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Crystal structures of heptakis(2,6-di-*O*-ethyl)cyclomaltoheptaose [heptakis(2,6-di-*O*-ethyl)-β-cyclodextrin]. Solvent-regulated helical assembly of macrocycles

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Abstract

Heptakis(2,6-di-*O*-ethyl)-β-cyclodextrin (DE-β-CD) was crystallized in two forms from hexane and 95% aqueous methanol, respectively: A form I crystal with the space group $P2_12_12_1$ and a form II crystal with the space group $P3_1$. In both crystals, DE-β-CD molecules are in a round shape with intramolecular O-3–H···O-2 hydrogen bonds. In the form I crystal, the DE-β-CD molecules are arranged along the twofold screw axis to form a helically extended polymeric chain by including the 6-*O*-ethyl groups of the adjacent molecule. One hexane molecule with twofold disorder is located in the intermolecular channel along the *a*-axis. In contrast, the DE-β-CD molecules in the form II crystal form a helical arrangement along the threefold screw axis. One methanol and one water molecule are included on the O-6 side of the molecular cavity. The water molecule links the methanol molecule and two ethoxy groups of the adjacent DE-β-CD molecule with hydrogen bonds. The result suggests the important role of solvent in the formation of helical arrangement of DE-β-CD molecules.

Keywords: Heptakis(2,6-di-*O*-ethyl)-β-cyclodextrin; Crystal structure; Macrocyclic structure; Helical assembly

1. Introduction

A great number of cyclodextrin derivatives have been synthesized with the purpose of improving complexing ability, introducing functional groups, and changing physical properties such as solubility, etc. [1]. Crystal structures of a number of crystalline complexes of methylated cyclodextrins have been determined, and it has been shown that methylation changes the molecular recognition property as well as the macrocyclic structure [2]. Ethylated cyclodextrins exhibit quite different physical properties from their methylated counterparts. They are sparingly soluble in water [3] but form complexes with water-soluble pharmaceuticals such as diltiazem ((2SA-*cis*)-3-(acetyloxy)-5-[2-(dimethylamino)-ethyl]-2,3-dihydro-2-(4-methoxyphenyl)-1,5-benzothiazepin-4(5*H*)-one) [4] and isosorbide dinitrate (1,4:3,6-dianhydro-D-glucitol dinitrate) [5]. Ethylated cyclodextrins retarded the release of these pharmaceuticals from compressed tablets and have been suggested as useful for drug delivery. We have determined

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Table 1
Crystal data and summary of structure determination

	Hexane complex	Methanol complex
Formula	$C_{70}H_{126}O_{35}\cdot C_6H_{14}$	$C_{70}H_{126}O_{35}\cdot 2CH_4O\cdot 2H_2O$
Formula weight	1613.9	1625.8
Space group	$P2_12_12_1$	$P3_1$
Z	4	3
a (Å)	14.708(3)	18.205(5)
b (Å)	23.927(9)	18.205(5)
c (Å)	25.764(6)	22.385(9)
V (Å^3)	9067(4)	6425(4)
D_{calcd} (g cm^{-3})	1.182	1.260
Temperature (K)	150	150
Reflections	8501	7433
R (all data)	0.116	0.117
R ($F_o>4\sigma$)	0.092	0.090
wR_2 (all data)	0.266	0.267
Residual density (e Å^{-3})	0.58, −0.42	0.83, −0.44

the crystal structure of two forms of heptakis(2,6-di-*O*-ethyl)cyclomaltoheptaose [heptakis(2,6-di-*O*-ethyl)-β-cyclodextrin] (DE-β-CD) to evaluate the effect of ethylation on the macrocyclic structure.

2. Results and discussion

DE-β-CD was crystallized by the slow evaporation. Crystal data are given in Table 1. An orthorhombic crystal with the space group $P2_12_12_1$ (form I) was obtained from a hexane solution, while a trigonal form with the space group $P3_1$ (form II) was crystallized from a 95% aqueous methanol solution. Structures of these DE-β-CD crystals are shown in Fig. 1. Some parameters describing the macrocyclic conformation are given in Table 2. The molecule is in a round shape which is maintained by intramolecular O-2···H–O-3′ hydrogen bonds between adjacent glucose units. The O-2···O-3′ distances between adjacent glucose units are 2.84–3.10 Å in the form I crystal and 2.77–3.02 Å in the form II crystal. These intramolecular hydrogen bonds impose restrictions on the rotational flexibility around the glycosidic linkage. As a result, the tilt angle of each glucose unit is limited in a relatively narrow range: 8.2–20.9° in form I and 10.7–18.6° in form II. Seven glycosidic oxygen atoms are roughly coplanar with the r.m.s. deviation of 0.097 Å (form I) and 0.057 Å (form II). They form a nearly regular heptagon with the mean radius of 5.1 Å and side length of 4.4 Å. These macrocyclic structures are very similar to the structure of heptakis(2,6-di-*O*-methyl)-β-cyclodextrin [6,7] and their complexes [8,9]. The average value of O-2···O-3′ distances given in Table 2 is in good agreement with 2.91 Å of heptakis(2,6-di-*O*-methyl)-β-cyclodextrin [6] having the twofold helical packing structure similar to that observed in the form I crystal. The intramolecular O-2···H–O-3′ hydrogen bonds are responsible for maintaining these macrocyclic conformation because permethylated β-cyclodextrin no more retains the round structure [10].

