Structure and Absolute Configuration of Vibsanine E isolated from Leaves of *Viburnum odoratissimum* Ker

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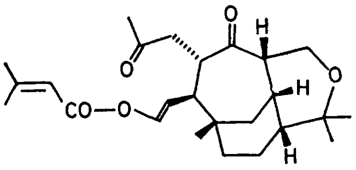
X-Ray analysis has established the structure and absolute configuration of vibsanine E, $C_{25}H_{36}O_5$, isolated from leaves of *Viburnum odoratissimum*. It is a ββ-dimethylacrylic acid ester of a novel diterpene. The junction of the two six-membered rings, both of which have the chair conformation, is *cis*. The seven-membered ring also takes the chair form. Crystals are monoclinic, space group $P2_1$, with a = 10.907, b = 8.941, c = 12.829 Å, β = 107.63°, Z = 2. The structure was solved by the vector-search method and refined by the least-squares method to R 0.043 for 2 171 independent reflections. The absolute configuration was determined by the Bijvoet method by utilizing the anomalous scattering of light atoms for Cu-K_α radiation.

VIBSANINE E (1), $C_{25}H_{36}O_5$, m.p. 147—148 °C, $[\alpha]_D^{25}$ −59° (CCl_4), was isolated as a compound related to a new plant growth inhibitor, vibsanine B, in 4.7×10^{-5}% yield from the leaves of *Viburnum odoratissimum* (Caprifoliaceae).[1] Its structure was tentatively elucidated on the basis of chemical and spectral evidence.[1] To establish this novel skeleton and the stereochemistry, an *X*-ray analysis of compound (1) was carried out.



(1)

EXPERIMENTAL

Spectral Data.—Compound (1) had m.p. 147—148 °C (from methanol) (Found: C, 72.3; H, 8.7. $C_{25}H_{36}O_5$ requires C, 72.1; H, 8.7%), $[\alpha]_D^{25}$ −59° (*c* 2.1, CCl_4), *m/e* 416.2545 (M^+, calc. for $C_{25}H_{36}O_5$: *M*, 416.2562), 316, 149, and 83, $\lambda_{max.}$ (EtOH) 230 nm (ε 2.0×10^4), $\nu_{max.}$ (CCl_4) no O–H absorption, 1 730, 1 213 (–CO–O–), 1 709 (C=O), 1 644 (C=C), 950 (*trans*-C=C), and 846 cm^{-1} (–CH=C<), δ (60 MHz; $CDCl_3$) 0.84 (3 H, s, CH_3–C$\lessgtr$), 1.07 and 1.23 [3 H each, s, $(CH_3)_2C$–O–], 1.91br and 2.18br [3 H each, s, $(CH_3)_2C$=CH–], 2.04 (3 H, s, CH_3C=O), 3.55 (1 H, dd, *J* 12 and 3 Hz), and 4.15 (1 H, d, *J* 12 Hz), (–O–CH_2–CH<), 5.13 (1 H, dd, *J* 12.5 and 12 Hz, –CH–C*H*=CH–O–CO–), 5.17br (1 H, s, $(CH_3)_2C$=C*H*–), and 7.00 (1 H, d, *J* 12.5 Hz, –CH=C*H*–O–CO–).

Crystal Data.—$C_{25}H_{36}O_5$, $M = 416.6$. Monoclinic, a = 10.907(3), b = 8.941(3), c = 12.829(4) Å, β = 107.63(5)°, U = 1 192.3 Å^3, Z = 2, D_o = 1.16 g cm^{-3}, D_x = 1.16 g cm^{-3}. Cu-K_α radiation, λ = 1.5418 Å. Space group $P2_1$.

Crystallographic Measurements.—Preliminary photographic investigation showed the crystal system to be monoclinic with space group $P2_1$. The unit cell constants and intensities were measured on a Rigaku Denki computer-controlled four-circle diffractometer with Ni-filtered Cu-K_α radiation. The θ–2θ scan method was used with scan speed of 4° min^{-1} in 2θ. The scan range was calculated for each reflection by the formula $\Delta\theta = 1.1° + 0.15 \tan\theta$, where θ is the Bragg angle. The backgrounds were counted for 8 s at the start and end points of the scan range. Attenuators were automatically inserted to keep the maximum counting rate below 10^4 c.p.s. The intensities of standard reflections, measured every 50 reflections, showed no significant variation through the data collection. The intensities of 2 175 independent reflections were measured within the range $\sin\theta/\lambda < 0.59$, and corrected for the Lorentz and polarization factors.

