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Crystal structure of a small amphiphilic compound: heptane-1,2,3-triol

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The crystal structure of heptane-1,2,3-triol (space group $P2_1/c$, $a = 20.488(8)$, $b = 4.810(2)$, $c = 9.087(5)$Å, $\beta = 103.03(4)°$) was determined by X-ray diffraction methods and refined to $R = 0.072$ ($R_w = 0.062$). The molecules adopt an all-*trans* conformation. They are arranged tail-to-tail in the crystal lattice and linked by hydrogen bonds which involve all hydroxyl groups and form infinite chains in the *b*,*c* plane.

The crystallization of membrane proteins is more difficult than that of soluble proteins because detergents have to be added for their solubilization. Michel [1] has shown that the addition of small amphiphilic substances to the crystallization setups often improves the quality of the membrane protein crystals. In some cases the crystals did not grow at all without small amphiphiles which are thought to replace some of the detergent molecules in the mixed micelles thus providing a better fit into the proteins' crystal lattice. Heptane-1,2,3-triol (**1**) (Fig. 1) is one of the most successful among the small amphiphilic substances. We have solved its crystal structure in order to investigate the molecular conformation and the interaction of the molecules in the crystalline state.

Crystal data. Crystals of heptane-1,2,3-triol (Oxyl-GmbH, Boblingen, high melting point racemate), grown from aqueous solution, $C_7H_{16}O_3$, $M = 148$ g/mol, monoclinic space group $P2_1/c$, $a = 20.488(8)$, $b = 4.810(2)$, $c = 9.087(5)$Å, $\beta = 103.03(4)°$, $V = 872.5$ Å^3, $\lambda_{CuK_\alpha} = 1.5418$ Å.

1243 unique reflections ($2\theta_{max} = 120°$, $2\theta/\omega$ scan) were collected on a STOE four-circle diffractometer, corrected for Lorentz- and polarization effects and used for structure determination with direct methods [2]. Convergence of atomic parameters during full-matrix least-squares refinement [3] was very slow, especially for C7 which had to be held fixed during the last cycles of anisotropic refinement. All of the hydrogen atoms except for the $-CH_3$ hydrogens were located from difference Fourier maps. The final R-factor is 0.072 ($R_w = 0.062$).

Atomic parameters, bond lengths and angles are given in Table I. The geometric parameters are comparable to those of related amphiphilic molecules [4,5].

Fig. 2 shows a packing diagram of **1**. In the crystal lattice the hydrocarbon chains of the molecules adopt an all-*trans* conformation as observed for meso-(2*R*,4*R*,6*S*)-2,4,6-heptanetriol [4]. This is in contrast to meso-(2*S*,4*S*,6*S*)-2,4,6-heptanetriol [5] where the ends of the all-*trans* chains are formed by the 2- and 4-hydroxyl groups and the torsion angles C1–C2–C3–C4 and C4–C5–C6–C7 are 55.3° and 70.3°.

In **1**, adjacent molecules are arranged tail-to-tail as expected for amphiphilic substances. The packing is stabilized by strong intermolecular hydrogen bonds in which all of the –OH groups take part (Table I). The hydrogen bonds form infinite chains which are energetically more favourable than isolated bondings due to the

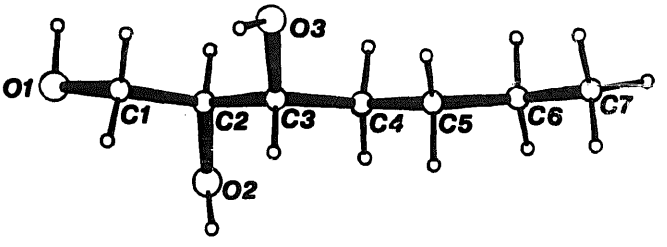

Fig. 1. Numbering scheme and conformation of heptane-1,2,3-triol (**1**).

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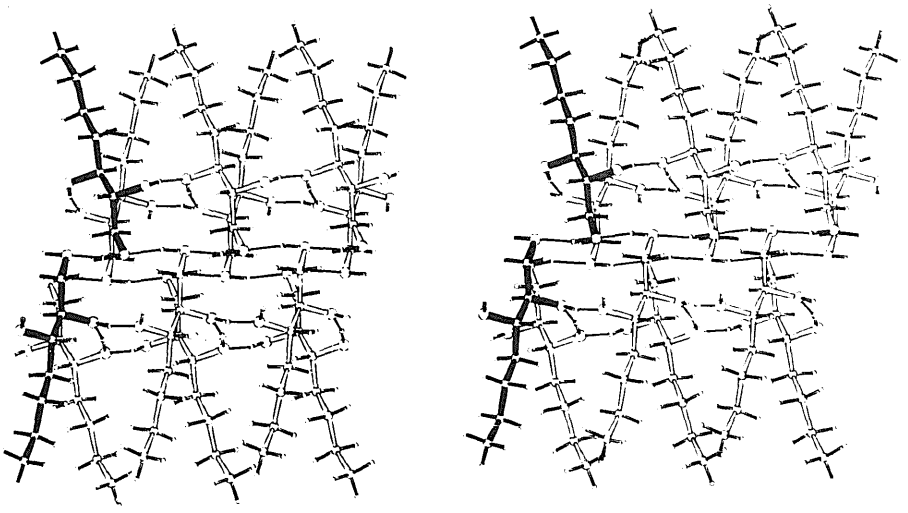

Fig. 2. Stereo view of the crystal packing of **1**. Two molecules are drawn filled, hydrogen bonds O-H · · · O are indicated by thin lines.

cooperative effect. These chains are in th *b*, *c* plane, with the linear O1-H · · · O1-H · · · O1-H chains in the *b*-direction and the S-shaped O2-H · · · O3-H · · · O_2-H · · · O3-H-chains in the *c*-direction. The ability to form strong hydrogen bonds may be one explanation why **1** improves the quality of membrane protein crystals. Another reason might be that it is used as a racemic mixture, whereas most detergents used in the crystallization of membrane proteins are optically pure substances.

