Structural Studies of Some Hydroxyeriobrucinol Derivatives

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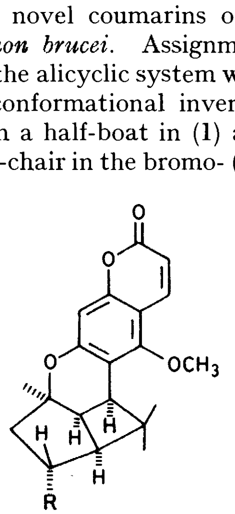
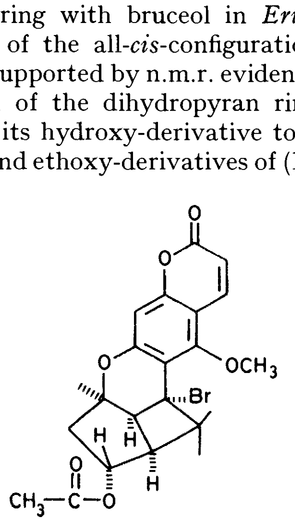
Single-crystal *X*-ray structure determinations of the acetate derivative of hydroxyeriobrucinol methyl ether (1) and eriobrucinol methyl ether (2) have been carried out and confirm their structures and relative configurations. A tentative assignment of absolute configuration for the system has been made on the basis of a structure determination carried out on a non-stoicheiometric brominated derivative (3) of (1), and is consistent with that derived for (−)-bruceol. Conformational inversion of the dihydropyran ring from a half-boat in (1) to a half-chair in the bromo-derivative is observed and parallels that noted in solution for these compounds.

IN a previous publication [1] chemical and spectroscopic evidence has been presented for the structure and relative configuration of eriobrucinol and hydroxyeriobrucinol, two novel coumarins occurring with bruceol in *Eriostemon brucei*. Assignment of the all-*cis*-configuration for the alicyclic system was supported by n.m.r. evidence of conformational inversion of the dihydropyran ring from a half-boat in (1) and its hydroxy-derivative to a half-chair in the bromo- (3) and ethoxy-derivatives of (1).



(1) R = OCOCH$_3$
(2) R = H



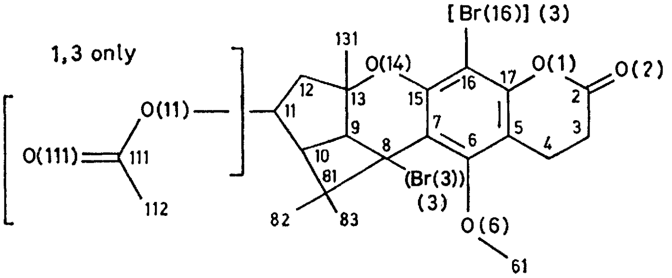
(3)

To confirm the results single-crystal *X*-ray structure determinations of (1)—(3) have been undertaken, the data available from (3) permitting a tentative assignment of the absolute configuration for these compounds.

CRYSTALLOGRAPHY

General Features and Procedure.—For each compound, a unique data set was measured within a pre-set $2\theta_{\max.}$ limit, determined by the scope of the data, using a Syntex $P\bar{1}$ four-circle diffractometer in conventional 2θ—θ scan mode. Monochromatic Mo-K_{α} radiation was used; T was 295(1) K. N Independent reflections were obtained, N_0 with $I > 2\sigma(I)$ being considered 'observed' and used in the refinement after solution of the structure by direct methods, an absorption correction being applied to the data of (3) only. Refinement was basically by 9 × 9 block-diagonal least-squares methods; where hydrogen atom parameters were refined, they were included in the block of the parent carbon atom. Anisotropic thermal parameters were used for the non-hydrogen atoms. Where $(x,y,z)_{\mathrm{H}}$ could not be refined, these were obtained from difference-maps where possible and 'improved' to tetrahedral and trigonal estimates, U_{H} being set at $[\bar{U}_{\mathrm{ii}}$ (parent C,0) + 0.01]. Residuals R,R' are quoted. Reflection weights were $[\sigma^2(F_0) + 0.0003\ (F_0)^2]^{-1}$. Neutral atom scattering factors were used, corrected for anomalous dispersion (f' and f'') in the case of the non-hydrogen atoms.[2-4] Computation was carried out using the '*X*-RAY 76' program system [5] implemented by S. R. Hall on a CYBER 73 computer. Material deposited comprises structure-factor amplitudes, thermal parameters, and hydrogen atom geometries.†

Atom numbering for crystallographic purposes is as shown in (4), hydrogen atoms being numbered according to the parent carbon, suffixed a—c for distinction where necessary.



(4)

A special note is in order concerning the structure determination of (3). This determination was carried out primarily with the intention of assignment of absolute configuration. The compound is difficult to prepare, isolate, crystallize, and preserve, tending to decompose easily. Preparation and crystallization of the compound was followed immediately by mounting on the diffractometer with rapid data collection, the whole operation being accomplished in 12 h. [An added set of 'Friedel pairs' with 15° < 2θ < 20° was measured, those with $I > 10\sigma(I)$ being considered in confirmation of the assignment established by the residual below.]

Solution of the structure revealed that bromination had not simply resulted in formation of the monobromo-derivative by insertion of Br(8), but had proceeded further by partial bromination of Br(16), the crystal resulting being

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† In Supplementary Publication No. SUP 22951 (18 pp.). For details see Notice to Authors, No. 7, *J. Chem. Soc., Perkin Trans. 2*, 1979, Index Issue.

