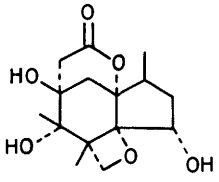
The Structures of Pseudoanisatin and Its Novel Base-catalysed Rearrangement Product

Isao Kouno, Hiroshi Irie, and Nobusuke Kawano*
Faculty of Pharmaceutical Sciences, Nagasaki University, Bunkyo-cho, Nagasaki 852, Japan

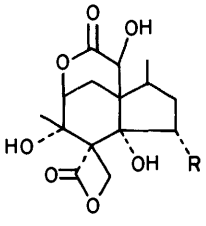
The oxidation product of pseudoanisatin (**4**), the structure of which was known from an *X*-ray crystallographic analysis, has been assigned as (**7**) on the basis of chemical and spectral evidence. A base-catalysed rearrangement product of pseudoanisatin, assigned structure (**8**) from an *X*-ray crystallographic analysis, is formed, it is concluded, *via* a novel stereoselective reaction which involves steric inversions at C-3 and C-4.

Pseudoanisatin was first isolated from Japanese star anise (*Illicium anisatum* LINN., Magnoliaceae) by Lane *et al.*[1] One of us proposed[2] structure (**1**) as that most likely for the compound on the basis of spectral and chemical evidence. Subsequently, however, we found that, because of two singlet signals assignable to carbonyl carbons at 206 and 174 p.p.m. (in [$^2H_5$]pyridine), the ^{13}C n.m.r. spectrum of pseudoanisatin was not consistent with this structure. In its i.r. spectrum pseudoanisatin showed a strong carbonyl band at 1 710 cm^{-1}, and the presence of a ketonic group in the molecule was confirmed by the formation of an oxime ($C_{15}H_{23}NO_6$, m.p. 260—261 °C).

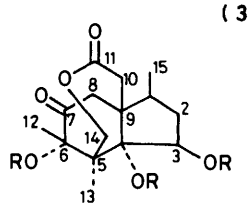
The presence of three methyl and four methylene groups and one lactone ring in the molecule had been established by the original formulation of structure (**1**). The 360 MHz ^1H n.m.r. spectrum [in $(CD_3)_2SO$] of pseudoanisatin showed the presence of one secondary [δ 5.77 (d)] and two tertiary [δ 6.23 (s) and 6.62 (s)] hydroxy groups. On the basis of these findings the following modifications to the original formulation were necessary: a ketonic group at C-7, a tertiary hydroxy group at C-4, and a lactone ring between the carboxy (C-11) and the primary alcoholic (C-14) groups. The carbon skeleton of pseudoanisatin was then seen to be the same as that of anisatin (**2**) and neoanisatin (**3**),[3–5] potent convulsant constituents of the same plant.



(**1**)



(**2**) R = OH
(**3**) R = H



(**4**) R = H
(**4a**) R = Ac

Finally, pseudoanisatin ($C_{15}H_{22}O_6$) was subjected to an *X*-ray crystallographic analysis.[6] It formed monoclinic prisms from ethyl acetate and from the analysis the ORTEP drawing shown in Figure 1 was obtained. In addition to the ε-lactone ring of the new structure (**4**) it is noteworthy that the configuration of C-3 for pseudoanisatin is the reverse of that found in anisatin (**2**). In a ^1H n.m.r. spectrum (in [$^2H_5$]pyridine) of (**4**), proton–proton coupling (*J* 2.5 Hz) through 4 σ-bonds was observed as two signals [δ 3.24 (dd, 8-H), and 3.88 (dd, 10-H)]; this indicated a W arrangement formed by the three carbons C-8, C-9, and C-10. This finding shows that (**4**) has the same conformation in the crystalline state as it has in pyridine solution.

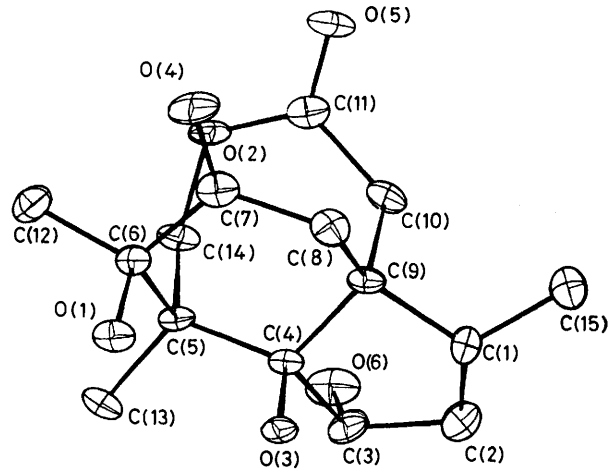
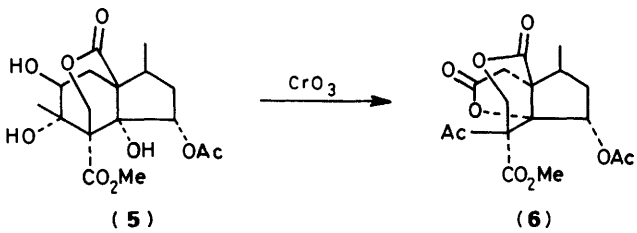


