# *The Structure of Kainic Acid, the Most Active Component of Digenea simplex Ag*. I. The Molecular and Crystal Structure of Zinc Kainate Dihydrate*

By Hideo WATASE and Isamu NITTA

(Received May 21, 1957)

*Digenea simplex Agardh*, distributed over a wide area from the Mediterranean Sea, through the Red Sea and Indian Ocean, to the South Chinese Sea and the southern sea near Japan, is an important seaweed which has been well-known as an anthelmintic since more than one thousand years ago. From the beginning of this century, numerous senior workers of this country endeavoured to find out the active components of this substance. In 1953, Murakami, Takemoto and their collaborators⁽¹⁾ succeeded in isolating the most active component, an acidic and optically active** compound of a comparatively small molecule $C_{10}H_{15}O_4N$, m.p. 251° (decomp.), with an intense anthelmintic effect equivalent to about ten times that of santonin without by-effects. They named it kainic acid (digenic acid) after "*Kaininso*", the Japanese name of the mother alga.

Many studies based on organic chemistry were attempted to determine the chemical structure of this interesting compound. In connection with these we have carried out the structure determination by a more direct method, X-ray crystal analysis.

As an orthodox X-ray procedure applied to a chemically unknown structure, the research was commenced with the zinc salt containing a heavy atom such as zinc. From its electron-density projections along the two principal crystal axes, the three-dimensional structure of the molecule in the zinc salt was determined thoroughly and quantitatively except for the absolute configuration. This X-ray result coincided with the conclusions⁽²⁾ deduced from the chemical behavior.

This paper deals with the structure determination of the zinc salt in detail.

## Experimental

By adding zinc acetate to an aqueous kainic acid solution, two hydrogens of kainic acid are replaced by a zinc atom, and the crystal of the zinc salt with two waters of crystallization is obtained⁽³⁾. Crystalline zinc kainate dihydrate ($C_{10}H_{13}O_4NZn\cdot 2H_2O$) is of a colorless prism elongated along a crystal axis chosen as the *c* axis, having a plane of cleavage perpendicular to another principal axis (*a* axis), and insoluble in water and usual organic solvents. It melts with decomposition at higher than 300°C, but one of

---

* This paper was presented at the Antumnal Joint Meeting of Chemical Societies of Japan, Tokyo, 1956.

1) S. Murakami, T. Takemoto and Z. Shimizu, *J. Pharm. Soc. Japan*, **73**, 1026 (1953); ibid., **74**, 560 (1954).

** $[\alpha]_D^{29}$: −14.8° ($c$=1, $H_2O$).

2) M. Miyasaki, ibid., **75**, 695 (1955); Y. Ueno, H. Nawa, J. Ueyanagi, H. Morimoto, R. Nakamori and T. Matsuoka, ibid., **75**, 840 (1955); S. Murakami, T. Takemoto, Z. Tei and K. Daigo, ibid., **75**, 869 (1955); H. Morimoto and R. Nakamori, ibid., **76**, 294 (1956); *Proc. Japan Acad.*, **32**, 41 (1956); T. Takemoto, Z. Tei and K. Daigo, *J. Pharm. Soc. Japan*, **76**, 298 (1956).

3) Y. Ueno, H. Nawa, J. Ueyanagi, H. Morimoto, R. Nakamori and T. Matsuoka, ibid., **75**, 807 (1955).

the two waters of crystallization is easily desiccated in a desiccator or by warming it about 40°C, the crystal being broken in pieces to become white powder.

Resulting from the preliminary X-ray examinations, the crystal belonged to the orthorhombic system, and the dimensions of the unit cell were as follows;

$$a=25.50\pm0.07\text{Å}$$
$$b=\ 6.93\pm0.03\text{Å}$$
$$c=\ 7.60\pm0.03\text{Å}$$

Systematic absences of reflexions were recognized only in $(h\ 0\ 0)$, $(0\ k\ 0)$ and $(0\ 0\ l)$ when $h$, $k$ and $l$ were odd respectively, thus leading to the space group of $D_2^4$-$P2_12_12_1$. Since the unit cell with this crystal symmetry has four crystallographic equivalent general positions⁴⁾, it must contain four molecules or integral multiple of four. Judging from the volume of the unit cell, in the present case, four chemical formula units were contained in the unit cell, namely an asymmetric unit was one formula unit.

The axial periods of the $b$ and $c$ axes seemed to be short enough to permit a good resolution of many of the atoms, although the $a$ axis was too long for a projection to provide any useful picture of the structure, and so the investigation was directed to determination of the projections along the $b$ and $c$ axes.

Two specimens of the single crystal were prepared to take the photographs around the $b$ and $c$ axes. The one used for $(h\ 0\ l)$ zone was obtained by cutting the crystal at right angle to the elongated $c$ axis, and the cross-section perpendicular to the $b$ axis was 0.08×0.3 mm. The other used for $(h\ k\ 0)$ zone had a rhombic cross-section with the following diagonals at right angles to the axis of rotation; 0.15 mm. along the $a$ axis and 0.08 mm. along the $b$ axis.

Then, integrated Weissenberg photographs were taken with filtered Cu $K_\alpha$ radiation, rotating each crystal around each axis in limited angular range, and the reflexions from 221 planes of $(h\ 0\ l)$ and 199 of $(h\ k\ 0)$ were observed out of 249 and 227 possible ones respectively. By comparing with a calibrated scale, the intensities of the reflexions were estimated visually, multiple-film technique being used for accurate measurements of the strong and the weak reflexions, of which the relative intensities ranged from 10.000 to 1 for $(h\ 0\ l)$ zone and from 60.000 to 1 for $(h\ k\ 0)$ zone. The corrections for absorption were made for $(h\ 0\ l)$ in the usual way and were neglected for $(h\ k\ 0)$, the linear absorption coefficient for Cu $K_\alpha$ radiation being $\mu=27.2\ \text{cm}^{-1}$. Relative structure factors were then deduced from these intensity data by the ordinary process.

## Heavy-Atom and Trial Methods

The space group involved is $D_2^4$–$P2_12_12_1$, and there is no center of symmetry in the crystal. For the sake of convenience in practice, each two-dimensional projection was treated separately with the origin lying on the two-fold screw axis so that the origin was a center of symmetry in the projection. Therefore, the origins used in this analysis are not identical in the two different projections. The relation between the coordinates of the two projections along the $b$ and $c$ axes are clearly shown in Fig. 1. In this account, however, the atomic parameters (Table I) and the final electron-density projections (Figs. 2 and 3) are described reducing to the usual cell.

From the general feature of the reflexions of $(h\ 0\ l)$ and $(h\ k\ 0)$, the position of the zinc atom was easily determined without ambiguity, and the contributions of this atom to the structure factors were then calculated from its parameters, assuming a value of $B=2.0\ \text{Å}^2$ as the temperature factor. By considering the values of the contributions of zinc, the observed structure factors could be nearly reduced from the relative values to those in the absolute scale.

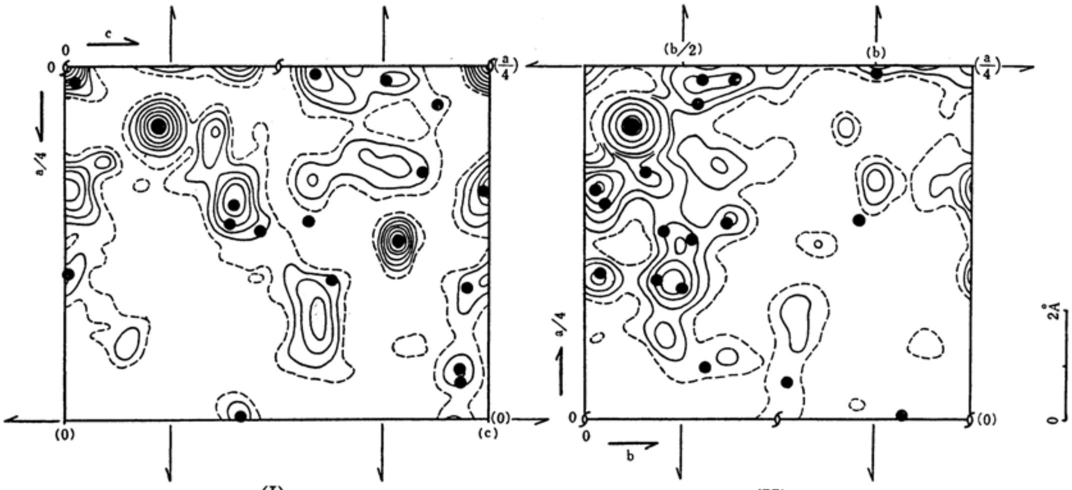
Using the structure factors whose signs appeared to be reliable from the contributions of the zinc atom, the first Fourier summations of the electron-density projections along the $b$ and $c$ axes were calculated, and the maps (I) and (II) of Fig. 1 were derived. As listed in Tables II and III, 100 terms of $F(h\ 0\ l)$ were used for the map (I) projected on (0 1 0) and 79 terms of $F(h\ k\ 0)$ for the map (II) projected on (0 0 1).

