The Crystal Structure of a 1*H*-1-Benzazonine and its 1-Benzazepinone Precursor

By Fred D. Sancilio* and J. F. Blount

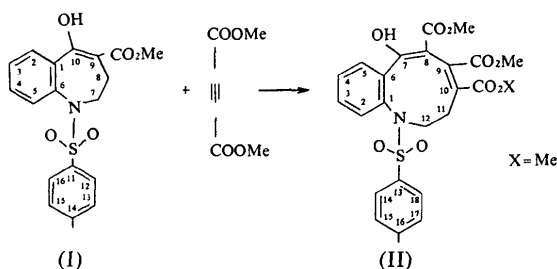*Hoffmann-La Roche Inc., Chemical Research Department, Nutley, New Jersey* 07110, *U.S.A.*

$C_{19}H_{18}NO_5ClS$, monoclinic, $P2_1/n$, $a=10\cdot611$ (10), $b=9\cdot246$ (10), $c=26\cdot674$ (7) Å, $\beta=92\cdot08$ (7)° and $Z=4$. The final R is $0\cdot042$. $C_{26}H_{26}NO_9ClS$ is monoclinic, Pc, $a=7\cdot835$, $b=10\cdot525$ (2), $c=11\cdot571$ (2) Å, $\beta=91\cdot37$ (2)°, $Z=2$ and a final $R=0\cdot068$.

Introduction

Previous investigation into the reaction of cyclic-β-keto esters with dimethyl acetylenedicarboxylate revealed that a ring expansion, rather than a Michael addition, had taken place (Lennon, McLean, McWatt & Proctor, 1974).

X-ray crystal structure analyses were undertaken to confirm the assigned structure of the resulting 1*H*-1-benzazonine (II)† and its precursor (I).

No previous investigations into the stereochemistry of this nine-membered ring system have been reported.

Crystals of both (I) and (II) were obtained by the method of Lennon, McLean, McWatt & Proctor (1974). A suitable crystal of (I) measuring $0\cdot22 \times 0\cdot09 \times 0\cdot06$ mm was mounted on a glass capillary along its *a* axis. The crystal of (II) measuring $0\cdot50 \times 0\cdot13 \times 0\cdot05$ mm was mounted along its *a* axis. Preliminary oscillation and Weissenberg photographs showed both to have monoclinic symmetry.

Cell constants were determined from a least-squares fit of 14 reflections accurately measured with a Hilger–Watts four-circle diffractometer employing Ni-filtered Cu $K\alpha$ radiation ($\lambda=1\cdot5418$ Å). Data were collected on the same instrument using a $\theta–2\theta$ scan method with pulse-height discrimination. The intensity data for (I) and (II) were corrected for Lorentz, polarization and absorption effects.

The molecular structure of (I), the benzazepinone, was solved by normal Patterson and Fourier tech-

niques. The structure of (II) was solved by the multiple solution procedure (Germain, Main & Woolfson, 1970) after initial attempts to solve the structure by the heavy-atom method failed. The phases of 391 reflections with $E \geq 1\cdot60$ were calculated and an E map revealed all but two [C(23) and C(26)] of the non-hydrogen atoms. A Fourier calculation based on these atoms resulted in the location of only one of the missing pair [C(23)].

Both structures were refined by full-matrix least squares minimizing $w(|F_o| - |F_c|)^2$. The weight is given by: $w = 1/(A + |F_o| + B|F_o|^2)$ where: for (I) $A = 3\cdot90$, $B = 0\cdot0097$; for (II) $A = 4\cdot00$, $B = 0\cdot0213$.

A difference synthesis calculated at the end of anisotropic refinement for (I) revealed all hydrogen atoms except one. A similar calculation for (II) showed most of the hydrogens and in addition a peak ($0\cdot7$ e Å^{-3}) situated where C(26) would have been expected had X (see reaction diagram) been an ethyl moiety. A new carbon atom, C(26), was introduced to account for this peak. The atomic multiplier of C(26) was arbitrarily set to $0\cdot2$. The hydrogen atoms were added at their calculated positions. In the final refinement the hydrogen atoms were included in the structure factor calculations, but their parameters were not refined. The final discrepancy indices R_1 and R_2 are $0\cdot042$ and $0\cdot058$ for (I) and $0\cdot068$ and $0\cdot098$ for (II) respectively, where: $R_1 = \sum ||F_o| - |F_c||/\sum |F_o|$ and $R_2 = [\sum w||F_o| - |F_c||^2/w|F_o|^2]^{1/2}$.