Figure 1. The ORTEP drawing of pseudoanisatin (**4**)

As result of the new structural formulation for (**4**) the earlier formulations given for pseudoanisatin derivatives[2] such as the triacetate (**4a**), a periodate oxidation product, and a base-catalysed isomerisation product needed to be revised. As reported previously,[2] the oxidation product of (**4**) with sodium periodate has a methyl ketone group. A similar oxidation product derived from anisatin (**2**) has been reported in the course of the structural elucidation of (**2**) and (**3**).[3] On oxidation with chromic acid–acetate acid or chromium trioxide–pyridine, methyl noranisatinate acetate ($C_{17}H_{25}O_9$) (**5**) afforded a keto lactone ($C_{17}H_{20}O_9$) (**6**).[3] Therefore, the novel structure (**7**) was



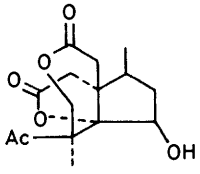
(**5**) (**6**)

Table 1. ^{13}C N.m.r. spectral data of compounds (4), (7), and (8)*

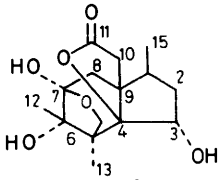
Assigned carbon	Pseudoanisatin (4)	Oxidation product (7)	Isomerisation product (8)
Me-12q	18.37	27.60	19.02
-13q	13.76 (a)	18.56 (a)	12.41 (a)
-15q	13.92 (a)	18.80 (a)	13.92 (a)
CH_2-2t	43.83 (b)	44.53	47.79
-8t	35.22	36.03	39.12
-10t	43.07 (b)	40.34	41.23
-14t	69.57	70.25	72.17
CH-1d	40.20	48.04	45.08
-3d	78.18	79.78	77.26
C-9s	47.73	49.68	48.60
-4s	84.68	96.95	102.19
-5s	48.82	57.27	52.77
-6s	79.26	208.22	78.02
-7s	206.54	175.88	106.85
-11s	174.25	172.00	176.57

* All data were obtained from [$^2H_5$]pyridine solutions: (a) and (b) mean that the assignments may be reversed in each vertical column.

deduced for the periodate oxidation product of (4). We now realised that (4) afforded the same oxidation product (7) in good yield not only with sodium periodate but also with pyridinium chlorochromate (PCC). The ^{13}C n.m.r. data (see Table 1) of (7) are compatible with the structure. In particular, the C-4 signal (δ 96.95), showing a considerable downfield shift in comparison with that of (4) (δ 84.68), suggested lactone ring formation with the hydroxy group at C-4.



(7)



(8)

When treated with sodium methoxide in methanol, (4) gave a translactonisation product as reported previously. The same product was also obtainable in good yield by boiling a methanolic solution of (4) with potassium carbonate, indicating that completely anhydrous conditions were not necessarily required. However, the product was not obtainable on addition of water. The i.r. spectrum of the isomer indicated the presence of a γ-lactone function (1 760 cm^{-1}) in place of the ε-lactone (1 710 cm^{-1}) of the pseudoanisatin molecule. The ^{13}C n.m.r. spectrum of the isomer (Table 1) showed a singlet signal at δ 106.85, suggesting transformation of the ketonic group into a hemiacetal ring. In its ^1H n.m.r. spectrum (in [$^2H_5$]pyridine) the shape of the signal assigned to the C-3 proton was much changed in comparison with that for compound (4); this suggested some stereochemical change at C-3.

