Crystal and Molecular Structure of Alnuserol, a New 11-Hydroxylated C_{31} Dammarane-type Triterpene from *Alnus serrulatoides* [1]

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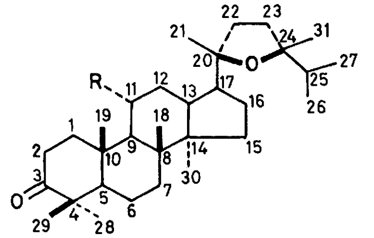
The molecular structure and absolute configuration of alnuserol, (1), a novel 11-hydroxylated C_{31} dammarane-type triterpene from *Alnus serrulatoides* Call., were determined to be (11*R*,20*S*,24*R*)-20,24-epoxy-11-hydroxy-24-methyldammaran-3-one (1) by a combination of spectroscopic and *X*-ray crystallographic methods. Crystals are orthorhombic, space group $P2_12_12_1$, $a = 6.599(2)$, $b = 14.921(3)$, $c = 28.443(8)$ Å, $Z = 4$. The structure was determined from diffractometer data by direct methods and refined by full-matrix least-squares techniques to *R* 0.054 for 2 064 reflections.

In contrast to many examples of 11-hydroxylated steroids in animals and micro-organisms,[2] 11-hydroxylated triterpenoids rarely occur in higher plants.[3-5] We now have isolated a novel 11-hydroxylated C_{31} dammarane-type triterpene, alnuserol, from the male flowers of *Alnus serrulatoides* Call. Alnuserol (1), $C_{31}H_{52}O_3$, had u.v., i.r., and ^1H and ^{13}C n.m.r. spectral characteristics typical of a non-conjugated carbonyl and a secondary hydroxyl-group, two further quaternary carbon atoms bearing an oxygen atom (probably an ether), and nine methyl groups. The mass spectrum included ions at *m/e* 141 (base peak), 123, and 43 suggesting a relationship with alnincanone (2).[6] The complete structure (1) was determined by an *X*-ray crystallographic study. Final atomic co-ordinates, bond lengths, and angles are given in Tables 1—3. The structure of the molecule is shown in the Figure. Since the o.r.d. and the c.d. curves of alnuserol exhibited a positive Cotton effect (*cf.* alnincanone)[7-9] and a positive maximum, respectively, the absolute configuration is as given in (1). It was also

Table 1

Final atomic parameters (× 10^4), with standard deviations in parentheses

Atom	*x*	*y*	*z*
C(1)	4 160(62)	4 699(58)	7 688(54)
C(2)	4 983(79)	5 603(64)	7 532(78)
C(3)	3 735(62)	6 405(60)	7 643(61)
C(4)	2 958(63)	6 480(57)	8 142(56)
C(5)	2 733(58)	5 535(54)	8 374(52)
C(6)	1 294(65)	5 555(58)	8 798(57)
C(7)	1 402(66)	4 680(57)	9 067(53)
C(8)	789(53)	3 866(54)	8 768(49)
C(9)	2 094(53)	3 838(52)	8 303(47)
C(10)	2 259(55)	4 761(53)	8 022(48)
C(11)	1 452(60)	3 023(57)	8 008(47)
C(12)	1 597(63)	2 135(55)	8 272(49)
C(13)	477(56)	2 174(52)	8 742(46)
C(14)	1 185(54)	2 976(55)	9 039(45)
C(15)	−54(74)	2 822(61)	9 491(52)
C(16)	−54(74)	1 789(60)	9 561(53)
C(17)	602(61)	1 368(54)	9 083(51)
C(18)	−1 512(62)	3 966(60)	8 665(59)
C(19)	386(63)	4 940(64)	7 713(54)
C(20)	−572(69)	516(60)	8 953(59)
C(21)	−2 731(80)	699(75)	8 800(86)
C(22)	528(86)	−76(65)	8 597(60)
C(23)	1 936(86)	−617(66)	8 905(68)
C(24)	720(75)	−765(56)	9 356(63)
C(25)	2 068(87)	−684(73)	9 803(68)
C(26)	865(111)	−739(93)	10 252(76)
C(27)	3 852(132)	−1 336(108)	9 818(103)
C(28)	4 594(84)	7 021(70)	8 409(70)
C(29)	991(75)	7 046(68)	8 140(66)
C(30)	3 473(61)	2 870(61)	9 179(53)
C(31)	−513(114)	−1 645(72)	9 325(88)
O(1)	3 428(47)	6 990(43)	7 347(41)
O(2)	2 609(47)	2 932(40)	7 578(33)
O(3)	−678(44)	−38(40)	9 370(40)