Two DE-β-CD molecules are superimposed as shown in Fig. 2. The backbone pyranose

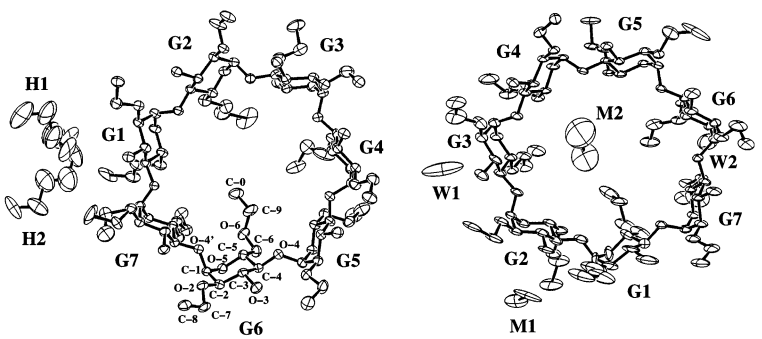

Fig. 1. Structure and numbering of heptakis(2,6-di-*O*-ethyl)cyclomaltoheptaose [heptakis(2,6-di-*O*-ethyl)-β-cyclodextrin] (DE-β-CD) crystallized form hexane (form I, left) and from 95% aqueous methanol (form II, right). Thermal ellipsoids are drawn with 30% probability. The disordered hexane molecule is denoted by H1 and H2. W1 and W2 are water molecules and M1 and M2 denote methanol molecules.

Table 2
Parameters describing macrocyclic conformation

Residue	Form I	Form II	Form I	Form II	Form I	Form II	Form I	Form II
	O-4···center distance (Å) [a]		O-4 angle (°)		Tilt-angle (°) [b]		Planarity (Å) [c]	
G1	5.06	5.08	118.1	118.4	19.2	14.7	−0.074	0.102
G2	4.98	4.83	117.9	117.6	21.0	10.7	0.154	−0.077
G3	5.17	5.18	119.8	119.4	13.0	16.1	−0.013	−0.012
G4	5.07	5.26	117.7	120.5	11.1	15.9	−0.089	0.050
G5	4.99	4.88	117.9	117.2	18.8	18.6	−0.021	−0.019
G6	5.10	4.96	118.4	117.9	20.9	12.9	0.135	0.012
G7	5.09	5.30	117.6	117.7	8.2	16.2	−0.091	−0.056
Average	5.07	5.07	118.2	118.4	16.0	15.0	0.097	0.057
	O-4···O-4′ distance (Å)		O-2···O-3′ distance (Å)					
G1···G2	4.43	4.54	2.84	2.78				
G2···G3	4.42	4.44	3.10	2.79				
G3···G4	4.35	4.27	2.94	2.90				
G4···G5	4.48	4.46	2.85	2.90				
G5···G6	4.34	4.46	2.83	2.87				
G6···G7	4.44	4.40	2.94	3.02				
G7···G1	4.35	4.26	2.89	2.77				
Average	4.40	4.40	2.91	2.86				

[a] The distance from the center of gravity of seven O-4 atoms to each O-4 atom.
[b] The tilt angle is defined as an angle made by the plane through seven O-4 atoms and the plane through C-1, C-4, O-4, and O-4′ of each 2,6-di-*O*-methylglucosyl residue.
[c] The distance of each O-4 atom from the least-squares plane through seven O-4 atoms.

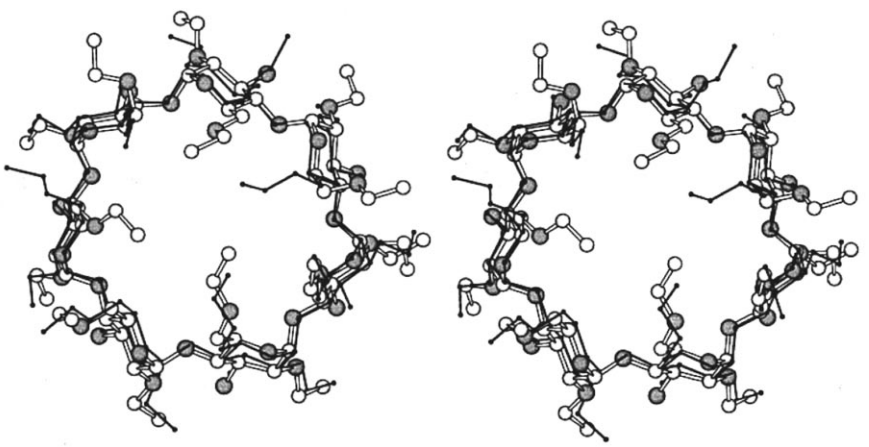

Fig. 2. Superposition of form I and II structures. The structure of form II is drawn with thin solid lines.