TABLE 1

Atomic co-ordinates for (1) and (2). Fractional cell parameters (x,y,z), × 10^3, H; × 10^4, C,O

(1)

Atom	x	y	z
O(1)	0 966(5)	−0 930(5)	2 082(3)
C(2)	−0 018(8)	−1 715(8)	1 972(5)
O(2)	−0 821(6)	−1 416(6)	1 523(4)
C(3)	0.027(9)	−2 871(8)	2 381(6)
H(3)	−061(7)	−336(7)	237(5)
C(4)	0 949(9)	−3 128(8)	2 904(5)
H(4)	095(8)	−388(7)	314(5)
C(5)	1 948(7)	−2 287(7)	3 029(4)
C(6)	2 941(8)	−2 442(8)	3 543(5)
O(6)	3 014(6)	−3 534(5)	3 980(3)
C(61)	3 519(12)	−4 578(9)	3 554(7)
H(61a)	436(8)	−433(8)	332(5)
H(61b)	305(8)	−474(8)	303(5)
H(61c)	365(8)	−534(8)	380(5)
C(7)	3 829(7)	−1 567(7)	3 691(3)
C(8)	4 895(8)	−1 701(8)	4 251(5)
H(8)	472(7)	−231(7)	465(4)
C(81)	6 262(8)	−1 911(7)	3 911(5)
C(82)	6 876(10)	−3 071(9)	4 235(7)
H(82a)	633(8)	−370(7)	397(5)
H(82b)	677(7)	−306(7)	487(5)
H(82c)	785(7)	−323(7)	400(4)
C(83)	6 342(9)	−1 919(9)	3 024(5)
H(83a)	596(7)	−121(7)	275(4)
H(83b)	599(7)	−272(7)	271(4)
H(83c)	722(7)	−191(7)	269(4)
C(9)	5 308(9)	−0 457(9)	4 621(6)
H(9)	521(8)	−027(8)	520(5)
C(10)	6 698(8)	−0 705(7)	4 349(5)
H(10)	719(7)	−089(6)	493(4)
C(11)	7 126(8)	0 425(9)	3 915(5)
H(11)	717(7)	030(8)	338(4)
O(11)	8 326(5)	0 862(4)	4 207(3)
C(111)	9 325(8)	0 150(8)	4 059(5)
O(111)	9 236(6)	−0 765(5)	3 637(4)
C(112)	10 477(10)	0 625(12)	4 417(7)
H(112a)	1 084(8)	153(8)	424(5)
H(112b)	1 047(9)	048(9)	495(5)
H(112c)	1 120(8)	001(8)	443(5)
C(12)	6 196(9)	1 429(8)	4 088(7)
H(12a)	624(9)	206(8)	375(5)
H(12b)	643(8)	184(7)	459(5)
C(13)	4 949(9)	0 735(7)	4 195(5)
C(131)	3 834(11)	1 472(12)	4 563(8)
H(131a)	314(8)	076(8)	467(5)
H(131b)	364(9)	225(9)	433(5)
H(131c)	410(9)	159(9)	511(6)
O(14)	4 587(5)	0 470(5)	3 368(3)
C(15)	3 694(7)	−0 452(7)	3 256(5)
C(16)	2 766(10)	−0 263(8)	2 727(6)
H(16)	269(9)	034(7)	253(5)
C(17)	1 901(7)	−1 184(7)	2 627(5)

(2)

Atom	x	y	z
O(1)	2 787(3)	2 363(7)	3 571(11)
C(2)	2 895(5)	3 562(11)	4 048(17)
O(2)	3 336(4)	4 044(7)	3 293(13)
C(3)	2 483(6)	4 112(11)	5 345(19)
H(3)	257(5)	507(11)	560(16)
C(4)	2 038(6)	3 470(14)	6 162(19)
H(4)	175(5)	375(11)	693(17)
C(5)	1 961(5)	2 231(10)	5 720(16)
C(6)	1 514(4)	1 453(10)	6 493(15)
O(6)	1 157(3)	1 936(7)	7 917(11)
C(61)	1 463(9)	1 917(16)	9 732(32)
H(61a)	179(5)	232(13)	970(23)
H(61b)	142(7)	113(10)	976(22)
H(61c)	123(5)	264(11)	1 051(17)
C(7)	1 386(5)	0 314(10)	5 901(15)
C(8)	0 918(5)	−0 463(11)	6 796(17)
H(8)	098(4)	−049(8)	841(13)
C(81)	0 222(4)	−0 168(9)	6 471(14)

TABLE 1 (*continued*)

Atom	x	y	z
C(82)	−0 135(6)	−0 107(14)	8 258(20)
H(82a)	004(5)	050(9)	901(16)
H(82b)	−007(5)	−089(9)	890(15)
H(82c)	−054(5)	−013(11)	813(17)
C(83)	0 060(7)	0 880(15)	5 278(21)
H(83a)	027(5)	098(11)	426(15)
H(83b)	019(5)	162(9)	577(16)
H(83c)	−041(5)	094(10)	492(15)
C(9)	0 835(5)	−1 695(10)	5 928(16)
H(9)	092(4)	−238(8)	661(14)
C(10)	0 142(5)	−1 481(11)	5 539(15)
H(10)	−019(4)	−197(8)	623(13)
C(11)	0 072(6)	−1 522(12)	3 419(18)
H(11a)	−029(5)	−106(10)	288(15)
H(11b)	−009(5)	−243(9)	306(15)
C(12)	0 709(8)	−1 334(12)	2 588(20)
H(12a)	071(6)	−058(9)	253(18)
H(12b)	075(5)	−184(9)	139(15)
C(13)	1 138(5)	−1 912(10)	4 020(16)
C(131)	1 264(7)	−3 259(14)	3 647(25)
H(131a)	155(5)	−370(10)	467(16)
H(131b)	152(5)	−305(10)	257(16)
H(131c)	088(5)	−367(10)	347(18)
O(14)	1 741(3)	−1 314(6)	3 916(11)
C(15)	1 781(4)	−0 128(10)	4 533(16)
C(16)	2 242(5)	0 524(12)	3 754(20)
H(16)	256(5)	024(11)	303(15)
C(17)	2 320(4)	1 688(11)	4 358(16)

