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THE X-RAY ANALYSIS OF DIHYDROHELIANGINE MONOCHLOROACETATE

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Abstract—In connection with heliangine, extracted from leaves of *Helianthus tuberosus* L., the crystal structure of dihydroheliangine monochloroacetate, $C_{22}H_{29}O_7Cl$, has been determined by X-ray methods. The tetragonal unit cell with dimensions, a = 13·77, c = 11·95 Å, contains four molecules, the space group being $P4_1 - C_4^2$ or $P4_3 - C_4^4$. Using a three-dimensional Patterson function and minimum functions, a majority of atomic positions were determined. Further elucidation of the structure was continued by alternative application of successive least squares treatment and Fourier syntheses. The structure thus determined is fully consistent with the chemical results obtained by Morimoto *et al.* The final R-value is 0·134 (using 1680 data with $\sin^2 \theta/\lambda^2 < 0{\cdot}20$) or 0·152 (using 2419 data with $\sin^2 \theta/\lambda^2 < 0{\cdot}27$).

INTRODUCTION

In colaboration with the chemical study[1] of heliangine, extracted from leaves of *Helianthus tuberosus* L., the X-ray study was attemped. Since heliangine has a secondary hydroxyl group,[1] a halogenoacetate derivative was considered but crystals suitable for X-ray analysis could not be obtained. Consequently, dihydroheliangine was chosen as a starting material and crystals of its monobromoacetate and monochloroacetate were prepared. A preliminary study indicated that the former was not suitable for our measurements and, therefore, the X-ray analysis of dihydroheliangine monochloroacetate, $C_{22}H_{29}O_7Cl$, was undertaken for the elucidation of the structure of heliangine, although the weight of the chlorine atom could be insufficient for the investigation by heavy atom methods.

EXPERIMENTAL

Small colorless flat crystals of the sample used for the X-ray investigation were obtained by several recrystallizations from MeOH. CuKα radiation was employed for the experiment. The dimensions of the tetragonal unit cell are a = 13·77 and c = 11·95 Å (single crystal oscillation and Weissenberg photographs). There are four molecules in a unit cell, $D_m = 1{\cdot}31$ (by flotation method) $D_x = 1{\cdot}29\ \text{cm}^{-3}$. The space group is $P4_1 - C_4^2$ or $P4_3 - C_4^4$.

Intensities of reflections were visually estimated from integrating Weissenberg photographs (10 layers about c axis and 9 layers about a axis, respectively) at room temp, and obtained 3185 independent data excluding zero intensity reflections. Since the absorption effect was not remarkable no correction was made (specimens measuring about 0·4 × 0·3 × 0·15). The absolute structure factors were obtained following the ordinary procedure.

STRUCTURE DETERMINATION

As the first step of the structure analysis, a three-dimensional Patterson function P (uvw) was calculated. Two Harker sections H(uv½) and H(uv¼), especially the latter,

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[1] H. Morimoto, Y. Sanno and H. Oshio, *Tetrahedron* **22**, 3173 (1966).

were useful to obtain the position of the chlorine atom. These sections are shown in Fig. 1. Though there were still several possibilities, the coordinates (x = 0·721, y = 0·358, z = 0·497) seemed probable as the chlorine position to explain the vector map. Then the minimum function diagrams[2] were obtained with 2, 3 and 4 superpositions, respectively, by adopting the above mentioned chlorine coordinates. Maxima found (22) in these diagrams were interpreted as atoms (R = 0·52). Though it was not possible to distinguish oxygen and carbon atoms at this early stage, the lactone ring could fortunately be recognized.