Structure Determination and Refinement.—Our attempt to solve the structure by MULTAN [2] was unsuccessful. Since a structure-model could only be partially constructed on the basis of the structural formula suggested by chemical study, the vector-search method was applied to solve the structure.[3] The skeleton chosen as the rigid group consisted of two six-membered rings containing the C(1)—C(9) and O(1) atoms, whose conformation was assumed to take a chair form. The orientational search followed by a translational one were carried out using the program RICS [4] for each ring-junction, *trans* [5] and *cis*.[6] A three-dimensional Fourier synthesis phased by the skeleton of *cis*-junction revealed the remaining non-hydrogen atoms.

The co-ordinates and isotropic temperature factors of the non-hydrogen atoms were refined by the block-diagonal least-squares method [7] with the carbon scattering factor. Types of atoms and bonds were assigned on the basis of the temperature factors and bond lengths and angles, and determined unambiguously by subsequent refinement. The hydrogen atoms were located on a difference Fourier synthesis computed after anisotropic refinement for non-hydrogen atoms. The four strongest reflections, 020, 110, 120, and 011, were omitted from the subsequent calculations. The final refinement, including hydrogen atoms with isotropic temperature factors,† was carried out using the following weighting scheme; $w = 0.5$ for $F_o = 0$, $w = [\sigma^2(F_o) + 0.002F_o^2]^{-1}$ for $F_o > 0$, where $\sigma(F_o)$ was calculated from counting statistics. The final R value was 0.043 for 2 171 independent reflections (R 0.037 without zero reflections). The final atomic co-ordinates are given in Table 1. Observed and calculated structure factors and atom thermal parameters are listed in Supplementary Publication No. SUP 22867 (11 pp.).‡

Absolute Configuration.—The absolute configuration of

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† The hydrogen atoms of the 15-methyl group occupy two kinds of sites, and the minor sites of the hydrogen atoms were not included in the refinement.

‡ See Notice to Authors No. 7 in *J.C.S. Perkin II*, 1979, Index Issue.