a mixture of mono- and di-bromide complex, with associated difficulties in refinement.* Tentative assignment of the absolute configuration proceeded by the following additional steps in the refinement. f'' Was removed from the bromine scattering factor and the population of Br(16) refined as a variable, refinement proceeding to convergence. f'' Was then restored with the Br(16) population constrained and the tentative chirality established by refinement to convergence for both parties, the residuals obtained being 0.0675 and 0.0695. For the chirality with the lower residual, the Br(16) population was added to the variables and final refinement proceeded to convergence. Although the statistical significance of the result is unambiguous, and it is comforting to note the agreement of the established chirality with that of a related but *independent* system in the following paper (itself not without difficulties), we feel that the difficulties associated with the present experiment are such that the assignment of absolute configuration should only be taken as 'probable'; if a related derivative of greater tractability should become available in future, the experiment should be repeated. Data on all structures in this and the following paper are given consistently in the same chirality. Axial systems in the Figures are right-handed.

Crystal Data.—(1), $C_{22}H_{24}O_6$, $M = 384.4$, orthorhombic, space group $P2_12_12_1$ (D_2^4, No. 19), $a = 10.762(5)$, $b = 10.840(5)$, $c = 16.88(1)$ Å, $U = 1\,969(2)$ Å^3, $D_m = 1.30(1)$ g cm^{-3}, $D_c = 1.30$ g cm^{-3}, $Z = 4$. $F(000) = 680$. $\mu_{Mo} = 1.01$ cm^{-1}. $2\theta_{max.} = 45°$, $N = 1\,240$, $N_o = 878$, $R = 0.053$, $R' = 0.052$.

(2), $C_{20}H_{22}O_4$, $M = 326.4$, orthorhombic, space group $P2_12_12_1$ (D_2^4, No. 19), $a = 21.858(7)$, $b = 11.022(3)$, $c = 7.213(2)$ Å, $U = 1\,737.7(15)$ Å^3. $D_m = 1.25(1)$ g cm^{-3}, $D_c = 1.25$ g cm^{-3}, $Z = 4$. $F(000) = 696$. $\mu_{Mo} = 0.93$ cm^{-1}. $2\theta_{max.} = 40°$, $N = 975$, $N_o = 591$, $R = 0.051$, $R' = 0.049$.

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* It is interesting to note that in the structure determination [6] of dibromodeoxybruceol similar difficulties with partial occupancy of an aromatic substitution site were encountered.

TABLE 2

Atomic co-ordinates for (3). Fractional cell parameters $(x,y,z) \times 10^3$

Atom	x	y	z
O(1)	797(1)	007(2)	141(1)
C(2)	880(3)	−025(3)	070(3)
O(2)	878(2)	−132(2)	027(2)
C(3)	978(4)	067(3)	057(3)
H(3)	1 056(24)	062(24)	−009(28)
C(4)	969(2)	181(3)	110(3)
H(4)	1 046(22)	212(25)	100(26)
C(5)	882(2)	214(2)	182(3)
C(6)	861(2)	333(2)	236(3)
O(6)	951(2)	425(2)	232(2)
C(61)	1 091(3)	411(3)	317(3)
H(61a)	1 098(—)	402(—)	421(—)
H(61b)	1 120(—)	331(—)	284(—)
H(61c)	1 155(—)	475(—)	314(—)
C(7)	771(2)	357(3)	294(2)
C(8)	752(2)	480(3)	361(2)
Br(8)	914.8(3)	500(—)	535.4(3)
C(81)	713(3)	605(3)	252(3)
C(82)	814(3)	707(3)	310(3)
H(28a)	791(—)	781(—)	245(—)
H(82b)	901(—)	675(—)	314(—)
H(82c)	818(—)	731(—)	409(—)
C(83)	706(3)	584(3)	096(3)
H(83a)	683(—)	658(—)	031(—)
H(83b)	640(—)	518(—)	053(—)
H(83c)	793(—)	554(—)	099(—)
C(9)	638(2)	500(3)	396(2)
H(9)	642(17)	515(28)	514(21)
C(10)	593(3)	611(28)	292(3)
H(10)	613(21)	688(24)	368(25)
C(11)	464(3)	574(3)	164(3)
H(11)	489(24)	618(26)	085(26)
O(11)	360(2)	617(2)	210(2)
C(111)	325(3)	750(3)	176(3)
O(111)	397(3)	808(2)	129(3)
C(112)	226(4)	791(4)	242(4)
H(112a)	171(—)	754(—)	200(—)
H(112b)	243(—)	766(—)	348(—)
H(112c)	200(—)	880(—)	232(—)
C(12)	460(3)	433(2)	186(3)
H(12a)	366(22)	376(26)	168(25)
H(12b)	539(21)	397(24)	096(24)
C(13)	527(3)	398(3)	339(3)
C(131)	446(3)	395(3)	428(3)
H(131a)	491(—)	371(—)	532(—)
H(131b)	374(—)	333(—)	385(—)
H(131c)	407(—)	479(—)	427(—)
O(14)	590(2)	278(2)	352(2)
C(15)	685(2)	265(2)	301(3)
C(16)	700(2)	145(3)	255(3)
H(16) *	644(—)	076(—)	267(—)
Br(16) *	583.9(8)	021.0(9)	246.3(8)
C(17)	790(2)	123(2)	195(2)

* Population: H, 0.641; Br, 0.359(8).

