Octa-O-acetyl-α,α-trehalose ethanol disolvate

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The glycosidic torsion angles φ_H and $\varphi_{H'}$ of the title compound, $C_{28}H_{38}O_{19} \cdot 2C_2H_5OH$, with values of −40.2 and −42.6°, respectively, are closely similar to those in the structure of the same compound crystallized from ethyl acetate. Of particular interest is that the solvent molecules in this structure take up a similar volume to those in the ethyl acetate solvate, thereby highlighting relationships between solvent and solute in these crystal structures.

Comment

Investigation of the conformation of carbohydrates in the solid state is usually performed using either NMR spectroscopy or X-ray crystallography. These techniques can also reveal insights about the effects of intramolecular stabilization factors, such as hydrogen bonds (Färnbäck, 2003). When an oligosaccharide crystallizes in the solid state, the extent to which conformational changes occur, relative to the major conformation in solution, may vary a good deal. Trehaloses are non-reducing disaccharides. The naturally occurring α,α-trehalose, α-D-Glcp-(1↔1)-α-D-Glcp, has antifreeze cell-protecting properties (Argülles, 2000). We describe here the structure of octa-O-acetyl-α,α-trehalose as an ethanol solvate, (I).

(I)
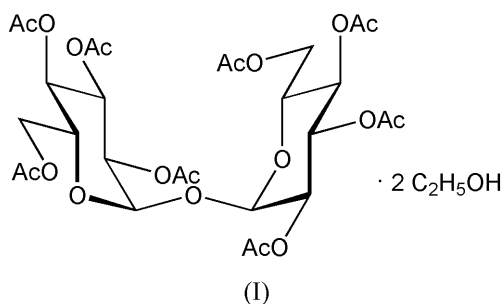
The non-derivatized α,α-trehalose does not show any internal hydrogen bonding in the global energy minimum conformation (Liu *et al.*, 1997) and the title compound crystallizes in a conformation similar to that determined by molecular mechanics calculations of α,α-trehalose. The glycosidic torsion angles φ_H (C1′−O1−C1−H1) and $\varphi_{H'}$ (H1′−C1′−C1−H1) have values of −40.2 and −42.6°, respectively (Fig. 1), similar to those of the ethyl acetate solvate (Baddeley *et al.*, 2001), *viz.* −41.8 and −43.2°. In both sugar residues, the hydroxymethyl torsion angle ω (O5−C5−C6−O6 and O5′−C5′−C6′−O6′) indicates the *gauche–trans* conformation, which is one of the two important conformations in solution. The carbonyl groups of the O-acetyl groups
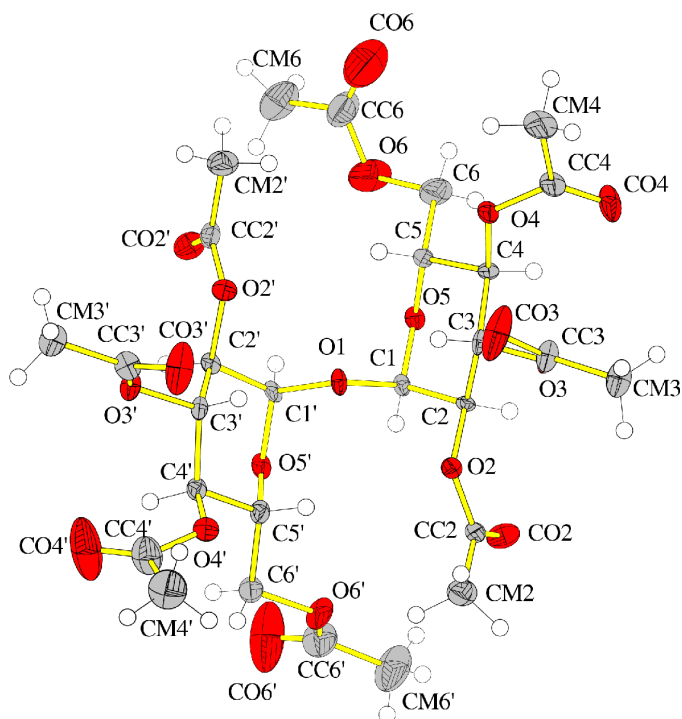
Figure 1
The molecular structure of (I), showing 50% probability displacement ellipsoids. Disordered solvent molecules have been omitted for clarity.
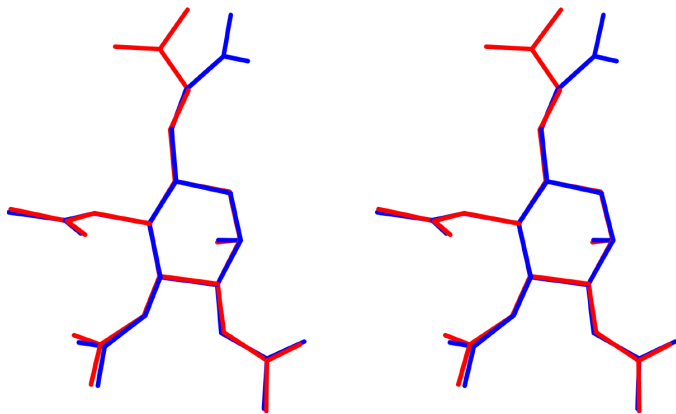