The program *MULTAN* (Germain, Main & Woolfson, 1970) was used for the multiple solution problem. Both structures were refined with a locally modified version of *ORFLS* (Busing, Martin & Levy, 1962). *ORFFE* was used for error analysis (Busing, Martin & Levy, 1964). Atomic scattering curves were those of Cromer & Waber (1965). Scattering factors of the hydrogen atoms are those of Stewart, Davidson & Simpson (1965). Anomalous dispersion corrections for the Cl and S atoms were obtained from Cromer (1965). Figs. 1 and 2 show selected bond lengths and angles for (I) and (II) in the crystalline state. Fig. 3 shows a stereoscopic drawing of each of the two compounds. Tables 1 and 2 present the crystal data and a summary of data collection and solution procedures used. Tables

---

Table 1. *Crystal data*

	(I)	(II)
Space group	*Pc*	*P*2$_1$/*n*
a (Å)	7·835 (2)	10·611 (10)
b	10·525 (2)	9·246 (10)
c	11·571 (2)	26·674 (7)
β (°)	91·37 (2)	92·08 (7)
Z	2	4

Table 2. *Data collection and solution*

	(I)	(II)
2*θ* max	152·0	113·8
Number of reflexions	2356	4194
Number of observeds	1886	2275
Solution	Heavy atom	*MULTAN*
Refinement	FMLS	FMLS
Heavier atoms	Anisotropic	Anisotropic
Hydrogens	Fixed	Fixed

Table 3. *Final atomic parameters* ($\times 10^4$, *for* H $\times 10^3$) *for* (I) *with standard deviations in parentheses*

	x	*y*	*z*
Cl	3933 (3)	−26676 (16)	1763 (2)
S	9779	6934 (9)	2548
O(1)	10661 (5)	892 (4)	3649 (3)
O(2)	9799 (5)	−536 (3)	2039 (4)
O(3)	6700 (4)	2742 (3)	−458 (3)
O(4)	7681 (6)	4963 (3)	125 (3)
O(5)	7943 (6)	5435 (3)	2021 (3)
N(1)	7841 (5)	1129 (3)	2691 (3)
C(1)	5911 (5)	1265 (4)	961 (3)
C(2)	4706 (6)	666 (4)	242 (4)
C(3)	4108 (6)	−537 (5)	476 (5)
C(4)	4727 (6)	−1142 (4)	1443 (5)
C(5)	5942 (6)	−597 (4)	2184 (4)
C(6)	6539 (5)	616 (4)	1946 (3)
C(7)	7510 (7)	2302 (4)	3373 (4)
C(8)	6307 (6)	3208 (4)	2731 (4)
C(9)	6778 (6)	3467 (4)	1508 (4)
C(10)	6484 (5)	2555 (4)	680 (3)
C(11)	10716 (5)	1778 (3)	1589 (3)
C(12)	11546 (6)	2856 (4)	2008 (4)
C(13)	12123 (7)	3750 (4)	1260 (4)
C(14)	11900 (6)	3613 (4)	73 (4)
C(15)	11106 (7)	2515 (5)	−334 (4)
C(16)	10507 (6)	1608 (4)	405 (4)
C(17)	12528 (11)	4626 (7)	−740 (6)
C(18)	7486 (7)	4663 (4)	1146 (4)
C(19)	8694 (11)	6639 (5)	1681 (6)

	x	*y*	*z*	*B*
H(2)	432	119	−47	4·0
H(3)	308	−91	−8	4·0
HO(3)	730	363	−50	4·0
H(5)	646	−102	291	4·0
H(7)*A*	872	266	361	4·0
H(7)*B*	703	205	411	4·0
H(8)*A*	618	409	327	4·0
H(8)*B*	510	285	270	4·0
H(12)	1172	292	286	4·0
H(13)	1284	457	161	4·0
H(15)	1089	223	−125	4·0
H(16)	988	82	12	4·0
H(17)*A*	1172	530	−68	4·0
H(17)*B*	1375	476	−97	4·0
H(17)*C*	1207	425	−149	4·0
H(19)*A*	985	662	119	4·0
H(19)*B*	883	701	246	4·0
H(19)*C*	758	719	128	4·0

