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Structure of the Steroid Sapogenin: Spirosta-5,25(27)-diene-1β,3β,11α-triol Monohydrate

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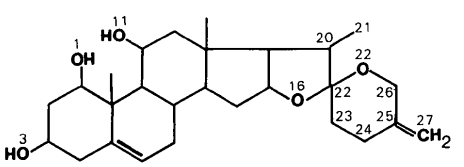
Abstract. $C_{27}H_{40}O_5.H_2O$, $M_r = 462{\cdot}63$, monoclinic, $P2_1$ (C_2^2), $a = 10{\cdot}085$ (4), $b = 7{\cdot}854$ (2), $c = 31{\cdot}956$ (15) Å, $\beta = 93{\cdot}11$ (3)°, $V = 2527$ (3) Å^3, $Z = 4$, $D_m = 1{\cdot}22$, $D_x = 1{\cdot}216$ Mg m^{-3}, λ(Cu $K\bar{\alpha}$) = 1·54184 Å, $\mu = 0{\cdot}64$ mm^{-1}, $F(000) = 1008$, $T = 295$ (2) K, $R = 0{\cdot}038$ for 4262 unique observed reflections. The conformation of the symmetry-independent sapogenin molecules differs in some details. The main difference is shown by the flexible Δ^5 ring *B*. It assumes the sofa conformation in molecule (I) while in molecule (II) it exhibits the 8β–9α half-chair shape. The symmetry-independent sapogenin molecules (conformers) together with the water units are linked by eight hydrogen bonds forming two-dimensional networks parallel with the *ab* plane and separated by *c*/2.

Introduction. The title compound was isolated from the subterranean organs of the plant *Helleborus serbicus* Adam 1906 (Ranunculaceae), after autofermentation by column chromatography using silica gel. The crystals reached a melt at 519–522 K. The chemical structure (1) inferred from chemical reactions and spectroscopic data was substantiated by X-ray diffraction.



(1)

Experimental. Colourless crystal *ca* 0·2 × 0·2 × 0·4 mm. Density measured by flotation. Philips PW 1100 diffractometer, graphite-monochromated Cu $K\alpha$ radiation. $0{\cdot}017 \le \sin\theta/\lambda \le 0{\cdot}609$ Å^{-1}, ω–2θ scan, h −12 to 12, k 0 to 9, l 0 to 37. Cell parameters by least-squares fit for 14 centred reflections. Systematic absences: $k = 2n + 1$ in $0k0$. Of 4401 unique reflections, 4262 taken as observed with $I > 3{\cdot}0\sigma(I)$, 139 unobserved reflections. No absorption correction performed. Three standard reflections, intensity variation <2%. Structure solved by *MULTAN*78 (Main, Hull, Lessinger, Germain, Declercq & Woolfson, 1978) using 450 reflections with $E > 1{\cdot}50$ and successive structure factor, Fourier and difference Fourier calculations. Block-diagonal and full-matrix refinement. $\sum w(\Delta F)^2$ minimized for 66 heavy atoms (33 in each block). Final $R = 0{\cdot}038$, $wR = 0{\cdot}045$, $S = 0{\cdot}81$, $w = [\sigma^2(F_o) + 0{\cdot}25 \times 10^{-4} (F_o)^2]^{-1}$. Extinction coefficient $4{\cdot}15 \times 10^{-6}$. Max. peak height in final $\Delta\rho$ map 0·14 e Å^{-3}. Positions of H atoms generated from assumed geometries at $R = 0{\cdot}15$, remaining H atoms bound to O atoms and C(27) found in a difference Fourier map at $R = 0{\cdot}05$: treated isotropically in final stage of refinement. Max. Δ/σ for H atoms 1·18. Scattering factors from *International Tables for X-ray Crystallography* (1962). Program system applied: Enraf–Nonius (1982) *SDP* with local modifications adapted to a PDP 11/34 minicomputer (64 K).

Discussion. Atomic coordinates of non-H atoms are in Table 1.* The molecular geometry with standard atomic numbering for both symmetry-independent molecules (I) and (II) is shown in Fig. 1. The bond lengths and angles for non-H atoms are listed in Table 2.