For the structure and the conformation of isomer (8), a further *X*-ray crystallographic analysis was carried out to give the ORTEP drawing shown in Figure 2 for the non-hydrogen atoms. Consequently, the rearrangement by base of (4) into (8) involves unusual steric inversions at C-3 and C-4 in addition to translactonisation into a stable γ-lactone ring and acetal ring formation between C-7 and C-4. The steric inversion at C-4 is of especial interest since it involves conversion of a *cis* junction into a *trans*. Strain by the octahydro-*trans*-indan system of pseudoanisatin might be a driving force for the transformation. Since the transformation product (8) was obtained in good yield with almost complete steric inversion at C-3, we proposed [6] the

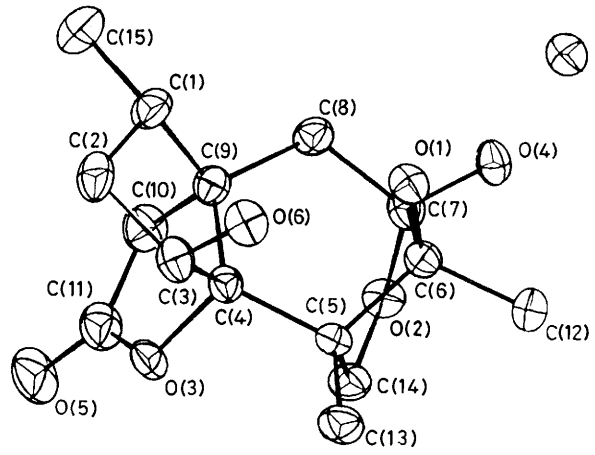
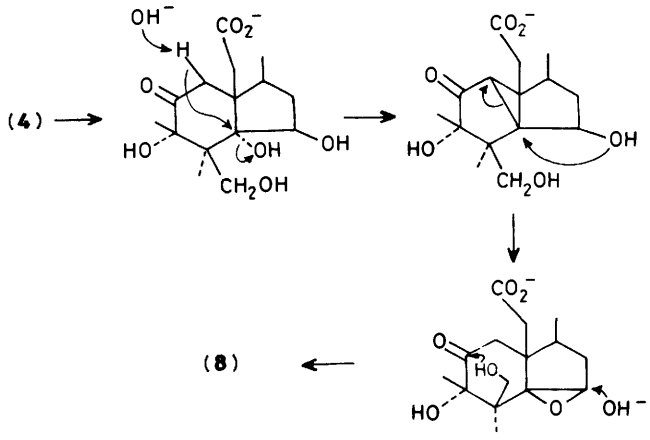
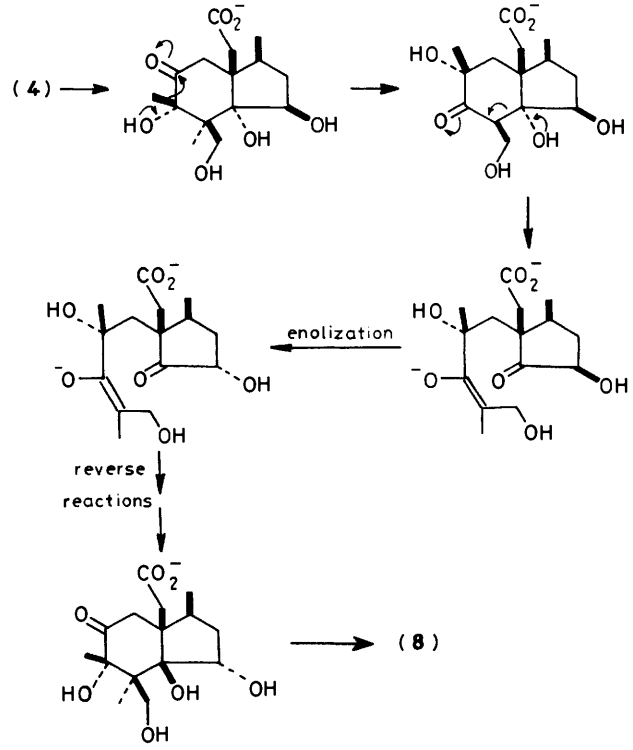


Figure 2. ORTEP drawing of the isomer (8)



Scheme 1. One plausible reaction mechanism for the transformation



Scheme 2. The transformation mechanism proposed by Professor D. H. R. Barton

reaction mechanism as shown in Scheme 1. Subsequently, Professor D. H. R. Barton suggested the mechanism shown in Scheme 2—we are very grateful for his kindness.

Experimental

^1H and ^{13}C N.m.r. spectra were recorded with JEOL PS-100 and FX-90Q instruments using tetramethylsilane as internal references. Mass spectra were obtained from a JEOL JMS-O1SG double-focussing instrument. U.v. and i.r. spectra were recorded with a Hitachi 323 recording spectrometer and JASCO IRA-2 grating i.r. spectrophotometer respectively. T.l.c. analysis was carried out by using 0.25 mm thick silica plates (Merck silica gel 60, GF_{254}). Merck silica gel 60 (70—230 mesh) was used for the column chromatography separations.