In each projection, the peak of the zinc atom was of course distinct in the expected position, having a reasonable height. However, since the signs for a number of the structure factors could not be given from the position of the zinc atom alone, these maps were sufficient neither for giving any useful information about the structure of the molecule nor for a perfectly straightforward analysis. In spite of such difficulties, it still seemed that the projection along the $b$ axis at the final stage would reveal the molecular structure better than the other, and the further analysis was tried with this projection.

Thus, at first, the $b$ axis projection was attacked by the Fourier method, based on the trial-and-error, in reference to the various peaks of the map (I). However, immediately it was judged to be scarcely possible to come to the correct result in

---

4) "Internationale Tabellen zur Bestimmung von Kristallstrukturen", Bornträger, Berlin (1935); "International Tables for X-ray Crystallography", Kynoch Press, Birmingham (1952).



(I) (II)

Fig. 1. First Fourier summations of electron-density projections, (I) projected on (0 1 0), (II) projected on (0 0 1). The signs of the structure factors used in the calculations were determined only by zinc. Contours are drawn at equal intervals on an arbitrary scale, but those on the zinc are reduced by a factor of five. Black circles indicate the final atomic positions, that of the zinc being large. The coordinates are taken among those used for the analysis, showing the relation between the two projections, and those to the usual cell are given in brackets.

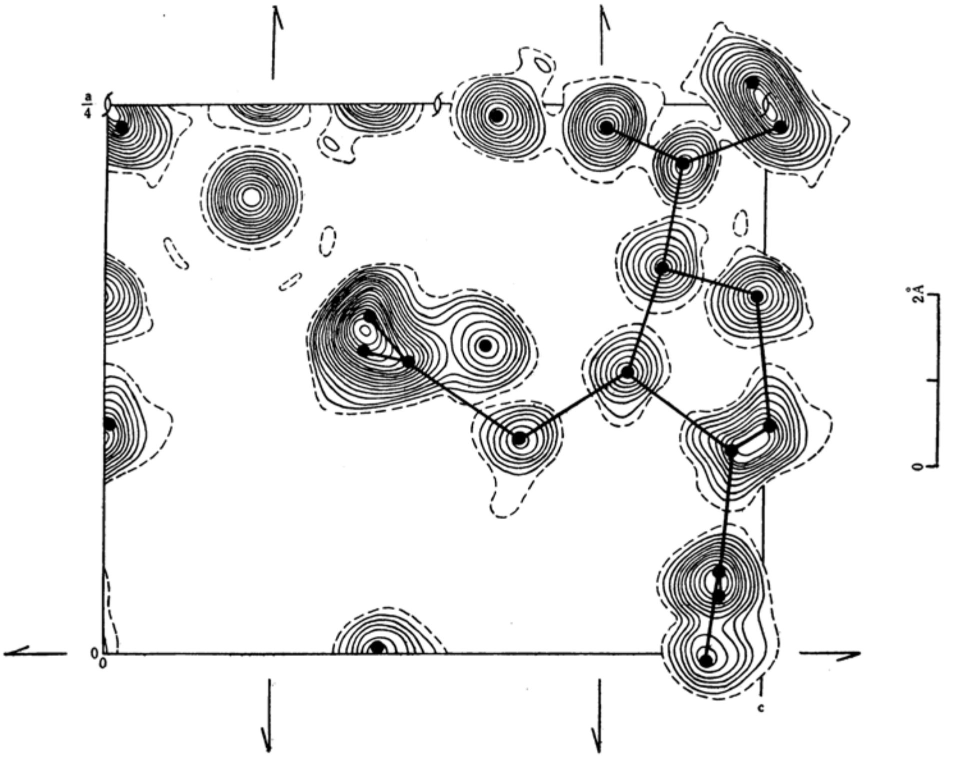


Fig. 2. Electron-density projection along the *b* axis. Contour lines at unit electron intervals, except for those on the zinc at five electrons intervals, the lowest line, broken line, being 3 electrons per Å$^2$. Black circles show the atomic positions, but the position of the zinc is omitted.

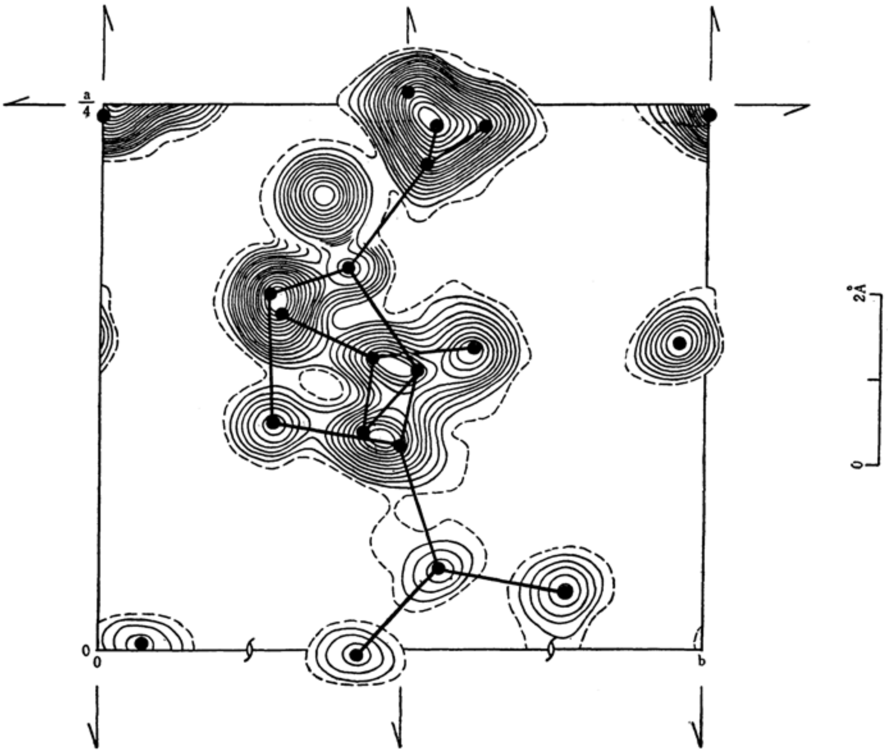


Fig. 3. Electron-density projection along the *c* axis. Contours and symbols are the same as those of Fig. 2.

such a way, although some of the peaks of this map seemed likely to be real, for example, the peak at the origin, because, in the cases of $h+l$ even, the structure factors with the positive contribution of the zinc were generally greater than its own contribution and those with the negative smaller. In addition to the already fixed zinc atom, these seemingly reliable peaks were made use of as the starting-point, and the structure factors of the lower order were tried without exception quantitatively. Thus an approximate distribution of the atoms in this projection being made reliable for the lower orders, the trial was carried on step by step from the lower to the higher orders, until all the atoms were located satisfactorily to permit the Fourier refinements. In this trial, the structure factors with small resultant value but with great contribution of the zinc atom could be used most effectively, and the change in the sign of (8 0 0) was a key to the further analysis. The electron-density projection of Fig. 2 was the final one thus obtained, and the atomic positions were further refined from this map.