TABLE 3

Molecular geometries (non-hydrogen atoms). Values for (1), (2), (3),* respectively

Atoms	Parameters
Distances (Å)	
O(1)–C(2)	1.37(1), 1.39(1), 1.37(4)
O(1)–C(17)	1.39(1), 1.38(1), 1.37(3)
C(2)–O(2)	1.19(1), 1.23(1), 1.22(4)
C(2)–C(3)	1.43(1), 1.43(2), 1.50(5)
C(3)–C(4)	1.36(1), 1.34(2), 1.36(4)
C(4)–C(5)	1'43(1), 1.41(2), 1.42(4)
C(5)–C(6)	1.39(1), 1.41(1), 1.44(4)
C(5)–C(17)	1.38(1), 1.39(2), 1.45(4)
C(6)–C(7)	1.37(1), 1.36(2), 1.33(4)
C(6)–O(6)	1.40(1), 1.39(1), 1.41(3)
O(6)–C(61)	1.45(1), 1.47(2), 1.49(3)
C(7)–C(8)	1.49(1), 1.48(2), 1.53(4)
C(7)–C(15)	1.42(1), 1.40(2), 1.39(4)
C(8)–C(81)	1.59(1), 1.57(1), 1.68(4)
C(8)–C(9)	1.55(1), 1.51(2), 1.42(4)
C(81)–C(10)	1.57(1), 1.60(2), 1.50(5)
C(81)–C(82)	1.52(1), 1.51(2), 1.53(4)
C(81)–C(83)	1.50(1), 1.48(2), 1.53(5)
C(9)–C(10)	1.59(1), 1.56(2), 1.53(4)
C(9)–C(13)	1.53(1), 1.55(2), 1.60(4)
C(10)–C(11)	1.50(1), 1.54(2), 1.58(3)
C(11)–C(12)	1.51(1), 1.53(2), 1.54(4)
C(11)–O(11)	1.46(1), 1.44(4)
O(11)–C(111)	1.35(1), 1.49(4)
C(12)–C(13)	1.55(1), 1.53(2), 1.47(3)
C(13)–O(14)	1.48(1), 1.48(1), 1.45(3)
C(13)–C(131)	1.49(2), 1.53(2), 1.46(5)
O(14)–C(15)	1.40(1), 1.38(1), 1.32(4)
C(15)–C(16)	1.36(1), 1.36(2), 1.40(4)
C(16)–C(17)	1.37(1), 1.37(2), 1.34(4)
Angles (°)	
C(17)–O(1)–C(2)	121.7(6), 122.4(9), 125(2)
O(1)–C(2)–O(2)	118.4(8), 115.9(10), 119(3)
O(1)–C(2)–C(3)	116.8(8), 117.2(10), 120(3)
O(2)–C(2)–C(3)	124.7(8), 126.9(11), 121(3)
C(2)–C(3)–C(4)	121.2(9), 121.4(12), 115(3)
C(3)–C(4)–C(5)	121.1(8), 119.9(12), 125(3)
C(4)–C(5)–C(6)	126.6(7), 125.4(10), 129(3)
C(4)–C(5)–C(17)	117.1(7), 120.4(10), 119(2)
C(6)–C(5)–C(17)	116.2(7), 114.1(10), 112(2)
C(5)–C(6)–O(6)	118.5(7), 116.4(9), 114(2)
C(5)–C(6)–C(7)	124.6(8), 125.4(10), 125(3)
O(6)–C(6)–C(7)	116.8(7), 118.0(9), 121(3)
C(6)–O(6)–C(61)	114.9(7), 113.3(10), 121(2)
C(6)–C(7)–C(8)	125.7(7), 122.7(10), 126(3)
C(6)–C(7)–C(15)	115.1(7), 114.7(9), 120(3)
C(8)–C(7)–C(15)	119.2(7), 122.2(10), 114(2)
C(7)–C(8)–C(81)	119.7(7), 118.9(9), 118(2)
C(7)–C(8)–C(9)	113.0(7), 115.0(10), 120(2)
C(81)–C(8)–C(9)	90.2(6), 90.4(8), 89(2)
C(8)–C(81)–C(82)	112.9(7), 112.5(9), 110(2)
C(8)–C(81)–C(83)	114.4(7), 118.5(10), 116(2)
C(8)–C(81)–C(10)	89.3(6), 89.0(8), 85(2)
C(82)–C(81)–C(83)	109.2(8), 109.7(10), 105(3)
C(82)–C(81)–C(10)	112.8(7), 110.1(9), 118(3)
C(83)–C(81)–C(10)	117.2(7), 115.7(10), 122(2)
C(8)–C(9)–C(10)	90.4(7), 93.2(9), 94(2)
C(8)–C(9)–C(13)	118.3(8), 117.3(9), 116(3)
C(10)–C(9)–C(13)	104.2(7), 106.2(9), 106(2)
C(9)–C(10)–C(81)	89.7(7), 87.4(8), 92(2)
C(9)–C(10)–C(11)	106.9(7), 105.8(9), 109(2)
C(81)–C(10)–C(11)	122.7(7), 117.1(10), 114(2)
C(10)–C(11)–C(12)	107.0(8), 107.1(10), 101(2)
C(10)–C(11)–O(11)	111.8(7), 105(2)
C(12)–C(11)–O(11)	106.7(7), 102(2)
C(11)–O(11)–C(111)	117.2(6), 114(2)
O(11)–C(111)–O(111)	120.6(8), 115(3)
O(11)–C(111)–C(112)	113.3(8), 111(3)
O(111)–C(111)–C(112)	126.0(9), 132(3)
C(11)–C(12)–C(13)	104.3(7), 103.7(11), 112(2)
C(12)–C(13)–C(9)	104.3(7), 105.9(10), 103(2)
C(12)–C(13)–O(14)	102.3(7), 109.0(9), 112(2)
C(9)–C(13)–O(14)	110.2(7), 111.0(9), 107(2)
C(13)–O(14)–C(15)	116.6(6), 117.5(8), 119(2)
O(14)–C(15)–C(7)	117.9(7), 121.1(9), 125(2)
O(14)–C(15)–C(16)	119.2(7), 114.4(10), 115(2)
C(7)–C(15)–C(16)	122.9(8), 124.4(11), 120(3)
C(15)–C(16)–C(17)	118.1(8), 117.3(11), 119(3)
C(16)–C(17)–O(1)	115.3(7), 117.8(10), 119(2)
C(16)–C(17)–C(5)	123.1(8), 123.8(10), 124(3)
O(1)–C(17)–C(5)	121.6(7), 118.3(10), 117(2)

* (3) only: Br(8)–C(8), 2.02(2); Br(16)–C(16), 1.82(3) Å; Br(8)–C(8)–C(7,81,9), 104(1), 114(2), 112(2)°; Br(16)–C(16)–C(15,17), 122(2), 117(2)°.