* Lists of structure factors, anisotropic thermal parameters, H-atom coordinates, distances involving H and torsion angles have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 42375 (32 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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Table 1. *Final fractional atomic coordinates for non-*H *atoms and equivalent isotropic temperature parameters (with e.s.d.'s in parentheses)*

$B_{eq} = \frac{4}{3}$ trace (B*$\mathbf{G}$) where $\mathbf{G}$ is the direct metric tensor.

	x	y	z	B_{eq}(Å^2)		x	y	z	B_{eq}(Å^2)
(*a*) Molecule (I)					(*b*) Molecule (II)				
C(1)	1·1228 (4)	0·2853	0·3980 (1)	3·3 (1)	C(1′)	0·6666 (3)	−0·0531 (4)	0·4018 (1)	3·1 (1)
C(2)	1·1006 (4)	0·3632 (5)	0·4402 (1)	3·7 (1)	C(2′)	0·6326 (3)	0·0082 (5)	0·4452 (1)	3·5 (1)
C(3)	1·1292 (4)	0·5523 (5)	0·4421 (1)	3·3 (1)	C(3′)	0·6136 (3)	0·1976 (4)	0·4465 (1)	3·3 (1)
C(4)	1·0561 (4)	0·6428 (5)	0·4057 (1)	3·3 (1)	C(4′)	0·5043 (3)	0·2481 (5)	0·4145 (1)	3·9 (1)
C(5)	1·0859 (3)	0·5577 (4)	0·3651 (1)	2·7 (1)	C(5′)	0·5340 (3)	0·1914 (4)	0·3712 (1)	3·1 (1)
C(6)	1·1573 (4)	0·6404 (5)	0·3378 (1)	3·4 (1)	C(6′)	0·5282 (3)	0·3038 (5)	0·3403 (1)	3·8 (1)
C(7)	1·1915 (4)	0·5684 (5)	0·2968 (1)	3·8 (1)	C(7′)	0·5476 (3)	0·2652 (5)	0·2954 (1)	3·8 (1)
C(8)	1·0954 (3)	0·4285 (5)	0·2827 (1)	3·0 (1)	C(8′)	0·5418 (3)	0·0743 (4)	0·2867 (1)	3·0 (1)
C(9)	1·0856 (3)	0·2903 (5)	0·3174 (1)	2·6 (1)	C(9′)	0·6293 (3)	−0·0180 (4)	0·3210 (1)	2·8 (1)
C(10)	1·0441 (3)	0·3701 (5)	0·3604 (1)	2·5 (1)	C(10′)	0·5675 (3)	0·0013 (4)	0·3651 (1)	2·8 (1)
C(11)	0·9951 (3)	0·1429 (5)	0·3000 (1)	2·8 (1)	C(11′)	0·6697 (3)	−0·2013 (4)	0·3092 (1)	3·0 (1)
C(12)	1·0359 (4)	0·0733 (5)	0·2579 (1)	3·2 (1)	C(12′)	0·6979 (3)	−0·2316 (5)	0·2632 (1)	3·4 (1)
C(13)	1·0392 (3)	0·2116 (5)	0·2245 (1)	3·0 (1)	C(13′)	0·5930 (3)	−0·1554 (4)	0·2327 (1)	3·1 (1)
C(14)	1·1360 (3)	0·3476 (5)	0·2421 (1)	3·3 (1)	C(14′)	0·5865 (3)	0·0354 (4)	0·2431 (1)	3·1 (1)
C(15)	1·1581 (4)	0·4598 (6)	0·2038 (1)	4·5 (1)	C(15′)	0·5079 (4)	0·1130 (5)	0·2055 (1)	4·2 (1)
C(16)	1·1634 (4)	0·3316 (6)	0·1685 (1)	4·2 (1)	C(16′)	0·5625 (4)	0·0141 (5)	0·1687 (1)	4·1 (1)
C(17)	1·1061 (4)	0·1598 (6)	0·1838 (1)	3·7 (1)	C(17′)	0·6311 (3)	−0·1472 (5)	0·1863 (1)	3·9 (1)
C(18)	0·8996 (3)	0·2847 (6)	0·2144 (1)	3·5 (1)	C(18′)	0·4587 (3)	−0·2444 (5)	0·2375 (1)	4·1 (1)
C(19)	0·8916 (3)	0·3551 (5)	0·3645 (1)	3·3 (1)	C(19′)	0·4369 (3)	−0·1012 (5)	0·3671 (1)	3·9 (1)
C(20)	1·0205 (4)	0·0947 (6)	0·1459 (1)	4·3 (1)	C(20′)	0·5845 (4)	−0·2886 (6)	0·1554 (1)	5·1 (1)
C(21)	1·0469 (6)	−0·0918 (6)	0·1348 (2)	6·7 (2)	C(21′)	0·6934 (5)	−0·4071 (8)	0·1414 (2)	9·2 (2)
C(22)	1·0447 (4)	0·2246 (6)	0·1113 (1)	4·2 (1)	C(22′)	0·5111 (4)	−0·1909 (5)	0·1200 (1)	4·4 (1)
C(23)	0·9277 (5)	0·2610 (8)	0·0812 (1)	5·8 (2)	C(23′)	0·3998 (4)	−0·2858 (6)	0·0967 (1)	5·2 (1)
C(24)	0·9655 (6)	0·3907 (9)	0·0477 (2)	7·5 (2)	C(24′)	0·3389 (4)	−0·1856 (6)	0·0599 (1)	5·9 (1)
C(25)	1·0861 (6)	0·3318 (6)	0·0271 (1)	6·7 (2)	C(25′)	0·4433 (5)	−0·1102 (6)	0·0338 (1)	6·0 (1)
C(26)	1·1959 (5)	0·2832 (8)	0·0577 (1)	5·9 (2)	C(26′)	0·5539 (5)	−0·0271 (6)	0·0590 (1)	6·3 (2)
C(27)	1·0942 (6)	0·3270 (10)	−0·0137 (2)	9·5 (3)	C(27′)	0·4373 (6)	−0·1116 (9)	−0·0072 (1)	8·5 (2)
O(1)	1·0927 (3)	0·1061 (4)	0·3991 (1)	5·2 (1)	O(1′)	0·6774 (2)	−0·2347 (3)	0·4054 (1)	4·0 (1)
O(3)	1·0906 (3)	0·6145 (4)	0·4821 (1)	3·9 (1)	O(3′)	0·5832 (2)	0·2478 (3)	0·4881 (1)	4·0 (1)
O(11)	0·9902 (3)	−0·0012 (3)	0·3274 (1)	3·5 (1)	O(11′)	0·7870 (2)	−0·2559 (3)	0·3338 (1)	3·6 (1)
O(16)	1·0808 (3)	0·3771 (4)	0·1327 (1)	4·4 (1)	O(16′)	0·4588 (2)	−0·0449 (4)	0·1399 (1)	4·3 (1)
O(22)	1·1531 (3)	0·1653 (4)	0·0889 (1)	5·0 (1)	O(22′)	0·6076 (3)	−0·1367 (4)	0·0916 (1)	5·4 (1)
O(*W*)	1·1246 (3)	−0·0298 (4)	0·4799 (1)	3·9 (1)	O(*W*′)	0·6395 (2)	−0·4057 (3)	0·4808 (1)	4·2 (1)