In the same way, the two-dimensional analysis along the *c* axis was examined on the basis of the *x* parameters determined above. The electron-density projection was derived as shown in Fig. 3 and the atomic parameters of this projection were obtained. The *x* parameters for the two projections were in complete

TABLE I

ATOMIC PARAMETERS

| Atom | $x/a$ | $y/b$ | $z/c$ |
|---|---|---|---|
| Zn | 0.2081 | 0.3643 | 0.220 |
| N | $0.162_5$ | 0.273 | 0.987 |
| $C_1$ | $0.222_3$ | 0.533 | 0.873 |
| $C_2$ | $0.175_0$ | 0.407 | 0.840 |
| $C_3$ | $0.127_5$ | 0.523 | 0.790 |
| $C_4$ | $0.093_4$ | 0.497 | 0.950 |
| $C_5$ | $0.104_1$ | 0.287 | 0.007 |
| $C_6$ | $0.099_2$ | 0.433 | 0.627 |
| $C_7$ | $0.133_3$ | 0.450 | 0.460 |
| $C_8$ | $0.036_7$ | 0.560 | 0.933 |
| $C_9$ | $0.025_8$ | 0.773 | 0.933 |
| $C_{10}$ | $0.002_5$ | 0.073 | 0.413 |
| $O_1$ | $0.240_0$ | 0.550 | 0.020 |
| $O_2$ | $0.240_0$ | 0.630 | 0.757 |
| $O_3$ | $0.152_5$ | 0.300 | 0.400 |
| $O_4$ | $0.138_3$ | 0.617 | 0.390 |
| $O_5(H_2O)$ | $0.245_0$ | 0.000 | 0.590 |
| $O_6(H_2O)$ | $0.140_8$ | 0.957 | 0.573 |

agreement. All the parameters are listed in Table I (to the usual cell).

At this stage, the discrepancy indices ($R=\sum||F_o|-|F_c||/\sum|F_o|$) are 0.156 for ($h$ 0 $l$) and 0.146 for ($h$ $k$ 0), employing the data up to sin $\theta/\lambda=0.640$, assuming the values of the unobserved structure factors to be precisely zero, and neglecting the contribution of the hydrogen atoms. In the structure-factor calculations, the values $B=2.0$ Å$^2$ for ($h$ 0 $l$), with the exception of ($h$ 0 0), and 3.0 Å$^2$ for ($h$ $k$ 0) and ($h$ 0 0) were used as the temperature factors common to all the atoms. The atomic scattering factors were taken for zinc from the Internationale Tabellen[4] modifying as $Zn^{++}$ and for the other three from McWeeny's paper[5]; for oxygen $\bar{f}_o=1/3$ $(f^{\parallel}+2f^{\perp})$ and for carbon the value for 'valence states'.

The observed and the calculated structure factors together with the contributions of the zinc atom are listed in Tables II and III.

TABLE II

OBSERVED AND CALCULATED STRUCTURE FACTORS $F(h\ 0\ l)$, TOGETHER WITH THE CONTRIBUTIONS OF THE ZINC ATOM

The values for ($h$ 0 0) are listed in Table III.

* These structure factors were employed on the first Fourier summations (Fig. 1), using the signs of $F_{Zn}$.

| $h\ k\ l$ | $1/4F_o$ | $1/4F_c$ | $1/4F_{Zn}$ |
|---|---|---|---|
| 1 0 1 | 6.6 | 6.7 | 4.8 |
| 2 0 1 | 1.2 | −0.8 | −12.5 |
| 3 0 1 | 5.8 | 6.3 | 3.4 |
| 4 0 1 | 22.8* | −22.0 | −21.7 |
| 5 0 1 | 21.5 | 24.6 | 1.2 |
| 6 0 1 | 15.0* | −15.2 | −23.3 |
| 7 0 1 | 8.1 | −8.2 | −1.1 |
| 8 0 1 | 10.9* | −8.9 | −18.3 |
| 9 0 1 | 15.0 | −15.3 | −2.9 |
| 10 0 1 | 4.6 | −4.8 | −9.5 |
| 11 0 1 | 11.1 | −10.7 | −3.4 |
| 12 0 1 | 2.7 | −2.6 | 0.0 |
| 13 0 1 | 12.0 | 13.1 | −3.1 |
| 14 0 1 | 12.3* | 12.9 | 7.7 |
| 15 0 1 | 2.4 | 1.9 | −2.0 |
| 16 0 1 | 19.6* | 19.8 | 12.6 |
| 17 0 1 | 10.5 | −10.8 | −0.7 |
| 18 0 1 | 16.6* | 16.7 | 12.7 |
| 19 0 1 | 3.3 | −5.1 | 0.7 |
| 20 0 1 | 13.3* | 13.0 | 9.6 |
| 21 0 1 | — | −0.5 | 1.5 |
| 22 0 1 | 3.2* | 3.9 | 4.8 |
| 23 0 1 | 3.2 | 5.8 | 1.7 |
| 24 0 1 | — | −0.7 | −0.5 |
| 25 0 1 | — | 0.2 | 1.5 |
| 26 0 1 | 2.7* | −3.4 | −4.3 |
| 27 0 1 | — | −0.5 | 1.0 |
| 28 0 1 | 2.5* | −3.2 | −6.2 |
| 29 0 1 | — | −2.5 | 0.3 |
| 30 0 1 | 4.6* | −6.0 | −6.1 |
| 31 0 1 | — | 0.3 | −0.3 |
| 32 0 1 | 2.2* | −3.9 | −4.5 |
| 0 0 2 | 8.5 | 9.3 | −22.1 |
| 1 0 2 | 15.2 | 17.9 | −2.1 |
| 2 0 2 | 25.6* | −23.9 | −19.1 |
| 3 0 2 | 3.0 | −0.1 | −6.3 |
| 4 0 2 | 16.6* | −16.7 | −10.2 |
| 5 0 2 | 3.5 | 3.6 | −8.0 |
| 6 0 2 | 4.0 | −3.8 | 0.0 |
| 7 0 2 | 22.2* | −20.7 | −7.5 |
| 8 0 2 | 18.0* | 18.9 | 10.2 |
| 9 0 2 | 9.7 | −8.4 | −4.9 |
| 10 0 2 | 19.5* | 20.8 | 15.2 |
| 11 0 2 | 2.2 | 2.3 | −1.6 |
| 12 0 2 | 22.2* | 19.9 | 15.8 |
| 13 0 2 | 2.5 | 4.3 | 1.4 |
| 14 0 2 | 12.7* | 12.7 | 12.3 |
| 15 0 2 | 2.7 | 2.6 | 3.9 |
| 16 0 2 | — | 0.6 | 6.2 |
| 17 0 2 | 2.8 | 2.3 | 4.7 |
| 18 0 2 | — | 2.5 | 0.0 |
| 19 0 2 | 4.5 | 4.1 | 4.1 |
| 20 0 2 | — | −1.3 | −5.6 |
| 21 0 2 | — | 0.2 | 2.6 |
| 22 0 2 | 7.4* | −7.9 | −7.9 |
| 23 0 2 | 3.2 | −3.7 | 0.8 |
| 24 0 2 | 6.7* | −8.8 | −8.1 |
| 25 0 2 | — | −1.4 | −0.9 |
| 26 0 2 | 4.6* | −5.5 | −6.1 |
| 27 0 2 | 3.7 | −4.2 | −2.0 |
| 28 0 2 | 1.8 | −1.7 | −3.1 |
| 29 0 2 | 3.0 | −3.3 | −2.3 |
| 30 0 2 | 1.6 | −1.6 | 0.4 |
| 31 0 2 | 2.8 | −4.2 | −1.9 |
| 32 0 2 | 2.3 | 3.1 | 2.6 |
| 1 0 3 | 3.1 | −2.3 | −10.7 |
| 2 0 3 | 5.8 | 7.6 | 8.4 |
| 3 0 3 | 12.6 | −13.0 | −7.5 |
| 4 0 3 | 5.0 | 5.1 | 14.6 |
| 5 0 3 | 1.3 | 1.8 | −2.5 |
| 6 0 3 | 26.2* | 26.0 | 16.0 |
| 7 0 3 | 10.4 | 8.1 | 2.4 |
| 8 0 3 | 17.8* | 15.2 | 12.6 |
| 9 0 3 | 8.4* | 9.7 | 6.7 |
| 10 0 3 | 4.1 | 5.1 | 6.8 |
| 11 0 3 | 13.4* | 11.7 | 8.2 |
| 12 0 3 | 7.8 | −8.1 | 0.0 |
| 13 0 3 | 17.2* | 15.7 | 7.5 |
| 14 0 3 | 3.1 | −2.6 | −5.7 |
| 15 0 3 | 3.5 | 3.5 | 4.8 |
| 16 0 3 | 9.2* | −7.8 | −9.3 |

