# Crystal and Molecular Structure of a Silver Salt of Antibiotic A-130A

By **Hirozo Koyama*** and **Kazuko Utsumi-Oda**, Shionogi Research Laboratory, Shionogi & Co., Ltd., Fukushimaku, Osaka 553, Japan

The crystal structure of the title compound has been determined by three-dimensional *X*-ray analysis from diffractometer data. Crystals are orthorhombic, space group $P2_12_12_1$, $a = 28.179(5)$, $b = 9.582(2)$, $c = 18.096(3)$, $Z = 4$. The structure was solved by direct methods and refined by full-matrix least-squares calculations to $R$ 0.065 for 3 977 independent observed reflexions. Hydrogen atoms were located. The absolute configuration was determined by the anomalous dispersion method. The molecule is wrapped around the $Ag^+$ cation, and held in this configuration by two very strong hydrogen bonds between the carboxylate oxygen atoms and the two alcohol groups of the terminal six-membered ring.

THE antibiotic A-130A, $C_{47}H_{78}O_{13}$, was isolated [1] as the sodium salt from a culture of *Streptomyces hygroscopicus* strain A-130A and has an antimicrobial activity *in vitro* against gram-positive bacteria and mycobacteria. From its biological activity and physicochemical properties, the antibiotic A-130A was thought to belong to the family of polyether monocarboxylic acid antibiotics. The structures of several polyether antibiotics have recently been established [2-24] by *X*-ray diffraction methods. In the earlier reports,[21,25] the structure of antibiotic A-130A was suggested to be (I), from an *X*-ray crystallographic analysis of the silver salt. The structure of this compound was found to be very similar to that of dianemycin [12] and identical to that of RO 21-6150.[21] The present *X*-ray crystal structure analysis was undertaken in order to obtain more detailed information of the molecular conformation.

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[1] T. Kubota (the late), H. Hinoh, M. Mayama, K. Motokawa, and Y. Yasuda, *J. Antibiotics*, 1975, **28**, 931.

[2] A. Agtarap, J. W. Chamberlin, M. Pinkerton, and L. K. Steinrauf, *J. Amer. Chem. Soc.*, 1967, **89**, 5737.

[3] L. K. Steinrauf, M. Pinkerton, and J. W. Chamberlin, *Biochem. Biophys. Res. Comm.*, 1968, **33**, 29.

[4] T. Kubota, S. Matsutani, M. Shiro, and H. Koyama, *Chem. Comm.*, 1968, 1541.

[5] M. Pinkerton and L. K. Steinrauf, *J. Mol. Biol.*, 1970, **49**, 533.

[6] M. Shiro and H. Koyama, *J. Chem. Soc.* (*B*), 1970, 243.

[7] S. M. Johnson, J. Herrin, S. J. Liu, and I. C. Paul, *Chem. Comm.*, 1970, 72.

[8] M. Alléaume and D. Hickel, *Chem. Comm.*, 1970, 1422.

[9] W. K. Lutz, F. K. Winkler, and J. D. Dunitz, *Helv. Chim. Acta*, 1971, **54**, 1103.

[10] C. A. Maier and I. C. Paul, *Chem. Comm.*, 1971, 181.

[11] J. F. Blount and J. W. Westley, *Chem. Comm.*, 1971, 927.

[12] E. W. Czerwinski and L. K. Steinrauf, *Biochem. Biophys. Res. Comm.*, 1971, **45**, 1284.

[13] M. Alléaume and D. Hickel, *J.C.S. Chem. Comm.*, 1972, 175.

[14] E. C. Bissell and I. C. Paul, *J.C.S. Chem. Comm.*, 1972, 967.

[15] N. D. Jones, M. O. Chaney, J. W. Chamberlin, R. L. Hamill, and S. Chen, *J. Amer. Chem. Soc.*, 1973, **95**, 3399.

[16] H. Kinashi, N. Ōtake, H. Yonehara, S. Sato, and Y. Saito, *Tetrahedron Letters*, 1973, 4955.

[17] T. J. Petcher and H. P. Weber, *J.C.S. Chem. Comm.*, 1974, 697.

[18] N. Ōtake, M. Koenuma, H. Kinashi, S. Sato, and Y. Saito, *J.C.S. Chem. Comm.*, 1975, 92.

[19] M. Alléaume, B. Busetta, C. Farges, P. Gachon, A. Kergomard, and T. Staron, *J.C.S. Chem. Comm.*, 1975, 411.

[20] J. F. Blount and J. W. Westley, *J.C.S. Chem. Comm.*, 1975, 533.

[21] J. F. Blount, R. H. Evans, jun., C. M. Liu, T. Hermann, and J. W. Westley, *J.C.S. Chem. Comm.*, 1975, 853.

[22] C. Riche and C. Pascard-Billy, *J.C.S. Chem. Comm.*, 1975, 951.

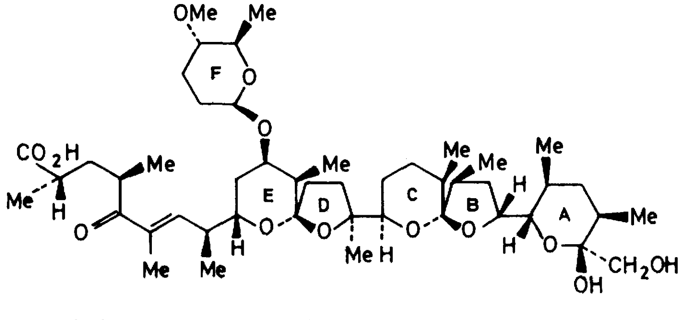
[23] H. Kinashi, N. Ōtake, H. Yonehara, S. Sato, and Y. Saito, *Acta Cryst.*, 1975, **B31**, 2411.

[24] M. Koenuma, H. Kinashi, N. Ōtake, S. Sato, and Y. Saito, *Acta Cryst.*, 1976, **B32**, 1267.

[25] H. Koyama and K. Okada, 10th Internat. Congr. Crystallography, Amsterdam, 1975, Abstract S18.

## EXPERIMENTAL

Crystals of (I) were isolated according to the method of ref. 26 and recrystallized from ethyl alcohol as colourless prisms, m.p. 157—160 °C, elongated along the *b* axis.



Preliminary space-group data were determined from Weissenberg and precession photographs by use of Cu-$K_\alpha$ ($\lambda$ = 1.541 8 Å) radiation, and accurate unit-cell dimensions were obtained by least-squares refinement of the setting angles of 20 reflexions measured on an automatic diffractometer.