Table 2. *Bond lengths* (Å) *and angles* (°) *with e.s.d.'s in parentheses for molecules* (I) *and* (II)

	(I)	(II)		(I)	(II)		(I)	(II)
C(1)–C(2)	1·509 (4)	1·525 (5)	C(9)–C(10)	1·587 (5)	1·579 (4)	C(16)–O(16)	1·424 (5)	1·432 (4)
C(1)–C(10)	1·554 (4)	1·559 (4)	C(9)–C(11)	1·558 (5)	1·548 (4)	C(17)–C(20)	1·536 (5)	1·542 (5)
C(1)–O(1)	1·441 (3)	1·435 (4)	C(10)–C(19)	1·555 (4)	1·548 (4)	C(20)–C(21)	1·534 (7)	1·525 (7)
C(2)–C(3)	1·514 (6)	1·501 (5)	C(11)–C(12)	1·529 (5)	1·531 (5)	C(20)–C(22)	1·534 (6)	1·525 (5)
C(3)–C(4)	1·519 (5)	1·515 (4)	C(11)–O(11)	1·433 (5)	1·449 (4)	C(22)–C(23)	1·509 (6)	1·510 (6)
C(3)–O(3)	1·442 (5)	1·436 (4)	C(12)–C(13)	1·524 (5)	1·522 (4)	C(22)–O(16)	1·417 (5)	1·426 (5)
C(4)–C(5)	1·504 (5)	1·499 (5)	C(13)–C(14)	1·533 (5)	1·537 (4)	C(22)–O(22)	1·418 (5)	1·431 (5)
C(5)–C(6)	1·330 (5)	1·323 (5)	C(13)–C(17)	1·552 (5)	1·553 (4)	C(23)–C(24)	1·541 (8)	1·517 (5)
C(5)–C(10)	1·538 (5)	1·545 (4)	C(13)–C(18)	1·538 (4)	1·539 (4)	C(24)–C(25)	1·488 (8)	1·500 (6)
C(6)–C(7)	1·485 (5)	1·490 (5)	C(14)–C(15)	1·534 (5)	1·530 (5)	C(25)–C(26)	1·487 (7)	1·490 (6)
C(7)–C(8)	1·517 (5)	1·525 (5)	C(15)–C(16)	1·515 (6)	1·536 (5)	C(26)–O(22)	1·444 (6)	1·435 (5)
C(8)–C(9)	1·559 (5)	1·549 (4)	C(16)–C(17)	1·557 (6)	1·535 (5)	C(25)–C(27)	1·311 (7)	1·308 (5)
C(8)–C(14)	1·521 (5)	1·519 (4)						
C(2)–C(1)–C(10)	115·0 (5)	115·5 (4)	C(1)–C(10)–C(19)	111·6 (5)	109·8 (4)	C(13)–C(17)–C(16)	102·8 (5)	104·7 (5)
C(2)–C(1)–O(1)	109·4 (5)	105·1 (4)	C(5)–C(10)–C(9)	112·3 (5)	107·8 (4)	C(13)–C(17)–C(20)	119·8 (6)	119·9 (5)
C(10)–C(1)–O(1)	109·8 (4)	112·1 (4)	C(5)–C(10)–C(19)	109·4 (5)	107·8 (4)	C(16)–C(17)–C(20)	104·1 (5)	104·1 (5)
C(1)–C(2)–C(3)	113·4 (5)	111·9 (5)	C(9)–C(10)–C(19)	110·6 (5)	111·4 (4)	C(17)–C(20)–C(21)	113·8 (6)	115·3 (6)
C(2)–C(3)–C(4)	110·2 (5)	109·3 (5)	C(9)–C(11)–C(12)	113·5 (5)	116·3 (4)	C(17)–C(20)–C(22)	104·0 (5)	103·4 (5)