TABLE 1

Final atomic co-ordinates with estimated standard deviations in parentheses

	x	y	z
C(1)	0.253 9(2)	0.041 1(3)	0.237 2(2)
C(2)	0.377 9(2)	0.119 2(4)	0.307 1(2)
C(3)	0.336 1(3)	0.243 2(5)	0.371 5(2)
C(4)	0.236 5(3)	0.351 0(4)	0.299 6(2)
C(5)	0.114 9(2)	0.267 2(3)	0.235 1(2)
C(6)	0.006 9(2)	0.368 0(3)	0.165 3(2)
C(7)	0.060 3(2)	0.305 4(4)	0.001 3(2)
C(8)	0.168 1(2)	0.197 5(3)	0.058 6(2)
C(9)	0.147 5(2)	0.140 8(3)	0.166 2(2)
C(10)	0.453 0(3)	−0.000 3(5)	0.387 2(3)
C(11)	0.300 0(2)	0.255 3(3)	0.063 7(2)
C(12)	0.417 2(2)	0.156 5(3)	0.115 9(2)
C(13)	0.520 1(2)	0.183 9(3)	0.059 9(2)
C(14)	0.475 0(2)	0.142 7(3)	−0.059 5(2)
C(15)	0.559 8(3)	0.185 1(5)	−0.126 8(3)
C(16)	0.462 8(2)	0.194 8(3)	0.240 3(2)
C(17)	0.603 9(2)	0.161 6(3)	0.292 2(2)
C(18)	0.683 5(2)	0.262 6(4)	0.349 4(2)
C(19)	0.880 2(2)	0.304 6(4)	0.487 1(2)
C(20)	1.012 9(3)	0.251 7(4)	0.522 7(2)
C(21)	1.102 2(2)	0.291 4(4)	0.616 0(2)
C(22)	1.234 1(3)	0.226 8(5)	0.642 4(3)
C(23)	1.080 6(3)	0.397 5(4)	0.698 2(2)
C(24)	−0.122 0(3)	0.284 9(5)	0.129 3(3)
C(25)	−0.010 1(3)	0.509 4(4)	0.224 4(3)
O(1)	0.041 7(2)	0.419 9(2)	0.071 4(1)
O(2)	0.314 5(2)	0.373 7(3)	0.023 2(2)
O(3)	0.376 0(2)	0.074 4(3)	−0.099 4(2)
O(4)	0.812 6(2)	0.225 4(3)	0.396 6(2)
O(5)	0.831 6(2)	0.401 0(3)	0.525 3(2)
H(C1a)	0.274(3)	−0.042(4)	0.192(3)
H(C1b)	0.216(3)	−0.015(4)	0.292(3)
H(C3a)	0.415(3)	0.304(5)	0.414(3)
H(C3b)	0.292(3)	0.192(4)	0.426(3)
H(C4a)	0.212(3)	0.433(5)	0.348(3)
H(C4b)	0.274(3)	0.407(5)	0.246(3)
H(C5)	0.080(3)	0.216(4)	0.295(3)
H(C7a)	−0.024(3)	0.248(5)	−0.029(3)
H(C7b)	0.084(3)	0.357(4)	−0.059(3)
H(C8)	0.162(3)	0.108(4)	0.010(3)
H(C9)	0.070(3)	0.075(4)	0.137(3)
H(10a)	0.485(4)	−0.082(5)	0.349(3)
H(C10b)	0.526(3)	0.051(5)	0.442(3)
H(C10c)	0.399(4)	−0.045(6)	0.432(4)
H(C12)	0.394(3)	0.044(4)	0.107(2)
H(C13a)	0.550(3)	0.299(5)	0.065(3)
H(C13b)	0.605(3)	0.126(4)	0.099(3)
H(C15a)	0.524(4)	0.194(5)	−0.200(3)
H(C15b)	0.598(4)	0.276(7)	−0.102(4)
H(C15c)	0.629(4)	0.110(7)	−0.115(4)
H(C16)	0.454(3)	0.310(4)	0.246(2)
H(C17)	0.632(3)	0.051(4)	0.284(3)
H(C18)	0.656(3)	0.370(5)	0.375(3)
H(C20)	1.032(3)	0.174(4)	0.473(3)
H(C22a)	1.241(3)	0.153(5)	0.586(3)
H(C22b)	1.300(4)	0.302(6)	0.644(4)
H(C22c)	1.267(3)	0.172(5)	0.719(3)
H(C23a)	1.088(4)	0.504(5)	0.670(3)
H(C23b)	1.137(3)	0.379(5)	0.764(3)
H(C23c)	1.001(4)	0.378(6)	0.709(4)
H(C24a)	−0.118(3)	0.180(5)	0.094(3)
H(C24b)	−0.191(3)	0.341(5)	0.074(3)
H(C24c)	−0.148(4)	0.262(5)	0.199(3)
H(C25a)	0.071(3)	0.576(5)	0.246(3)
H(C25b)	−0.030(4)	0.484(5)	0.290(3)
H(C25c)	−0.086(3)	0.571(5)	0.181(3)

TABLE 2

Bond lengths and angles with estimated standard deviations in parentheses

(*a*) Bond lengths (Å)

C(1)–C(2)	1.545(4)	C(1)–C(9)	1.526(4)
C(2)–C(3)	1.532(5)	C(2)–C(10)	1.535(5)
C(2)–C(16)	1.590(4)	C(3)–C(4)	1.534(5)
C(4)–C(5)	1.529(4)	C(5)–C(6)	1.537(4)
C(5)–C(9)	1.541(4)	C(6)–C(24)	1.533(5)
C(6)–C(25)	1.514(5)	C(6)–O(1)	1.444(4)
C(7)–C(8)	1.526(4)	C(7)–O(1)	1.417(4)
C(8)–C(9)	1.549(4)	C(8)–C(11)	1.511(4)
C(11)–C(12)	1.531(4)	C(11)–O(2)	1.211(3)
C(12)–C(13)	1.525(4)	C(12)–C(16)	1.559(4)
C(13)–C(14)	1.505(4)	C(14)–C(15)	1.493(5)
C(14)–O(3)	1.210(4)	C(16)–C(17)	1.510(4)
C(17)–C(18)	1.312(5)	C(18)–O(4)	1.394(4)
C(19)–C(20)	1.458(5)	C(19)–O(4)	1.370(4)
C(19)–O(5)	1.192(4)	C(20)–C(21)	1.342(5)
C(21)–C(22)	1.491(5)	C(21)–C(23)	1.489(5)