Pseudoanisatin (**4**).—Following the reported method,[7] compound (**4**) was obtained as colourless prisms from EtOAc, m.p. 207—208 °C; $\lambda_{max.}$(EtOH) 304 nm (ε 21 $dm^3 mol^{-1} cm^{-1}$); δ_H (360 MHz; [$^2H_5$]pyridine) 0.88 (3 H, d, *J* 7 Hz, 1-Me), 1.43—1.55 (1 H, m, 1-H), 1.63 (3 H, s, 5-Me), 1.74 (3 H, s, 6-Me), 2.55—2.80 (2 H, m, 2-H), 2.74 (1 H, d, *J* 15 Hz, 10-H), 2.80 (1 H, d, *J* 16 Hz, 8-H), 3.24 (1 H, dd, *J* 16 and 2.5 Hz, 8-H), 3.88 (1 H, dd, *J* 15 and 2.5 Hz, 10-H), 3.96 (1 H, d, *J* 14 Hz, 14-H), 4.75—4.80 (1 H, m, 3-H), and 6.04 (1 H, d, *J* 14 Hz, 14-H); δ_H [360 MHz; $(CD_3)_2SO$)] 0.86 (3 H, d, *J* 6.5 Hz, 1-Me), 1.17 and 1.18 (each 3 H, s, Me), 2.18 (1 H, d, *J* 16.5 Hz, 8-H), 2.78 (1 H, dd, *J* 16.5 and 2 Hz, 8-H), 2.23 and 3.33 (each 1 H, d, *J* 15 Hz, 10-H), 3.68 and 5.41 (each 1 H, d, *J* 13.2 Hz, 14-H), 1.11 and 2.44 (each 1 H, m, 2-H), 4.13 (1 H, m, 3-H), 2.25—2.35 (1 H, m, 1-H), 5.77 (1 H, d, *J* 5 Hz, 3-OH), 6.23 (1 H, s, OH), and 6.62 (1 H, s, OH); ^{13}C n.m.r. (Table 1); *m/z* 298 (M^+), 280 (M − 18), 255, 237, and 221.

Pseudoanisatin Triacetate (**4a**).—A solution of (**4**) (50 mg) in pyridine (1 ml)–acetic anhydride (0.5 ml) was allowed to react for 3 days. On complete removal of the solvent, there remained an oily substance, which was crystallised from ether–hexane and recrystallised from the same solvent to give colourless plates (30 mg), m.p. 89—90 °C; δ_H (90 MHz; $CDCl_3$) 0.96 (3 H, d, *J* 6 Hz, 1-Me), 1.10 and 1.87 (each 3 H, s, Me), 2.07 (3 H, s, COMe), 2.11 (6 H, s, 2 COMe), 2.18 and 2.37 (each 1 H, d, *J* 14 Hz), 2.71 and 2.91 (each 1 H, d, *J* 15 Hz), 4.18 and 4.54 (each 1 H, d, *J* 14 Hz), and 5.15—5.35 (1 H, m, 3-H).

Pseudoanisatin Oxime.—A mixture of (**4**) (20 mg), ahydrous sodium acetate (12 mg), and hydroxylamine hydrochloride (10 mg) in pyridine (0.5 ml) was gently refluxed in an oil-bath for 1 h and evaporated under diminished pressure. The reactant was triturated with water, filtered, and washed with water. Recrystallisations from EtOAc yielded the oxime (8 mg), m.p. 260—261 °C (Found: C, 57.7; H, 7.45; N, 4.25. $C_{15}H_{23}NO_6$ requires C, 57.5; H, 7.4; N, 4.45%).

X-*Ray Crystallographic Analysis of Pseudoanisatin.*—The *X*-ray crystallographic analysis was performed on a microcomputer controlled four-circle diffractometer [9] with Cu-K_α radiation (λ = 1.5418 Å) in the 2θ—θ scan mode for 2θ ≤ 120°.

Crystal data. $C_{15}H_{22}O_6$, M = 298.33, monoclinic, a = 18.424, b = 7.828, c = 10.279 Å, β = 97.60°, U = 1 469.4 Å^3, Z = 4, D_c = 1.357, D_m = 1.357 g cm^{-3}, space group *C*2. Of the 1 169 independent reflections measured, 1 141 having $|F_o| \geq 3\sigma|F_o|$ were used for the structure analysis. The structure was solved by the direct method using MULTAN,[10] and was refined by the block diagonal least-squares method. In the final refinement, anisotropic thermal parameters were used for the non-hydrogen atoms. All the hydrogen atoms except that for the hydroxy group were introduced at calculated positions (isotropic thermal vibration parameter B = 4.5) but were not refined. The final R value was 0.070. Computations for refinement were performed with an FACOM M-200 computer using the program UNICS II.[11] Final atomic co-ordinates are given in Table 2, and bond lengths and bond angles in Tables 3 and 4.

