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Studies of *C*-Substituted Tartaric Acid. II. On the Configurations of Isomeric 2-Methyltartaric Acids, 1, 2-Dihydroxycyclohexane-1, 2-dicarboxylic Acid and 2, 3-Dimethyltartaric Acids

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The assignments of the erythro-threo configuration to isomeric 2-methyltartaric acids and the cis-trans configuration to isomeric 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acids were made on the basis of the infrared absorption spectra of their calcium salts. Thus, the isomer of 2-methyltartaric acid, with a m. p. of 146°C, corresponds to the erythro form, and the other isomer, with a m. p. of 161°C, to the threo form; also the one isomer of isomeric 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acids with a m. p. of 154°C corresponds to the cis (meso) form, and the other, with a m. p. of 180°C, to the trans (racemic) form. The configurations of the compounds are discussed in comparison with those of tartaric acid and 2, 3-dimethyltartaric acid, the latter of which was recently decided by optical resolution by present author (S. Tatsumi, This Bulletin, in press.).

2-Methyltartaric acid, 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acid and 2, 3-dimethyltartaric acid are interesting substances in relation to tartaric acid from the stereochemical point of view. In the previous paper¹⁾ it has been reported that two racemic forms of 2-methyltartaric acid, the melting points of which are 146°C (Ia) and 161°C (Ib), were prepared and that both racemic substances were then resolved into their optically active isomers. In an earlier publication from our laboratory,²⁾ it was also reported that a Raney nickel catalyst treated with aqueous solutions of these optically active hydroxy acids has an asymmetric activity in the hydrogenation of methyl acetoacetate to methyl 3-hydroxybutyrate, and that a high asymmetric activity is obtained when the catalyst is treated with optically active Ib, while opticallyactive Ia has only a low asymmetric effect on Raney nickel under the same conditions. Thus it has been supposed that the difference in the asymmetric effects of Ia and Ib depends upon their erythro-threo isomerism. However, there have been no reports on the configurations of isomeric 2-methyltartaric acids.

1, 2-Dihydroxycyclohexane-1, 2-dicarboxylic acid,*¹ which is a kind of *C, C'*-disubstituted tartaric acid, was prepared from 1, 2-cyclohexanedione and then separated into two optically inactive isomeric forms, the melting points of which are 154°C (IIa) and 180°C (IIb).*¹ It is, however, unknown at the present time which steric isomer is cis (meso) and which is trans (racemic).

On the other hand, the present author and others¹⁾ have reported that 2, 3-dimethyltartaric acid has two optically inactive modifications, the melting points of which are 180°C (IIIa) and 187°C (IIIb), and that IIIb could be resolved into two optically active isomers, while IIIa could not. This shows clearly that IIIb corresponds to the threo (racemic) form and IIIa, to the erythro (meso) form.

In the present study, the configurations of the isomeric 2-methyltartaric acids and 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acids were assigned on the basis of a study of the infrared spectra of their calcium salts in comparison with the configurations of meso and racemic tartaric acid (IVa and IVb) and those of meso and racemic 2, 3-dimethyltartaric acid. There have been several reports³⁾ on the configurations of aliphatic or alicyclic diol, but these cannot always be applied to an α, α'-dihydroxydicarboxylic acid. In the present paper, the configurations of isomeric *C*-substituted and *C, C'*-disubstituted tartaric acids are also predicted.

The physical constants and analytical data of the acids and their salts used in the present work are listed in Table I.

Experimental

Materials.—Ia (or Ib) and IIIa (or IIIb) were prepared from α-acetoxyacetoacetate and diacetyl respectively by the method described in the previous

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1) S. Tatsumi, Y. Izumi, M. Imaida, Y. Fukuda and S. Akabori, This Bulletin, in press.

2) Y. Izumi, S. Tatsumi, M. Imaida, Y. Fukuda and S. Akabori, ibid., in press.

*1 The preparation of this hydroxy acid and its separation into the two isomeric forms will be described in this Bulletin in the near future.

3) L. P. Kuhn, *J. Am. Chem. Soc.*, **74**, 2492 (1952); **76**, 4323 (1954); **80**, 5950 (1958); N. Mori, S. Omura and Y. Tsuzuki, This Bulletin, **38**, 1037 (1965).