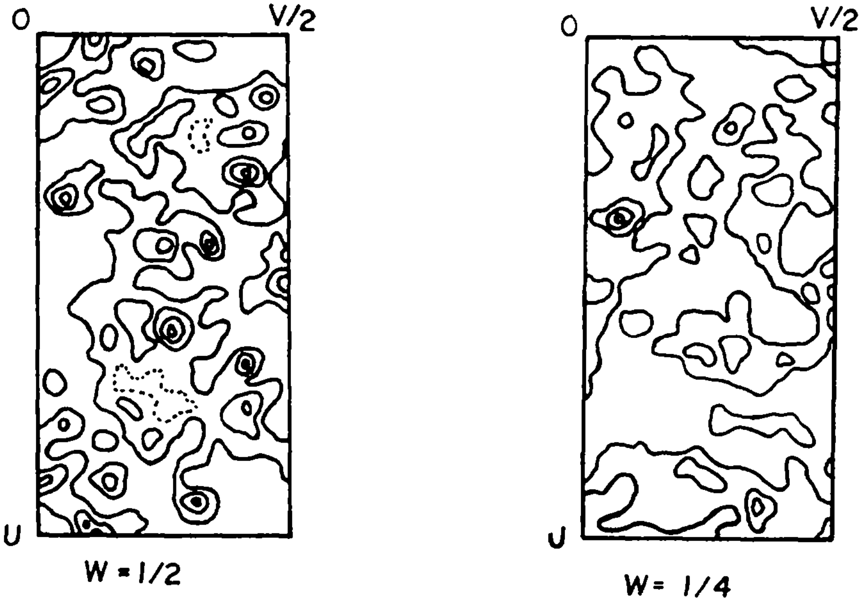


FIG. 1. Harker sections at W = ½ and W = ¼.

In the present work the least squares method was adopted not only to refine atomic coordinates but also to ascertain the existence of atoms by their temperature factors.* If the location of an atom is not proper, the value of its temperature factor would become diverge after successive treatment of least squares. The whole structure is elucidated by alternative application of the least squares method and Fourier syntheses. The least squares method with diagonal approximation is adequate for that purpose.

Thus without calculating trial electron density distribution, two cycles of least squares treatment were carried out to confirm whether these atomic positions are adequate (R = 0·40). Of the 22 proposed atoms, 5 atoms were found to be inadequate. The first three-dimensional electron density synthesis was calculated with phase angles based on the 17 atoms thus obtained, where 29 maxima were interpreted as atoms (R = 0·38).

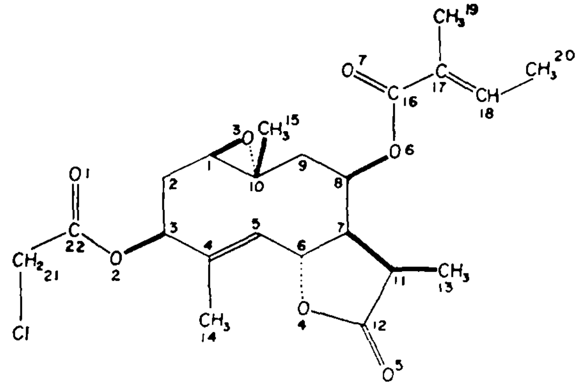
As the next stage, after two cycles of least squares refinement, R-value decreased to 0·35 and 9 atoms were found to be inadequate. The second electron density

* This method has been proposed by one of the authors.[3]

[2] M. J. Buerger, *Acta Cryst.* **4**, 531 (1951).

[3] Y. Tomiie, I. Nitta, A. Furusaki, N. Sakabe, Y. Hirata, H. Matsuda, M. Nishikawa, K. Kamiya and M. Asai, Presented at the 18th *Annual Meeting of the Chemical Society of Japan.* April (1965).

synthesis with phase angles based on the remaining 20 atoms was evaluated to afford the coordinates of 30 atoms (R = 0·33). After two cycles of least squares treatment (R = 0·30), 8 atoms out of 30 proved to be spurious considering their temperature factors, bond lengths and angles. The third synthesis of the electron density with phase angles based on 22 atoms visualized a whole structure of the molecules as given in Fig. 2. This corresponds to the steric structure shown as (I) or its mirror image.



Further refinements were continued using the isotropic least squares method and in accordance, R-value decreased from 0·21 to 0·13. The atomic coordinates are listed in Table 1, and bond distances and angles are shown in Figs. 3a and 3b. Individual values of isotropic temperature factors now range from 2·0 to 4·9.

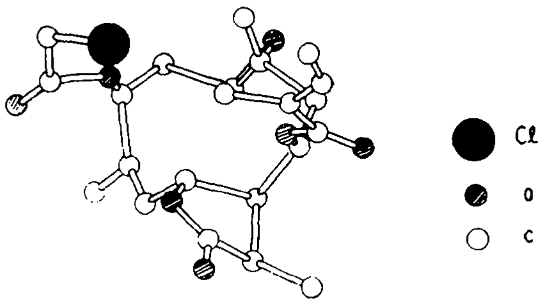


Fig. 2. Stereo-model of dihydroheliangine monochloroacetate from X-ray analysis evidence.