C(2)–C(3)–O(3)	107·9 (5)	109·4 (4)	C(9)–C(11)–O(11)	114·1 (5)	111·2 (4)	C(21)–C(20)–C(22)	115·6 (6)	114·7 (6)
C(4)–C(3)–O(3)	112·2 (5)	111·7 (4)	C(12)–C(11)–O(11)	106·0 (5)	106·6 (4)	C(20)–C(22)–C(23)	115·9 (6)	115·8 (5)
C(3)–C(4)–C(5)	109·9 (5)	111·8 (5)	C(11)–C(12)–C(13)	112·2 (5)	113·3 (5)	C(20)–C(22)–O(16)	105·1 (5)	104·5 (5)
C(4)–C(5)–C(6)	119·3 (5)	119·2 (5)	C(12)–C(13)–C(14)	106·1 (5)	106·3 (4)	C(20)–C(22)–O(22)	107·6 (5)	107·5 (5)
C(4)–C(5)–C(10)	116·3 (5)	117·3 (5)	C(12)–C(13)–C(17)	115·3 (5)	115·4 (5)	C(23)–C(22)–O(16)	108·6 (6)	109·5 (5)
C(6)–C(5)–C(10)	124·0 (5)	123·5 (5)	C(12)–C(13)–C(18)	111·0 (5)	110·0 (4)	C(23)–C(22)–O(22)	109·8 (6)	110·3 (5)
C(5)–C(6)–C(7)	123·6 (6)	125·5 (5)	C(14)–C(13)–C(17)	101·1 (5)	100·5 (4)	O(16)–C(22)–O(22)	109·7 (5)	108·9 (5)
C(6)–C(7)–C(8)	111·3 (5)	111·7 (5)	C(14)–C(13)–C(18)	112·0 (5)	111·9 (4)	C(22)–C(23)–C(24)	110·7 (7)	112·7 (6)
C(7)–C(8)–C(9)	110·9 (5)	108·4 (4)	C(17)–C(13)–C(18)	110·9 (5)	112·2 (4)	C(23)–C(24)–C(25)	109·9 (8)	111·7 (6)
C(7)–C(8)–C(14)	111·0 (5)	110·8 (4)	C(8)–C(14)–C(13)	114·1 (5)	114·4 (4)	C(24)–C(25)–C(26)	112·7 (8)	113·6 (6)
C(9)–C(8)–C(14)	110·3 (5)	111·6 (4)	C(8)–C(14)–C(15)	119·9 (5)	118·3 (5)	C(24)–C(25)–C(27)	123·1 (9)	123·9 (7)
C(8)–C(9)–C(10)	111·8 (5)	110·4 (4)	C(13)–C(14)–C(15)	103·0 (5)	104·2 (4)	C(26)–C(25)–C(27)	124·2 (9)	122·5 (8)
C(8)–C(9)–C(11)	108·8 (5)	114·2 (4)	C(14)–C(15)–C(16)	103·0 (5)	102·0 (5)	C(25)–C(26)–O(22)	112·3 (7)	111·8 (6)
C(10)–C(9)–C(11)	115·2 (5)	115·4 (4)	C(15)–C(16)–C(17)	108·3 (6)	108·1 (5)	C(16)–O(16)–C(22)	107·4 (5)	105·8 (5)
C(1)–C(10)–C(5)	102·1 (4)	107·8 (4)	C(15)–C(16)–O(16)	112·9 (6)	112·1 (5)	C(22)–O(22)–C(26)	113·9 (6)	113·3 (5)
C(1)–C(10)–C(9)	110·7 (4)	112·2 (4)	C(17)–C(16)–O(16)	105·0 (5)	105·5 (5)			