---

5) R. McWeeny, *Acta Cryst.*, **4**, 513 (1951).

| | | | |
|---|---|---|---|
| 17 0 3 | 3.0 | −2.2 | 1.5 |
| 18 0 3 | 15.3* | −13.9 | −9.5 |
| 19 0 3 | 3.4 | 3.0 | −1.8 |
| 20 0 3 | 7.5* | −7.0 | −7.2 |
| 21 0 3 | — | 1.5 | −3.7 |
| 22 0 3 | 5.1* | −6.0 | −3.7 |
| 23 0 3 | 3.5* | −4.1 | −4.5 |
| 24 0 3 | 3.1 | −0.6 | 0.4 |
| 25 0 3 | 3.8* | −5.5 | −3.9 |
| 26 0 3 | 1.8 | 0.2 | 3.3 |
| 27 0 3 | 2.6 | −2.4 | −2.5 |
| 28 0 3 | 3.9* | 5.5 | 4.7 |
| 29 0 3 | 1.7 | −2.0 | −0.8 |
| 30 0 3 | 2.2* | 3.7 | 4.7 |
| 31 0 3 | 1.0 | 0.2 | 0.9 |
| 0 0 4 | 10.3* | 10.0 | 12.6 |
| 1 0 4 | 9.9 | 10.8 | 2.9 |
| 2 0 4 | 13.6* | 14.2 | 10.9 |
| 3 0 4 | 2.5 | 1.2 | 8.5 |
| 4 0 4 | 8.8 | 10.1 | 5.8 |
| 5 0 4 | 13.8* | 12.1 | 10.9 |
| 6 0 4 | 4.4 | 7.9 | 0.0 |
| 7 0 4 | 9.1* | 6.9 | 10.4 |
| 8 0 4 | 3.6 | −4.9 | −5.9 |
| 9 0 4 | 5.8* | 5.7 | 7.0 |
| 10 0 4 | 9.6* | −8.4 | −9.2 |
| 11 0 4 | — | −0.6 | 2.3 |
| 12 0 4 | 7.3* | −7.9 | −9.7 |
| 13 0 4 | 2.8 | −3.2 | −2.2 |
| 14 0 4 | 3.1* | −1.8 | −7.9 |
| 15 0 4 | 4.8* | −4.8 | −5.8 |
| 16 0 4 | 2.2 | −1.6 | −3.9 |
| 17 0 4 | 12.6* | −12.7 | −7.0 |
| 18 0 4 | — | −0.4 | 0.0 |
| 19 0 4 | 8.9* | −9.0 | −6.2 |
| 20 0 4 | 3.1* | 2.6 | 3.6 |
| 21 0 4 | 3.7* | −4.8 | −4.1 |
| 22 0 4 | 6.1* | 8.1 | 5.2 |
| 23 0 4 | 2.8 | −2.6 | −1.3 |
| 24 0 4 | 6.7* | 7.3 | 5.5 |
| 25 0 4 | 2.7 | 1.8 | 1.5 |
| 26 0 4 | 3.7* | 3.5 | 4.0 |
| 27 0 4 | 1.8 | 1.6 | 3.1 |
| 28 0 4 | 1.6 | −1.0 | 2.0 |
| 29 0 4 | 2.3* | 2.7 | 3.6 |
| 1 0 5 | 26.6* | 26.8 | 11.1 |
| 2 0 5 | 2.3 | −1.7 | −4.0 |
| 3 0 5 | 6.0* | 5.9 | 7.4 |
| 4 0 5 | 10.2* | −10.2 | −7.2 |
| 5 0 5 | 3.8 | −4.5 | 2.8 |
| 6 0 5 | 9.4* | −7.7 | −8.0 |
| 7 0 5 | 1.8 | 3.9 | −2.6 |
| 8 0 5 | 9.8* | −10.5 | −6.5 |
| 9 0 5 | 1.9 | 1.1 | −7.4 |
| 10 0 5 | 1.9 | −0.7 | −3.4 |
| 11 0 5 | 3.4* | −2.1 | −9.2 |
| 12 0 5 | 2.0 | 1.1 | 0.0 |
| 13 0 5 | 5.1* | −6.1 | −8.6 |
| 14 0 5 | 3.1 | 4.6 | 2.9 |
| 15 0 5 | 3.9* | −4.9 | −5.6 |
| 16 0 5 | 3.6* | 3.2 | 5.0 |
| 17 0 5 | — | −0.1 | −1.9 |
| 18 0 5 | 3.2* | 3.9 | 5.2 |
| 19 0 5 | 3.8 | 5.4 | 2.1 |
| 20 0 5 | 5.1* | 7.1 | 4.1 |
| 21 0 5 | 7.7* | 8.4 | 4.6 |
| 22 0 5 | 2.7 | 2.7 | 2.1 |
| 23 0 5 | 5.3* | 4.7 | 5.5 |
| 24 0 5 | 2.6 | 2.2 | −0.3 |
| 25 0 5 | 6.9* | 6.2 | 4.8 |
| 26 0 5 | 1.1 | −1.1 | −1.9 |
| 27 0 5 | 3.1* | 4.1 | 3.0 |
| 28 0 5 | 1.8 | −1.7 | −2.7 |
| 0 0 6 | 10.4* | −12.4 | −5.0 |
| 1 0 6 | — | 0.1 | −2.7 |
| 2 0 6 | 4.2 | −3.2 | −4.3 |
| 3 0 6 | 10.3* | −9.9 | −7.6 |
| 4 0 6 | 6.3 | −5.7 | −2.4 |
| 5 0 6 | 16.1* | −13.2 | −9.9 |
| 6 0 6 | — | 0.7 | 0.0 |
| 7 0 6 | 12.0* | −9.4 | −9.6 |
| 8 0 6 | 3.2 | −4.1 | 2.4 |
| 9 0 6 | 7.1* | −5.6 | −6.5 |
| 10 0 6 | — | −1.2 | 3.7 |
| 11 0 6 | 6.6 | −5.1 | −2.3 |
| 12 0 6 | 4.3 | 4.7 | 4.1 |
| 13 0 6 | — | −1.8 | 2.1 |
| 14 0 6 | 4.9* | 6.1 | 3.3 |
| 15 0 6 | 5.9* | 7.3 | 5.7 |
| 16 0 6 | 3.1 | 0.8 | 1.7 |
| 17 0 6 | 6.8* | 5.9 | 7.0 |
| 18 0 6 | 4.2 | −5.2 | 0.0 |
| 19 0 6 | 7.2* | 7.3 | 6.3 |
| 20 0 6 | 3.1 | −4.2 | −1.6 |
| 21 0 6 | 5.1* | 3.4 | 4.1 |
| 22 0 6 | 2.6 | −1.4 | −2.3 |
| 23 0 6 | — | 0.2 | 1.4 |
| 24 0 6 | 2.4 | −2.5 | −2.4 |
| 25 0 6 | 1.3 | −0.7 | −1.5 |
| 1 0 7 | 7.0* | −4.6 | −8.9 |
| 2 0 7 | 2.1 | 3.7 | 1.1 |
| 3 0 7 | 4.2* | −2.4 | −6.2 |
| 4 0 7 | 3.0 | 2.8 | 2.0 |
| 5 0 7 | 4.7 | −4.8 | −2.2 |
| 6 0 7 | — | 0.2 | 2.2 |
| 7 0 7 | 2.1 | 3.1 | 2.1 |
| 8 0 7 | 3.6 | −3.6 | 1.8 |
| 9 0 7 | 5.5* | 7.2 | 6.1 |
| 10 0 7 | 4.6 | −2.1 | 1.0 |
| 11 0 7 | 12.2* | 12.3 | 7.7 |
| 12 0 7 | 2.0 | −1.2 | 0.0 |
| 13 0 7 | 8.5* | 7.5 | 7.2 |
| 14 0 7 | 1.9 | −1.1 | −0.9 |
| 15 0 7 | 3.8* | 4.6 | 4.8 |
| 16 0 7 | 3.3 | −4.4 | −1.5 |
| 17 0 7 | 1.9 | 1.1 | 1.6 |
| 18 0 7 | 4.2 | −4.3 | −1.6 |
| 19 0 7 | 3.7 | −3.0 | −1.8 |