Supplementary data available [No. SUP. 56060 (3 pp.)]: thermal parameters for compounds (**4**) and (**8**). See Instructions for Authors (1984), section 4, *J. Chem. Soc., Perkin Trans. 1*, 1984, Issue 1. Structure factors available from the editorial office on request.

Oxidation of Pseudoanisatin (**4**) *with Sodium Periodate.*—Compound (**4**) (50 mg) dissolved in water (1.0 ml) was mixed with a solution of sodium periodate (33 mg) in water (1.0 ml) and allowed to stand at room temperature for 2 days. Crystals were collected and recrystallised from EtOAc to give minute colourless needles of (**7**) (36 mg, 72%), m.p. 218—219 °C (Found: C, 61.05; H, 6.65. $C_{15}H_{20}O_6$ requires C, 60.80; H, 6.8%); $\nu_{max.}$ 3 500 (OH), 1 790 (γ-lactone), 1 730, 1 715, 1 260, 1 130, and 1 035 cm^{-1}; δ_H (100 MHz; [$^2H_5$]pyridine) 1.18 (3 H, d, *J* 6.5 Hz, 1-Me), 1.76 (3 H, s, 5-Me), 2.18 (3 H, s, 5-Ac), 2.53 and 3.72 (each 1 H, d, *J* 17 Hz), 2.80 and 3.40 (each 1 H, d, *J* 13 Hz), 4.37 and 5.57 (each 1 H, d, *J* 13.5 Hz), 4.58 (1 H, m, 3-H), and 4.92 (1 H, br s, OH); *m/z* 296 (M^+), 278, 253, and 236.

Oxidation of Pseudoanisatin (**4**) *with PCC.*—A mixture of compound (**4**) (50 mg), PCC (pyridinium chlorochromate) (60 mg), and CH_2Cl_2 (50 ml) was stirred for 3 h at room temperature. The reaction mixture was mixed with diethyl ether (100 ml) and filtered. The filtrate was evaporated to dryness and chromatographed on silica gel (4 g). Elution with $CHCl_3$–MeOH (98:2) followed by recrystallisation from EtOAc gave colourless needles (30 mg, 60%), m.p. 218—219 °C, identical with (**7**) (mixed m.p., t.l.c., i.r., and ^1H n.m.r.).

The Monoacetate of the Oxidation Product (**7**).—Compound (**7**) (25 mg) in pyridine (0.3 ml) was mixed with acetic anhydride (0.3 ml) and allowed to stand at room temperature for 1 day. The reaction mixture was added to ice-water and the white precipitate formed was filtered off and washed with water. On recrystallisation from ethanol it gave needles (22 mg), m.p. 192—193 °C (Found: C, 59.95; H, 6.7. $C_{17}H_{22}O_7$ requires C, 60.35; H, 6.6%); δ_H (100 MHz; $CDCl_3$) 1.11 (3 H, d, *J* 7 Hz), 1.44 (3 H, s, Me), 2.15 and 2.23 (each 3 H, s, Ac), 2.39 and 3.32 (each 1 H, d, *J* 17.5 Hz), 2.69 and 3.08 (each 1 H, d, *J* 13.5 Hz), 4.23 and 4.97 (each 1 H, d, *J* 13 Hz), and 5.5—5.7 (1 H, m, 3-H).

Isomerisation of Pseudoanisatin (**4**) *with Sodium Methoxide.*—A solution of pseudoanisatin (**4**) (55 mg) and sodium methoxide (30 mg) in anhydrous methanol (10 ml) was gently refluxed for 4 h. The cooled solution was passed through a column of Amberlite IR-120 (H^+-form, 20 ml) and the column was washed with methanol. The solution and washings were combined and evaporated to give crystalline substance (50 mg), which was recrystallised from EtOAc, m.p. 220—221 °C (Found: C, 60.2; H, 7.6. $C_{15}H_{22}O_6$ requires C, 60.4; H, 7.45%); $\nu_{max.}$(Nujol) 3 300 (OH) and 1 760 cm^{-1} (γ-lactone); δ_H (100 MHz; [$^2H_5$]pyridine) 0.87 (3 H, d, *J* 7 Hz, 1-Me), 1.44 and 1.69 (each 3 H, s, Me), 1.50 (1 H, dd, *J* 13 and 4 Hz, 2-H), 1.90 (1 H, dd, *J* 13 and 6 Hz, 2-H), 2.36 and 2.71 (each 1 H, d, *J* 13 Hz), 2.6—2.9 (1 H, m, 1-H), 2.90 and 3.21 (each 1 H, d, *J* 18 Hz), 3.74 and 4.21 (each 1 H, d, *J* 10 Hz), and 4.41 (1 H, dd, *J* 4 and 1 Hz, 3-H); δ_H [90 MHz; $(CD_3)_2SO$] 0.93 (3 H, d, *J* 7 Hz), 1.09 and 1.17 (each 3 H, s, Me), 5.99 and 7.03 (each 1 H, s, OH), and 6.87 (1 H, d, *J* 6 Hz, 3-OH); *m/z* 298 (M^+), 280, 265, 249, and 221.