*Crystal Data*.—$C_{47}H_{77}AgO_{13}$, $M$ = 958.0. Orthorhombic, $a$ = 28.179(5), $b$ = 9.582(2), $c$ = 18.096(3) Å, $U$ = 4 886 Å$^3$, $D_m$ = 1.305 (by flotation), $Z$ = 4, $D_c$ = 1.302, $F(000)$ = 2 036. Space group $P2_12_12_1$ ($D_2^4$, No. 19), from systematic absences: $h00$ for $h$ odd, $0k0$ for $k$ odd, and $00l$ for $l$ odd. Mo-$K_\alpha$ radiation, $\lambda$ = 0.710 7 Å; $\mu$(Mo-$K_\alpha$) = 4.668 cm$^{-1}$.

Three-dimensional intensity data were collected on a Hilger and Watts automatic four-circle Y 290 diffractometer controlled by a PDP 8 computer. Integrated intensities were measured for $\theta < 27.5°$ by the $\theta$—$2\theta$ scan technique with Mo-$K_\alpha$ radiation and a scintillation counter (with zirconium filter and pulse-height analyser). Each reflexion was integrated in 80 steps of 0.01°. A standard reflexion was monitored every 10 reflexions. Scan counts ($P$) and background counts ($B_1$, $B_2$) were combined to yield the integrated intensities $I = P - 2(B_1 + B_2)$.

A total of 6 253 independent reflexions was measured, of which 3 977 having $I > 3\sigma(I)$ were considered observed. All intensities were corrected for Lorentz and polarization factors, and structure amplitudes were derived. No absorption corrections were applied since the specimen was considered to be sufficiently small (0.28 × 0.36 × 0.31 mm).

*Structure Analysis*.—The structure was solved by the SEARCHER programme for automatic heavy-atom analysis, written [27,28] for the CDC 3600 computer (later modified for CDC 6600 computer). Initial co-ordinates for the silver atom were easily derived from a three-dimensional Patterson synthesis. The atomic co-ordinates of 60 light atoms, which were treated as carbon atoms, were found from the first cycle (CDC 6600 computer), and the co-ordinates of these 61 atoms refined [29] by full-matrix least-squares calculations. After three cycles of isotropic and a further three cycles of anisotropic least-squares refinement, $R$ decreased to 0.089 for observed reflexions. A three-dimensional difference-Fourier synthesis was then calculated and the positions of the 77 hydrogen atoms were found. The final five cycles of full-matrix least-squares refinement were carried out with anisotropic temperature factors, the function minimized being $\Sigma w(F_o - F_c)^2$ with unit weights; hydrogen atoms were included in the structure-factor calculations with isotropic temperature factors ($B$ fixed at 2.425 Å$^2$). In the final calculations the hydrogen co-ordinates were also permitted to vary (a shift factor of 0.35 was applied), and at this stage $R$ was 0.065 for the 3 977 reflexions.

TABLE 1

Final fractional atomic co-ordinates (× 10$^4$), with estimated standard deviations in parentheses

| Atom | $x$ | $y$ | $z$ |
|---|---|---|---|
| Ag+ | 3 993(0) | 8 838(1) | 5 242(0) |
| C(1) | 2 449(3) | 9 866(13) | 6 070(5) |
| C(2) | 1 897(3) | 9 709(13) | 6 045(5) |
| C(3) | 1 681(3) | 10 271(13) | 5 322(6) |
| C(4) | 1 711(3) | 11 805(14) | 5 217(6) |
| C(5) | 1 602(4) | 12 201(16) | 4 432(6) |
| C(6) | 1 973(4) | 12 304(14) | 3 848(5) |
| C(7) | 2 406(3) | 11 838(14) | 3 973(5) |
| C(8) | 2 833(4) | 11 834(13) | 3 447(5) |
| C(9) | 3 138(3) | 10 553(12) | 3 573(5) |
| C(10) | 2 876(3) | 9 186(13) | 3 474(5) |
| C(11) | 3 197(3) | 7 960(10) | 3 521(5) |
| C(12) | 3 621(3) | 8 166(13) | 2 998(4) |
| C(13) | 3 854(3) | 9 528(13) | 3 097(5) |
| C(14) | 4 244(3) | 9 911(14) | 2 537(5) |
| C(15) | 4 522(3) | 11 013(16) | 2 945(6) |
| C(16) | 4 487(3) | 10 595(12) | 3 759(5) |
| C(17) | 4 926(3) | 9 835(12) | 4 052(5) |
| C(18) | 5 111(3) | 8 627(17) | 3 607(6) |
| C(19) | 5 488(4) | 7 804(16) | 3 980(6) |
| C(20) | 5 318(4) | 7 342(12) | 4 736(7) |
| C(21) | 5 156(3) | 8 584(12) | 5 185(5) |
| C(22) | 5 538(3) | 9 635(12) | 5 478(6) |
| C(23) | 5 283(3) | 10 233(12) | 6 147(6) |
| C(24) | 5 012(3) | 9 050(11) | 6 452(5) |
| C(25) | 4 572(3) | 9 352(10) | 6 879(5) |
| C(26) | 4 660(3) | 10 050(12) | 7 618(6) |
| C(27) | 4 179(3) | 10 467(13) | 7 957(6) |
| C(28) | 3 872(3) | 11 285(13) | 7 440(5) |
| C(29) | 3 823(3) | 10 579(10) | 6 692(4) |
| C(30) | 1 780(4) | 8 298(17) | 6 169(8) |
| C(31) | 1 374(5) | 12 661(16) | 5 727(7) |
| C(32) | 1 816(4) | 12 884(16) | 3 114(6) |
| C(33) | 3 109(4) | 13 165(14) | 3 518(6) |
| C(34) | 3 250(3) | 6 600(12) | 4 621(5) |
| C(35) | 2 716(3) | 6 596(13) | 4 841(6) |
| C(36) | 2 624(4) | 5 422(13) | 5 370(6) |
| C(37) | 2 926(4) | 5 486(12) | 6 024(6) |
| C(38) | 3 446(3) | 5 540(11) | 5 768(5) |
| C(39) | 3 791(4) | 5 788(16) | 6 378(6) |
| C(40) | 2 477(5) | 4 308(16) | 6 884(9) |
| C(41) | 3 932(5) | 6 887(14) | 3 014(6) |
| C(42) | 4 368(4) | 11 836(13) | 4 224(7) |
| C(43) | 4 936(4) | 6 275(14) | 4 699(7) |
| C(44) | 6 011(4) | 8 984(14) | 5 707(6) |
| C(45) | 4 939(4) | 9 171(14) | 8 142(6) |
| C(46) | 3 397(4) | 11 549(19) | 7 781(7) |
| C(47) | 3 618(3) | 11 532(12) | 6 111(6) |
| O(48) | 2 638(2) | 9 709(12) | 6 665(4) |
| O(49) | 2 649(2) | 10 067(11) | 5 481(3) |
| O(50) | 1 194(3) | 12 462(13) | 4 258(4) |
| O(51) | 3 523(2) | 10 628(7) | 3 055(3) |
| O(52) | 4 102(2) | 9 580(8) | 3 782(3) |
| O(53) | 4 800(1) | 9 380(7) | 4 771(3) |
| O(54) | 4 912(2) | 8 141(7) | 5 826(3) |
| O(55) | 4 286(2) | 10 215(7) | 6 417(3) |
| O(56) | 3 577(2) | 9 341(8) | 6 748(4) |
| O(57) | 3 531(2) | 10 878(8) | 5 436(3) |
| O(58) | 3 381(2) | 7 806(7) | 4 254(3) |
| O(59) | 3 519(2) | 6 681(7) | 5 286(3) |
| O(60) | 2 891(3) | 4 328(10) | 6 499(4) |