rings are well superimposed, and the major structural difference is observed in the conformation of ethyl groups bonded to O-6. Except for the 2-*O*-ethyl group in the G7 unit of the hexane complex, all ethyl groups bonded to O-2 are in trans conformation and point away from the center of the macrocycle. In contrast, the orientational difference of the 6-*O*-ethyl groups is caused by the conformational difference of the C-6–O-6 bond. In the form I crystal, four C-6–O-6 bonds are in the (+)-gauche conformation with respect to the C-5–O-5 bond, while the C-6–O-6 bonds in the G1, G3, and G5 residues show the (−)-gauche conformation. These two types of conformation of C-6–O-6 bonds are also

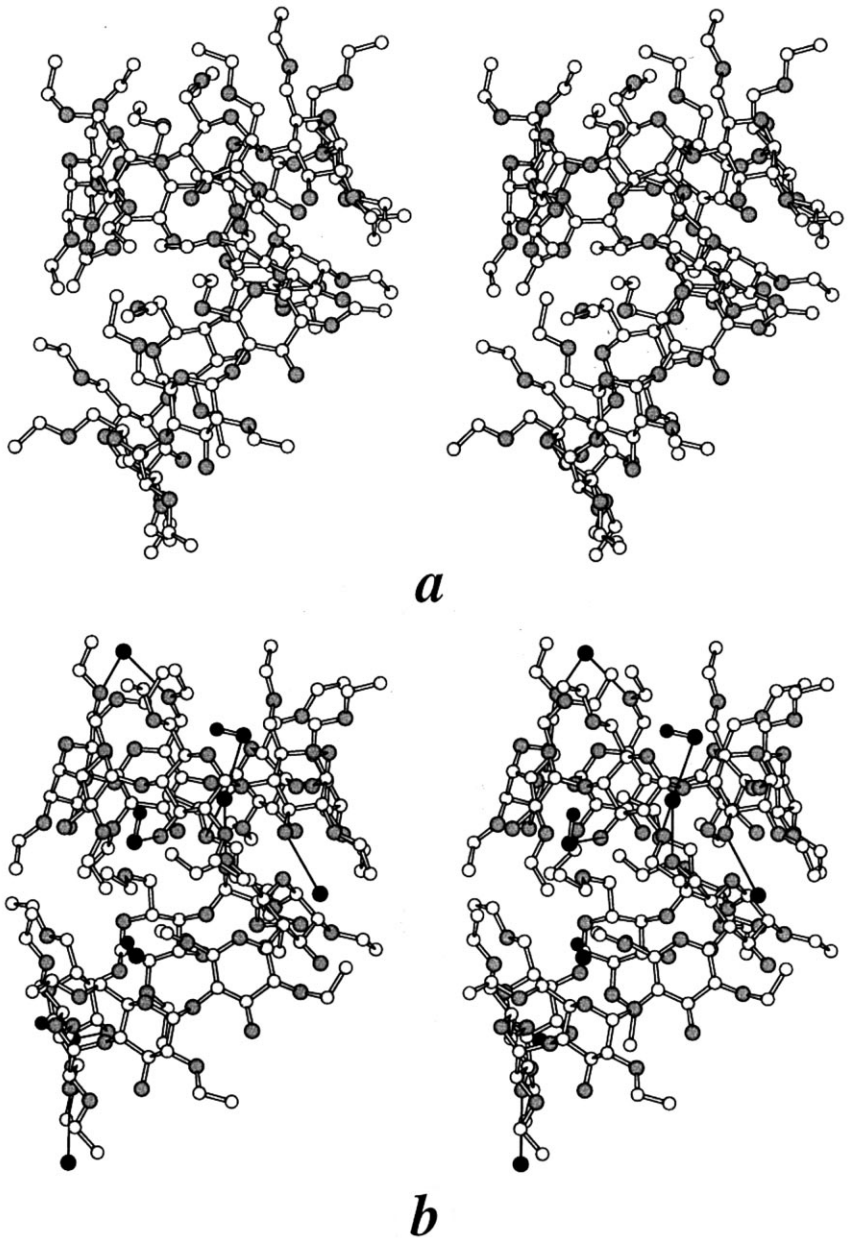

Fig. 3. Stereo drawings representing intermolecular contacts of two adjacent molecules arranged along the screw axis in form I (a) and form II (b) crystals. Methanol and water molecules are shown by filled circles. Hydrogen bonds are denoted by thin solid lines.

observed in the form II crystal: (+)-gauche C-6–O-6 bonds in the G1, G6, and G7 residues and (−)-gauche C-6–O-6 bonds in the other residues.

