave the following result:

0.2197 gave 0.0775 $BaSO_4$. $Ba=20.70$.

$(C_{10}H_5O_8)_2Ba \cdot H_2O$ requires $Ba=20.8$ per cent.

Tetramethyl Prehnitate, $C_6H_2(CO_2Me)_4$.—Tetramethyl prehnitate has already been isolated by Baeyer (*Annalen*, 1873, **166**, 333) by the action of methyl iodide on the silver salt of the acid. A repetition of this process yielded the ester in beautiful, colourless

needles, which, after crystallisation from methyl alcohol, melted at 108—109° (Baeyer gives 104—109°). (Found, C=54.1; H=4.5. Calc., C=54.2; H=4.5 per cent.)

Triethyl Hydrogen Prehnitate, $C_6H_2(CO_2Et)_3 \cdot CO_2H$.

This ester, which does not seem to have been previously obtained, is readily formed when prehnitic acid is treated with alcohol and sulphuric acid in the usual manner. It was purified by repeated crystallisation from a mixture of benzene and light petroleum, when it separated in colourless clusters of needles, which melt at about 108—110°:

0.123 gave 0.2625 CO_2 and 0.0601 H_2O . C=58.2; H=5.4.

$C_{17}H_{18}O_8$ requires C=58.3; H=5.1 per cent.

Triethyl hydrogen prehnitate is readily soluble in most organic solvents with the exception of light petroleum. Its probable constitution has already been discussed in the introduction (p. 1905).

Dimethyl Dihydrogen Prehnitate, $C_6H_2(CO_2Me)_2(CO_2H)_2$.*

It has already been pointed out by Meyer and Sudborough (*Ber.*, 1894, **27**, 159) that when a methyl-alcoholic solution of prehnitic acid is treated with hydrogen chloride in the cold, only a dimethyl ester is formed. This result has been confirmed, but the melting point of the ester when crystallised from a mixture of acetone and light petroleum was found to be about 191°, and not 176—177°, as stated by them. The *silver* salt was analysed:

0.0519 gave 0.0225 Ag. Ag=43.3.

$C_{12}H_8O_8Ag_2$ requires Ag=43.5 per cent.

Mellophanic Acid (Benzene-1 : 2 : 3 : 4-tetracarboxylic Acid).

Oxidation of 1 : 4-Dimethylnaphthalene.—1 : 4-Dimethylnaphthalene (2 c.c.), prepared as described by Giovannozzi (*Gazzetta*, 1882, **12**, 147), was mixed with 40 per cent. nitric acid (20 c.c.), and heated in a sealed tube at 170—180° for eight hours. The clear solution was evaporated to dryness on the water-bath, when a semi-solid, crystalline mass was obtained, which evidently consisted of a mixture of acids.

In order to separate the mellophanic acid, a somewhat tedious process of purification had to be adopted. The crude acid was dissolved in as little water as possible, and the solution treated with excess of stannous chloride and concentrated hydrochloric acid for two hours on the water-bath. The strongly acid mixture was then

* By an oversight, Stewart states (*Stereochemistry*, p. 341) that prehnitic acid forms a tetramethyl ester when esterified in the usual manner.

evaporated to dryness, the residue dissolved in water, and the tin precipitated with hydrogen sulphide. After separating the tin sulphide, the solution was again evaporated to dryness, and the mixture of phthalic and mellophanic acids extracted with dry ether in a Soxhlet apparatus, when it was found that the amino-acids, which were present as hydrochlorides, were not dissolved. As preliminary experiments showed it to be a matter of some difficulty to separate the mellophanic and phthalic acids by fractional crystallisation, they were converted into their silver salts in the usual manner, and the dry silver salts were digested with methyl iodide in benzene solution for some hours on the water-bath. After separating from the silver iodide, the benzene was removed, when a viscid oil was obtained, which on trituration with ether partly solidified. The solid ester, which was found to consist of *methyl mellophanate*, was separated and purified by repeated crystallisation from methyl alcohol:

0.124 gave 0.2455 CO_2 and 0.0552 H_2O . $\text{C}=54.0$; $\text{H}=4.9$.

$\text{C}_{14}\text{H}_{14}\text{O}_8$ requires $\text{C}=54.2$; $\text{H}=4.5$ per cent.

Methyl mellophanate, which does not appear to have been previously described, separates from methyl alcohol in long, glistening needles, melting at $133-135^\circ$. It is readily soluble in benzene, ethyl acetate, or acetone, but only sparingly so in ether, light petroleum, or cold methyl alcohol.

In order to obtain the free acid, the methyl ester was hydrolysed in the usual manner with alcoholic potassium hydroxide, and, after removing the alcohol on the water-bath, the solution was acidified, evaporated to dryness, and the acid extracted with ether in a Soxhlet apparatus. The crude acid was purified by crystallisation from hydrochloric acid, when it was found to soften slightly at 225° , and melt and decompose at 238° with formation of the anhydride (compare Baeyer, *loc. cit.*). (Found, $\text{C}=47.02$; $\text{H}=2.3$. Calc., $\text{C}=47.2$; $\text{H}=2.3$ per cent.) The basicity of the acid was determined by titration with normal sodium hydroxide, when it was found that 0.0648 neutralised 0.0404 NaOH , whereas a tetrabasic acid, $\text{C}_{10}\text{H}_6\text{O}_8$, should neutralise 0.04081 NaOH .

Mellophanic acid is readily soluble in water or acetone, but only sparingly so in most organic solvents.

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