Observed and calculated structure amplitudes and anisotropic temperature factors are listed in Supplementary

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[26] T. Kubota (the late), ref. 1.

[27] H. Koyama and K. Okada, 1970, SEARCHER, a Fortran program for the automatic heavy-atom analysis of organic compounds, Shionogi Research Laboratory, Osaka, Japan.

[28] H. Koyama and K. Okada, *Acta Cryst.*, 1970, **B26**, 444.

[29] W. L. Busing, K. O. Martin, and H. A. Levy, ORFLS, A Fortran crystallographic least-squares program, Oak Ridge National Laboratory, Tennessee, Report ORNL TM 305, 1962.

publication No. SUP 21976 (13 pp., 1 microfiche).* Atomic scattering factors used in all calculations were taken from ref. 30 for non-hydrogen and from ref. 31 for hydrogen atoms. Final positional parameters, with their estimated standard deviations, are given in Tables 1 and 2.

TABLE 2

Final fractional hydrogen atomic co-ordinates ($\times 10^3$)

| Atom | *x* | *y* | *z* | Atom | *x* | *y* | *z* |
|---|---|---|---|---|---|---|---|
| H(2) | 177 | 1 034 | 646 | H(33a) | 328 | 1 301 | 313 |
| H(3a) | 181 | 980 | 496 | H(33b) | 290 | 1 409 | 344 |
| H(3b) | 128 | 1 004 | 538 | H(33c) | 316 | 1 338 | 398 |
| H(4) | 192 | 1 211 | 533 | H(34) | 339 | 575 | 435 |
| H(7) | 243 | 1 140 | 437 | H(35a) | 262 | 756 | 503 |
| H(8) | 274 | 1 169 | 308 | H(35b) | 261 | 627 | 453 |
| H(9) | 327 | 1 052 | 399 | H(36a) | 274 | 454 | 517 |
| H(10a) | 279 | 936 | 299 | H(36b) | 242 | 504 | 520 |
| H(10b) | 264 | 936 | 374 | H(37) | 285 | 636 | 620 |
| H(11) | 308 | 706 | 344 | H(38) | 350 | 467 | 557 |
| H(12) | 353 | 812 | 269 | H(39a) | 384 | 511 | 662 |
| H(14a) | 440 | 899 | 241 | H(39b) | 367 | 659 | 666 |
| H(14b) | 411 | 1 014 | 225 | H(39c) | 414 | 586 | 623 |
| H(15a) | 472 | 1 100 | 279 | H(40a) | 224 | 384 | 671 |
| H(15b) | 436 | 1 176 | 281 | H(40b) | 246 | 358 | 711 |
| H(17) | 508 | 1 055 | 406 | H(40c) | 242 | 506 | 697 |
| H(18a) | 522 | 916 | 328 | H(41a) | 402 | 682 | 345 |
| H(18b) | 484 | 824 | 349 | H(41b) | 381 | 588 | 292 |
| H(19a) | 556 | 866 | 409 | H(41c) | 412 | 703 | 275 |
| H(19b) | 565 | 719 | 372 | H(42a) | 412 | 1 226 | 406 |
| H(20) | 550 | 677 | 497 | H(42b) | 458 | 1 253 | 415 |
| H(22) | 563 | 1 032 | 523 | H(42c) | 441 | 1 146 | 457 |
| H(23a) | 506 | 1 097 | 613 | H(43a) | 487 | 551 | 490 |
| H(23b) | 539 | 1 087 | 631 | H(43b) | 470 | 679 | 456 |
| H(24) | 521 | 861 | 673 | H(43c) | 496 | 573 | 434 |
| H(25) | 444 | 859 | 692 | H(44a) | 591 | 803 | 589 |
| H(26) | 482 | 1 096 | 754 | H(44b) | 616 | 985 | 588 |
| H(27a) | 409 | 958 | 798 | H(44c) | 609 | 851 | 540 |
| H(27b) | 423 | 1 073 | 839 | H(45a) | 494 | 979 | 855 |
| H(28) | 397 | 1 211 | 731 | H(45b) | 483 | 838 | 829 |
| H(30a) | 187 | 776 | 571 | H(45c) | 521 | 919 | 804 |
| H(30b) | 191 | 784 | 639 | H(46a) | 321 | 1 202 | 764 |
| H(30c) | 156 | 815 | 608 | H(46b) | 346 | 1 193 | 821 |
| H(31a) | 145 | 1 252 | 622 | H(46c) | 336 | 1 050 | 798 |
| H(31b) | 141 | 1 350 | 577 | H(47a) | 388 | 1 235 | 600 |
| H(31c) | 121 | 1 196 | 565 | H(47b) | 338 | 1 213 | 626 |
| H(32a) | 159 | 1 227 | 278 | H(56) | 337 | 928 | 670 |
| H(32b) | 168 | 1 377 | 325 | H(57) | 333 | 1 048 | 544 |
| H(32c) | 199 | 1 261 | 286 | | | | |