Isomerisation of Compound (**4**) *with Potassium Carbonate.*—Compound (**4**) (10 mg) in methanol (5 ml) was gently refluxed

Table 2. Final atomic co-ordinates ($\times 10^4$) of the non-hydrogen atoms of pseudoanisatin (**4**), with e.s.d.s in parentheses

Atoms	*x*	*y*	*z*
O(1)	2 135(4)	5 445(0)	523(6)
O(2)	3 044(4)	4 490(10)	4 470(6)
O(3)	3 321(3)	7 340(10)	736(6)
O(4)	2 742(4)	2 118(10)	1 947(8)
O(5)	3 895(4)	2 542(10)	4 780(7)
O(6)	3 928(4)	8 977(11)	4 044(7)
C(1)	4 689(5)	6 405(15)	1 790(11)
C(2)	4 708(6)	8 275(17)	2 333(12)
C(3)	3 934(6)	8 696(14)	2 652(11)
C(4)	3 460(5)	7 086(13)	2 153(9)
C(5)	2 726(5)	6 680(13)	2 653(9)
C(6)	2 365(5)	5 053(13)	1 921(9)
C(7)	2 924(6)	3 587(14)	1 849(9)
C(8)	3 696(6)	4 027(15)	1 547(10)
C(9)	4 020(5)	5 591(14)	2 319(9)
C(10)	4 249(6)	5 106(15)	3 798(9)
C(11)	3 724(6)	3 959(15)	4 394(9)
C(12)	1 678(6)	4 401(16)	2 432(11)
C(13)	2 211(6)	8 224(14)	2 482(10)
C(14)	2 831(6)	6 259(14)	4 167(9)
C(15)	5 423(6)	5 467(20)	2 087(12)

Table 3. Bond lengths (Å) of pseudoanisatin (**4**), with e.s.d.s in parentheses

O(1)–C(6)	1.475(10)	C(4)–C(5)	1.543(13)
O(2)–C(11)	1.331(12)	C(4)–C(9)	1.553(14)
O(2)–C(14)	1.461(13)	C(5)–C(6)	1.580(13)
O(3)–C(4)	1.458(10)	C(5)–C(13)	1.531(14)
O(4)–C(7)	1.205(13)	C(5)–C(14)	1.576(13)
O(5)–C(11)	1.205(13)	C(6)–C(7)	1.550(14)
O(6)–C(3)	1.449(13)	C(6)–C(12)	1.520(15)
C(1)–C–(2)	1.565(17)	C(7)–C(8)	1.534(15)
C(1)–C(9)	1.548(14)	C(8)–C(9)	1.536(14)
C(1)–C(15)	1.534(15)	C(9)–C(10)	1.569(13)
C(2)–C(3)	1.541(16)	C(10)–C(11)	1.507(15)
C(3)–C(4)	1.579(14)		