3, 4, 5 and 6 present final positional and thermal parameters for (I) and (II).*

Results and discussion

The conformation of the seven-membered ring of (I) is similar to that of a previously reported system (Sternbach, Sancilio & Blount, 1974). The enolic C–O bond distance, 1·346 (5) Å, is slightly shorter than the normal C–OH distance of 1·36 Å, yet considerably longer than the normal carbonyl distance of 1·23 Å. The observed torsion angle for C(6)–C(10)–C(11)–C(12) of 81° indicates a lack of conjugation of the

---

* A list of structure factors has been deposited with the British Library Lending Division as Supplementary Publication No. SUP 31608 (19 pp., 1 microfiche). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England.
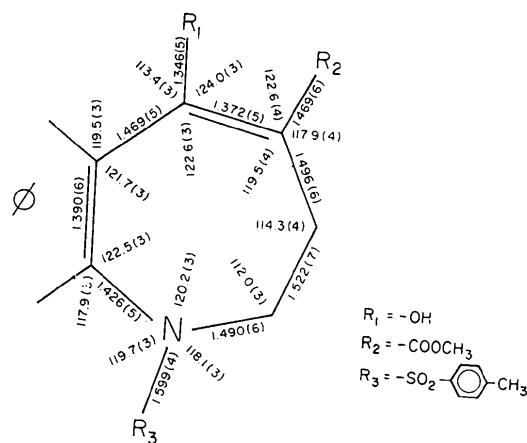

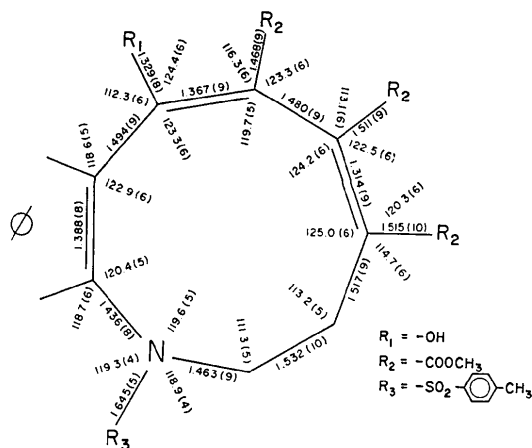Fig. 1. Selected bond distances and angles for (I).

Fig. 2. Selected bond distances and angles for (II).

double bonds within the seven-membered ring. The conformation of the nine-membered ring of (II) is shown in Fig. 3. The double bonds within this ring system are unconjugated much as is found in (I).

The S–N bond distances differ significantly in the two compounds investigated. The S–N bond length is 1·599 (4) Å for (I) and 1·645 (5) Å for (II). The S–N single bond in sulphamic acid is 1·76 Å (Sass, 1960). A recent investigation (Cameron, Prout, Denton, Spagna & White, 1975) reports a wide range of S–N

Table 4. *Final anisotropic thermal parameters for* (I) *with standard deviations in parentheses*

The anisotropic temperature factor has the form $\exp\left[-(h^2 B_{11} + k^2 B_{22} + l^2 B_{33} + 2hk B_{12} + 2hl B_{13} + 2kl B_{23})\right]$.

