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THE SYNTHESIS AND X-RAY STRUCTURE DETERMINATION OF CIS-1,2-BIS(2-CARBOXY-2-PROPYL)CYCLOHEXANE

Richard P. Dodge, Donald K. Wedegaertner, William J. Darden, Jr., and Edward B. Samuel
University of the Pacific, Stockton, California

Quintin Johnson
Lawrence Radiation Laboratory, Livermore, California

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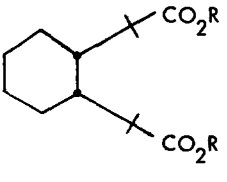
Recently, cis-1,2-di-t-butylcyclohexane has been synthesized, and the skew-boat conformation was determined to be slightly more stable than the chair conformer.[1]

We wish to report the synthesis and x-ray structure of the closely related compound, cis-1,2-bis(2-carboxy-2-propyl)cyclohexane (Ia). The atmospheric pressure hydrogenation (PtO_2 catalyst) of a refluxing acetic acid solution of 1,2-bis(2-carboxy-2-propyl)benzene[2] gave Ia. The crude material obtained after removal of the Pt catalyst by filtration and evaporation of the acetic acid generally melted at about 185-187°.

After recrystallization from ethyl acetate, Ia had an m.p. of 199-199.5°; IR(KBr, cm^{-1}): 2900(C-H), 2600(O-H), 1685(C=O); and a correct elemental analysis. The dimethyl ester (Ib) was prepared by treating Ia with a slight excess of ethereal diazomethane, showed a single GC peak using a phenyldiethanolamine succinate column, and gave the following NMR (δ, in CCl_4): 3.60(singlet, 6H); 2.30(unresolved multiplet; 2H); 1.58(unresolved multiplet, 8H); and 1.19(singlet, 12H). The bis-p-bromophenacyl ester (Ic), prepared by a standard procedure,[3] gave a proper elemental analysis and NMR spectrum.

Two crystalline forms of Ic were obtained: one melted at 125-126°; the other at 154-156°. After the lower m.p. crystals melted, they resolidified at about 130° and melted again at the higher temperature.



Ia, R = H
Ib, R = CH_3
Ic, R = $CH_2COC_6H_4$-p-Br

Substance Ia used in the x-ray study was recrystallized from ethanol. It was found to have space group symmetry $\underline{P}2_1/\underline{c}$ with four molecules per unit cell. The cell dimensions were $\underline{a}$ = 7.99 Å, $\underline{b}$ = 24.06 Å, $\underline{c}$ = 8.15 Å, β = 112.6°; the x-ray density was 1.17 g/cm^3. Intensities of 1349 reflections were measured by the stationary-counter, stationary-crystal method using a computer controlled diffractometer. The background counts were estimated from 2θ scans taken away from the Bragg reflections and applied to the set of data as a function of theta. All reflections out to a maximum 2θ angle of 40° were recorded using Zr-filtered Mo $\underline{K}\alpha$ radiation. Most of the data above 40° in 2θ were not significantly above background so that little if any significant non-zero data are missing.

Data were reduced to give normalized structure factors ($\underline{E}$'s) for use in the symbolic addition procedure. Application of the centro-symmetric symbolic addition procedure gave the correct solution in a straightforward manner.[4] Refinement of the structure was by conventional full-matrix least-squares methods. All but two hydrogen atoms (those involved in hydrogen bonding) were located by a difference Fourier synthesis. Final least-squares refinements used anisotropic temperature factors and fixed atomic parameters for the hydrogen atoms. The final $\underline{R}$-factor was 0.12. Final position parameters are given in Table 1. The complete table of $\underline{F}_o$-$\underline{F}_c$ data plus anisotropic temperature factors are available from the authors (RPD).

The molecular structure shown in Fig. 1 is in the chair conformation with isobutyric acid groups cis. The calculated bond distances shown have an estimated standard deviation of about 0.02 Å. Both this figure and the rather high $\underline{R}$ factor are accounted for by the weakness of the reflections at high scattering angles (no weak data were deleted) resulting from the low scattering power of this

Table 1. Final position parameters in cis-1,2-bis(2-carboxy-2-propyl)cyclohexane.