(1) R = OH

(2) R = H

Table 2

Interatomic distances (Å), with standard deviations in parentheses

C(1)–C(2)	1.554(12)	C(11)–O(2)	1.439(8)
C(1)–C(10)	1.586(10)	C(12)–C(13)	1.530(9)
C(2)–C(3)	1.483(12)	C(13)–C(14)	1.550(9)
C(3)–C(4)	1.506(11)	C(13)–C(17)	1.562(10)
C(3)–O(1)	1.246(9)	C(14)–C(15)	1.546(10)
C(4)–C(5)	1.554(10)	C(14)–C(30)	1.575(10)
C(4)–C(28)	1.553(12)	C(15)–C(16)	1.566(11)
C(4)–C(29)	1.552(11)	C(16)–C(17)	1.549(11)
C(5)–C(6)	1.519(10)	C(17)–C(20)	1.531(11)
C(5)–C(10)	1.583(10)	C(20)–C(21)	1.508(13)
C(6)–C(7)	1.552(10)	C(20)–C(22)	1.519(12)
C(7)–C(8)	1.527(10)	C(20)–O(3)	1.458(9)
C(8)–C(9)	1.562(9)	C(20)–C(23)	1.530(13)
C(8)–C(14)	1.554(9)	C(23)–C(24)	1.500(12)
C(8)–C(18)	1.561(10)	C(24)–C(25)	1.592(12)
C(9)–C(10)	1.618(9)	C(24)–C(31)	1.568(13)
C(9)–C(11)	1.534(9)	C(24)–O(3)	1.421(10)
C(10)–C(19)	1.514(10)	C(25)–C(26)	1.516(15)
C(11)–C(12)	1.554(10)	C(25)–C(27)	1.496(17)

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[1] For a preliminary account of this work see T. Hirata, K. Murai, and T. Suga, *Chem. Lett.*, 1977, 95.

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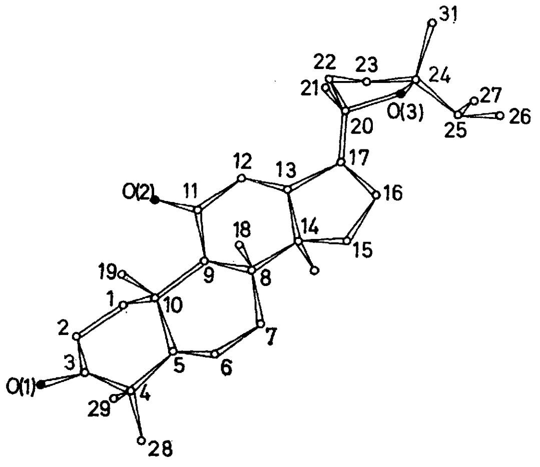
found that the molecules are packed along the *a* axis, and are linked by O(OH) ··· O(CO) intermolecular hydrogen bonds [with C(11)–OH ··· O 116.4°, O ··· O 2.98 Å, and O–H 0.96 Å] around the 2_1 screw axis in the *b* direction. Intermolecular distances are listed in Table 4. Thus, the structure of alnuserol has been established to be (11*R*,20*S*,24*R*)-20,24-epoxy-11-hydroxy-24-methyldammaran-3-one (1).