Table I. Melting points and analytical data on the acids used and on their salts

Acid and salt	M. p., °C	Empirical formula	Anal. Calcd. (%) Found (%) C	H
2-Methyltartaric acid (Ia)	146	$C_5H_8O_6$	36.59 36.73	4.91 4.89
2-Methyltartaric acid (Ib)	161	$C_5H_8O_6$	36.59 36.53	4.91 4.93
1, 2-Dihydroxycyclohexane-1, 2-dicarboxylic acid (IIa)	154	$C_8H_{12}O_6$	47.06 47.14	5.92 5.96
1, 2-Dihydroxycyclohexane-1, 2-dicarboxylic acid (IIb)	180	$C_8H_{12}O_6$	47.06 46.72	5.92 5.97
meso-2, 3-Dimethyltartaric acid (IIIa)	180	$C_6H_{10}O_6$	40.45 40.31	5.66 5.64
DL-2, 3-Dimethyltartaric acid (IIIb)	187	$C_6H_{10}O_6$	40.45 41.00	5.66 5.60
meso-Tartaric acid (IVa)	140	$C_4H_6O_6$	32.01 32.11	4.03 4.00
DL-Tartaric acid (IVb)	206	$C_4H_6O_6$	32.01 32.09	4.03 3.99
Ia-Ca	—	$C_5H_6O_6Ca \cdot 2H_2O$	25.21 25.17	4.23 4.34
Ib-Ca	—	$C_5H_6O_6Ca \cdot 2H_2O$	25.21 25.08	4.23 4.17
IIa-Ca	—	$C_8H_{10}O_6Ca \cdot H_2O$	36.91 37.66	4.65 4.70
IIb-Ca	—	$C_8H_{10}O_6Ca$	39.66 39.57	4.16 4.20
IIIa-Ba	—	$C_6H_8O_6Ba \cdot 2H_2O$	20.62 20.31	3.46 3.54
IIIb-Ba	—	$C_6H_8O_6Ba \cdot 2H_2O$	20.62 20.39	3.46 3.66
IVa-Ba	—	$C_4H_4O_6Ba \cdot H_2O$	15.83 15.60	1.99 2.07
IVb-Ba	—	$C_4H_4O_6Ba \cdot 5H_2O$	12.79 13.08	3.76 3.36

paper.[1] IIa*[1] (or IIb*[1]) was prepared from 1, 2-cyclohexanedione, and IVa (or IVb) was prepared from glyoxal by Pollak's procedure.[4]

The calcium salts were obtained by the neutralization of aqueous solutions containing the acids and an equimolar amount of calcium chloride, with a sodium hydroxide solution. The barium salts were obtained similarly by the neutralization of aqueous solutions of the acids with a barium hydroxide solution. The data for these acids and salts are listed in Table I.

Spectra.—The infrared spectra were recorded using a Shimadzu IR spectrophotometer; further details were also recorded using a Perkin-Elmer Model 221 spectrophotometer equipped with a lithium fluoride prism.

Results and Discussion

The Infrared Spectra of the Salts.—The spectra of Ia-calcium salt (Ia-Ca) and Ib-calcium salt (Ib-Ca) are shown in Fig. 1.

A characteristic difference between the spectrum of Ia-Ca and that of Ib-Ca was observed in the region around 3600 cm^{-1}. In this region Ia-Ca had a single sharp band, while Ib-Ca did not. A similar difference between the spectra of IIa-Ca and IIb-Ca was also observed, as is shown in Fig. 2. It is likely that these differences depend on the erythro-threo or meso-racemic (cis-trans) configurations of the salts.