Table 4. Bond angles (°) of pseudoanisatin (**4**), with e.s.d.s in parentheses

C(11)–O(2)–C(14)	120.8(8)	O(1)–C(6)–C(7)	102.3(7)
C(2)–C(1)–C(9)	103.9(8)	O(1)–C(6)–C(12)	105.1(7)
C(9)–C(1)–C(15)	117.0(9)	C(5)–C(6)–C(7)	112.2(7)
C(2)–C(1)–C(15)	113.4(9)	C(5)–C(6)–C(12)	115.0(8)
C(1)–C(2)–C(3)	107.3(9)	C(7)–C(6)–C(12)	110.8(8)
O(6)–C(3)–C(2)	111.7(8)	O(4)–C(7)–C(6)	120.5(9)
O(6)–C(3)–C(4)	111.4(8)	O(4)–C(7)–C(8)	120.4(9)
C(2)–C(3)–C(4)	104.2(8)	C(6)–C(7)–C(8)	118.9(9)
O(3)–C(4)–C(3)	103.4(7)	C(7)–C(8)–C(9)	112.4(8)
O(3)–C(4)–C(5)	108.3(6)	C(1)–C(9)–C(4)	101.4(8)
O(3)–C(4)–C(9)	103.8(7)	C(1)–C(9)–C(8)	114.7(8)
C(3)–C(4)–C(5)	121.7(8)	C(1)–C(9)–C(10)	108.3(7)
C(3)–C(4)–C(9)	103.6(7)	C(4)–C(9)–C(8)	109.6(7)
C(5)–C(4)–C(9)	113.9(8)	C(4)–C(9)–C(10)	112.2(7)
C(4)–C(5)–C(6)	109.8(7)	C(8)–C(9)–C(10)	110.1(8)
C(4)–C(5)–C(13)	110.8(8)	C(9)–C(10)–C(11)	115.6(7)
C(4)–C(5)–C(14)	111.9(7)	O(2)–C(11)–O(5)	118.3(9)
C(6)–C(5)–C(13)	111.4(7)	O(2)–C(11)–C(10)	119.7(9)
C(6)–C(5)–C(14)	106.8(7)	O(5)–C(11)–C(10)	121.8(9)
C(13)–C(5)–C(14)	105.7(7)	O(2)–C(14)–C(5)	113.7(7)
O(1)–C(6)–C(5)	110.1(7)		

with K_2CO_3 (100 mg) for 7 h. The methanol filtrate was treated with Amberlite IR-120 resin in the same way as described above to give the same isomer (8 mg), m.p. and mixed m.p. 220—221 °C, identical with the isomerisation product (**8**) (t.l.c. and i.r.).

Table 5. Final atomic co-ordinates ($\times 10^4$) of the non-hydrogen atoms of the isomer (**8**), with e.s.d.s in parentheses

Atoms	*x*	*y*	*z*
O(1)	950(2)	−51(4)	565(7)
O(2)	498(2)	2 476(5)	−2 414(6)
O(3)	1 255(3)	3 877(4)	1 555(8)
O(4)	677(3)	479(5)	−3 481(7)
O(5)	1 683(3)	5 642(5)	492(10)
O(6)	1 493(3)	812(5)	3 490(7)
O(7)	868(3)	−2 345(5)	−933(7)
C(1)	2 490(4)	1 836(7)	633(12)
C(2)	2 403(4)	2 273(8)	2 605(11)
C(3)	1 632(4)	2 078(7)	3 001(10)
C(4)	1 284(3)	2 516(6)	1 210(10)
C(5)	522(3)	2 117(6)	754(10)
C(6)	519(4)	851(6)	−290(10)
C(7)	836(4)	1 270(7)	−2 093(10)
C(8)	1 621(4)	1 456(7)	−1 917(10)
C(9)	1 836(4)	2 349(7)	−358(10)
C(10)	1 921(4)	3 712(8)	−1 062(12)
C(11)	1 633(4)	4 538(7)	354(13)
C(12)	−217(4)	320(7)	−529(11)
C(13)	62(4)	2 175(8)	2 449(12)
C(14)	231(4)	2 946(7)	−732(11)
C(15)	3 197(4)	2 148(9)	−204(14)

Table 6. Bond lengths (Å) of the isomer (**8**), with e.s.d.s in parentheses

O(1)–C(6)	1.426(9)	C(3)–C(4)	1.564(11)
O(2)–C(7)	1.470(9)	C(4)–C(5)	1.565(10)
O(2)–C(14)	1.444(9)	C(4)–C(9)	1.587(10)
O(3)–C(4)	1.488(9)	C(5)–C(6)	1.568(10)
O(3)–C(11)	1.353(11)	C(5)–C(13)	1.542(11)
O(4)–C(7)	1.372(9)	C(5)–C(14)	1.527(11)
O(5)–C(11)	1.196(12)	C(6)–C(7)	1.541(10)
O(6)–C(3)	1.435(9)	C(6)–C(12)	1.537(11)
C(1)–C(2)	1.528(12)	C(7)–C(8)	1.529(11)
C(1)–C(9)	1.569(11)	C(8)–C(9)	1.561(11)
C(1)–C(15)	1.541(13)	C(9)–C(10)	1.566(12)
C(2)–C(3)	1.527(11)	C(10)–C(11)	1.485(13)