In the orthorhombic crystal, DE-β-CD molecules are arranged along the twofold screw axis parallel to the *a*-axis, as shown in Fig. 3(a). Intermolecular contacts less than 3.5 Å are given in Table 3. Short contacts are observed mostly between molecules arranged helically along the screw axis. Three ethyl groups are located inside the adjacent molecule. The ethyl group attached to O-6 of the G5 residue is inserted into the cavity, and the terminal methyl group is located at the center of the cavity. The 6-*O*-ethyl groups of the G4 and G6 residues fill the vacant space at the O-2, O-3 end of the cavity. The O-6 side of the cavity is capped by the 6-*O*-ethyl groups of the G2, G4, and G6 residues. As shown in Fig. 4, a hexane molecule that is twofold disordered is located in the intermolecular

channel passing parallel to the *a*-axis. The hexane molecule was modeled on the electron density map, where the continuous electron density was observed in the intermolecular channel.

The trigonal crystal contains two methanol molecules, one of which is included within the cavity of DE-β-CD. One water molecule (W2) is also included in the DE-β-CD cavity and links the included methanol molecule (M2) and two O-6 atoms of adjacent DE-β-CD by hydrogen bonds (Fig. 3(b)). The other methanol and water molecules are located outside the DE-β-CD molecule. The methanol (M1) and water (W1) molecules form hydrogen bonds with the O-3H hydroxyl groups of the G2 and G3 units, respectively. The DE-β-CD molecules are arranged along the threefold screw axis to form a helically extended polymeric chain (Fig. 5). Three ethyl groups are located in the secondary hydroxyl side of the adjacent molecule. Two ethyl groups block this side of the DE-β-CD cavity. The 6-*O*-ethyl group of the G6 unit is inserted into the adjacent DE-β-CD cavity. The form II crystal differs in that the terminal methyl group of the 6-*O*-ethyl group is oriented aside from the center of the cavity to allow the co-inclusion of the methanol and water molecules.

The different crystal packing observed in the two crystal forms suggests that the helical arrangement is regulated by the solvent used in the crystallization. The helical arrangement with twofold screw symmetry is observed in several crystal structures of methylated β-cyclodextrins [6–9] and 6-*O*-monosubstituted β-cyclodextrins [11–14]. In those structures, substituent groups are inserted into the cavity of an adjacent molecule related with twofold screw symmetry. The threefold helical structure of form II of DE-β-CD should be caused by the inclusion of a methanol molecule. To include the methanol and water molecules, the ethyl group is shifted aside from the center of the cavity. As a result, the arrangement on the threefold screw axis may be more favored than it is on the twofold screw axis.

Table 3
Intermolecular contacts less than 3.5 Å

Atom	Atom	Distance	Symmetry operator
Form I crystal			
O-2(2)	C-1(5)	3.34	$(x+1/2, -y+1/2, -z+2)$
O-2(2)	O-5(5)	3.46	$(x+1/2, -y+1/2, -z+2)$
O-3(2)	C-2(5)	3.44	$(x+1/2, -y+1/2, -z+2)$
C-7(2)	O-5(7)	3.47	$(-x, y-1/2, -z+3/2)$
O-2(3)	C-6(6)	3.29	$(x+1/2, -y+1/2, -z+2)$
O-3(3)	O-5(5)	3.36	$(x+1/2, -y+1/2, -z+2)$
O-3(5)	C-0(2)	3.39	$(x+1/2, -y+1/2, -z+2)$
C-7(6)	O-5(1)	3.32	$(-x, y-1/2, -z+3/2)$
C-8(6)	O-5(1)	3.22	$(-x, y-1/2, -z+3/2)$
Form II crystal			
C-0(4)	O-3(1)	3.39	$(x, y+1, z)$
O-3(7)	O-6(1)	3.33	$(y-x, -x+1, z-1/3)$
O-5(2)	C-7(4)	3.31	$(y-x, -x+1, z-1/3)$
C-8(2)	O-5(5)	3.41	$(-y+1, x-y+1, z+1/3)$
O-4(3)	O-2(W)	3.30	$(-y+1, x-y+1, z+1/3)$
C-1(6)	O-3(4)	3.34	$(-y+1, x-y+1, z+1/3)$
O-5(6)	O-3(4)	3.33	$(-y+1, x-y+1, z+1/3)$
O-6(4)	C-8(7)	3.37	$(x, y-1, z)$
C-3(5)	O-5(7)	3.46	$(-y+1, x-y+1, z+1/3)$
C-1(7)	O-2(5)	3.48	$(-y+1, x-y+1, z+1/3)$
O-6(5)	C-1(M)	3.49	$(x-1, y-1, z)$
O-3(3)	C-6(6)	3.46	$(y-x, -x+1, -1/3)$
C-8(6)	O-5(1)	3.42	$(-y+1, x-y+1, z+1/3)$
O-2(W)	C-2(M)	3.25	$(-y+1, x-y+1, z+1/3)$
O-2(W)	O-2(M)	3.12	$(-y+1, x-y+1, z+1/3)$
O-1(M)	O-3(2)	2.72	
O-1(W)	O-3(3)	3.25	
O-2(W)	O-6(6)	2.82	
O-2(W)	O-6(7)	3.14	