The conformation of the symmetry-independent sapogenin molecules differs in some details. In both molecules (I) and (II) rings *A* and *C* have normal chair conformations, while ring *D* assumes a half-chair shape with a pseudo C_2 symmetry axis bisecting C(13)–C(14). However, the conformation of the flexible Δ^5 *B* ring differs, with that of molecule (I) possessing a sofa (envelope) form {puckering parameters of Cremer & Pople (1975): $Q = 0{\cdot}498\ (4)$ Å, $\varphi = 184{\cdot}8\ (5)$, $\theta = 58{\cdot}4\ (5)°$, with a lowest asymmetry factor (Kálmán, Czugler & Simon, 1982) $fC_s[C(5)] = 0{\cdot}029\ (4)$ Å} while that in molecule (II) assumes an 8*β*–9*α* half-chair form {$Q = 0{\cdot}539\ (4)$ Å, $\varphi = 212{\cdot}6\ (5)$, $\theta = 51{\cdot}1\ (4)°$, $fC_2[C(5)–C(6)] = 0{\cdot}016\ (4)$ Å}. Ring *E* fused with a *cis*-junction to ring *D* in molecule (I) exhibits a transitional form between half-chair and envelope {$Q = 0{\cdot}346\ (5)$ Å, $\varphi = 352{\cdot}5\ (8)°$ with $fC_s[O(16)] = 0{\cdot}045\ (4)$, $fC_2[C(17)] = 0{\cdot}049\ (4)$ Å} whilst in molecule (II) it is a half chair {$Q = 0{\cdot}376\ (5)$ Å, $\varphi = 347{\cdot}6\ (7)°$, $fC_2[C(17)] = 0{\cdot}028\ (4)$ Å} with a twofold symmetry axis bisecting C(17). The molecules of each conformer are arranged around a twofold screw axis with their *A* rings bearing two OH groups. The crystal water molecules develop hydrogen bonds between these screw-axis-related hydroxy groups. Each screw axis collects around itself the same conformers linked by three hydrogen bonds *via* the water molecules [*a,b,c* for molecule (I) and *d,e,f* for molecule (II)]. The symmetry-independent molecular helices separated by *a*/2 are crosslinked by hydrogen bonds (*g*) formed between O(11) and O(11′) atoms. The difference-map analysis suggests that O(11′) is the donor in these hydrogen bonds. The symmetry-independent water molecules are also linked directly (*h*) and in this linkage O(*W*) seems to act as donor. Thus two-dimensional hydrogen-bond networks are formed parallel with the *ab* plane separated by *c*/2. The intramolecular O(11)···O(1) and O(1′)···O(11′) hydrogen bonds are also drawn (*i,j*) in Fig. 2.