Atom	$\underline{x}/\underline{a}$	$\underline{y}/\underline{b}$	$\underline{z}/\underline{c}$
O_1	0.3278	-0.0522	0.4487
O_2	0.5876	-0.0490	0.4068
O_3	0.3194	-0.0121	0.0512
O_4	0.4221	-0.0606	-0.1240
C_1	0.0973	-0.1031	0.0664
C_2	-0.1077	-0.1181	0.0201
C_3	-0.1569	-0.1792	-0.0354
C_4	-0.0376	-0.2201	0.1051
C_5	0.1672	-0.2064	0.1560
C_6	0.2076	-0.1448	0.2155
C_7	0.4147	-0.1345	0.3262
C_8	0.4732	-0.1673	0.5054
C_9	0.5394	-0.1508	0.2341
C_{10}	0.4455	-0.0744	0.3923
C_{11}	0.1464	-0.0930	-0.1002
C_{12}	-0.0060	-0.0577	-0.2410
C_{13}	0.1780	-0.1433	-0.1988
C_{14}	0.3079	-0.0523	-0.0506

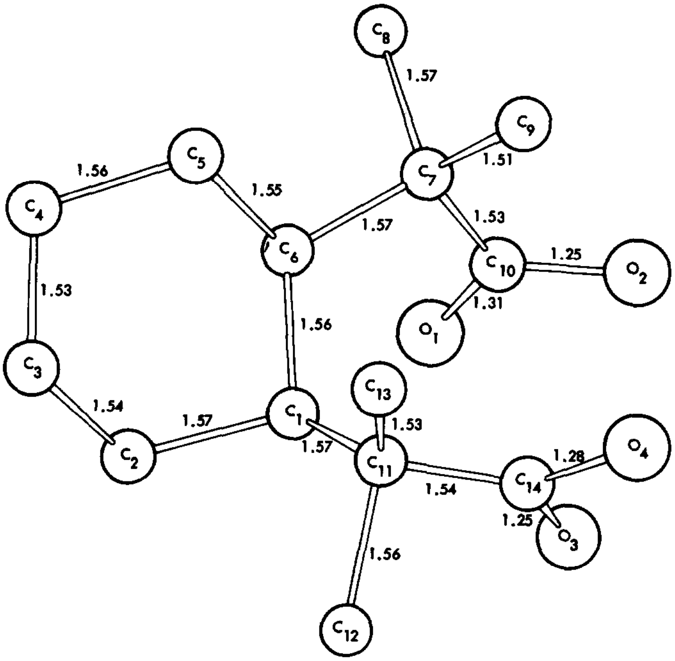


Figure 1. Molecular structure of cis-1,2-bis(2-carboxy-2-propyl)cyclohexane.

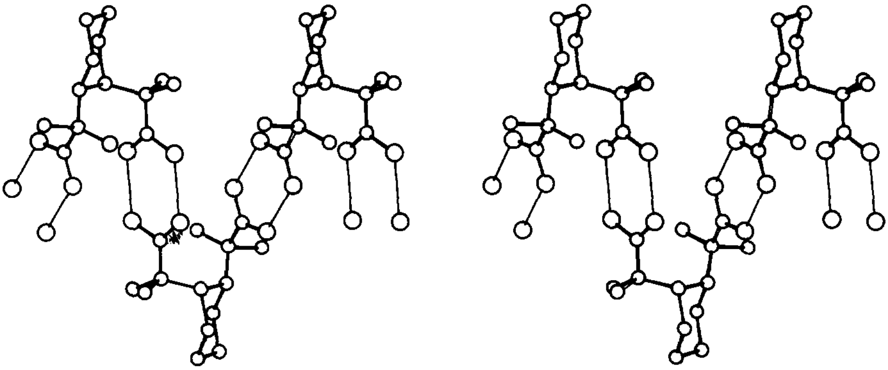


Figure 2. Stereogram of cis-1,2-bis(2-carboxy-2-propyl)cyclohexane.

light-atom structure to Mo radiation. The correctness of the structure is established by the absence of spurious peaks in the final electron density and difference Fourier maps.

The crystal structure consists of infinite chains of hydrogen-bonded molecules; a portion of one chain is shown in the stereogram of Fig. 2. Distances between hydrogen-bonded oxygen atoms (shown by single connection in Fig. 2) were found to be 2.68 Å for O_1-O_2 and 2.60 Å for O_3-O_4.

It is worthy of note that over a range of temperatures, the NMR spectrum of *cis*-1,2-di-*t*-butylcyclohexane indicated a substantial amount of both the skew-boat and chair conformations exist in solution. The skew-boat conformation was more stable by 0.2 kcal/mol.[1] However, Ia exists in the chair conformation at least in the crystalline solid.

Although bond distances are normal, the C_1-C_6-C_7 and the C_6-C_1-C_{11} angles are unusually large (120 degrees), indicating a substantial repulsion between the two isobutyric acid groups.

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