| | | | |
|---|---|---|---|
| 20 0 7 | 2.7 | −2.8 | −1.2 |
| 21 0 7 | 2.4 | −1.9 | −3.9 |
| 22 0 7 | 2.2 | −2.3 | −0.6 |
| 0 0 8 | 3.4 | 2.0 | 0.5 |
| 1 0 8 | 2.8 | 1.1 | 2.0 |
| 2 0 8 | 3.4 | 4.9 | 0.5 |
| 3 0 8 | 7.0* | 6.9 | 5.6 |
| 4 0 8 | — | 0.0 | 0.2 |
| 5 0 8 | 7.9* | 6.9 | 7.3 |
| 6 0 8 | 2.7 | 2.8 | 0.0 |
| 7 0 8 | 9.0* | 8.6 | 7.2 |
| 8 0 8 | 2.7 | 0.8 | −0.2 |
| 9 0 8 | 3.3* | 2.9 | 4.8 |
| 10 0 8 | — | −0.1 | −0.4 |
| 11 0 8 | — | 0.3 | 1.7 |
| 12 0 8 | 2.7 | 2.0 | −0.4 |
| 13 0 8 | 2.7 | −2.5 | −1.6 |
| 14 0 8 | — | 0.0 | −0.4 |
| 15 0 8 | 4.2* | −3.3 | −4.3 |
| 16 0 8 | 2.3 | −0.8 | −0.2 |
| 17 0 8 | 5.3* | −5.6 | −5.3 |
| 18 0 8 | 1.8 | −2.8 | 0.0 |
| 1 0 9 | 5.5* | 6.1 | 6.0 |
| 2 0 9 | — | 0.2 | 0.3 |
| 3 0 9 | 4.8* | 5.7 | 4.1 |
| 4 0 9 | 1.8 | 1.9 | 0.7 |
| 5 0 9 | — | 1.2 | 1.5 |
| 6 0 9 | 2.4 | 1.5 | 0.8 |
| 7 0 9 | 1.7 | 0.7 | −1.5 |
| 8 0 9 | 2.3 | 1.8 | 0.6 |
| 9 0 9 | 3.1* | −3.8 | −4.0 |
| 10 0 9 | 2.1 | −2.0 | 0.3 |
| 11 0 9 | 7.3* | −5.1 | −5.2 |
| 12 0 9 | — | −0.4 | 0.0 |

TABLE III

OBSERVED AND CALCULATED STRUCTURE FACTORS $F(h\ k\ 0)$, TOGETHER WITH THE CONTRIBUTIONS OF THE ZINC ATOM.

* These structure factors were employed on the first Fourier summations (Fig. 1), using the signs of $F_{Zn}$.

| $h\ k\ l$ | $1/4F_o$ | $1/4F_c$ | $1/4F_{Zn}$ |
|---|---|---|---|
| 0 0 0 | | 162 | 28 |
| 2 0 0 | 42.3* | −43.2 | −24.2 |
| 4 0 0 | 2.8 | 2.6 | 12.6 |
| 6 0 0 | 0.3 | −0.6 | 0.0 |
| 8 0 0 | 24.3* | 26.8 | −12.0 |
| 10 0 0 | 2.3 | −5.0 | 17.6 |
| 12 0 0 | 6.7 | −6.4 | −17.7 |
| 14 0 0 | 8.8 | 10.0 | 13.0 |
| 16 0 0 | 9.0 | −8.0 | −6.4 |
| 18 0 0 | 6.2 | −6.6 | 0.0 |
| 20 0 0 | 11.0* | 9.9 | 5.5 |
| 22 0 0 | 5.0* | −4.6 | −7.6 |
| 24 0 0 | 10.3* | 7.5 | 7.4 |
| 26 0 0 | 9.2* | −8.1 | −5.2 |
| 28 0 0 | 4.8* | 4.5 | 2.6 |
| 30 0 0 | 3.1 | 3.3 | 0.3 |
| 32 0 0 | 0.9 | −1.0 | −2.0 |
| 1 1 0 | 9.5 | 10.5 | 5.0 |
| 2 1 0 | 39.1* | −38.8 | −8.2 |
| 3 1 0 | 27.6* | −29.2 | −14.3 |
| 4 1 0 | 13.9* | 15.3 | 14.0 |
| 5 1 0 | 13.6* | 12.7 | 18.1 |
| 6 1 0 | 12.2* | −11.9 | −14.9 |
| 7 1 0 | 12.5* | −10.1 | −16.7 |
| 8 1 0 | 21.5* | 19.6 | 11.5 |
| 9 1 0 | 4.5 | 3.3 | 10.8 |
| 10 1 0 | 13.7* | −15.5 | −6.0 |
| 11 1 0 | 12.5 | 10.6 | −3.4 |
| 12 1 0 | — | 1.6 | 0.0 |
| 13 1 0 | — | −0.1 | −3.0 |
| 14 1 0 | — | 0.4 | 5.1 |
| 15 1 0 | 4.8 | 5.0 | 7.7 |
| 16 1 0 | 2.3 | −1.5 | −7.4 |
| 17 1 0 | 9.9* | −9.0 | −9.2 |
| 18 1 0 | 7.0* | 6.6 | 7.3 |
| 19 1 0 | 18.4* | 17.0 | 7.8 |
| 20 1 0 | 1.2 | −1.0 | −5.3 |
| 21 1 0 | 6.5* | −6.2 | −4.9 |
| 22 1 0 | 4.3 | 3.8 | 2.6 |
| 23 1 0 | 1.9 | 1.7 | 1.5 |
| 24 1 0 | 1.2 | −1.2 | 0.3 |
| 25 1 0 | — | 1.9 | 1.6 |
| 26 1 0 | 2.9 | −2.8 | −2.1 |
| 27 1 0 | 2.8* | −2.2 | −3.2 |
| 28 1 0 | 6.2* | 5.2 | 3.0 |
| 29 1 0 | 3.5* | 2.8 | 3.6 |
| 30 1 0 | — | −1.9 | −2.8 |
| 31 1 0 | 1.7 | −1.8 | −2.9 |
| 32 1 0 | 1.0 | 0.8 | 2.0 |
| 0 2 0 | 19.2 | −23.1 | 2.9 |
| 1 2 0 | 18.3* | −19.2 | −21.8 |
| 2 2 0 | 8.4 | 8.1 | −2.5 |
| 3 2 0 | 2.0 | 0.5 | 15.1 |
| 4 2 0 | 3.9 | −5.3 | 1.1 |
| 5 2 0 | 11.2 | 13.4 | −5.3 |
| 6 2 0 | 17.5 | 17.1 | 0.0 |
| 7 2 0 | 16.5 | −14.5 | −5.0 |
| 8 2 0 | 17.2 | −19.2 | −1.3 |
| 9 2 0 | 22.8* | 23.6 | 13.0 |
| 10 2 0 | 6.3 | 5.6 | 1.9 |
| 11 2 0 | 17.4* | −16.9 | −15.5 |
| 12 2 0 | 0.6 | −0.9 | −2.0 |
| 13 2 0 | 12.2* | 12.0 | 14.1 |
| 14 2 0 | 2.1 | 1.1 | 1.4 |
| 15 2 0 | 11.9* | −11.5 | −8.7 |
| 16 2 0 | 8.5 | −7.7 | −0.6 |
| 17 2 0 | 8.5 | 6.9 | 2.8 |
| 18 2 0 | 5.7 | 4.9 | 0.0 |
| 19 2 0 | 2.6 | 2.1 | 3.1 |
| 20 2 0 | 1.9 | 0.2 | 0.7 |
| 21 2 0 | 7.2* | −7.6 | −6.1 |
| 22 2 0 | 7.2 | −7.1 | −0.9 |
| 23 2 0 | 6.6* | 6.3 | 7.0 |