Table 7. Bond angles (°) of the isomer (**8**), with e.s.d.s in parentheses

C(7)–O(2)–C(14)	109.0(5)	O(1)–C(6)–C(12)	109.5(6)
C(4)–O(3)–C(11)	112.5(6)	C(5)–C(6)–C(7)	100.1(5)
C(2)–C(1)–C(9)	105.2(6)	C(5)–C(6)–C(12)	112.5(6)
C(2)–C(1)–C(15)	115.1(7)	C(7)–C(6)–C(12)	111.8(6)
C(9)–C(1)–C(15)	115.3(7)	O(2)–C(7)–O(4)	109.0(5)
C(1)–C(2)–C(3)	104.2(6)	O(2)–C(7)–C(6)	103.0(5)
O(6)–C(3)–C(2)	111.1(6)	O(2)–C(7)–C(8)	109.5(5)
O(6)–C(3)–C(4)	115.0(6)	O(4)–C(7)–C(6)	112.6(6)
C(2)–C(3)–C(4)	102.0(6)	O(4)–C(7)–C(8)	111.4(6)
O(3)–C(4)–C(3)	99.6(5)	C(6)–C(7)–C(8)	110.7(6)
O(3)–C(4)–C(5)	105.8(5)	C(7)–C(8)–C(9)	113.9(6)
O(3)–C(4)–C(9)	105.3(5)	C(1)–C(9)–C(4)	102.6(5)
C(3)–C(4)–C(5)	120.1(6)	C(1)–C(9)–C(8)	110.8(6)
C(3)–C(4)–C(9)	107.8(5)	C(1)–C(9)–C(10)	114.0(6)
C(5)–C(4)–C(9)	115.8(5)	C(4)–C(9)–C(8)	116.0(5)
C(4)–C(5)–C(6)	110.4(5)	C(4)–C(9)–C(10)	102.0(5)
C(4)–C(5)–C(13)	110.4(6)	C(8)–C(9)–C(10)	110.8(6)
C(4)–C(5)–C(14)	109.8(5)	C(9)–C(10)–C(11)	106.5(7)
C(6)–C(5)–C(13)	116.0(6)	O(3)–C(11)–O(5)	120.5(8)
C(6)–C(5)–C(14)	98.4(5)	O(3)–C(11)–C(10)	110.7(7)
C(13)–C(5)–C(14)	111.0(6)	O(5)–C(11)–C(10)	128.6(9)
O(1)–C(6)–C(5)	111.6(5)	O(2)–C(14)–C(5)	107.0(6)
O(1)–C(6)–C(7)	111.0(5)		

The Monoacetate of the Isomer (**8**).—Compound (**8**) (30 mg) dissolved in pyridine (1 ml) was mixed with acetic anhydride (0.5 ml) and allowed to stand for 1 day. The solvent was

evaporated to dryness and the residue was dissolved in EtOAc. The solution was washed with water, dried, and evaporated to dryness. The oily substance was purified by silica gel chromatography eluting with a chloroform–methanol (99:1—98:2) mixture to give colourless oil (20 mg); δ_H (90 MHz; $CDCl_3$) 1.03 (3 H, d, *J* 6 Hz), 1.06 and 1.34 (each 3 H, s, Me), 2.19 (3 H, s, Ac), 1.55—2.6 (3 H, m, 1-H and 2-H), 1.98 and 2.32 (each 1 H, d, *J* 13.5 Hz), 2.76 and 3.00 (each 1 H, d, *J* 19 Hz), 3.56 and 3.96 (each 1 H, d, *J* 10 Hz), 4.72 (1 H, s, OH), and 5.16 (1 H, dd, *J* 4 and 1 Hz, 3-H).

X-*Ray Crystallographic Analysis of the Isomer* (**8**).—The *X*-ray crystallographic analysis was performed on a Rigaku RU-200 AFC-5 diffractometer with Cu-K_α radiation (λ = 1.5418 Å) in the 2θ—θ scan mode for $2\theta \leq 120°$.

Crystal data. $C_{15}H_{22}O_6 \cdot H_2O$, M = 316.34, Orthorhombic, a = 19.229(12), b = 10.757(7), c = 7.440(8) Å, U = 1 538.9(12) Å^3, Z = 4, D_c = 1.360, D_m = 1.360 g cm^{-3}, space group $P2_12_12_1$. 1 332 Independent reflections having $|F_o| \geq 2\sigma|F_o|$ were used for the structure analysis. The structure was solved by the direct method using MULTAN 78,[12] and was refined by the block diagonal least-squares method. In the final refinement, anisotropic thermal parameters were used for the non-hydrogen atoms. All the hydrogen atoms except those for the hydroxy groups were introduced at calculated positions with an isotropic thermal vibration parameter of B = 4.0, but not refined. The final R value was 0.050. Computations for refinement were performed with a FACOM-200 computer using the program UNICS II.[11] Final atomic co-ordinates are given in Table 5, and bond lengths and bond angles in Tables 6 and 7.*

* For details of the Supplementary available see the crystallographic analysis of compound (**4**) on p. 2513.

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