(3), $C_{22}H_{22.64}Br_{1.36}O_6$ (as established by the structure analysis), $M = 491.7$, monoclinic, space group $P2_1$ (C_2^2, No. 4), $a = 10.990(9)$, $b = 10.779(9)$, $c = 9.852(8)$ Å, $\beta = 110.40(6)°$, $U = 1\,094(1)$ Å^3. $D_m = 1.49(1)$ g cm^{-3}, $D_c = 1.49$ g cm^{-3}, $Z = 2$. $F(000) = 540.5$. $\mu_{Mo} = 25.3$ cm^{-1}. $2\theta_{max.} = 40°$. $N = 1\,076$, $N_o = 923$, $R = 0.068$, $R' = 0.078$.

DISCUSSION

In all three structure determinations, the space group is non-centrosymmetric, with one molecule of the compound in question comprising the asymmetric unit of the structure. Because of the limited data accessible throughout and the non-stoicheiometry of (3), the bond lengths are relatively imprecise; such features of interest as are to be found primarily concern the angular and conformational geometry and we now discuss these in detail.

Within the fused coumarin ring system, geometry is normal, the most prominent feature being the angular asymmetry about C(2) commonly observed in coumarin studies and presumed to be consequent of the interaction of O(2) with the hydrogen (or other substituent) at C(3).

TABLE 4

Least-squares planes defined by the conjugated fragments, in the form $pX + qY + rZ = s$. The Å frame (R.H.) is defined by $X = ax$, $Y = by$, $Z = cz$. Atom deviations, δ, are in Å; σ is the e.s.d. of the defining atoms (Å)

	(1)	(2)	(3) *
10^4p	−5 400	6 402	3 443
10^4q	−3 959	3 106	−2 822
10^4r	7 428	7 026	8 954
s	1 722	4 872	3 934
σ	0.04	0.06	0.04
δ (defining atoms)			
O(1)	−0.07	0.03	0.06
C(2)	0.02	0.01	−0.03
O(2)	0.06	0.08	−0.02
C(3)	0.02	−0.10	−0.03
C(4)	0.03	−0.09	−0.04
C(5)	−0.04	0.01	0.04
C(6)	−0.04	0.04	−0.02
O(6)	0.00	0.10	0.01
C(7)	0.01	−0.05	−0.02
C(8)	0.03	0.01	0.01
O(14)	0.04	0.00	−0.05
C(15)	0.02	−0.04	−0.01
C(16)	−0.02	−0.01	0.08
C(17)	−0.04	0.01	0.06
δ (other atoms)			
C(9)	0.79	−0.12	−0.23
C(81)	−1.28	−1.22	−1.29
C(82)	−1.73	−0.84	−0.81
C(83)	−2.44	−2.41	−2.36
C(10)	−0.47	−1.36	−1.48
C(11)	−0.77	−2.52	−2.76
O(11)	−0.92		−2.96
C(12)	0.41	−2.11	−2.19
C(13)	0.98	−0.59	−0.75
C(61)	−1.28	1.45	1.19

* (3) only: δ Br (8,16), 1.80, −0.04 Å.

The methoxy-methyl group C(61) is interesting in that it lies well out of the plane of the ring system; given the absence of large nearby substituent, it is usual to find aromatic methoxy-substituents lying coplanar with the ring system but with angular asymmetry at the point of attachment. In the present case, the environment of C(6) is presumably somewhat crowded, not only by the bulk of the methyl hydrogens associated with C(82,83) but also by '*peri*'-interactions with H(4) and H(8).

TABLE 5

Torsion angles within the fused alicyclic portion of the skeleton are given for (1), (2), (3), respectively

Atoms	Angles (°)
C(14)–C(15)–C(7)–C(8)	0.8, 1.7, 3.9
C(15)–C(7)–C(8)–C(9)	30.5, −8.9, −12.7
C(15)–C(7)–C(8)–C(81)	−73.8, −114.4, −118.9
C(8)–C(81)–C(10)–C(9)	−4.4, 0.3, 2.8
C(8)–C(81)–C(10)–C(11)	−114.4, −106.1, −109.5
C(10)–C(81)–C(8)–C(7)	121.3, 118.8, 120.6
C(10)–C(81)–C(8)–C(9)	4.5, −0.4, −3.0
C(7)–C(8)–C(9)–C(10)	−127.1, −122.1, −118.8
C(7)–C(8)–C(9)–C(13)	−20.7, −12.1, −9.5
C(81)–C(8)–C(9)–C(10)	−4.4, 0.4, 2.9
C(81)–C(8)–C(9)–C(13)	102.0, 110.4, 112.2
C(8)–C(9)–C(10)–C(81)	4.5, −0.4. −3.3
C(8)–C(9)–C(10)–C(11)	128.8, 117.1, 112.7
C(13)–C(9)–C(10)–C(81)	−114.8, −120.0, −121.6
C(13)–C(9)–C(10)–C(11)	9.4, −2.5, −5.5
C(9)–C(10)–C(11)–C(12)	13.7, −18.2, −11.8
C(81)–C(10)–C(11)–C(12)	114.6, 77.1, 89.5
C(10)–C(11)–C(12)–C(13)	−31.4, 31.9, 27.5
C(11)–C(12)–C(13)–C(9)	37.1, −33.2, −31.3
C(11)–C(12)–C(13)–O(14)	−77.7, −152.7, −146.4
C(8)–C(9)–C(13)–C(12)	−126.4, −80.1, −80.5
C(8)–C(9)–C(13)–O(14)	−17.3, 38.1, 37.9
C(10)–C(9)–C(13)–C(12)	−28.1, 22.3, 21.7
C(10)–C(9)–C(13)–O(14)	81.0, 140.4, 140.0
C(9)–C(13)–O(14)–C(15)	51.5, −46.4, −49.1
C(12)–C(13)–O(14)–C(15)	162.0, 69.9, 63.5
C(13)–O(14)–C(15)–C(7)	−45.0, 28.0, 30.4