TABLE Ia

Final atomic parameters for heptane-1,2,3-triol

Atomic co-ordinates are fractional. Standard deviations are given in parentheses.

Atom	*x*	*y*	*z*	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
O1	0.5067(1)	−0.1960(3)	0.3280(3)	0.0820(5)	0.0609(5)	0.0630(5)	0.0001(5)	0.0067(5)	0.0014(5)
O2	0.6403(1)	0.0034(3)	0.3329(2)	0.1074(5)	0.0625(5)	0.0520(5)	0.0014(5)	0.0222(5)	−0.0088(5)
O3	0.6746(1)	−0.6258(3)	0.5674(2)	0.0876(5)	0.0620(5)	0.0527(5)	0.0008(5)	0.0244(4)	0.0017(5)
C1	0.5636(2)	−0.2582(4)	0.4450(3)	0.0833(5)	0.0700(5)	0.0578(5)	0.0048(5)	0.0159(5)	0.0012(5)
C2	0.6278(1)	−0.2642(4)	0.3878(3)	0.0841(5)	0.0555(5)	0.0499(5)	−0.0001(5)	0.0167(5)	−0.0051(5)
C3	0.6885(2)	−0.3604(4)	0.5108(3)	0.0831(5)	0.0614(5)	0.0533(5)	−0.0030(5)	0.0178(5)	−0.0061(5)
C4	0.7516(2)	−0.3888(4)	0.4480(3)	0.0866(5)	0.0920(5)	0.0696(5)	0.0033(5)	0.0234(5)	−0.0050(5)
C5	0.8128(2)	−0.4705(5)	0.5693(3)	0.0890(5)	0.1485(5)	0.0917(5)	0.0135(5)	0.0170(5)	−0.0003(5)
C6	0.8739(2)	−0.5308(5)	0.5036(4)	0.0861(5)	0.2435(5)	0.1267(5)	0.0444(5)	0.0297(5)	0.0192(5)
C7	0.9332(−)	−0.6329(−)	0.6110(−)	0.1193(−)	0.2263(−)	0.1805(−)	0.0532(−)	0.0279(−)	0.0320(−)
HO1	0.4960(−)	−0.3836(−)	0.2708(−)	0.0800(−)					
HO2	0.6576(−)	0.1305(−)	0.4202(−)	0.0890(−)					
HO3	0.6582(−)	−0.6005(−)	0.6658(−)	0.0850(−)					
H1A	0.5616(−)	−0.4585(−)	0.4932(−)	0.0850(−)					
H1B	0.5687(−)	−0.1058(−)	0.5335(−)	0.0850(−)					
H2	0.6185(−)	−0.4179(−)	0.2945(−)	0.0760(−)					
H3	0.7016(−)	−0.2040(−)	0.5958(−)	0.0780(−)					
H4A	0.7420(−)	−0.5583(−)	0.3634(−)	0.0980(−)					
H4B	0.7592(−)	−0.2006(−)	0.3915(−)	0.0980(−)					
H5A	0.8029(−)	−0.6351(−)	0.6349(−)	0.1320(−)					
H5B	0.8276(−)	−0.2833(−)	0.6404(−)	0.1320(−)					
H6B	0.8869(−)	−0.3610(−)	0.4458(−)	0.1810(−)					
H6A	0.8578(−)	−0.7068(−)	0.4232(−)	0.1810(−)					
H7A	0.9519(−)	−0.4787(−)	0.6998(−)	0.2270(−)					
H7B	0.9716(−)	−0.6930(−)	0.5584(−)	0.2270(−)					
H7C	0.9184(−)	−0.8173(−)	0.6717(−)	0.2270(−)					

TABLE Ib

Bondlengths (Å) for heptane-1,2,3-triol with S.D.

S.D. in parentheses.

C1–O1	1.422(3)
C2–O2	1.424(3)
C3–O3	1.429(3)
C1–C2	1.521(4)
C2–C3	1.544(4)
C3–C4	1.531(4)
C4–C5	1.524(4)
C5–C6	1.530(5)
C6–C7	1.461(3)

TABLE Ic

Valence angles (°) for heptane-1,2,3-triol, with S.D.

S.D. in parentheses.

C2–C1–O1	112.1(2)
C1–C2–O2	109.9(2)
C3–C2–O2	110.3(2)
C3–C2–C1	112.1(2)
C2–C3–O3	109.6(2)
C4–C3–O3	107.9(2)
C4–C3–C2	111.5(2)
C5–C4–C3	112.3(2)
C6–C5–C4	112.3(3)
C7–C6–C5	115.6(3)

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