TABLE 3

Determination of the absolute configuration

| *h* | *k* | *l* | $F_c(hkl)$ | $F_c(h\bar{k}l)$ | $I(hkl) \gtrless I(h\bar{k}l)$ |
|---|---|---|---|---|---|
| 1 | 1 | 5 | 54.3 | 24.1 | < |
| 2 | 1 | 2 | 165.2 | 169.1 | > |
| 4 | 1 | 2 | 77.5 | 55.5 | < |
| 4 | 1 | 3 | 38.4 | 59.0 | > |
| 4 | 1 | 4 | 43.2 | 36.5 | < |
| 4 | 1 | 9 | 35.8 | 32.5 | < |
| 6 | 1 | 1 | 78.7 | 46.7 | < |
| 6 | 1 | 7 | 39.9 | 49.4 | > |
| 6 | 1 | 8 | 46.0 | 58.5 | > |
| 9 | 1 | 11 | 31.6 | 34.2 | > |
| 10 | 1 | 5 | 54.4 | 34.5 | < |
| 10 | 1 | 8 | 12.2 | 29.5 | > |
| 11 | 1 | 5 | 27.7 | 52.4 | > |
| 12 | 1 | 7 | 39.1 | 37.8 | < |
| 14 | 1 | 9 | 16.2 | 24.0 | > |

*Absolute Configuration.*—In the final stage of the analysis the absolute configuration of the molecule was determined by the anomalous dispersion method.[32] The differences between $I_0(hkl)$ and $I_0(h\bar{k}l)$ were measured visually from the photographs rotated around the *b* axis, taken with Cr-$K_\alpha$ radiation ($\lambda = 2.290\,9$ Å). Structure factors were calculated for all *hkl* and $h\bar{k}l$ reflexions, with a scattering factor [33] for the silver atom of the form: $f_{Ag} = f_{Ag} + \Delta f'_{Ag} + i\Delta f''_{Ag}$, with $\Delta f'_{Ag}$ $-$ 0.924 and $\Delta f''_{Ag}$ 8.235. The results (see Table 3) unanimously indicated that the parameters of Tables 1 and 2 represent the left-hand co-ordinate system.

## DISCUSSION

The configuration of the molecule is illustrated [34] in Figure 1. The molecule is a new member of the polyether antibiotics containing four six-membered (A, C, E, and F) and two five-membered rings (B and D). The junctions B/C and D/E are of spiro-conformation, *i.e.* in each case the two rings have only one atom in common. The molecule are very similar in structure and stereochemistry to dianemycin,[12] except for the differences at atoms C(10)—(12), C(19), and C(34).

Intramolecular bond distances and angles are given in Table 4, together with their estimated standard deviations computed from the least-squares residuals. Mean estimated standard deviations are *ca.* 0.014 Å and 0.8°. The observed C–C distances lie in the range 1.409—1.567 Å (mean 1.509 Å), and C–O distances in the range 1.360—1.464 Å (mean 1.422 Å). Most observed bond distances and angles are comparable to those found in other polyether antibiotics including monesin,[5,9] polyetherin A (nigericin),[6] salinomycin,[23] and lysocellin.[24] The C(2)–C(30) bond (1.409 Å) is considerably shorter than the normal single-bond distance. Two or three differences which appear to be significant in terms of the estimated standard deviations are more likely to indicate

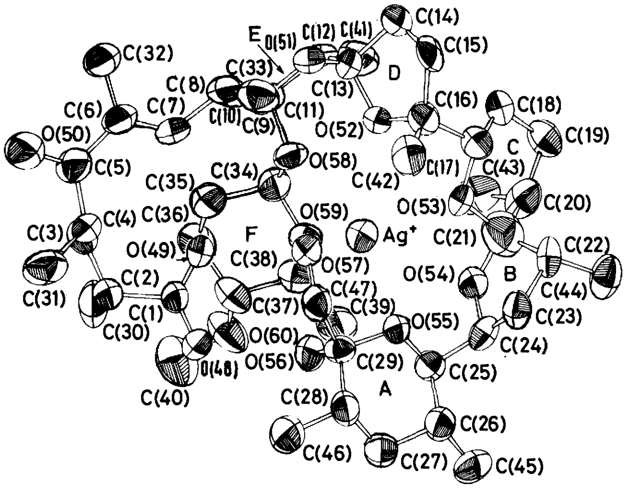

FIGURE 1 An ORTEP drawing of the molecule, showing the atom numbering system used

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* See Notice to Authors No. 7 in *J.C.S. Perkin II*, 1975, Index issue.

[30] P. A. Doyle and P. S. Turner, *Acta Cryst.*, 1968, **A24**, 390.

[31] R. F. Stewart, E. R. Davidson, and W. T. Simpson, *J. Chem. Phys.*, 1965, **42**, 3175.

[32] J. M. Bijvoet, A. F. Peerdeman, and A. J. van Bommel, *Nature*, 1951, **168**, 271.

[33] 'International Tables for *X*-Ray Crystallography,' vol. 4, Kynoch Press, Birmingham, 1974, pp. 149.

[34] C. K. Johnson, ORTEP, A Fortran thermal-ellipsoid plot program, Oak Ridge, National Laboratory, Tennessee, Report ORNL 3794, 1965.

TABLE 4

Interatomic distances (Å) and angles (°), with standard deviations in parentheses

(*a*) Bond distances

| | | | |
|---|---|---|---|
| C(1)–C(2) | 1.561 (13) | C(19)–C(20) | 1.516 (18) |
| C(1)–O(48) | 1.212 (12) | C(20)–C(21) | 1.511 (16) |
| C(1)–O(49) | 1.221 (12) | C(20)–C(43) | 1.485 (18) |
| C(2)–C(3) | 1.540 (15) | C(21)–C(22) | 1.567 (14) |
| C(2)–C(30) | 1.409 (20) | C(21)–O(53) | 1.464 (12) |
| C(3)–C(4) | 1.484 (18) | C(21)–O(54) | 1.414 (12) |
| C(4)–C(5) | 1.503 (16) | C(22)–C(23) | 1.521 (16) |
| C(4)–C(31) | 1.557 (18) | C(22)–C(44) | 1.527 (15) |
| C(5)–C(6) | 1.489 (16) | C(23)–C(24) | 1.473 (15) |
| C(5)–O(50) | 1.216 (15) | C(24)–C(25) | 1.490 (13) |
| C(6)–C(7) | 1.317 (16) | C(24)–O(54) | 1.455 (12) |
| C(6)–C(32) | 1.506 (16) | C(25)–C(26) | 1.515 (14) |
| C(7)–C(8) | 1.533 (15) | C(25)–O(55) | 1.425 (11) |
| C(8)–C(9) | 1.516 (16) | C(26)–C(27) | 1.540 (15) |
| C(8)–C(33) | 1.500 (18) | C(26)–C(45) | 1.492 (16) |
| C(9)–C(10) | 1.514 (16) | C(27)–C(28) | 1.495 (15) |
| C(9)–O(51) | 1.434 (11) | C(28)–C(29) | 1.520 (14) |
| C(10)–C(11) | 1.485 (15) | C(28)–C(46) | 1.494 (15) |
| C(11)–C(12) | 1.536 (13) | C(29)–C(47) | 1.507 (14) |
| C(11)–O(58) | 1.432 (11) | C(29)–O(55) | 1.439 (11) |
| C(12)–C(13) | 1.471 (17) | C(29)–O(56) | 1.377 (12) |
| C(12)–C(41) | 1.507 (18) | C(34)–C(35) | 1.555 (15) |
| C(13)–C(14) | 1.538 (14) | C(34)–O(58) | 1.382 (13) |
| C(13)–O(51) | 1.409 (13) | C(34)–O(59) | 1.424 (12) |
| C(13)–O(52) | 1.423 (11) | C(35)–C(36) | 1.499 (17) |
| C(14)–C(15) | 1.507 (18) | C(36)–C(37) | 1.458 (16) |
| C(15)–C(16) | 1.530 (15) | C(37)–C(38) | 1.537 (16) |
| C(16)–C(17) | 1.529 (15) | C(37)–O(60) | 1.407 (15) |
| C(16)–C(42) | 1.495 (17) | C(38)–C(39) | 1.489 (16) |
| C(16)–O(52) | 1.460 (12) | C(38)–O(59) | 1.413 (12) |
| C(17)–C(18) | 1.502 (18) | C(40)–O(60) | 1.360 (18) |
| C(17)–O(53) | 1.417 (12) | C(47)–O(57) | 1.394 (13) |
| C(18)–C(19) | 1.484 (18) | | |