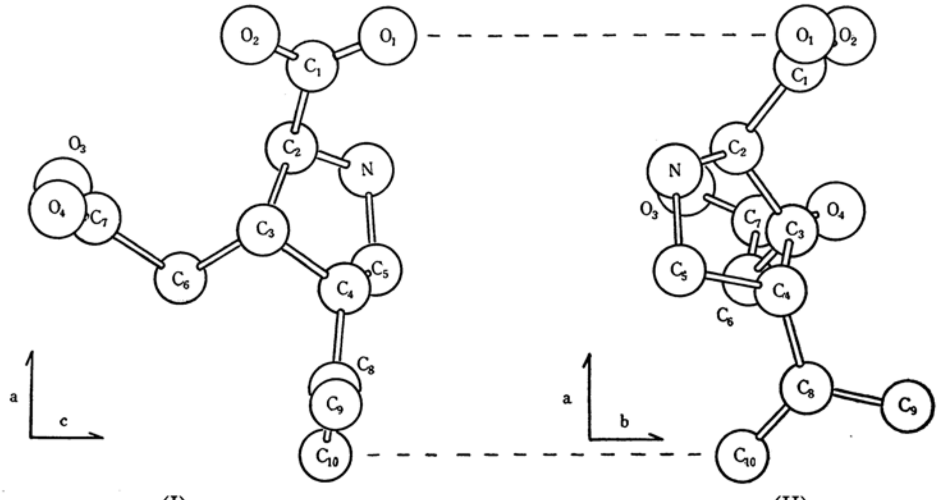
| | | | |
|---|---|---|---|
| 24 2 0 | 1.9 | −1.4 | 0.9 |
| 25 2 0 | 7.4* | −5.7 | −5.9 |
| 26 2 0 | 1.4 | 2.0 | −0.6 |
| 27 2 0 | 5.6* | 5.1 | 3.6 |
| 28 2 0 | 1.0 | −1.2 | 0.2 |
| 29 2 0 | — | −0.6 | −0.9 |
| 30 2 0 | — | −0.9 | 0.1 |
| 31 2 0 | 1.1 | −0.5 | −1.2 |
| 1 3 0 | 1.7 | 1.3 | −2.6 |
| 2 3 0 | 11.7 | −12.2 | −7.6 |
| 3 3 0 | 6.9 | −8.0 | 7.1 |
| 4 3 0 | 22.9* | 22.5 | 13.4 |
| 5 3 0 | 12.8* | −11.4 | −9.2 |
| 6 3 0 | 10.7* | −9.1 | −14.3 |
| 7 3 0 | 11.7* | 11.5 | 8.7 |
| 8 3 0 | 3.7 | 3.4 | 11.3 |
| 9 3 0 | 6.0 | −7.4 | −5.6 |
| 10 3 0 | 2.7 | −4.1 | −6.0 |
| 11 3 0 | 9.2 | −11.0 | 1.8 |
| 12 3 0 | 4.6 | 6.1 | 0.0 |
| 13 3 0 | 7.2 | 7.1 | 1.6 |
| 14 3 0 | 2.6 | 3.0 | 5.3 |
| 15 3 0 | 7.6* | −7.2 | −4.4 |
| 16 3 0 | 8.8* | −8.0 | −7.8 |
| 17 3 0 | 4.1* | 3.8 | 5.1 |
| 18 3 0 | 9.2* | 8.3 | 7.7 |
| 19 3 0 | 5.1* | −5.4 | −4.4 |
| 20 3 0 | 7.7* | −5.9 | −5.7 |
| 21 3 0 | 4.3* | 4.9 | 2.7 |
| 22 3 0 | — | −0.8 | 2.9 |
| 23 3 0 | 3.8 | −3.4 | −0.9 |
| 24 3 0 | 2.6 | 2.6 | 0.3 |
| 25 3 0 | 1.7 | 0.9 | −1.0 |
| 26 3 0 | 1.6 | −2.2 | −2.4 |
| 27 3 0 | 2.5 | 2.1 | 1.9 |
| 28 3 0 | 2.8* | 2.9 | 3.2 |
| 29 3 0 | 2.2 | −1.8 | −2.2 |
| 30 3 0 | 5.4* | −5.5 | −3.1 |
| 0 4 0 | 4.6 | −5.2 | −14.4 |
| 1 4 0 | 9.9 | −8.5 | −3.6 |
| 2 4 0 | 12.9* | 11.6 | 12.4 |
| 3 4 0 | 6.8 | 5.4 | 2.5 |
| 4 4 0 | 7.8* | −8.1 | −6.7 |
| 5 4 0 | 5.6 | −5.8 | −0.8 |
| 6 4 0 | 3.3 | −2.0 | 0.0 |
| 7 4 0 | 2.4 | −2.3 | −0.8 |
| 8 4 0 | 11.0* | 9.4 | 6.7 |
| 9 4 0 | 1.5 | −2.7 | 2.2 |
| 10 4 0 | 11.6* | −11.1 | −10.3 |
| 11 4 0 | 1.1 | −2.0 | −2.7 |
| 12 4 0 | 12.7* | 11.4 | 10.6 |
| 13 4 0 | 1.0 | 0.3 | 2.5 |
| 14 4 0 | 11.7* | −9.6 | −8.0 |
| 15 4 0 | 2.7 | −2.5 | −1.6 |
| 16 4 0 | 1.2 | 1.1 | 4.1 |
| 17 4 0 | 3.8 | 3.0 | 0.5 |
| 18 4 0 | — | −0.4 | 0.0 |
| 19 4 0 | — | 0.0 | 0.6 |
| 20 4 0 | 3.0* | −3.2 | −3.6 |
| 21 4 0 | 3.0 | −2.6 | −1.2 |
| 22 4 0 | 3.2* | 3.5 | 5.1 |
| 23 4 0 | 3.9 | 3.6 | 1.4 |
| 24 4 0 | 4.1* | −4.8 | −5.2 |
| 25 4 0 | 0.7 | 0.7 | −1.2 |
| 26 4 0 | 2.9* | 3.1 | 3.7 |
| 27 4 0 | — | −1.2 | 0.7 |
| 28 4 0 | 3.2* | −2.8 | −1.8 |
| 29 4 0 | — | −0.4 | −0.2 |
| 1 5 0 | 2.4 | −1.9 | −2.6 |
| 2 5 0 | 1.7 | 0.2 | 2.4 |
| 3 5 0 | 6.3* | 5.5 | 7.4 |
| 4 5 0 | 4.3* | −4.3 | −4.1 |
| 5 5 0 | 14.9* | −12.1 | −9.7 |
| 6 5 0 | 7.8* | 7.5 | 4.6 |
| 7 5 0 | 12.1* | 10.6 | 9.2 |
| 8 5 0 | 2.9 | −2.4 | −3.7 |
| 9 5 0 | 6.4* | −5.8 | −6.1 |
| 10 5 0 | 1.9 | 4.1 | 2.0 |
| 11 5 0 | 6.0 | 7.0 | 2.1 |
| 12 5 0 | — | −0.3 | 0.0 |
| 13 5 0 | 1.9 | 3.0 | 1.9 |
| 14 5 0 | 3.0 | −2.7 | −1.8 |
| 15 5 0 | 5.5* | −4.4 | −4.9 |
| 16 5 0 | 1.2 | 2.3 | 2.6 |
| 17 5 0 | 7.3* | 7.5 | 6.0 |
| 18 5 0 | — | 0.2 | −2.7 |
| 19 5 0 | 2.9* | −2.6 | −5.2 |
| 20 5 0 | 1.1 | −1.0 | 2.0 |
| 21 5 0 | 4.4* | 4.6 | 3.4 |
| 22 5 0 | 1.0 | −0.9 | −1.0 |
| 23 5 0 | — | −0.9 | −1.1 |
| 24 5 0 | — | −0.3 | −0.2 |
| 25 5 0 | 0.8 | −1.0 | −1.1 |
| 26 5 0 | — | 0.4 | 0.9 |
| 27 5 0 | — | 1.4 | 2.3 |
| 0 6 0 | 3.8 | −1.1 | −3.2 |
| 1 6 0 | 3.8 | 3.6 | 7.8 |
| 2 6 0 | 4.3 | 5.4 | 2.7 |
| 3 6 0 | 11.6* | −9.7 | −5.5 |
| 4 6 0 | 1.9 | −2.0 | −1.5 |
| 5 6 0 | 8.4 | 7.7 | 1.9 |
| 6 6 0 | 2.7 | 4.3 | 0.0 |
| 7 6 0 | 1.9 | 2.4 | 1.8 |
| 8 6 0 | — | 0.5 | 1.5 |
| 9 6 0 | 6.4* | −8.3 | −5.0 |
| 10 6 0 | 1.0 | −1.4 | −2.3 |
| 11 6 0 | 6.9* | 7.7 | 6.3 |
| 12 6 0 | 3.0 | 2.4 | 2.5 |
| 13 6 0 | 5.0* | −5.9 | −5.8 |
| 14 6 0 | 2.6 | −2.3 | −1.9 |
| 15 6 0 | 1.8 | 1.5 | 3.8 |
| 16 6 0 | — | 0.5 | 1.1 |
| 17 6 0 | — | −1.6 | −1.3 |
| 18 6 0 | 1.0 | 1.3 | 0.0 |
| 19 6 0 | 1.5 | 0.9 | −1.4 |
| 20 6 0 | 1.5 | −1.5 | −0.9 |
| 21 6 0 | 1.0 | 1.3 | 2.9 |
| 22 6 0 | 1.9 | 2.0 | 1.3 |