TABLE 3

Bond angles (°), with standard deviations in parentheses

C(2)–C(1)–C(10)	112.2(6)	C(11)–C(12)–C(13)	110.0(5)
C(1)–C(2)–C(3)	116.8(7)	C(12)–C(13)–C(14)	111.4(5)
C(2)–C(3)–C(4)	116.8(7)	C(12)–C(13)–C(17)	118.7(6)
C(2)–C(3)–O(1)	121.3(7)	C(14)–C(13)–C(17)	103.6(5)
C(4)–C(3)–O(1)	121.9(7)	C(8)–C(14)–C(13)	110.2(5)
C(3)–C(4)–C(5)	111.3(6)	C(8)–C(14)–C(15)	117.2(5)
C(3)–C(4)–C(28)	104.8(6)	C(8)–C(14)–C(30)	111.1(5)
C(3)–C(4)–C(29)	108.4(6)	C(13)–C(14)–C(15)	100.5(5)
C(5)–C(4)–C(28)	109.1(6)	C(13)–C(14)–C(30)	110.8(5)
C(5)–C(4)–C(29)	114.5(6)	C(15)–C(14)–C(30)	106.5(5)
C(28)–C(4)–C(29)	108.2(6)	C(14)–C(15)–C(16)	104.4(6)
C(4)–C(5)–C(6)	112.0(6)	C(15)–C(16)–C(17)	106.9(6)
C(4)–C(5)–C(10)	113.6(6)	C(13)–C(17)–C(16)	103.3(6)
C(6)–C(5)–C(10)	112.8(6)	C(13)–C(17)–C(20)	116.7(6)
C(5)–C(6)–C(7)	110.3(6)	C(16)–C(17)–C(20)	115.5(6)
C(6)–C(7)–C(8)	111.9(6)	C(17)–C(20)–C(21)	113.5(7)
C(7)–C(8)–C(9)	111.2(5)	C(17)–C(20)–C(22)	114.1(7)
C(7)–C(8)–C(14)	110.6(5)	C(17)–C(20)–O(3)	107.3(6)
C(7)–C(8)–C(18)	106.8(6)	C(21)–C(20)–C(22)	111.9(7)
C(9)–C(8)–C(14)	107.6(5)	C(21)–C(20)–O(3)	105.9(7)
C(9)–C(8)–C(18)	111.9(5)	C(22)–C(20)–O(3)	103.1(6)
C(14)–C(8)–C(18)	108.7(5)	C(20)–C(22)–C(23)	102.5(7)
C(8)–C(9)–C(10)	115.5(5)	C(22)–C(23)–C(24)	103.3(7)
C(8)–C(9)–C(11)	110.5(5)	C(23)–C(24)–C(25)	111.0(7)
C(10)–C(9)–C(11)	114.3(5)	C(23)–C(24)–C(31)	111.2(7)
C(1)–C(10)–C(5)	105.8(5)	C(23)–C(24)–O(3)	106.1(7)
C(1)–C(10)–C(9)	106.0(5)	C(25)–C(24)–C(31)	114.1(7)
C(1)–C(10)–C(19)	108.6(6)	C(25)–C(24)–O(3)	107.3(6)
C(5)–C(10)–C(9)	108.2(5)	C(31)–C(24)–O(3)	106.7(7)
C(5)–C(10)–C(19)	114.4(6)	C(24)–C(25)–C(26)	111.0(8)
C(9)–C(10)–C(19)	113.3(6)	C(24)–C(25)–C(27)	112.5(8)
C(9)–C(11)–C(12)	113.7(5)	C(26)–C(25)–C(27)	110.5(9)
C(9)–C(11)–O(2)	113.8(5)	C(20)–O(3)–C(24)	111.7(6)
C(12)–C(11)–O(2)	110.0(5)		



Molecular structure of alnuserol (1) showing the atom numbering system used. Atoms are carbon unless labelled otherwise

TABLE 4

Intermolecular separations (<3.5 Å)

C(29) ··· O(2^{I})	3.396	O(2) ··· C(29^{III})	3.396
C(3) ··· O(2^{II})	3.388	O(2) ··· C(3^{III})	3.388
O(1) ··· O(2^{II})	2.982	O(2) ··· O(1^{IV})	2.982

Roman numeral superscripts refer to the following transformations of the atomic co-ordinates:

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

EXPERIMENTAL

Mass spectra were recorded on a Hitachi RMS 4 mass spectrometer at 70 eV. ^{1}H N.m.r. spectra were taken with a Varian T 60 spectrometer, with tetramethylsilane as internal standard. The natural-abundance ^{13}C n.m.r. spectrum was determined with a JEOL JNM FX 100 spectrometer operating at 15.1 MHz. The crystallographic analysis was performed on a Syntex $P2_1$ diffractometer.