| | |
|---|---|
| O(48) · · · H(56)–O(56) | 2.673 (9) |
| O(49) · · · H(57)–O(57) | 2.604 (9) |

(*b*) Valency angles

| | | | |
|---|---|---|---|
| C(2)–C(1)–O(48) | 116.9(8) | C(21)–C(20)–C(43) | 110.3(9) |
| C(2)–C(1)–O(49) | 116.7(8) | C(20)–C(21)–C(22) | 118.6(8) |
| O(48)–C(1)–O(49) | 126.2(9) | C(20)–C(21)–O(53) | 110.0(8) |
| C(1)–C(2)–C(3) | 112.6(8) | C(20)–C(21)–O(54) | 110.6(9) |
| C(1)–C(2)–C(30) | 108.6(9) | C(22)–C(21)–O(53) | 107.9(8) |
| C(3)–C(2)–C(30) | 112.2(10) | C(22)–C(21)–O(54) | 104.4(8) |
| C(2)–C(3)–C(4) | 115.5(9) | O(53)–C(21)–O(54) | 104.0(6) |
| C(3)–C(4)–C(5) | 111.0(10) | C(21)–C(22)–C(23) | 100.7(7) |
| C(3)–C(4)–C(31) | 114.2(9) | C(21)–C(22)–C(44) | 115.3(9) |
| C(5)–C(4)–C(31) | 107.6(10) | C(23)–C(22)–C(44) | 110.5(9) |
| C(4)–C(5)–C(6) | 122.8(9) | C(22)–C(23)–C(24) | 104.6(9) |
| C(4)–C(5)–O(50) | 119.3(10) | C(23)–C(24)–C(25) | 118.4(9) |
| C(6)–C(5)–O(50) | 117.7(10) | C(23)–C(24)–O(54) | 105.6(8) |
| C(5)–C(6)–C(7) | 120.3(10) | C(25)–C(24)–O(54) | 110.9(7) |
| C(5)–C(6)–C(32) | 116.3(10) | C(24)–C(25)–C(26) | 114.0(8) |
| C(7)–C(6)–C(32) | 123.2(10) | C(24)–C(25)–O(55) | 106.1(7) |
| C(6)–C(7)–C(8) | 128.2(9) | C(26)–C(25)–O(55) | 110.7(8) |
| C(7)–C(8)–C(9) | 110.7(9) | C(25)–C(26)–C(27) | 108.7(8) |
| C(7)–C(8)–C(33) | 110.6(9) | C(25)–C(26)–C(45) | 113.4(9) |
| C(9)–C(8)–C(33) | 112.3(9) | C(27)–C(26)–C(45) | 110.8(9) |
| C(8)–C(9)–C(10) | 113.9(8) | C(26)–C(27)–C(28) | 113.3(8) |
| C(8)–C(9)–O(51) | 106.8(8) | C(27)–C(28)–C(29) | 112.0(9) |
| C(10)–C(9)–O(51) | 109.5(8) | C(27)–C(28)–C(46) | 110.4(9) |
| C(9)–C(10)–C(11) | 112.3(8) | C(29)–C(28)–C(46) | 111.2(8) |
| C(10)–C(11)–C(12) | 109.7(8) | C(28)–C(29)–C(47) | 112.7(8) |
| C(10)–C(11)–O(58) | 110.7(7) | C(28)–C(29)–O(55) | 109.5(7) |
| C(12)–C(11)–O(58) | 107.6(7) | C(28)–C(29)–O(56) | 111.2(8) |
| C(11)–C(12)–C(13) | 112.6(8) | C(47)–C(29)–O(55) | 104.6(7) |
| C(11)–C(12)–C(41) | 109.6(9) | C(47)–C(29)–O(56) | 112.3(7) |
| C(13)–C(12)–C(41) | 117.3(9) | O(55)–C(29)–O(56) | 105.8(7) |
| C(12)–C(13)–C(14) | 116.7(9) | C(35)–C(34)–O(58) | 112.5(9) |
| C(12)–C(13)–O(51) | 111.1(7) | C(35)–C(34)–O(59) | 107.4(8) |
| C(12)–C(13)–O(52) | 110.8(9) | O(58)–C(34)–O(59) | 120.5(7) |
| C(14)–C(13)–O(51) | 104.9(9) | C(34)–C(35)–C(36) | 109.4(9) |
| C(14)–C(13)–O(52) | 102.4(7) | C(35)–C(36)–C(37) | 112.6(10) |
| O(51)–C(13)–O(52) | 110.1(8) | C(36)–C(37)–C(38) | 108.2(9) |
| C(13)–C(14)–C(15) | 102.5(8) | C(36)–C(37)–O(60) | 114.9(10) |
| C(14)–C(15)–C(16) | 104.7(10) | C(38)–C(37)–O(60) | 106.1(9) |
| C(15)–C(16)–C(17) | 113.9(8) | C(37)–C(38)–C(39) | 113.7(9) |
| C(15)–C(16)–C(42) | 110.4(10) | C(37)–C(38)–O(59) | 110.5(8) |
| C(15)–C(16)–O(52) | 104.4(8) | C(39)–C(38)–O(59) | 103.8(9) |
| C(17)–C(16)–C(42) | 111.4(9) | C(29)–C(47)–O(57) | 113.9(9) |
| C(17)–C(16)–O(52) | 105.9(8) | C(9)–O(51)–C(13) | 115.3(7) |
| C(42)–C(16)–O(52) | 110.2(8) | C(13)–O(52)–C(16) | 111.3(7) |
| C(16)–C(17)–C(18) | 117.4(8) | C(17)–O(53)–C(21) | 117.2(7) |
| C(16)–C(17)–O(53) | 105.2(7) | C(21)–O(54)–C(24) | 111.3(7) |
| C(18)–C(17)–O(53) | 109.9(9) | C(25)–O(55)–C(29) | 116.7(6) |
| C(17)–C(18)–C(19) | 114.4(9) | C(11)–O(58)–C(34) | 115.7(7) |
| C(18)–C(19)–C(20) | 109.8(9) | C(34)–O(59)–C(38) | 113.6(7) |
| C(19)–C(20)–C(21) | 110.5(10) | C(37)–O(60)–C(40) | 112.6(10) |
| C(19)–C(20)–C(43) | 112.8(11) | O(48)–H(56)–O(56) | 162.7(9) |
| | | O(49)–H(57)–O(57) | 157.7(8) |