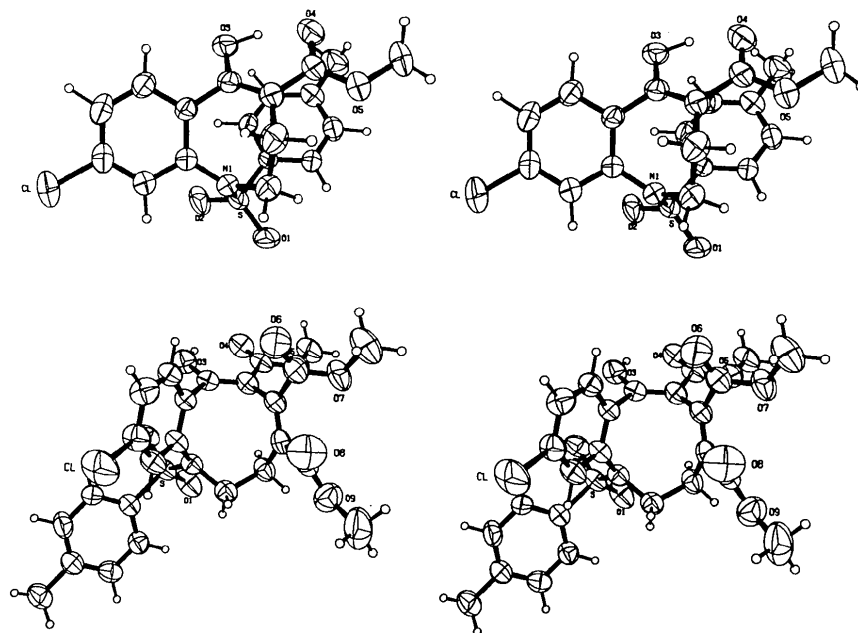|	B_{11} ($\times 10^4$)	B_{22} ($\times 10^5$)	B_{33} ($\times 10^5$)	B_{12} ($\times 10^5$)	B_{13} ($\times 10^5$)	B_{23} ($\times 10^5$)
Cl	351 (4)	1283 (15)	1911 (20)	1193 (21)	−386 (21)	214 (14)
S	180 (2)	722 (8)	931 (7)	−137 (9)	−372 (8)	247 (6)
O(1)	252 (7)	1506 (40)	1040 (28)	−499 (44)	−813 (36)	568 (29)
O(2)	221 (7)	603 (24)	1754 (42)	31 (32)	−277 (42)	150 (25)
O(3)	260 (7)	971 (29)	639 (19)	3 (34)	−183 (27)	83 (19)
O(4)	373 (10)	895 (30)	930 (26)	−81 (44)	−128 (41)	170 (23)
O(5)	327 (9)	766 (27)	1084 (31)	−107 (38)	−373 (39)	−40 (23)
N(1)	185 (6)	865 (30)	620 (20)	−251 (33)	−194 (26)	77 (20)
C(1)	155 (6)	796 (33)	625 (24)	−8 (35)	−58 (29)	−48 (22)
C(2)	166 (7)	966 (43)	841 (31)	−16 (39)	−215 (38)	−90 (27)
C(3)	170 (8)	1147 (50)	1180 (44)	−173 (47)	−269 (45)	−241 (36)
C(4)	175 (8)	984 (41)	1148 (41)	−323 (47)	−18 (45)	−88 (34)
C(5)	190 (7)	944 (40)	782 (30)	−298 (41)	−90 (37)	86 (26)
C(6)	153 (6)	795 (33)	653 (24)	−101 (34)	−15 (30)	10 (22)
C(7)	240 (9)	1042 (41)	643 (26)	−207 (50)	−30 (38)	−94 (27)
C(8)	213 (8)	1055 (42)	768 (30)	81 (47)	106 (38)	−238 (30)
C(9)	193 (7)	727 (31)	755 (26)	85 (39)	−64 (34)	−39 (25)
C(10)	174 (7)	753 (33)	630 (26)	131 (36)	−76 (31)	5 (22)
C(11)	149 (6)	661 (28)	743 (25)	36 (33)	−179 (29)	6 (22)
C(12)	211 (8)	862 (36)	729 (27)	−296 (44)	−83 (36)	−38 (27)
C(13)	238 (9)	809 (35)	886 (34)	−264 (46)	72 (42)	−45 (28)
C(14)	218 (8)	920 (41)	942 (35)	89 (47)	246 (43)	113 (31)
C(15)	219 (9)	1193 (49)	735 (31)	52 (51)	21 (40)	−14 (31)
C(16)	183 (7)	856 (36)	819 (30)	−4 (39)	−214 (36)	−168 (26)
C(17)	411 (19)	1389 (64)	1230 (56)	−329 (91)	439 (81)	308 (49)
C(18)	247 (9)	669 (33)	953 (37)	156 (46)	−201 (45)	−15 (27)
C(19)	438 (19)	722 (40)	1542 (64)	−544 (72)	−391 (82)	−62 (43)