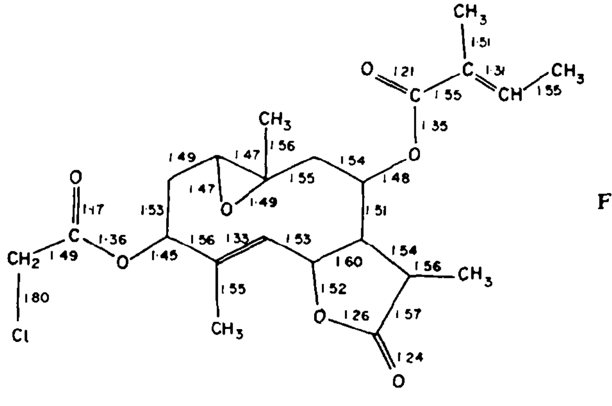


Fig. 3a

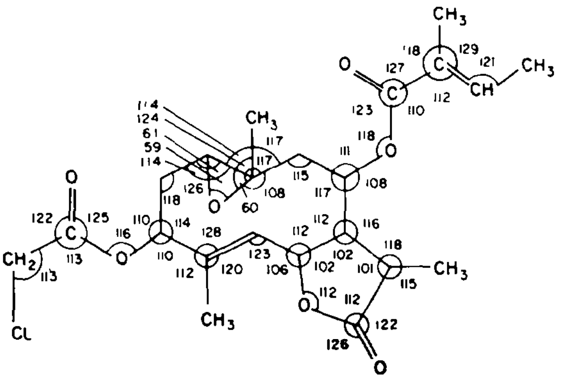


Fig. 3b

Fig. 3. Interatomic distances and angles determined in the present work.

Table 1. Atomic coordinates and temperature factors

Atom	x/a	y/b	z/c	B
Cl	0·7189	0·3633	0·4952	4·383
O(1)	0·5744	0·4709	0·7366	4·468
O(2)	0·6711	0·3401	0·7325	2·743
O(3)	0·8150	0·0968	0·8861	3·396
O(4)	0·5044	0·1703	0·5793	2·514
O(5)	0·4197	0·0830	0·4562	3·718
O(6)	0·6760	0·0383	0·5476	2·024
O(7)	0·7102	0·8921	0·4736	2·381
C(1)	0·7220	0·1463	0·8671	3·305
C(2)	0·7214	0·2513	0·8989	3·532
C(3)	0·6437	0·3164	0·8461	3·258
C(4)	0·5393	0·2721	0·8480	2·291
C(5)	0·5020	0·2059	0·7794	2·588
C(6)	0·5606	0·1555	0·6874	2·080
C(7)	0·5602	0·0396	0·7007	2·140
C(8)	0·6532	0·9945	0·6575	2·097
C(9)	0·7419	0·9991	0·7353	2·471
C(10)	0·7729	0·1029	0·7717	3·172
C(11)	0·4690	0·0119	0·6369	2·423
C(12)	0·4651	0·0931	0·5452	2·204
C(13)	0·4574	0·9056	0·5925	3·324
C(14)	0·4763	0·3137	0·9437	4·063
C(15)	0·8360	0·1623	0·6879	3·028
C(16)	0·7052	0·9792	0·4639	3·221
C(17)	0·7357	0·0411	0·3614	2·736
C(18)	0·7819	0·9898	0·2853	3·889
C(19)	0·7047	0·1464	0·3584	4·856
C(20)	0·8212	0·0384	0·1773	4·859
C(21)	0·6846	0·4592	0·5900	3·978
C(22)	0·6322	0·4236	0·6908	3·457

The arrangement of atoms in the unit cell is given in Fig. 4, showing the intermolecular relation in the crystal. The final electron density distribution is shown by means of superimposed contour sections in Fig. 5.