TABLE 4 (*Cont.*)

(*c*) Bond distances associated with hydrogen-atom positions

| | | | |
|---|---|---|---|
| C(2)–H(2) | 1.02 | C(32)–H(32c) | 0.72 |
| C(3)–H(3a) | 0.86 | C(33)–H(33a) | 0.86 |
| C(3)–H(3b) | 1.14 | C(33)–H(33b) | 1.07 |
| C(4)–H(4) | 0.70 | C(33)–H(33c) | 0.87 |
| C(7)–H(7) | 0.83 | C(34)–H(34) | 1.02 |
| C(8)–H(8) | 0.72 | C(35)–H(35a) | 1.02 |
| C(9)–H(9) | 0.85 | C(35)–H(35b) | 0.69 |
| C(10)–H(10a) | 0.91 | C(36)–H(36a) | 0.97 |
| C(10)–H(10b) | 0.84 | C(36)–H(36b) | 0.74 |
| C(11)–H(11) | 0.92 | C(37)–H(37) | 0.92 |
| C(12)–H(12) | 0.61 | C(38)–H(38) | 0.91 |
| C(14)–H(14a) | 1.01 | C(39)–H(39a) | 0.80 |
| C(14)–H(14b) | 0.67 | C(39)–H(39b) | 0.99 |
| C(15)–H(15a) | 0.62 | C(39)–H(39c) | 1.01 |
| C(15)–H(15b) | 0.87 | C(40)–H(40a) | 0.85 |
| C(17)–H(17) | 0.81 | C(40)–H(40b) | 0.80 |
| C(18)–H(18a) | 0.84 | C(40)–H(40c) | 0.76 |
| C(18)–H(18b) | 0.84 | C(41)–H(41a) | 0.84 |
| C(19)–H(19a) | 0.87 | C(41)–H(41b) | 1.03 |
| C(19)–H(19b) | 0.88 | C(41)–H(41c) | 0.73 |
| C(20)–H(20) | 0.87 | C(42)–H(42a) | 0.85 |
| C(22)–H(22) | 0.83 | C(42)–H(42b) | 0.92 |
| C(23)–H(23a) | 0.93 | C(42)–H(42c) | 0.73 |
| C(23)–H(23b) | 0.75 | C(43)–H(43a) | 0.83 |
| C(24)–H(24) | 0.87 | C(43)–H(43b) | 0.86 |
| C(25)–H(25) | 0.81 | C(43)–H(43c) | 0.83 |
| C(26)–H(26) | 0.99 | C(44)–H(44a) | 1.01 |
| C(27)–H(27a) | 0.87 | C(44)–H(44b) | 1.00 |
| C(27)–H(27b) | 0.84 | C(44)–H(44c) | 0.74 |
| C(28)–H(28) | 0.87 | C(45)–H(45a) | 0.96 |
| C(30)–H(30a) | 1.00 | C(45)–H(45b) | 0.85 |
| C(30)–H(30b) | 0.70 | C(45)–H(45c) | 0.80 |
| C(30)–H(30c) | 0.65 | C(46)–H(46a) | 0.72 |
| C(31)–H(31a) | 0.93 | C(46)–H(46b) | 0.88 |
| C(31)–H(31b) | 0.81 | C(46)–H(46c) | 1.07 |
| C(31)–H(31c) | 0.82 | C(47)–H(47a) | 1.10 |
| C(32)–H(32a) | 1.03 | C(47)–H(47b) | 0.91 |
| C(32)–H(32b) | 0.96 | O(56)–H(56) | 0.59 |
| | | O(57)–H(57) | 0.67 |

(*d*) Interatomic distances around the silver atom

| | | | |
|---|---|---|---|
| Ag$^+$ · · · O(52) | 2.751 (6) | Ag$^+$ · · · O(56) | 3.006 (7) |
| Ag$^+$ · · · O(53) | 2.483 (5) | Ag$^+$ · · · O(57) | 2.375 (7) |
| Ag$^+$ · · · O(54) | 2.875 (6) | Ag$^+$ · · · O(58) | 2.672 (6) |
| Ag$^+$ · · · O(55) | 2.636 (6) | Ag$^+$ · · · O(59) | 2.461 (6) |

a slight underestimation of errors. The C(1)–O(48) and C(1)–O(49) bond distances (1.212 and 1.221 Å) in the carboxylate group are shorter than expected for single bonds and hence may be inferred to show partial double-bond character. The C–H bond distances range from 0.62 to 1.14 Å, being shorter than the internuclear separations (1.08 Å) obtained spectroscopically.[35]

The bond angles in the side chain are as expected. The mean interbond angle in the six-membered rings is 110.6°, except for the angles at O(51), O(53), O(55), and O(59), which are slightly, but not significantly, greater than the normal tetrahedral angle of 109.4°. The mean

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[35] L. E. Sutton, *Chem. Soc. Special Publ.*, No. 18, 1965.

interbond angle in the five-membered rings is 103.7°, except for the angles at atoms O(52) and O(54). The mean C–O–C bond angles in the six- and five-membered rings are 115.7 and 111.3°. The arrangement of atoms around C(13) and C(21) is tetrahedral, so that the junctions B/C and D/E are of spiro-conformation. The mean of the angles around the spiro-carbon atoms [C(13) and C(21)] are *ca.* 109.3 and 109.2°. However angles C(12)–C(13)–C(14) and C(20)–C(21)–C(22) are significantly larger (mean 117°), than the inter-ring angles. A similar effect is noted in the other compound,[36-41] containing five- and six-membered rings joined at a spiro-carbon atom, and can be attributed to ring strain. Maximum distortion of the bond angles occurs at C(21).