| | | | |
|---|---|---|---|
| 23 6 0 | 3.3* | −4.7 | −3.4 |
| 24 6 0 | 1.2 | −1.4 | −1.3 |
| 1 7 0 | — | 0.7 | 0.5 |
| 2 7 0 | 1.9 | 1.1 | 2.9 |
| 3 7 0 | 1.2 | −2.4 | −1.5 |
| 4 7 0 | 3.7* | −4.1 | −5.1 |
| 5 7 0 | 2.6 | 3.2 | 1.8 |
| 6 7 0 | 5.2* | 6.2 | 5.7 |
| 7 7 0 | 1.4 | −2.6 | −1.7 |
| 8 7 0 | 5.0* | −5.3 | −4.7 |
| 9 7 0 | 1.4 | 1.2 | 1.2 |
| 10 7 0 | 3.8* | 3.8 | 2.6 |
| 11 7 0 | — | −0.7 | −0.4 |
| 12 7 0 | 1.0 | 0.0 | 0.0 |
| 13 7 0 | 1.0 | −0.1 | −0.4 |
| 14 7 0 | 3.4* | −3.2 | −2.4 |
| 15 7 0 | — | 0.1 | 1.0 |
| 16 7 0 | 4.1* | 5.7 | 3.5 |
| 17 7 0 | 0.8 | 0.0 | −1.2 |
| 18 7 0 | 2.0* | −2.4 | −3.6 |
| 19 7 0 | 0.6 | 1.0 | 1.1 |
| 20 7 0 | 0.6 | 2.1 | 2.7 |
| 0 8 0 | 3.7* | 3.4 | 4.0 |
| 1 8 0 | — | 0.0 | 2.4 |
| 2 8 0 | 3.4* | −5.1 | −3.5 |
| 3 8 0 | — | −1.2 | −1.7 |
| 4 8 0 | 2.1 | 2.5 | 1.8 |
| 5 8 0 | — | 0.0 | 0.6 |
| 6 8 0 | 0.9 | −1.4 | 0.0 |
| 7 8 0 | — | 0.2 | 0.6 |
| 8 8 0 | 0.9 | −1.8 | −1.9 |
| 9 8 0 | 1.8 | −1.8 | −1.6 |
| 10 8 0 | 2.1 | 2.5 | 3.0 |
| 11 8 0 | 2.3 | 2.0 | 2.0 |
| 12 8 0 | 1.7 | −2.4 | −3.1 |
| 13 8 0 | 3.1 | −3.8 | −1.9 |
| 14 8 0 | 1.2 | 1.8 | 2.5 |

## Determination of the Molecular Structure

From the agreement between the corresponding peaks in the two projections, the *x*, *y* and *z* parameters of all the atoms could be easily determined without requiring the three-dimensional analysis. The two water oxygens ($O_5$, $O_6$) were recognized by the fact that they are isolated from the other atoms in reasonable distances, and from the knowledge about bond lengths and bond angles the atoms of the molecule could be linked to each other in a reasonable way as indicated in the electron-density maps (Figs. 2 and 3). The four oxygen, one nitrogen and ten carbon atoms of the molecule were recognized to be as illustrated in Fig. 4, and these assignments will be discussed below. The bond lengths and the bond angles, calculated by the atomic parameters of Table I, are shown in Fig. 5, and it may be said these lengths will be correct at least to ±0.04Å.

In the upper, the middle and the lower part of the electron-density maps, there are seen three planar trigonal groupings formed by every four atoms in the molecule. The two of these, the upper and the middle grouping, are considered to be carboxyl groups, judging from the heights of their peaks and the short distances from these to the zinc atom (Figs. 6 and 7), and the bond lengths and the bond angles within these grouping; they are $C_2$—($C_1$—$O_1$, $O_2$) and $C_6$—($C_7$—$O_3$, $O_4$). The $C_3$—$C_6$ distance of 1.56 Å being of carbon-carbon



(I) (II)

Fig. 4. The structure of kainic acid, (I) viewed along the *b* axis, (II) viewed along the *c* axis.

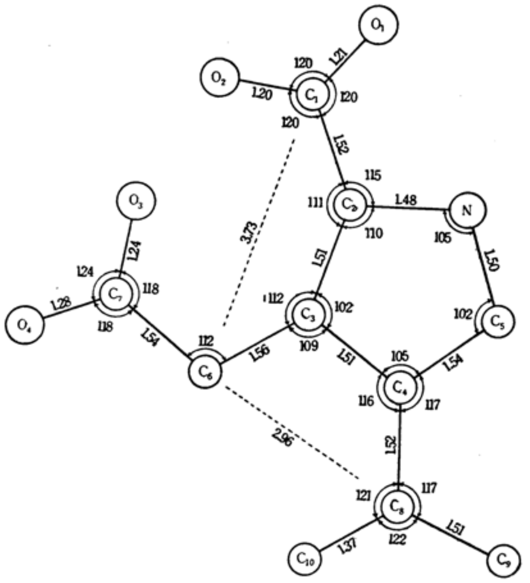


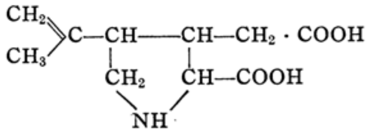
Fig. 5. Bond lengths (Å) and bond angles (°).

single bond, $C_3$—($C_6$—$C_7$—$O_3$, $O_4$) is an acetic acid group.

That of the lower part, having low peaks, is attributable to an isopropenyl group, $C_4$—($C_8$—$C_9$, $C_{10}$), since their bond lengths and bond angles are conformable to the charactericy of this group, the $C_8$—$C_{10}$ bond of 1.37 Å being its double bond.

The nitrogen atom is distinguished from the carbon atoms by the short distance from the zinc atom and by the height of its peak higher than the surrounding carbon atoms. The five-membered ring, N, $C_2$, $C_3$, $C_4$, $C_5$, is of pyrrolidine as identified by the values in Fig. 5.

Thus the structure of kainic acid is concluded to be 2-carboxy-3-carboxymethyl-4-isopropenylpyrrolidine.



As for the stereochemical configuration of the molecule, the carboxyl group of $C_2$ and the acetic acid group of $C_3$ take the *trans*-configuration relative to the ring, and the latter group and the isopropenyl group of $C_4$ are in the *cis*-configuration. In the isopropenyl group, the double bond $C_8$—$C_{10}$ is so located as to be nearer to the ring than the single bond $C_8$—$C_9$. These stereochemical configurations are well shown in Fig. 4.