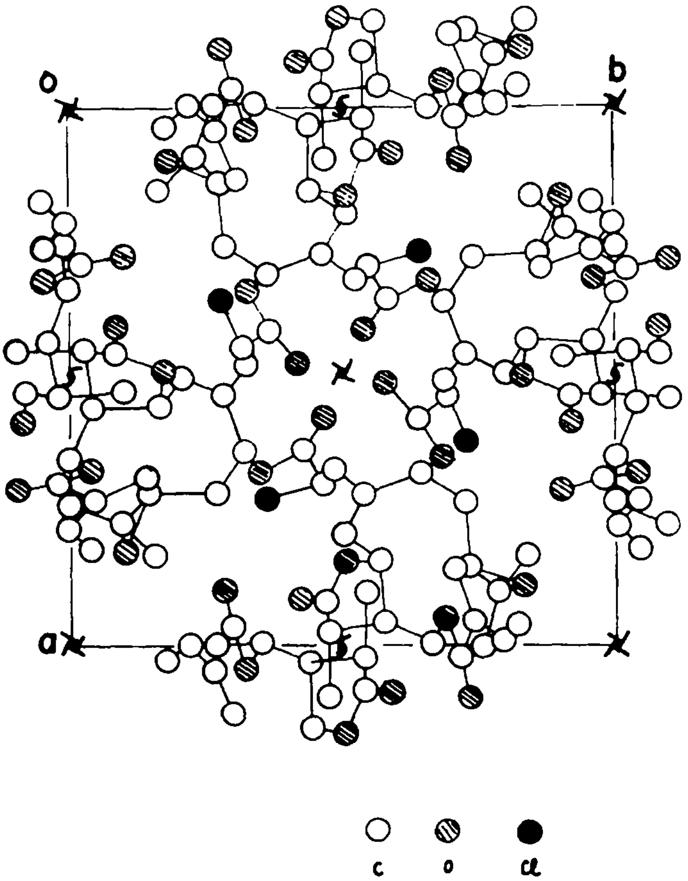


Fig. 4. Packing of the structure seen down the c axis.

DISCUSSION

In the present work a chlorine atom is used as a heavy atom for the structure determination instead of using bromine or iodine atoms. The ratio of the electron number between on the heavy atom and on the other atoms is 1:12·8. Still we were successful in determining the structure.

The procedure, using the minimum function methods and adopting the least squares treatment for the purpose of confirmation of the existence of atoms, seems to be recommended for the X-ray structure determination of complicated organic compounds.[8]

The anomalous dispersion of chlorine atom due to CuKα radiation was not large enough to determine the absolute configuration of this molecule.

From Fig. 5 it is possible to distinguish oxygen and carbon atoms easily. Also there is no doubt about the position of double bonds from the values of bond distances.

It is quite possible to derive the structure of naturally occurred heliangine from that of dihydroheliangine monochloroacetate which has been determined in the present work. Heliangine is known to have an exomethylene double bond,[1] while the I has only one methyl group (C-13) which is bonded with a secondary carbon atom. It is supposed that this methyl group corresponds to $=CH_2$ in heliangine.

The structural formula obtained by the chemical procedure by Morimoto *et al.*[1] is fully consistent with the X-ray result shown as I, though some steric structures were not given chemically. Thus the result of X-ray analysis clarified the stereochemical features of the molecule. The epoxy group has a *trans* configuration and it forms a regular triangle within experimental errors. Considerable steric strain seems to exist among atoms which constitute the ten-membered ring since all bond angles in the ring are larger than 112°. This affair may be visualized with Lapine-Leybold Models in which the ring has little flexibility because of rigid substituents on it.

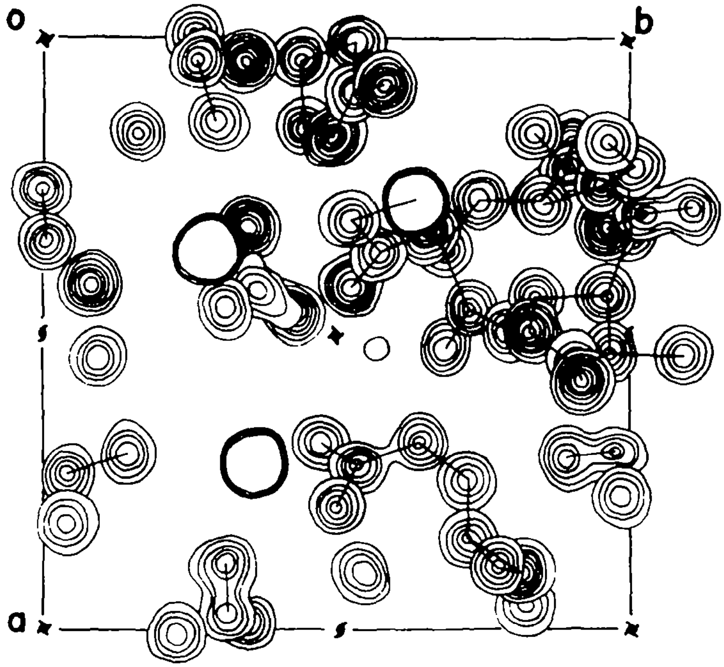


FIG. 5. The fourth three-dimensional electron density distribution shown by means of superimposed contour section projected on (001).

In the γ-lactone ring the ester group, C-6 and C-11 atoms are approximately coplanar. However the C-7 atom deviates slightly from this plane. The γ-lactone is thus in the envelope form with the C-7 atom on the *pseudo*-mirror of symmetry. In the crystal the tiglic acid residue is also nearly planar in spite of the single bond character of the C-16—C-17 bond. It may be of interest that the carbonyl group and C-17—C-18 double bond are in s-*cis* conformation.

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