TABLE 5

Equations of planes, and in square brackets, displacements (Å) of the atoms from means planes; *X*, *Y*, *Z* are orthogonal co-ordinates (Å)

Plane (I): C(26), C(27), C(29), O(55)

$$0.248\,7X + 0.966\,8Y - 0.056\,9Z = 11.800\,0$$

[C(25) −0.63, C(26) 0.00, C(27), 0.00, C(28) 0.60, C(29) 0.00, O(55) 0.00]

Plane (II): C(18), C(19), C(21), O(53)

$$0.607\,5X + 0.794\,1Y - 0.015\,2Z = 15.220\,7$$

[C(17) 0.58, C(18) 0.00, C(19) 0.00, C(20) −0.65, C(31) 0.00 O(53) 0.00]

Plane (III): C(9), C(10), C(12), C(13)

$$0.261\,3X - 0.266\,5Y + 0.927\,7Z = 5.609\,6$$

[C(9) 0.00, C(10) 0.00, C(11) 0.62, C(12) 0.00, C(13) 0.00, O(51) −0.60]

Plane (IV): C(34), C(35), C(37), C(38)

$$0.104\,1X + 0.902\,9Y + 0.416\,9Z = 10.154\,4$$

[C(34) 0.00, C(35) 0.00, C(36) −0.64, C(37) 0.00, C(38) 0.00, O(59) 0.64]

Plane (V): C(21), C(23), C(24), O(54)

$$-0.831\,0X + 0.496\,7Y - 0.250\,2Z = -10.309\,9$$

[C(21) −0.02, C(22) −0.55, C(23) 0.02, C(24) −0.04, O(54) 0.04]

Plane (VI): C(13), C(15), C(16), O(52)

$$-0.587\,8X + 0.776\,3Y + 0.227\,2Z = 1.942\,4$$

[C(13) 0.03, C(14) −0.55, C(15) −0.03, C(16) 0.05, O(52) −0.05]

Plane (VII): C(5)—(8)

$$0.267\,8X + 0.900\,0Y + 0.343\,8Z = 14.493\,4$$

[C(5) 0.00, C(6) 0.00, C(7) 0.00, C(8) 0.00, C(9) −0.79, C(32) −0.07, C(33) 1.39, O(50) −0.19]

Plane (VIII): C(4)—(6), O(50)

$$0.143\,6X + 0.962\,8Y + 0.228\,7Z = 13.743\,6$$

[C(4) 0.00, C(5) 0.00, C(6) 0.00, C(7) −0.20, C(32) 0.16, O(50) 0.00]

Plane (IX): C(1), C(2), O(48), O(49)

$$-0.084\,9X + 0.984\,0Y + 0.156\,1Z = 10.414\,9$$

[C(1) 0.01, C(2) 0.00, C(3) 0.37, C(30) −1.27, O(48) 0.00, O(49) 0.00]

The displacements of atoms from some least-squares mean planes and the various torsion angles are listed in Tables 5 and 6. The six-membered rings are in the normal chair form and the five-membered rings have the envelope conformation. The carboxylate group [C(1), C(2), O(48), and O(49)], carbonyl-containing group [C(4)—(6) and O(50)], and ethylene group [C(5)—(8)] are quite planar. The molecule is wrapped around the silver ion and co-ordinated to it by eight oxygen atoms. Moreover, the conformation of the molecule seems to be maintained by two very strong hydrogen bonds[42] (2.604 and 2.673 Å) between the carboxylate oxygen

TABLE 6

Torsion angles (°)

| | |
|---|---|
| O(48)–C(1)–C(2)–C(3) | 166.0 |
| O(48)–C(1)–C(2)–C(30) | −69.0 |
| O(49)–C(1)–C(2)–C(3) | −17.4 |
| O(49)–C(1)–C(2)–C(30) | 107.4 |
| C(1)–C(2)–C(3)–C(4) | −67.8 |
| C(30)–C(2)–C(3)–C(4) | 169.1 |
| C(2)–C(3)–C(4)–C(31) | −71.8 |
| C(2)–C(3)–C(4)–C(5) | 166.1 |
| C(3)–C(4)–C(5)–C(6) | −90.0 |
| C(3)–C(4)–C(5)–O(50) | 90.4 |
| C(31)–C(4)–C(5)–C(6) | 144.1 |
| C(31)–C(4)–C(5)–O(50) | −35.2 |
| C(4)–C(5)–C(6)–C(7) | 10.6 |
| C(4)–C(5)–C(6)–C(32) | −172.6 |
| O(50)–C(5)–C(6)–C(7) | −169.9 |
| O(50)–C(5)–C(6)–C(32) | 6.8 |
| C(5)–C(6)–C(7)–C(8) | 179.3 |
| C(32)–C(6)–C(7)–C(8) | 2.8 |
| C(6)–C(7)–C(8)–C(9) | −145.5 |
| C(6)–C(7)–C(8)–C(33) | 89.1 |
| C(7)–C(8)–C(9)–O(51) | 179.3 |
| C(7)–C(8)–C(9)–C(10) | 58.2 |
| C(33)–C(8)–C(9)–O(51) | −56.4 |
| C(33)–C(8)–C(9)–C(10) | −177.5 |
| C(11)–C(12)–C(13)–C(14) | −172.8 |
| C(11)–C(12)–C(13)–O(52) | 70.5 |
| C(41)–C(12)–C(13)–C(14) | 58.4 |
| C(41)–C(12)–C(13)–O(52) | −58.2 |
| C(9)–O(51)–C(13)–C(14) | −175.6 |
| C(9)–O(51)–C(13)–O(52) | −66.1 |
| C(15)–C(16)–C(17)–C(18) | −49.7 |
| C(15)–C(16)–C(17)–O(53) | −172.4 |
| O(52)–C(16)–C(17)–C(18) | 64.5 |
| O(52)–C(16)–C(17)–O(53) | −58.1 |
| C(42)–C(16)–C(17)–C(18) | −175.4 |
| C(42)–C(16)–C(17)–O(53) | 61.8 |
| C(19)–C(20)–C(21)–C(22) | −70.9 |
| C(19)–C(20)–C(21)–O(54) | 168.4 |
| C(43)–C(20)–C(21)–C(22) | 163.4 |
| C(43)–C(20)–C(21)–O(54) | 42.8 |
| C(17)–O(53)–C(21)–C(22) | 76.2 |
| C(17)–O(53)–C(21)–O(54) | −173.1 |
| C(23)–C(24)–C(25)–C(26) | −69.0 |
| C(23)–C(24)–C(25)–O(55) | 53.2 |
| O(54)–C(24)–C(25)–C(26) | 168.6 |
| O(54)–C(24)–C(25)–O(55) | −69.1 |
| C(28)–C(29)–C(47)–O(57) | −174.7 |
| O(55)–C(29)–C(47)–O(57) | 66.3 |
| O(56)–C(29)–C(47)–O(57) | −48.0 |
| C(10)–C(11)–O(58)–C(34) | 116.1 |
| C(12)–C(11)–O(58)–C(34) | −123.9 |
| C(11)–O(58)–C(34)–C(35) | −70.3 |
| C(11)–O(58)–C(34)–O(59) | 174.5 |
| C(36)–C(37)–O(60)–C(40) | −72.8 |
| C(38)–C(37)–O(60)–C(40) | 167.6 |