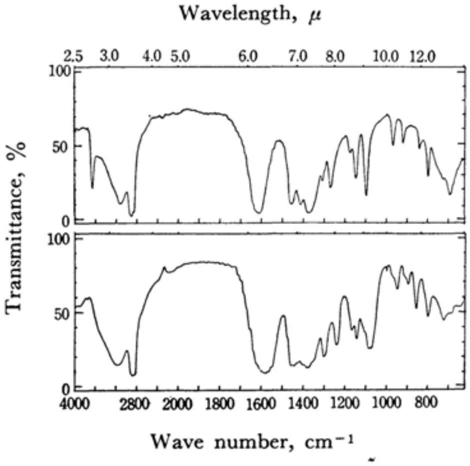

Fig. 1. Infrared spectra (Nujol) of:
Ia-Ca (upper curve)
Ib-Ca (lower curve)

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[4] F. Pollak, *Monatsh.*, **15**, 469 (1894).

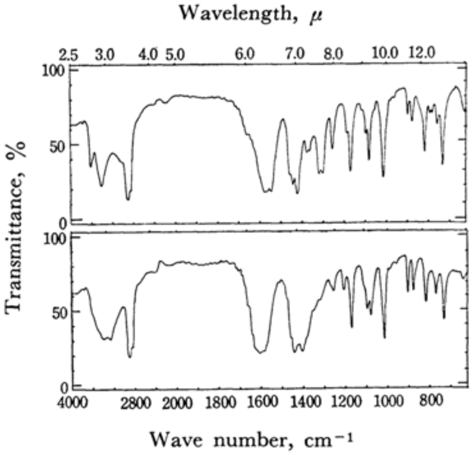

Fig. 2. Infrared spectra (Nujol) of:
IIa-Ca (upper curve)
IIb-Ca (lower curve)

To explain the configurations of these substances, the spectra of IIIa-Ba, IIIb-Ba, IVa-Ba and IVb-Ba, the configurations of which are well known, were measured and compared with the results described above. The spectra of these compounds of known configurations are shown in Figs. 3 and 4.

As is shown in Figs. 3 and 4, both IIIa-Ba and IVa-Ba had sharp bands similar to those of Ia-Ca and IIa-Ca shown in Figs. 1 and 2 in the region around 3600 cm^{-1}. IIIb-Ba and IVb-Ba did not have these bands, however, and thus were like Ib-Ca and IIb-Ca in this characteristic point.

On the other hand, as has been reported in the previous paper[1], IIIa and IIIb correspond to the erythro (meso) and threo (racemic) forms respectively; the optical resolution of the former is possible, but that of the latter is impossible. Moreover, IVa is the erythro (meso) form, and IVb is the threo (racemic) form.

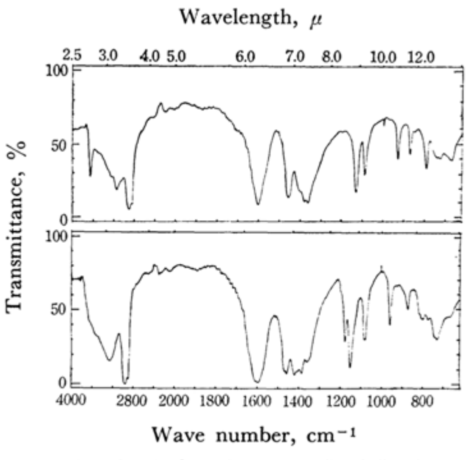

Fig. 3. Infrared spectra (Nujol) of:
IIIa-Ba (upper curve)
IIIb-Ba (lower cnrve)

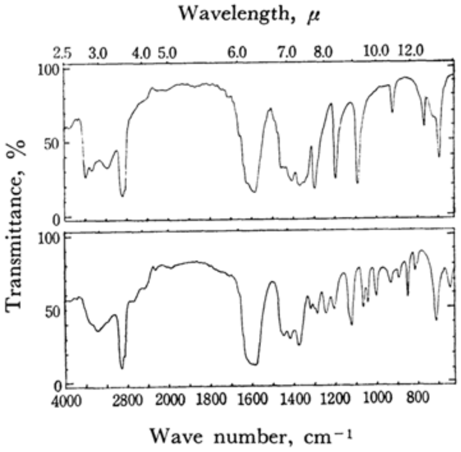

Fig. 4. Infrared spectra (Nujol) of:
IVa-Ba (upper curve)
IVb-Ba (lower curve)

Thus, from the configurations of these acids and the spectra of their salts, it may be supposed that both Ia and IIa are to be assigned to the same erythro or meso (cis) configuration as IIIa and IVa, and both Ib and IIb*2, to the same threo or racemic (trans) configuration as IIIb and IVb.