3. Experimental

DE-β-CD was prepared according to the literature [15] and crystallized by slow evaporation. The form I crystal with space group $P2_12_12_1$ was obtained from a hexane solution, while the form II crystal with space group $P3_1$ was prepared from a 95% aqueous methanol solution. Both crystals of DE-β-CD are fragile and easily break up in air by losing solvent molecules. Crystals were sealed in a glass capillary with a small amount of mother liquor. X-ray diffraction data were collected on a Nonius CAD4 diffractometer with graphite-monochromated CuK_α radiation. Several crystals were tested for measuring X-ray data with suitable quality for structure determination, but they showed poor diffraction power at high diffraction angle. Since the cooling of crystals enhanced the diffraction power, the intensity data were collected at 150 K.

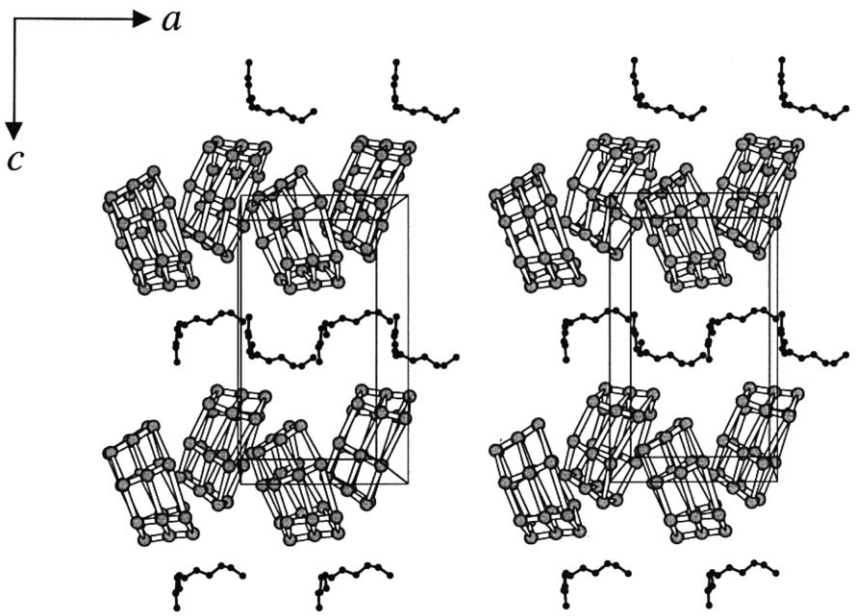

Fig. 4. Stereo drawing of the crystal packing of the form I crystal. Hexane molecules are shown by filled circles.

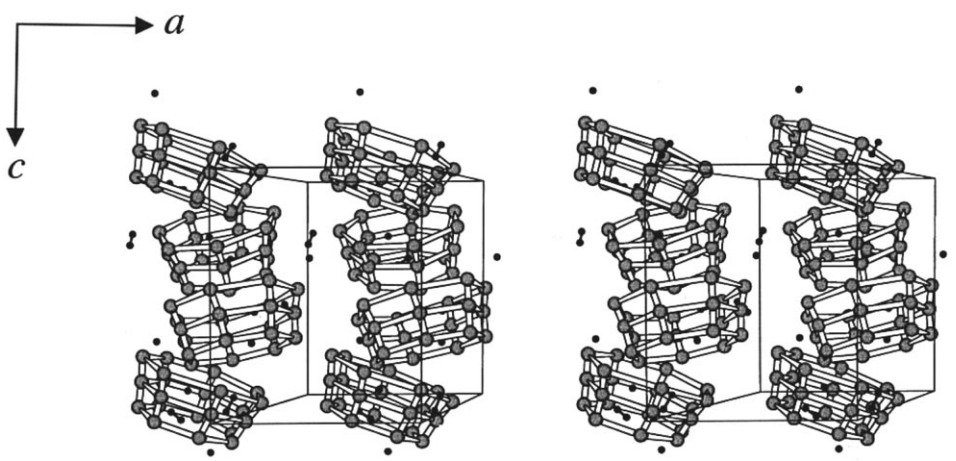

Fig. 5. Stereo drawing the crystal packing of the form II crystal. Water and methanol molecules are shown by filled circles.