Figure 2
Steroview of an overlay plot, showing the similarity of the two rings in the trehalose molecule.

are present in synclinal arrangements compared with the C—H bonds at each substituted secondary C atom. The distance between the two anomeric H atoms is 2.47 Å (these atoms have been positioned geometrically in this study). This calculated distance may be of importance for comparison with distances derived from NMR experiments (Poveda *et al.*, 1997), as has been shown for other trehalose systems. Both pyranoside rings are in a $^4C_1$ chair conformation, as indicated by their Cremer & Pople (1975) parameters, $Q = 0.573$ (2) Å, $q_2 = 0.009$ (2) Å, $q_3 = 0.573$ (2) Å, $\theta = 1.0$ (2)° and $\psi = 6$ (13)° for the O5→ C5 direction, and $Q = 0.550$ (2) Å, $q_2 = 0.064$ (2) Å, $q_3 = 0.546$ (2) Å, $\theta = 6.8$ (2)° and $\psi = 0.5$ (17)° for the O5′→ C5′ direction. The average C—C bond length is 1.526 (7) Å, close to the average C—C bond distance of 1.52 Å found in carbohydrates in crystal structures (Peréz *et al.*,
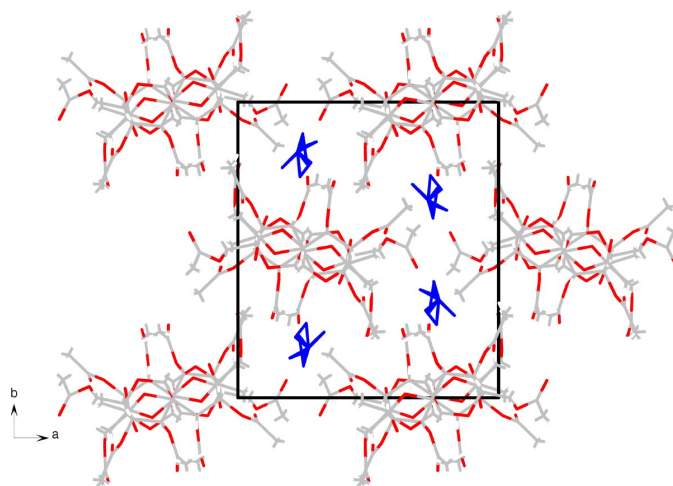

Figure 3
The packing of slightly more than one unit-cell content, viewed along the *c* axis. Disordered solvent molecules are shown in blue. H atoms have been omitted for clarity.

2000). The most salient difference between the two sugar residues is the conformation of the *O*-acetyl groups attached to C6 and C6′. The two sugar rings, optimally fitted to each other (Norrestam, 2004) as shown in Fig. 2, have an average deviation of the atomic positions of only 0.15 Å.

Two ethanol molecules are present in the asymmetric unit. The solvent molecules are modelled with twofold disorder in each position and are arranged in columns along the *c* axis, as shown in Fig. 3. The ethanol molecules display high displacement parameters, but give a stable convergent refinement, although isotropic displacement parameters were used. Both of the solvent molecules show plausible hydrogen bonds to the octa–*O*-acetyl trehalose molecule. A comparison with the ethyl acetate solvate (Baddeley *et al.*, 2001) shows that the unit-cell dimensions of the current ethanol disolvate are essentially the same for the *c* axis but 3% larger for *b* and 3% shorter for *a*. The unit-cell volume is 0.4% smaller for the ethanol disolvate; this may be attributed both to the lower temperature of the present study (110 K) in comparison with 150 K used in the study of the ethyl acetate solvate, and to a denser packing due to the possibility of hydrogen bonding in the ethanol disolvate. The solvent molecules are packed in a closely similar position seen in projection along the *b* axis, with small changes occurring in the packing along the *c* axis but with slightly larger deviations in the *a*-axis direction.