Fig. 3. *ORTEP* stereoscopic drawings of (I) (top) and (II) (below).

bond distances, 1·55–1·64 Å, in various *p*-tolylsulphonylamino-containing compounds. They attribute

Table 5. *Final atomic parameters* ($\times 10^4$, *for* H $\times 10^3$) *for* (II) *with standard deviations in parentheses*
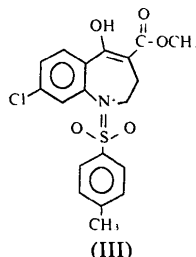
	x	*y*	*z*
Cl	−37 (3)	8120 (2)	1868 (1)
S	42 (2)	1851 (2)	2427 (1)
O(1)	769 (6)	620 (5)	2595 (2)
O(2)	−1139 (5)	1676 (5)	2178 (2)
O(3)	−1181 (5)	1516 (5)	1012 (2)
O(4)	−183 (5)	−625 (5)	591 (2)
O(5)	1897 (5)	−533 (5)	470 (2)
O(6)	1569 (5)	3678 (7)	126 (2)
O(7)	3505 (5)	2752 (6)	161 (2)
O(8)	3947 (6)	4706 (7)	968 (2)
O(9)	5057 (5)	3190 (6)	1454 (2)
N(1)	950 (5)	2737 (5)	2046 (2)
C(1)	415 (6)	3872 (7)	1739 (2)
C(2)	418 (7)	5270 (7)	1926 (2)
C(3)	−58 (7)	6370 (7)	1626 (3)
C(4)	−531 (7)	6127 (7)	1147 (3)
C(5)	−512 (6)	4716 (7)	967 (2)
C(6)	−31 (6)	3584 (6)	1253 (2)
C(7)	−37 (6)	2102 (6)	1031 (2)
C(8)	1017 (7)	1447 (7)	858 (2)
C(9)	2208 (6)	2272 (7)	836 (2)
C(10)	2992 (6)	2478 (7)	1223 (2)
C(11)	2917 (7)	1719 (7)	1725 (2)
C(12)	2319 (7)	2651 (7)	2127 (2)
C(13)	−188 (6)	2944 (7)	2962 (2)
C(14)	670 (7)	2916 (8)	3354 (3)
C(15)	462 (7)	3718 (8)	3781 (2)
C(16)	−605 (7)	4566 (8)	3812 (3)
C(17)	−1437 (7)	4607 (9)	3415 (3)
C(18)	−1247 (7)	3794 (9)	2985 (2)
C(19)	−837 (8)	5389 (9)	4286 (3)
C(20)	837 (8)	13 (7)	631 (2)
C(21)	1782 (9)	−2034 (8)	268 (3)
C(22)	2375 (8)	3002 (8)	336 (3)
C(23)	3779 (10)	3545 (10)	−290 (3)
C(24)	4047 (7)	3575 (9)	1193 (3)
C(25)	6158 (9)	4161 (12)	1475 (4)
C(26)*	7199	3503	1787