The five-membered pyrrolidine ring is in the present case considerably more distorted from the planar form than that of hydroxyproline[6], and this may owe mainly to the two side-chains attached to the neighboring $C_3$ and $C_4$, the side-chains closely approaching each other because of the *cis*-configuration. The distance between $C_6$ and $C_8$ is found to be about 3.0 Å, much larger but more adequate than the value of 2.6 Å calculated tentatively using the standard bond distances and bond angles.

## Description of the Crystal Structure

The views of the crystal structure along the *b* and *c* axes are illustrated in Figs. 6 and 7, giving the intermolecular distances. The unit cell contains four zinc cations, eight water molecules and four kainate anions, the molecular structure having already given in the last section. As a whole, the crystal structure is a layered one as can be supposed from the plane of cleavage.

The nitrogen, the four oxygens of the two carboxyl groups and the oxygen $O_5$ of the water surround the zinc, and these six atoms form an octahedron around it. The distances from the zinc to these oxygens, except for Zn...$O_4$ of 2.81 Å, vary from 2.02 to 2.15 Å, as generally found in the zinc salts of oxygen acids, and the distance between the zinc and the nitrogen is 2.21 Å, again the usual value for Zn...N. While the one water ($O_5$) is the coordinated water, the other ($O_6$) does not coordinate to the zinc. It is conceivable that the water $O_6$ is easily desiccated in a desiccator or by heating.

All the hydrogens of the two waters form the O—H...O hydrogen bonds between the two waters or the waters and oxygens of the carboxyl groups. These hydrogen bond distances are 2.68 Å of $O_5$—H...$O_6$, 2.81 Å of $O_5$—H...$O_2$, 2.73 Å of $O_6$—H...$O_3$ and 2.74 Å of $O_6$—H...$O_4$. The hydrogen attached to the nitrogen may be considered also to form the intermolecular hydrogen-bridge between the nitrogen of one molecule and a carboxyl group of another, its N—H...$O_1$ distance being 2.93 Å.

By all the above-mentioned interactions, the zinc cations, the waters and the kainate anions are linked to each other

---

[6] J. Zussman, *Acta Cryst.*, **4**, 493 (1951) ; J. Donohue, ibid., **5**, 419 (1952).

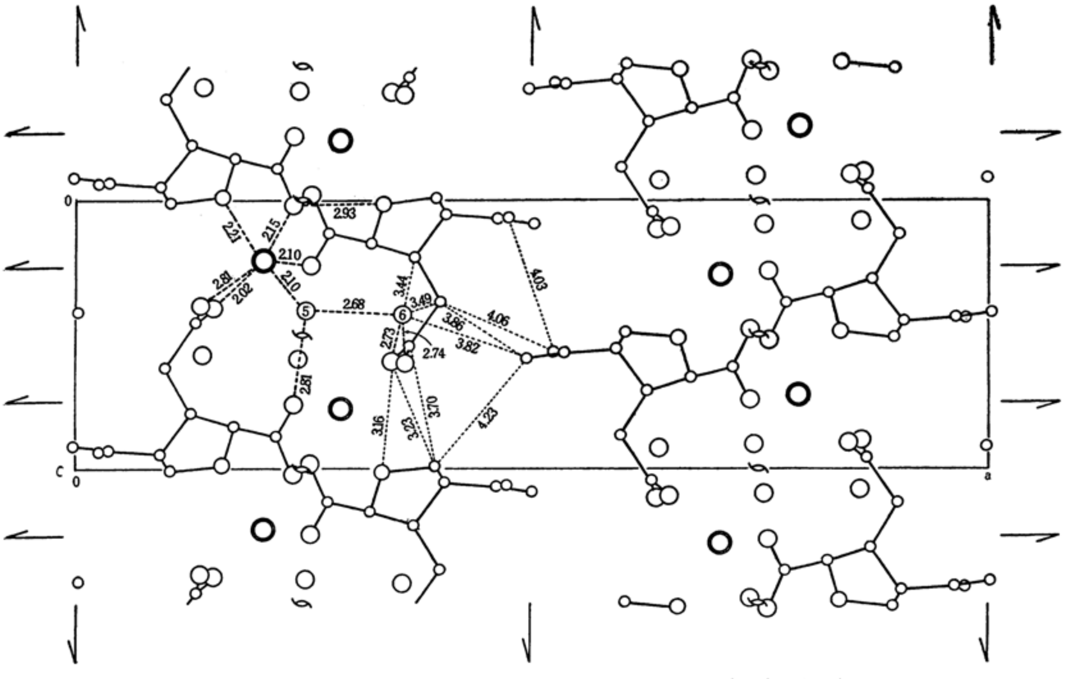


Fig. 6. View of the crystal structure along the *b* axis. The intermolecular distances are shown in Å. Double circles represent zinc, and single circles other atoms, being large, middle and small circles for oxygen, nitrogen and carbon, respectively.

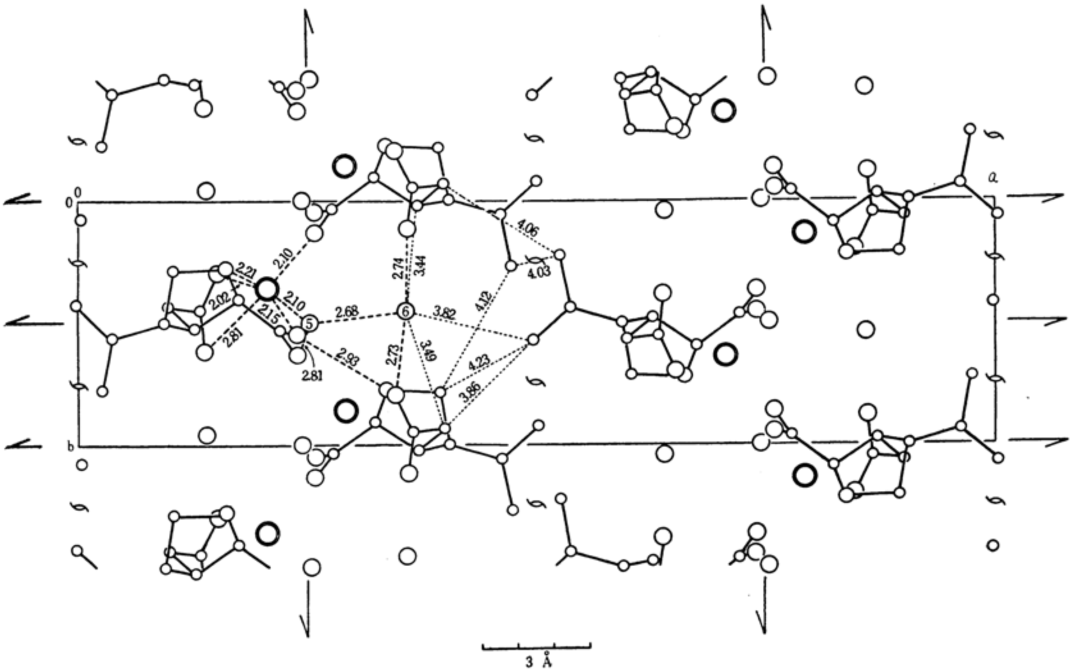


Fig. 7. View of the crystal structure along the *c* axis. The intermolecular distances are shown in Å. Symbols are the same as those of Fig. 6.

forming a layered structure perpendicular to the *a* axis, and between the layers only weak van der Waals attractive forces of the non-polar groups or atoms are operative. The distances of the closest approach between the layers are 3.86 Å of $C_{10}...C_6$, 4.03 Å of $C_9...C_9$ and 4.06 Å of $C_9...C_6$. It is obvious that the cleavage of (1 0 0) plane takes place here.

We wish to express our thanks to Professor-Emeritus S. Murakami, Dr. T. Takemoto and their collaborators of this University, and Drs. S. Kuwada, S. Tatsuoka, Y. Ueno and their collaborators of the Research Laboratories of Takeda Pharmaciutical Industries, Ltd., for supplying the specimens, kind discussions and micro-analyses. Thanks are also due to Drs. Y. Tomiie and H. Tani of this University for helpful advice and continued interest. Appreciations are also expressed to Messrs T. Siba, S. Sakakibara and M. Okumiya and Miss K. Koike of this University for their help in microanalysis.

*Department of Chemistry*
*Faculty of Science*
*Osaka University*
*Kita-ku, Osaka*