Both structures were solved by the direct method using the SnB program [16] and refined by the full-matrix least-squares method using the SHELX-97 program [17]. An application of the direct method combined with map modification produced a set of coordinates of a plausible structure, although one-third of the atoms were incorrectly located. The structure was examined and rebuilt using the TURBO-FRODO program [18]. The structure model was subjected to the restraint least-squares refinement, which slowly converged. The structures were refined by the full-matrix least-squares method which minimized the quantity $\Sigma\, w(|I_o|^2 - |I_c|^2)^2$ with $w = 1/[\sigma^2(I_o) + 0.1I_o]$. The coordinates of hydrogen atoms attached to methine and methylene groups were calculated and included in the structure factor calculation. The results are summarized in Table 1. Final atomic coordinates and isotropic temperature factors are given in Table 4.

Table 4
Atomic coordinates ($\times 10^4$) and isotropic temperature factors ($\times 10^3$)

Atom	x	y	z		U_{eq}
Form I crystal					
C-1(1)	182(5)	1117(3)	7340(3)	1.0	59(1)
C-2(1)	1049(5)	1410(3)	7211(3)	1.0	56(1)
O-2(1)	1765(3)	1071(2)	7411(2)	1.0	60(1)
C-3(1)	1044(5)	2007(3)	7424(3)	1.0	55(1)
O-3(1)	1859(3)	2289(2)	7286(2)	1.0	66(1)
O-4(1)	206(3)	2840(1)	7448(1)	1.0	52(1)
C-5(1)	−638(5)	1989(3)	7325(3)	1.0	58(1)
O-5(1)	−566(3)	1420(2)	7131(2)	1.0	59(1)
C-6(1)	−1464(5)	2224(3)	7047(3)	1.0	66(2)
O-6(1)	−1268(4)	2245(2)	6506(2)	1.0	73(1)
C-7(1)	2596(5)	1088(4)	7130(4)	1.0	79(2)
C-8(1)	3226(6)	640(3)	7328(3)	1.0	72(2)
C-9(1)	−2019(7)	2477(4)	6208(3)	1.0	92(3)
C-0(1)	−1769(14)	2452(6)	5648(4)	1.0	166(9)
C-1(2)	−597(5)	−170(3)	8938(3)	1.0	56(1)
C-2(2)	346(5)	−204(3)	8719(3)	1.0	55(1)
O-2(2)	981(3)	−339(2)	9123(2)	1.0	58(1)
C-3(2)	618(4)	334(3)	8455(2)	1.0	50(1)
O-3(2)	1445(3)	247(2)	8182(2)	1.0	57(1)
C-4(2)	−119(4)	514(2)	8072(3)	1.0	50(1)
O-4(2)	119(3)	1050(1)	7878(1)	1.0	51(1)
C-5(2)	−1056(5)	518(3)	8326(3)	1.0	58(1)
O-5(2)	−1217(3)	−21(2)	8548(2)	1.0	62(1)
C-6(2)	−1798(5)	633(4)	7942(3)	1.0	77(2)
O-6(2)	−2620(4)	709(3)	8229(3)	1.0	93(2)
C-7(2)	1389(9)	−866(3)	9075(4)	1.0	102(4)
C-8(2)	2054(8)	−966(4)	9492(4)	1.0	95(3)
C-9(2)	−3400(6)	788(6)	7922(6)	1.0	127(5)
C-0(2)	−4197(9)	856(11)	8313(8)	1.0	243(15)
C-1(3)	−1818(6)	463(3)	10778(3)	1.0	66(2)
C-2(3)	−899(6)	179(3)	10775(3)	1.0	65(2)
O-2(3)	−351(4)	388(2)	11193(2)	1.0	67(1)
C-3(3)	−425(5)	256(3)	10259(3)	1.0	57(1)
O-3(3)	385(4)	−61(2)	10248(2)	1.0	70(1)
C-4(3)	−1065(5)	82(3)	9826(3)	1.0	60(1)
O-4(3)	−611(3)	221(2)	9354(2)	1.0	56(1)
C-5(3)	−1980(5)	333(3)	9863(3)	1.0	62(2)
O-5(3)	−2366(4)	245(2)	10371(2)	1.0	69(1)
C-6(3)	−2664(6)	134(3)	9458(3)	1.0	77(2)
O-6(3)	−2699(5)	−457(2)	9415(3)	1.0	98(2)
C-7(3)	−448(9)	87(4)	11665(3)	1.0	100(3)
C-8(3)	55(7)	368(4)	12090(3)	1.0	83(2)
C-9(3)	−3275(8)	−728(4)	9768(4)	1.0	101(3)
C-0(3)	−3473(11)	−1323(4)	9570(5)	1.0	132(5)
C-1(4)	−2666(6)	2521(3)	11361(3)	1.0	62(2)
C-2(4)	−1882(5)	2223(3)	11641(3)	1.0	58(1)
O-2(4)	−1251(4)	2648(2)	11811(2)	1.0	65(1)
C-3(4)	−1429(5)	1797(3)	11302(3)	1.0	57(1)
O-3(4)	−788(4)	1503(2)	11607(2)	1.0	68(1)
C-4(4)	−2157(5)	1406(3)	11076(3)	1.0	56(1)
O-4(4)	−1687(3)	1047(2)	10725(2)	1.0	60(1)
C-5(4)	−2881(5)	1747(3)	10801(3)	1.0	64(2)
O-5(4)	−3276(3)	2136(2)	11164(2)	1.0	62(1)
C-6(4)	−3650(6)	1392(3)	10589(3)	1.0	82(2)
O-6(4)	−4196(8)	1722(3)	10253(3)	1.0	154(4)