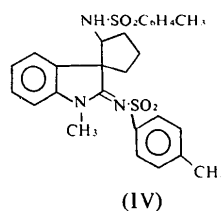|	*x*	*y*	*z*	*B*
H(2)	78	548	228	6·0
HO(3)	−130	60	89	7·0
H(4)	−88	694	93	6·0
H(5)	−88	450	62	6·0
H(11)*A*	379	142	184	6·0
H(11)*B*	239	81	168	6·0
H(12)*A*	254	226	247	6·0
H(12)*B*	269	367	211	6·0
H(14)	147	233	333	6·0
H(15)	110	368	407	6·0
H(17)	−221	523	343	6·0
H(18)	−188	383	269	6·0
H(19)*A*	−134	478	452	7·5
H(19)*B*	−135	629	421	7·5
H(19)*C*	−3	568	446	7·5
H(21)*A*	262	−240	16	7·5
H(21)*B*	116	−208	−2	7·5
H(21)*C*	149	−271	54	7·5
H(23)*A*	464	332	−40	9·0
H(23)*B*	371	462	−23	9·0
H(23)*C*	314	328	−57	9·0
H(25)*A*	685	372	168	9·0
H(25)*B*	592	512	161	9·0
H(25)*C*	645	430	112	9·0

* $B = 9·0$ Å^2.

the variances to a charge separation across the S–N bond, indicating that as this separation is increased by intervening atoms, the S–N bond distance rapidly decreases.

(III) represents a possible valence bond state for (I) in which there is a charge separation between atoms in close proximity.

(III)

An identical diagram can be constructed for structure (II). The charge separation in both (I) and (II) indicates a similar environment about each of the two nitrogen atoms, yet the N–S bond in (I) is considerably shorter than found in (II). Therefore, the contribution of the valence bond state, (III), to structure (I) appears greater than the contribution of the equivalent valence bond state of (II) to its crystalline structure.

The torsion angles about the N–C(phenyl) bonds are 78° in (I) and 90° in (II). Therefore, there is little conjugation of the N–S bond with the aromatic ring. Tickle & Prout (1975) reported an N–S bond distance of 1·55 Å (at the imino site) in (IV) and attributed this short distance to π electron delocalization from the indole ring system.

(IV)

The torsion angle about the N=C bond in (IV) is 9°, well in line with what would be expected for such a conjugated system, and far smaller than the angles found in (I) or (II).

In summary, while both N–S bond distances in (I) and (II) are considerably shorter than the formal single bond distance of 1·76 Å (Sass, 1960), and both N–S moieties are in similar locales, the valence bond structure of (I) seems to predominate to a greater degree than that of (II), suggesting that the S–N bond length in *p*-tolylsulphonylamino compounds may be affected by factors other than the simple conjugation of the nitrogen atom with an aromatic system as has been previously suggested.

Table 6. *Final anisotropic thermal parameters for* (II) *with standard deviations in parentheses*

The anisotropic temperature factor has the form $\exp\left[-(h^2B_{11}+k^2B_{22}+l^2B_{33}+2hkB_{12}+2hlB_{13}+2klB_{23})\right]$.