The observation of contacts from H(4) to the 61-methyl hydrogen atoms of 2.4(1), (1); 2.5(2), (2); and 2.1(2) Å, (3), lends support to this view; H(8) interactions are also relevant and discussed below.

Within the four-membered ring, bond lengths with one exception lie between 1.55 and 1.60 Å in (1) and (2), and angular geometry between 89 and 91° with the exception of $\mathrm{C(8)–\hat{C}(9)–C(10)}$ [93.2(9)] and $\mathrm{C(9)–\hat{C}(10)–C(81)}$ [87.4(8)°] in (2). Atom deviations from a least squares plane through the four-membered ring are ±0.03 (1) and ±0.00 Å (2). The dihedral angles between the four-membered ring plane and the coumarin plane (Table 4) are 71.8, (1); 52.7, (2); 53.6°, (3). While the above variation in the geometrical parameters of the four-membered ring may or may not be real and reflective of variation in ring strain, it is clear from the parameters quoted in Tables 4 and 5 and the molecular figures that the above variations in interplanar dihedral angles reflect genuine conformational changes. In all three molecules, the atoms C(9) and C(13) lie to the same side of the coumarin plane, but in (1), the deviations of these atoms are 0.79 and 0.98 Å, differing considerably from those of (2) (0.12, 0.59) and (3) (0.23, 0.75 Å) which are more nearly equal. Torsion angles C(15)–C(7)–C(8)–C(9) in the three compounds are 30.5, −8.9, and −12.7°, respectively, and, more generally around the dihydropyran ring, we find the torsion angles confirming the similarity of conformation of (2) and (3) and the difference of (1). Within the five-membered ring, we find the