(*b*) Bond angles (°)

C(2)–C(1)–C(9)	117.1(2)	C(1)–C(2)–C(3)	106.8(3)
C(1)–C(2)–C(10)	105.7(3)	C(1)–C(2)–C(16)	115.4(2)
C(3)–C(2)–C(10)	109.2(3)	C(3)–C(2)–C(16)	107.4(3)
C(10)–C(2)–C(16)	112.1(3)	C(2)–C(3)–C(4)	113.8(3)
C(3)–C(4)–C(5)	110.9(3)	C(4)–C(5)–C(6)	114.4(2)
C(4)–C(5)–C(9)	110.9(2)	C(6)–C(5)–C(9)	111.4(2)
C(5)–C(6)–C(24)	111.3(3)	C(5)–C(6)–C(25)	112.7(3)
C(5)–C(6)–O(1)	109.0(2)	C(24)–C(6)–C(25)	108.4(3)
C(24)–C(6)–O(1)	110.7(3)	C(25)–C(6)–O(1)	104.6(3)
C(8)–C(7)–O(1)	112.9(2)	C(7)–C(8)–C(9)	109.7(2)
C(7)–C(8)–C(11)	112.9(2)	C(9)–C(8)–C(11)	117.8(2)
C(1)–C(9)–C(5)	110.6(2)	C(1)–C(9)–C(8)	115.7(2)
C(5)–C(9)–C(8)	113.1(2)	C(8)–C(11)–C(12)	118.7(2)
C(8)–C(11)–O(2)	121.8(2)	C(12)–C(11)–O(2)	119.5(2)
C(11)–C(12)–C(13)	109.8(2)	C(11)–C(12)–C(16)	106.6(2)
C(13)–C(12)–C(16)	113.3(2)	C(12)–C(13)–C(14)	112.3(2)
C(13)–C(14)–C(15)	117.2(3)	C(13)–C(14)–O(3)	121.9(3)
C(15)–C(14)–O(3)	120.8(3)	C(2)–C(16)–C(12)	113.7(2)
C(2)–C(16)–C(17)	111.2(2)	C(12)–C(16)–C(17)	112.0(2)
C(16)–C(17)–C(18)	121.6(3)	C(17)–C(18)–O(4)	119.2(3)
C(20)–C(19)–O(4)	109.1(3)	C(20)–C(19)–O(5)	129.0(3)
O(4)–C(19)–O(5)	122.0(3)	C(19)–C(20)–C(21)	125.2(3)
C(20)–C(21)–C(22)	119.3(3)	C(20)–C(21)–C(23)	124.0(3)
C(22)–C(21)–C(23)	115.8(3)	C(6)–O(1)–C(7)	114.9(2)
C(18)–O(4)–C(19)	117.3(3)		