For further details of the spectrum in the 3600 cm^{-1} region, measurements were made of the spectra of the salts using a lithium fluoride prism. The observed frequencies were then calibrated against that of atmospheric vapor. Sharp bands of Ia-Ca, IIa-Ca, IIIa-Ba and IVa-Ba were observed at 3597, 3546, 3605 and 3554 cm^{-1} respectively, and no regular change in the intensity ratio with the concentration was observed. However, there were no similar bands in the spectra of Ib-Ca, IIb-Ca, IIIb-Ba and IVb-Ba. Hence, these bands must be due to intramolecular hydrogen bonds, which appear clearly only in the

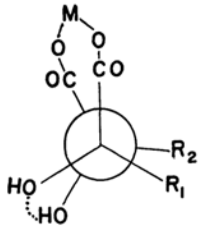

Fig. 5. Projections of the salts of:
Ia-Ca; M=Ca, $R_1=CH_3$ $R_2=H$
IIa-Ca; M=Ca, $\left\langle \begin{array}{l} (R_1)\text{-}CH_2\text{-}CH_2 \\ \qquad\qquad\quad | \\ (R_2)\text{-}CH_2\text{-}CH_2 \end{array}\right.$
IIIa-Ba; M=Ba, $R_1=R_2=CH_3$
IVa-Ba; M=Ba, $R_1=R_2=H$

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*2 Subsequently, IIb corresponding to the racemic form was resolved into the optically active isomers and the present assignment was proved to be correct. Details of this work will be published in this Bulletin in the near future.

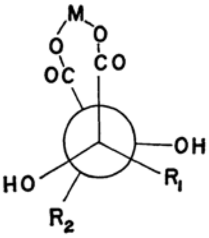

Fig. 6. Projections of the salts of:
Ib-Ca; M=Ca, $R_1=CH_3$, $R_2=H$
IIb-Ca; M=Ca, $\left\langle\begin{array}{l}(R_1)\text{-}CH_2\text{-}CH_2\\ \qquad\qquad\quad\ \ |\\ (R_2)\text{-}CH_2\text{-}CH_2\end{array}\right.$
IIIb-Ba; M=Ba, $R_1=R_2=CH_3$
IVb-Ba; M=Ba, $R_1=R_2=H$

erythro- or cis-type salts because of the definite conformational structure formed by the fixing of two carboxyl groups to a calcium or a barium metal, and by two fixing groups, carboxyl-metal and the alicyclic ring, as is shown in Fig. 5. It is likely that Ib-Ca, IIb-Ca, IIIb-Ba and IVb-Ba, which do not have intramolecular hydrogen bonds, have the threo or trans form and that they have the conformation shown in Fig. 6.

The configurations of isomeric 2-methyltartaric acids given above support the findings on their asymmetric hydrogenation effects upon a Raney nickel catalyst obtained in previous work.(2)

Summary

The configurations of isomeric 2-methyltartaric acids and 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acids have been determined on the basis of a study of the infrared spectra of their calcium salts in comparison with those of the barium salts of isomeric tartaric acids and 2, 3-dimethyltartaric acids, the configurations of which were already known. Both barium meso tartaric acid and barium meso 2, 3-dimethyltartaric acid have a sharp band due to intramolecular hydrogen bonds; however, the racemic salts do not. Similar differences have been observed in the spectra of the calcium salts prepared from isomeric 2-methyltartaric acids and isomeric 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acids. It has been concluded that these are due to a definite conformational structure caused by the fixing of two carboxyl groups with a metal. Thus, the form of 2-methyltartaric acid, with a m. p. of 146°C, was identified as the erthro form, and the form with a m. p. of 161°C, as the threo form. Further, the form of 1, 2-dihydroxycyclohexane-1, 2-dicarboxylic acid, with a m. p. of 154°C, was identified as the cis or meso form, and the other form, with a m. p. of 180°C, as the trans or racemic form.

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