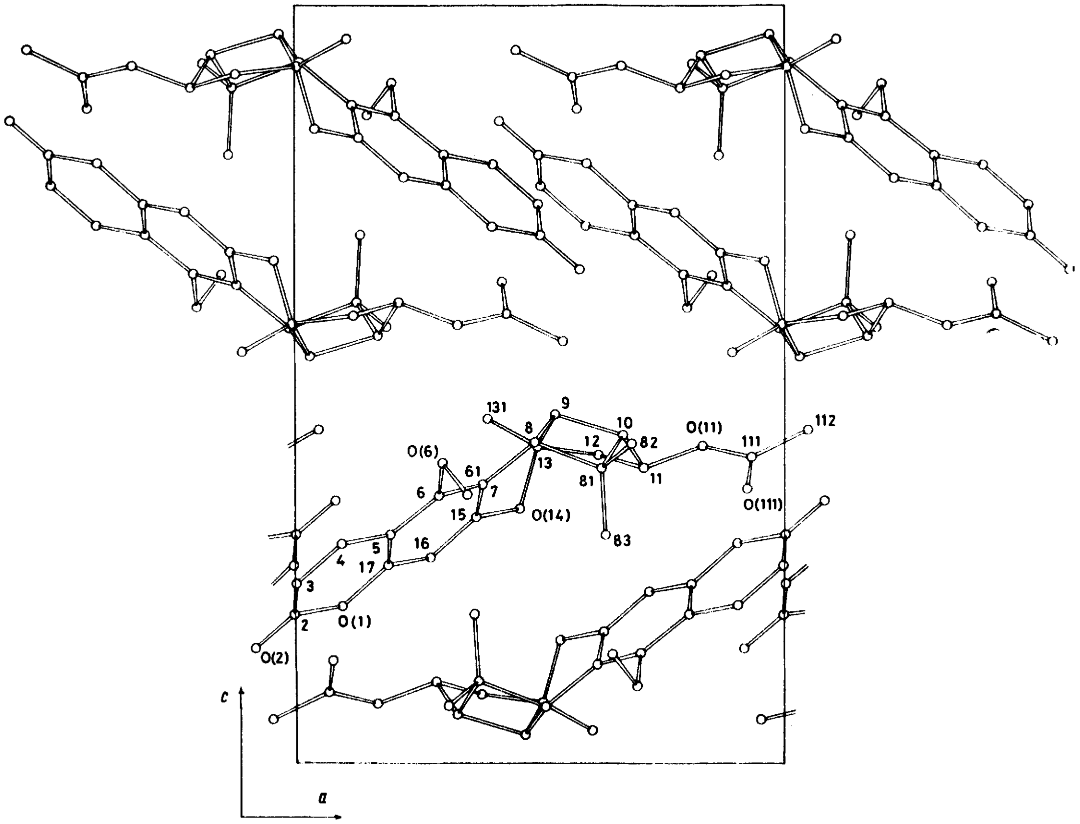

FIGURE 1 Unit-cell contents of (1) projected down *b*

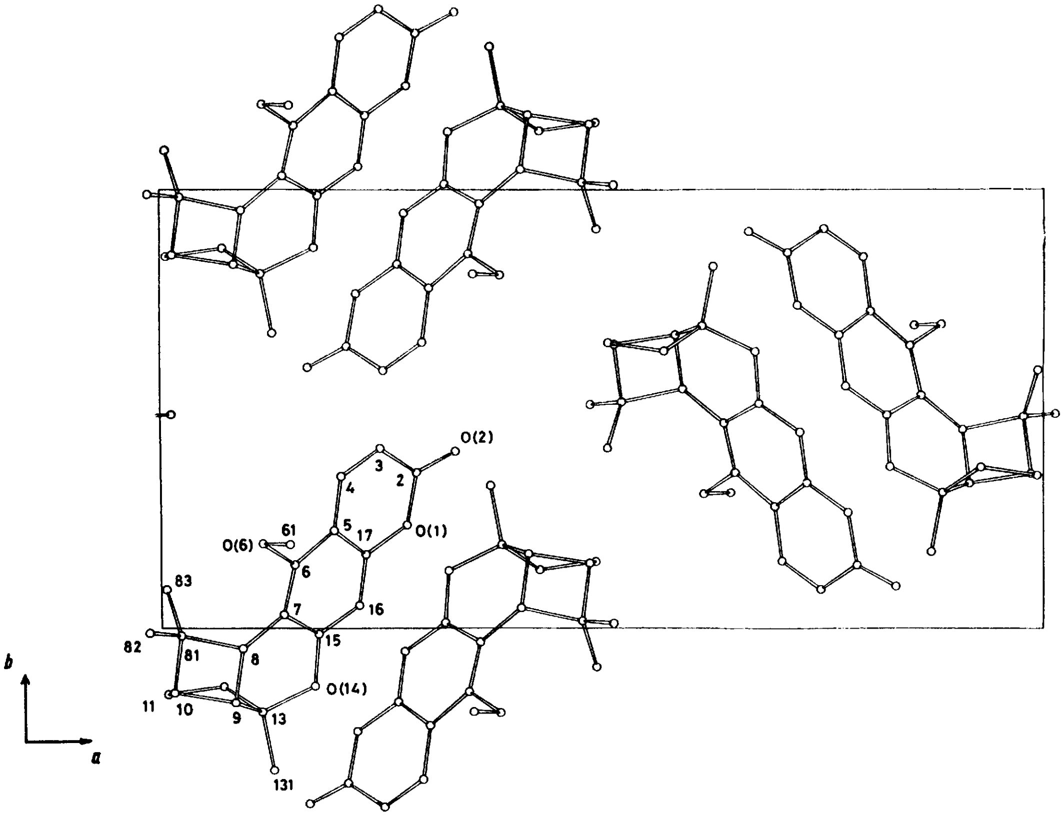

FIGURE 2 Unit-cell contents of (2) projected down *c*

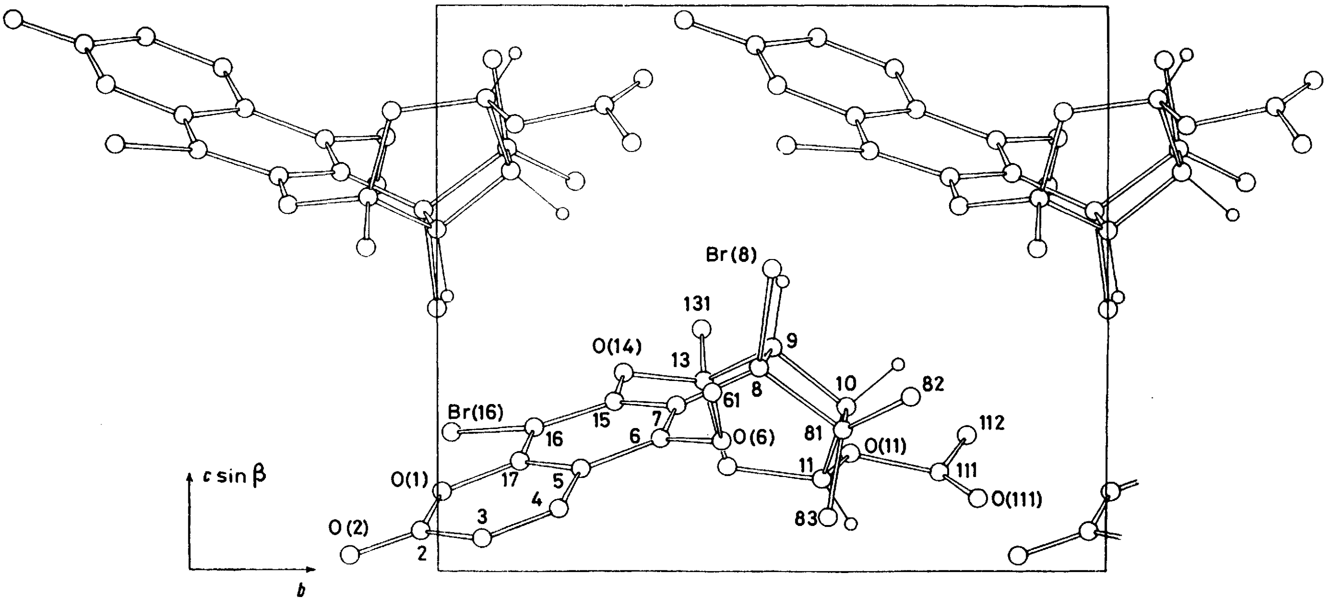

FIGURE 3 Unit-cell contents of (3) projected down *a*

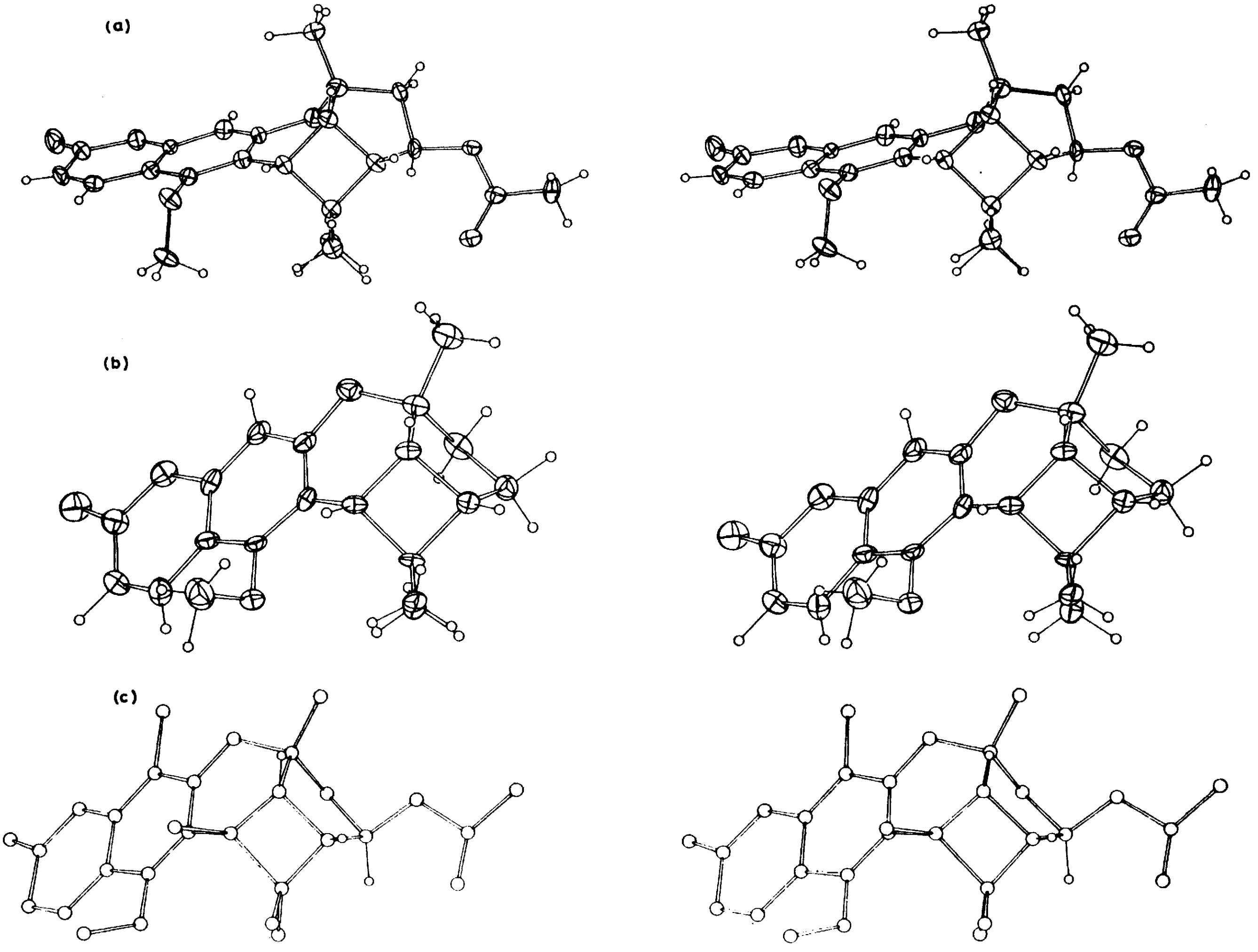

FIGURE 4 (a)—(c) Stereoscopic projections of the molecules of (1)—(3). Thermal ellipsoids shown for (1) and (2) are at the 20% probability level; hydrogen atoms have an arbitrary radius of 0.1 Å conformation to be controlled by the pseudo-coplanar constraint imposed on the C(13)–C(9)–C(10)–C(11) system by the cyclobutane ring; C(12) may deviate from these in either direction to adopt a pseudo-envelope conformation and in fact does so (Table 5), (1) differing in this respect from (2) and (3) which are similar.

It thus seems from the above and the Figures that, in spite of certain similarities, the conformation of the dihydropyran ring in (2) and (3) can be described as ' half-chair ', while that of (1) is ' half-boat ', and that coupled with these changes in conformation, changes in disposition, and conformation of the four- and five-membered rings are also found. This parallels the situation found for these compounds in solution [1] in which studies of the n.m.r. spectra were indicative that in (1) the dihydropyran ring adopted a half-boat conformation while (3) adopted a half-chair. This was rationalized in terms of interaction between H(8) and O(6) which lie almost coplanar in (1); in (3) in which H(8) is replaced by Br(8), this interaction is exacerbated and Br(8), in adopting a position well out of the ring plane