Extraction and Isolation.—The male flowers (10.3 kg) of *Alnus serrulatoides* Call. were immersed in acetone at room temperature for 2 months. The acetone solution on removal of solvent gave a brown viscous syrup, which was extracted with ether to give a viscous oil (66.7 g). A portion (10.0 g) of the oil was subjected to chromatographic separation to give alnuserol (1) (120 mg), m.p. 211—212 °C; $[\alpha]_D^{25}$ +260° (*c* 0.20, EtOH); $\lambda_{max.}$ (MeOH) 290 nm (ε 22.9); $\nu_{max.}$ (CCl_4) 3 621 (free OH) and 1 706 cm^{-1} (C=O); ^{1}H n.m.r. $\delta(CDCl_3)$ 0.9—1.2 (9 × Me) and 3.97 [1 H, m, C(11)–H]; ^{13}C n.m.r. $\delta(CDCl_3)$ 218.7 (s, C–3), 85.3 (s, C-20 and C-24), 71.1 (d, C-11), and 27.5, 25.1, 23.0, 20.8, 18.8, 17.6, 16.8, 16.3, and 16.1 (q, 9 × Me); *m/e* (rel. intensity) 472 (M^+; 0.5), 454 (2), 436 (6), 141 (100), 123 (49), and 43 (29); o.r.d. (*c* 0.33, MeOH) $[\phi]_{400}$ 1 070, $[\phi]_{304}$ 5 470, $[\phi]_{269}$ −2 150, $[\phi]_{230}$ 1 290; c.d. (*c* 0.33, MeOH) $[\theta]_{289}$ 955 (Found: C, 78.90; H, 11.10. $C_{31}H_{52}O_3$ requires C, 78.76; H, 11.09%). The acetate derivative: $\nu_{max.}$ (Nujol) 1 738 (OAc), 1 711 (C=O), and 1 236 cm^{-1} (C–O); ^{1}H n.m.r. $\delta(CDCl_3)$ 0.9—1.1 (9 × Me), 2.00 (2 H, s, OAc), and 5.20 [1 H, m, C(11)-H].

Crystallographic Measurements.—Single crystals of alnuserol (1) were obtained from hexane–ethyl acetate (9 : 1). Cell dimensions were derived by least-squares calculations from 2θ values of 13 well-centred, resolved Cu-K_α diffraction peaks. Of 2 262 reflections collected on a four-circle automatic diffractometer by use of Cu-K_α, 198 had $I < 1.96\sigma(I)$ and were not used in the refinement.

Crystal Data.—$C_{31}H_{52}O_3$, $M = 472.75$. Orthorhombic, $a = 6.599(2)$, $b = 14.921(3)$, $c = 28.443(8)$ Å, $U = 2\,800.6$ Å^3, $D_c = 1.119$ g cm^{-3}, $Z = 4$, $D_m = 1.07$ g cm^{-3}. Cu-K_α radiation, $\lambda = 1.541\,8$ Å; μ(Cu-K_α) = 5.3 cm^{-1}. Space group $P2_12_12_1$.

Structure Analysis and Refinement.—The structure factors were put on an absolute scale by the method of Wilson [10] ($B = 5.11$ Å^2) and normalized structure factors $|E_{hkl}|$ were then obtained by using the overall temperature parameter. The phases of 251 strong reflections with $|E| > 1.51$ were determined by direct methods, by use of the program MULTAN.[11] The *E* map for the best solution yielded positions for all 34 non-hydrogen atoms. The structure was refined by full-matrix least-squares methods. The weighting function used in the calculations was of the form $w = A$, where $A = 1$ if $|F_o| \geqslant 3.0$ or $A = 0.5$ if $|F_o| < 3.0$. An initial structure-factor calculation gave *R* 0.31 and subsequent least-squares calculations with isotropic thermal parameters for non-hydrogen atoms lowered *R* to 0.095.

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Anisotropic refinement for carbon and oxygen atoms and isotropic refinement for hydrogen atoms reduced R finally to 0.054. Observed and calculated structure factors, anisotropic thermal parameters, atom parameters of hydrogen atoms, o.r.d. curves for (1) and (2), and a view of the crystal structure of (1) along the *a* axis are listed in Supplementary Publication No. SUP 22177 (14 pp., 1 microfiche).*

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* See Notice to Authors No. 7 in *J.C.S. Perkin II*, **1977**, Index issue.