Table 4 (Continued)

Atom	x	y	z		U_{eq}
C-7(4)	−64(6)	2547(3)	12317(3)	1.0	75(2)
C-8(4)	−221(6)	3020(4)	12433(4)	1.0	88(3)
C-9(4)	−4418(9)	1534(5)	9778(4)	1.0	106(3)
C-0(4)	−4799(10)	1994(6)	9430(6)	1.0	138(5)
C-1(5)	−2607(5)	4422(3)	10328(3)	1.0	56(1)
C-2(5)	−2083(5)	4397(3)	10836(3)	1.0	58(1)
O-2(5)	−1319(4)	4761(2)	10793(2)	1.0	66(1)
C-3(5)	−1810(5)	3798(3)	10945(3)	1.0	57(1)
O-3(5)	−377(4)	3766(2)	11442(2)	1.0	69(1)
C-4(5)	−2625(5)	3429(3)	10919(3)	1.0	54(1)
O-4(5)	−2291(3)	2862(2)	10967(2)	1.0	58(1)
C-5(5)	−3151(5)	3492(3)	10424(3)	1.0	55(1)
O-5(5)	−3366(3)	4074(2)	10342(2)	1.0	56(1)
C-6(5)	−4033(5)	3176(3)	10416(3)	1.0	71(2)
O-6(5)	−4542(4)	3314(2)	10871(2)	1.0	76(1)
C-7(5)	−1080(6)	5046(4)	11260(3)	1.0	82(2)
C-8(5)	−336(7)	5461(4)	11133(4)	1.0	91(3)
C-9(5)	−5321(6)	2973(5)	10956(5)	1.0	107(4)
C-0(5)	−6053(11)	3060(8)	10588(7)	1.0	171(7)
C-1(6)	−1236(5)	4758(3)	8437(2)	1.0	50(1)
C-2(6)	−805(5)	5075(3)	8888(3)	1.0	58(1)
O-2(6)	119(3)	5154(2)	8757(2)	1.0	61(1)
C-3(6)	−947(5)	4775(3)	9398(2)	1.0	54(1)
O-3(6)	−664(4)	5131(2)	9818(2)	1.0	72(1)
C-4(6)	−1945(5)	4607(3)	9472(2)	1.0	54(1)
O-4(6)	−1978(3)	4272(2)	9922(2)	1.0	59(1)
C-5(6)	−2271(5)	4291(3)	9000(2)	1.0	58(1)
O-5(6)	−2144(3)	4636(2)	8544(2)	1.0	59(1)
C-6(6)	−3282(5)	4141(3)	9015(3)	1.0	66(2)
O-6(6)	−3467(4)	3722(2)	8633(2)	1.0	77(1)
C-7(6)	514(6)	5670(3)	8951(3)	1.0	68(2)
C-8(6)	1493(5)	5680(3)	8771(3)	1.0	70(2)
C-9(6)	−3296(10)	3167(3)	8805(4)	1.0	105(4)
C-0(6)	−3450(9)	2755(4)	8383(4)	1.0	99(3)
C-1(7)	201(5)	3315(2)	7133(3)	1.0	50(1)
C-2(7)	860(5)	3741(3)	7352(3)	1.0	61(2)
O-2(7)	1730(3)	3488(2)	7389(2)	1.0	65(1)
C-3(7)	520(5)	3939(3)	7881(3)	1.0	56(1)
O-3(7)	1085(3)	4387(2)	8060(2)	1.0	62(1)
C-4(7)	−454(5)	4134(2)	7841(2)	1.0	51(1)
O-4(7)	−717(3)	4262(2)	8356(1)	1.0	54(1)
C-5(7)	−1058(5)	3700(3)	7584(2)	1.0	55(1)
O-5(7)	−674(3)	3550(2)	7089(2)	1.0	54(1)
C-6(7)	−2003(4)	3924(3)	7483(3)	1.0	55(1)
O-6(7)	−2531(3)	3506(2)	7226(2)	1.0	57(1)
C-7(7)	2500(10)	3873(8)	0313(8)	0.45	71(5)
C-8(7)	2945(34)	3722(19)	6805(15)	0.45	229(32)
C-7′(7)	2372(8)	3666(8)	6985(6)	0.55	75(4)
C-8′(7)	2914(17)	4151(10)	7197(13)	0.55	174(19)
C-9(7)	3474(5)	3662(3)	7204(3)	1.0	70(2)
C-0(7)	−3990(6)	3233(4)	6895(4)	1.0	86(2)
C-1(H)	5272(38)	1594(32)	5720(30)	0.55	318(35)
C-2(H)	4455(33)	1473(22)	6065(16)	0.55	273(24)
C-3(H)	3807(30)	1987(19)	6050(3)	0.55	272(22)
C-4(H)	3007(31)	1845(22)	5704(15)	0.55	301(22)
C-5(H)	2122(30)	2141(18)	5850(16)	0.55	292(23)
C-6(H)	1319(33)	1804(22)	5605(14)	0.55	236(26)