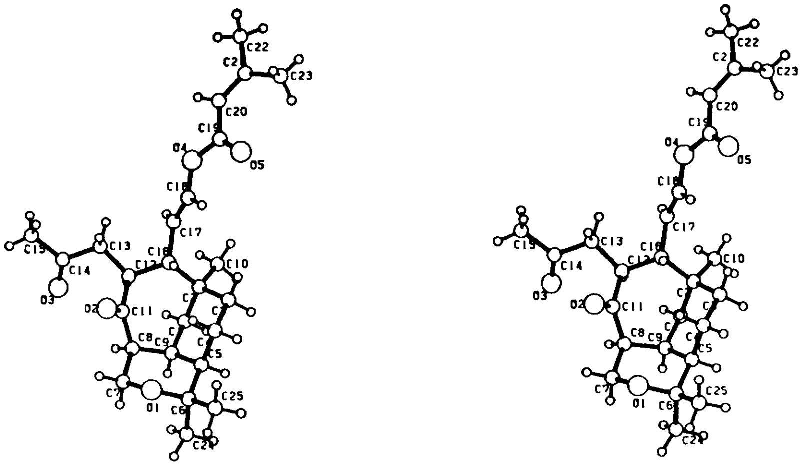
the molecule was determined by the Bijvoet method by utilizing the anomalous scattering of light-atoms for Cu-K_α radiation.[8,9] The sets of Bijvoet and reference reflections were chosen manually. A crystal cut to 0.3 × 0.4 × 0.5 mm was mounted with its *b* axis parallel to the ϕ axis of a four-circle diffractometer. The intensities of Bijvoet pair and its reference pair were measured alternately at least ten times, where θ–2θ scan technique was used with a scan speed of 2° min^{-1} in 2θ, and backgrounds were counted for 20 s at both sides of the scan range. The results are given in SUP 22867, and clearly indicates the correct enantiomer. The absolute configuration of the molecule is correctly represented by the atomic co-ordinates in Table 1 referred to a right-handed co-ordinate system.

Atomic scattering factors were taken from ref. 10. Computations were carried out on a TOSBAC–3400 computer at the Tottori University Computing Center, and on a ACOS–900 computer at the Computation Center of Osaka University.

RESULTS AND DISCUSSION

The *X*-ray analysis established the structure and absolute configuration of vibsanine E (1), a ββ-dimethylacrylic acid ester of a novel diterpene. The molecular structure, drawn by our version of PLUTO,[11] is shown in the Figure together with numbering scheme used in this paper. Bond lengths and angles are given in Table 2, and selected torsion angles in Table 3.

Both the six-membered rings have the chair form with torsion angles in the rings in the range 46.4—60.6°. The junction of the rings is *cis*. The seven-membered ring



Stereoscopic view of the molecule with the numbering of atoms. The correct absolute configuration is portrayed

also takes the chair form; C(1), C(9), C(11), and C(12) lie on a plane with a root mean square deviation of 0.03 Å, and C(2) and C(16) deviate to one side of the plane by 1.24 and 1.27 Å, respectively, and C(8) by 0.53 Å to the other. Although the ring has an sp^2 carbon, the conformation is a chair as for cycloheptane, where the chair form is the most stable conformation.[12] The methyl and $C_7H_9O_2$ groups occupy equatorial positions of the ring resulting that the torsion angle of C(10)–C(2)–C(16)–C(17) is small. The fact that the bond length C(2)–C(16) is longer than the standard value may reflect repulsion of the side groups. There is no abnormally short intermolecular distance in the crystal.

TABLE 3

Selected torsion angles (°)

C(9)–C(1)–C(2)–C(3)	51.6	O(1)–C(6)–C(5)–C(9)	−53.3
C(1)–C(2)–C(3)–C(4)	−53.8	C(1)–C(2)–C(16)–C(12)	−8.8
C(2)–C(3)–C(4)–C(5)	59.0	C(2)–C(16)–C(12)–C(11)	78.2
C(3)–C(4)–C(5)–C(9)	−56.0	C(16)–C(12)–C(11)–C(8)	−89.1
C(4)–C(5)–C(9)–C(1)	51.9	C(12)–C(11)–C(8)–C(9)	52.3
C(5)–C(9)–C(1)–C(2)	−52.1	C(11)–C(8)–C(9)–C(1)	−44.4
C(6)–C(5)–C(9)–C(8)	49.0	C(8)–C(9)–C(1)–C(2)	78.1
C(5)–C(9)–C(8)–C(7)	−46.4	C(9)–C(1)–C(2)–C(16)	−67.8
C(9)–C(8)–C(7)–O(1)	50.9	C(17)–C(16)–C(12)–C(13)	−34.0
C(8)–C(7)–O(1)–C(6)	−60.6	C(13)–C(12)–C(11)–O(2)	−28.6
C(7)–O(1)–C(6)–C(5)	60.4	C(10)–C(2)–C(16)–C(17)	−15.1

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