Experimental

Octa-*O*-acetyl-α,α-trehalose was synthesized from α,α-trehalose, in which the glucosyl groups have the D absolute configuration, by *O*-acetylation using standard procedures (Wolrom & Thompson, 1963). It was crystallized by slow evaporation from ethanol at ambient temperature, yielding needles which were collected and mounted in capillaries with some mother liquor. The scattering power of the crystals was very weak, and it was necessary to collect data with synchrotron radiation (SR) at beamline I711 at the Swedish SR facility MAXLAB, Lund, Sweden.

Crystal data

$C_{28}H_{38}O_{19} \cdot 2C_2H_6O$
$M_r = 770.72$
Orthorhombic, $P2_12_12_1$
$a = 13.756\ (4)$ Å
$b = 15.667\ (4)$ Å
$c = 17.934\ (4)$ Å
$V = 3865.0\ (17)$ Å^3
$Z = 4$
$D_x = 1.324$ Mg m^{-3}

Synchrotron radiation, $\lambda = 0.891$ Å
Cell parameters from 999 reflections
$\theta = 3.0{-}29.0°$
$\mu = 0.11$ mm^{-1}
$T = 110\ (2)$ K
Needle, colourless
$0.20 \times 0.05 \times 0.03$ mm

Data collection

Bruker SMART 1K area-detector diffractometer
ω scans
Absorption correction: numerical (X-RED32; Stoe & Cie, 1997)
$T_{min} = 0.97$, $T_{max} = 1.00$
76 752 measured reflections

9124 independent reflections
4887 reflections with $I > 2\sigma(I)$
$R_{int} = 0.090$
$\theta_{max} = 46.0°$
$h = -22 \rightarrow 22$
$k = 0 \rightarrow 25$
$l = 0 \rightarrow 28$

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.044$
$wR(F^2) = 0.112$
$S = 0.95$
9124 reflections
478 parameters

H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.05P)^2]$
  where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.002$
$\Delta\rho_{max} = 0.39$ e Å^{-3}
$\Delta\rho_{min} = -0.36$ e Å^{-3}

Table 1
Selected geometric parameters (Å, °).

C1—O5	1.423 (2)	C5—O5	1.445 (2)
C1—O1	1.425 (2)	C1′—O5′	1.426 (2)
O1—C1′	1.428 (2)	C5′—O5′	1.447 (3)
C1—O1—C1′	112.65 (12)	C1′—O5′—C5′	113.65 (12)
C1—O5—C5	113.34 (14)		
H1—C1—O1—C1′	−40.2	H1′—C1′—O1—C1	−42.6

Table 2
Hydrogen-bonding geometry (Å, °).

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
O11—H11$\cdots$CO3^i	0.82	2.15	2.948 (6)	168
O21—H21$\cdots$O5′	0.82	2.13	2.746 (6)	132

Symmetry code: (i) $1 - x, \frac{1}{2} + y, \frac{3}{2} - z$.

A 'rigid-bond' restraint was applied to the atomic displacement parameters (Rollet, 1970). H atoms were positioned geometrically and allowed to ride on their parent atoms, with C—H distances for CH, CH$_2$ and CH$_3$ groups set at 0.98, 0.97 and 0.96 Å, respectively. The absolute configuration is known from the stereochemistry of the reactants in the synthesis. Due to the absence of heavy atoms with anomalous scattering effects, Friedel pairs were merged. The four disordered solvent molecules were modelled with isotropic displacement parameters due to correlation problems with anisotropic parameters. The relative occupancies of the disordered solvent molecules are 0.486 (5):0.514 (5) for one and 0.410 (6):0.590 (6) for the other.

Data collection: *SMART* (Siemens, 1998); cell refinement: *SMART*; data reduction: *SAINT* (Siemens, 1998); program(s) used to solve structure: *SHELXS*97 (Sheldrick, 1997); program(s) used to refine structure: *SHELXL*97 (Sheldrick, 1997); molecular graphics: *DIAMOND* (Bergerhoff, 1996); software used to prepare material for publication: *PLATON* (Spek, 2003).

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