causes inversion of the ring, Br(8) · · · O(6) being 3.26(2) Å. If this is so, then clearly the correspondence of conformations in (2) and (3) requires explanation. In the absence of a substituent on the cyclopentane ring, the '*peri*'-interaction between H(8) and O(6) appears to control the overall stereochemistry, despite a contact between the hydrogens of C(11) and methyl 131 which is 2.5(1) Å. However, when an oxygen substituent is introduced as in (1), the O(11)–methyl 131 contact becomes the determinant, causing the cyclopentane ring to adopt the alternative conformation inverting the dihydropyran ring in the process. The overall molecular conformation may thus be controlled by variation in substituent(s) at C(8) and/or C(11).

In a previous experiment, application of the Horeau method to hydroxyeriobrucinol methyl ether had given a very low optical yield which tentatively suggested that the absolute configuration was opposite to that presented here from *X*-ray evidence. In interpreting the results it was assumed that the larger of the two groups flanking the carbon carrying the secondary hydroxy was the one containing C(10). It now appears from the *X*-ray structure that the C(11) oxygen is sterically hindered by the C(13) methyl group and thus essentially making the C(12) substituent much bulkier than predicted. A number of similar cases have been documented recently [7] and consequently the original results [1] must be regarded as inconclusive.

We gratefully acknowledge a grant from the Australian Research Grants Committee in support of this work.

[0/1086 *Received*, 9*th July*, 1980]

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