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[36] C. E. McEachan, A. T. McPhail, and G. A. Sim, *J. Chem. Soc. (C)*, 1966, 579.

[37] G. W. Smith, *Acta Cryst.*, 1970, **B26**, 1946.

[38] C. Knobler, C. Romers, P. B. Braun, and J. Hornstra, *Acta Cryst.*, 1972, **B28**, 2097.

[39] O. Dideberg and L. Dupont, *Acta Cryst.*, 1972, **B28**, 3014.

[40] M. H. J. Koch, *Acta Cryst.*, 1973, **B29**, 379.

[41] J. M. Franco, S. Martinez-Carrera, and S. Garcia-Blanco, *Acta Cryst.*, 1974, **B30**, 415.

[42] I. D. Brown, *Acta Cryst.*, 1976, **A32**, 24.

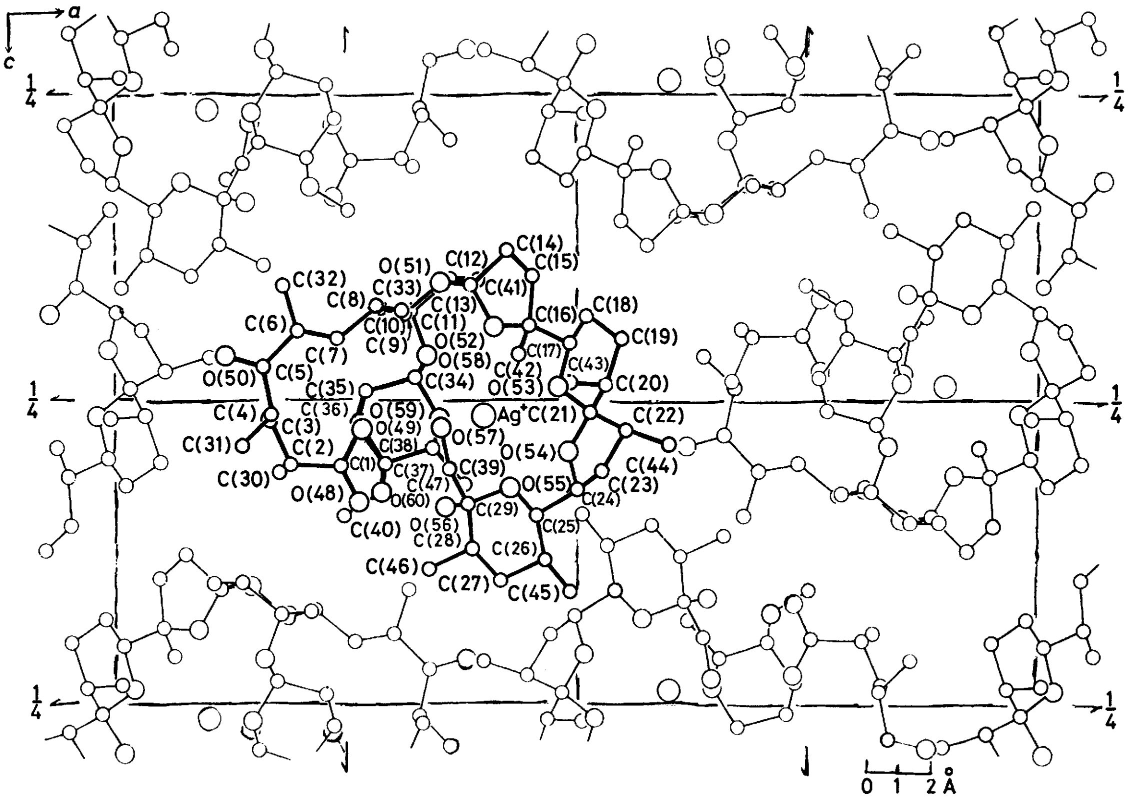

FIGURE 2 Packing of the structure viewed down the *b* axis

atoms and the two alcohol groups of the terminal six-membered ring A. The two oxygen atoms attached to C(34) are both co-ordinated to the silver ion, but the carboxylate oxygens are not among these. The co-ordination of silver does include one oxygen atom O(57) of the alcohol group of ring A. The silver ion is within 3.006 Å of eight oxygen atoms (see Table 4). The Ag · · · O contacts agree with distances reported for the silver salts of other polyether antibiotics: monensin,[2,5] polyetherin A (nigericin),[6] grisorixin,[8] X-537A,[10] X-206,[11] lysocellin,[18,24] RO 21-6150,[21] and emericid.[22]

The molecular packing arrangement along the *b* axis is illustrated in Figure 2. All intermolecular distances were calculated, and the most significant contacts (<3.600 Å) are given in Table 7. The shortest contact is C(22) · · · O($50^{III}$) 3.372 Å, and other intermolecular contacts are greater than the sum of the van der Waals radii. The normal van der Waals separation between a methyl carbon and an oxygen atom is 3.40 Å.[43]

TABLE 7

Intermolecular distances (<3.600 Å)

| | | | |
|---|---|---|---|
| C(22) · · · O($50^{I}$) | 3.372 | C(32) · · · O($56^{II}$) | 3.449 |
| C(23) · · · O($50^{I}$) | 3.465 | C(44) · · · O($50^{I}$) | 3.443 |

The Roman numerals as superscripts refer to the equivalent position relative to the reference molecule at *x*, *y*, *z*:

I $\frac{1}{2} + x, \frac{5}{2} - y, 1 - z$ II $\frac{1}{2} - x, 2 - y, -\frac{1}{2} + z$

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[43] L. Pauling, 'The Nature of the Chemical Bond,' 3rd edn., Cornell University Press, Ithaca, New York, 1960, p. 260.