	B_{11} ($\times 10^4$)	B_{22} ($\times 10^4$)	B_{33} ($\times 10^5$)	B_{12} ($\times 10^4$)	B_{13} ($\times 10^4$)	B_{23} ($\times 10^4$)
Cl	257 (4)	90 (3)	290 (5)	18 (2)	−6 (1)	−14 (1)
S	149 (2)	91 (2)	132 (3)	−16 (2)	8 (1)	−1 (1)
O(1)	237 (8)	85 (6)	196 (9)	21 (6)	13 (2)	5 (2)
O(2)	155 (7)	170 (8)	174 (8)	−61 (6)	8 (2)	−8 (2)
O(3)	126 (6)	129 (7)	210 (9)	−28 (5)	4 (2)	−12 (2)
O(4)	166 (7)	107 (7)	205 (9)	−27 (6)	4 (2)	−6 (2)
O(5)	141 (6)	131 (7)	207 (9)	17 (5)	0 (2)	−15 (2)
O(6)	170 (8)	267 (11)	225 (11)	48 (8)	8 (2)	33 (3)
O(7)	148 (6)	185 (8)	164 (8)	15 (6)	21 (2)	12 (2)
O(8)	221 (9)	184 (10)	286 (13)	−75 (8)	1 (3)	21 (3)
O(9)	118 (6)	183 (9)	274 (11)	−14 (6)	1 (2)	−8 (3)
N(1)	110 (6)	100 (7)	118 (8)	2 (5)	2 (2)	3 (2)
C(1)	119 (8)	90 (8)	117 (10)	−11 (6)	7 (2)	0 (2)
C(2)	141 (9)	101 (9)	147 (11)	−9 (7)	3 (2)	−4 (3)
C(3)	144 (9)	77 (9)	194 (13)	10 (7)	−1 (3)	−4 (3)
C(4)	132 (9)	98 (10)	209 (14)	6 (7)	−5 (3)	5 (3)
C(5)	112 (8)	125 (10)	138 (10)	−3 (7)	2 (2)	1 (3)
C(6)	96 (7)	91 (8)	124 (10)	−6 (6)	4 (2)	0 (2)
C(7)	102 (8)	83 (8)	130 (10)	−22 (7)	1 (2)	1 (2)
C(8)	126 (8)	85 (8)	145 (10)	−4 (7)	5 (2)	−3 (2)
C(9)	112 (7)	94 (8)	132 (11)	0 (7)	6 (2)	−2 (2)
C(10)	101 (7)	83 (8)	160 (11)	11 (6)	11 (2)	0 (3)
C(11)	123 (8)	123 (10)	148 (11)	27 (7)	6 (2)	0 (3)
C(12)	117 (8)	124 (9)	134 (11)	16 (7)	0 (2)	2 (3)
C(13)	111 (8)	98 (9)	129 (10)	−9 (7)	7 (2)	4 (2)
C(14)	114 (8)	137 (10)	149 (12)	15 (7)	5 (3)	1 (3)
C(15)	133 (9)	168 (11)	126 (11)	−12 (9)	0 (3)	2 (3)
C(16)	127 (9)	124 (10)	135 (11)	−8 (8)	7 (3)	1 (3)
C(17)	132 (9)	181 (12)	169 (13)	41 (9)	13 (3)	−4 (3)
C(18)	108 (8)	197 (13)	127 (11)	26 (8)	−2 (2)	−2 (3)
C(19)	156 (10)	201 (13)	153 (12)	5 (10)	12 (3)	−9 (3)
C(20)	144 (9)	109 (10)	112 (10)	0 (8)	2 (2)	−3 (3)
C(21)	222 (13)	110 (10)	213 (15)	28 (9)	6 (3)	−21 (3)
C(22)	127 (9)	124 (10)	151 (12)	−5 (8)	7 (3)	3 (3)
C(23)	219 (13)	228 (16)	184 (14)	−16 (12)	28 (3)	18 (4)
C(24)	123 (9)	148 (12)	149 (12)	−9 (8)	10 (3)	−10 (3)
C(25)	160 (12)	237 (17)	455 (28)	−54 (12)	37 (5)	−37 (6)

References

BUSING, W. R., MARTIN, K. O. & LEVY, H. A. (1962). Oak Ridge National Laboratory Report ORNL-TM-305.

BUSING, W. R., MARTIN, K. O. & LEVY, H. A. (1964). Oak Ridge National Laboratory Report ORNL-TM-306.

CAMERON, T. S., PROUT, K., DENTON, B., SPAGNA, R. & WHITE, E. (1975). *J. Chem. Soc. Perkin* II, pp. 176–185.

CROMER, D. T. (1965). *Acta Cryst.* 18, 17–23.

CROMER, D. T. & WABER, J. T. (1965). *Acta Cryst.* 18, 104–109.

GERMAIN, G., MAIN, P. & WOOLFSON, M. M. (1970). *Acta Cryst.* B26, 274–285.

LENNON, M., McLEAN, A., McWATT, I. & PROCTOR, G. (1974). *J. Chem. Soc. Perkin* I, pp. 1828–1833.

SASS, R. L. (1960). *Acta Cryst.* 13, 320–324.

STERNBACH, L. H., SANCILIO, F. D. & BLOUNT, J. F. (1974). *J. Med. Chem.* 17, 374–377.

STEWART, R. F., DAVIDSON, E. R. & SIMPSON, W. T. (1965). *J. Chem. Phys.* 42, 3175–3187.

TICKLE, I. J. & PROUT, C. K. (1975). *J. Chem. Soc.* (*C*), pp. 3401–3405.