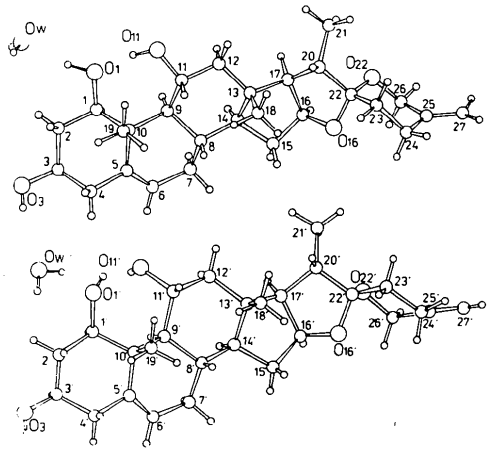

Fig. 1. Perspective view of conformers (I) (top) and (II) with atomic numbering. Numbers are for C unless indicated otherwise. The H atoms are shown but not labelled.

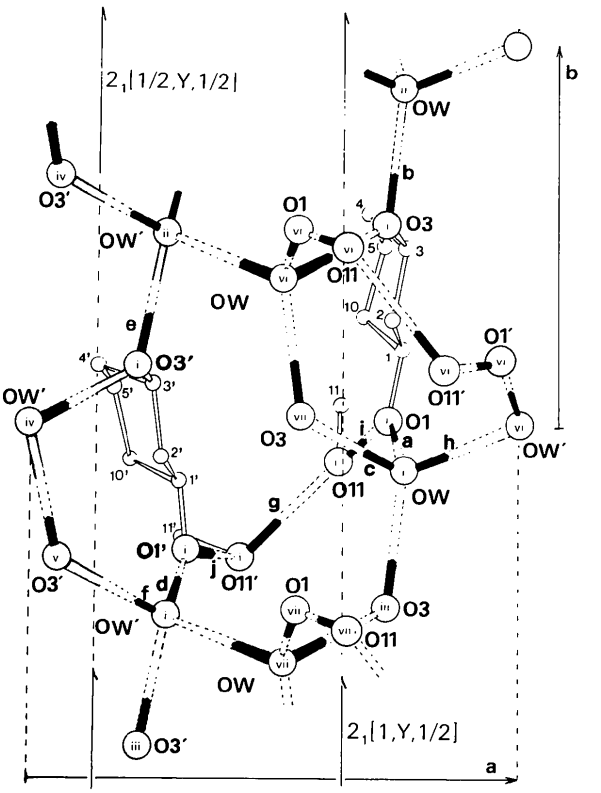

Fig. 2. Inter- and intramolecular hydrogen-bond system. The steroid molecules are represented only by their *A* rings. Hydrogen-bond parameters (Å and °):

	O···O	H···O	∠OH···O
(*a*) O(1)–H(O1)···O(*W*^{i})	2·796 (5)	1·84 (3)	170 (2)
(*b*) O(3)–H(O3)···O(*W*^{ii})	2·816 (5)	2·02 (5)	175 (4)
(*c*) O(*W*)–H(*WA*)···O(3^{vii})	2·785 (5)	2·12 (2)	170 (4)
(*d*) O(*W*′)–H(*WA*′)···O(1′^{ii})	2·803 (5)	1·93 (4)	153 (2)
(*e*) O(3′)–H(O3′)···O(*W*′^{iii})	2·792 (5)	2·15 (5)	139 (4)
(*f*) O(*W*′)–H(*WB*′)···O(3′^{iv})	2·780 (5)	2·08 (4)	170 (4)
(*g*) O(11′)–H(O11′)···O(11^{i})	2·879 (5)	1·99 (4)	174 (3)
(*h*) O(*W*)–H(*WB*)···O(*W*′^{vi})	2·804 (5)	1·95 (4)	175 (3)
(*i*) O(11)–H(O11)···O(1^{i})	2·602 (5)	1·61 (3)	171 (2)
(*j*) O(1′)–H(O1′)···O(11′^{i})	2·600 (5)	1·87 (3)	149 (3)

Symmetry codes: (i) *x*, *y*, *z*; (ii) *x*, *y* + 1, *z*; (iii) *x*, *y* − 1, *z*; (iv) 1 − *x*, *y* + ½, 1 − *z*; (v) 1 − *x*, *y* − ½, 1 − *z*; (vi) 2 − *x*, *y* + ½, 1 − *z*; (vii) 2 − *x*, *y* − ½, 1 − *z*.

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