Table 4 (Continued)

Atom	x	y	z		U_{eq}
C-1′(H)	966(49)	1740(21)	5202(25)	0.45	280(32)
C-2′(H)	949(46)	2166(25)	5643(18)	0.45	301(27)
C-3′(H)	755(59)	2751(20)	5454(20)	0.45	317(25)
C-4′(H)	675(54)	2783(18)	4859(20)	0.45	305(23)
C-5′(H)	622(66)	3411(18)	4705(20)	0.45	278(24)
C-6′(H)	693(72)	3444(27)	4103(21)	0.45	316(38)
Form II crystal					
C-1(1)	6536(8)	9219(7)	−418(8)	1.0	107(6)
C-2(1)	6223(10)	9742(9)	−33(9)	1.0	150(9)
C-3(1)	5272(9)	9307(7)	−14(7)	1.0	99(5)
C-4(1)	4865(7)	8985(7)	−601(5)	1.0	76(3)
C-5(1)	5192(6)	8443(8)	−872(4)	1.0	70(2)
C-6(1)	4871(9)	8245(10)	−1518(5)	1.0	126(6)
O-2(1)	6618(9)	9909(9)	548(7)	1.0	206(10)
O-3(1)	5027(8)	9893(7)	216(7)	1.0	155(6)
O-4(1)	3972(3)	8477(3)	−521(2)	1.0	53(1)
O-5(1)	6131(4)	8959(6)	−938(4)	1.0	103(3)
O-6(1)	5161(7)	7742(8)	−1782(4)	1.0	132(4)
C-7(1)	6512(17)	10427(18)	987(8)	1.0	169(10)
C-8(1)	6918(15)	10468(16)	1595(8)	1.0	181(11)
C-9(1)	4755(9)	6915(7)	−1526(8)	1.0	105(5)
C-0(1)	4909(11)	6352(10)	−1961(8)	1.0	136(7)
C-1(2)	7783(5)	7360(6)	408(5)	1.0	57(2)
C-2(2)	7924(6)	8115(6)	783(4)	1.0	61(2)
C-3(2)	7238(6)	8333(6)	689(4)	1.0	59(2)
C-4(2)	7151(6)	8443(7)	12(4)	1.0	67(2)
C-5(2)	7004(6)	7643(6)	−316(4)	1.0	62(2)
C-6(2)	6996(7)	7734(6)	−992(4)	1.0	80(3)
O-2(2)	7981(4)	7895(4)	1391(3)	1.0	67(1)
O-3(2)	7443(4)	9090(4)	1000(3)	1.0	73(2)
O-3(2)	7448(4)	6239(5)	1756(3)	1.0	79(2)
O-4(2)	6441(4)	8564(4)	−054(3)	1.0	68(1)
O-5(2)	7725(4)	7504(4)	−187(3)	1.0	61(1)
O-6(2)	7746(5)	8466(5)	−1184(3)	1.0	85(2)
C-7(2)	8466(8)	8595(8)	1805(5)	1.0	97(4)
C-8(2)	8704(8)	8237(9)	2332(5)	1.0	92(4)
C-9(2)	7861(12)	8512(11)	−1825(5)	1.0	129(6)
C-0(2)	8655(13)	9271(11)	−2006(7)	1.0	147(8)
C-1(3)	6071(6)	4133(7)	1050(4)	1.0	61(2)
C-2(3)	6670(6)	4758(7)	1496(4)	1.0	63(2)
C-3(3)	6796(5)	5618(7)	1370(4)	1.0	60(2)
C-4(3)	7081(5)	5868(6)	735(4)	1.0	52(2)
C-5(3)	6511(6)	5193(6)	296(3)	1.0	53(2)
C-6(3)	6881(6)	5396(6)	−329(3)	1.0	62(2)
O-2(3)	6296(5)	4503(6)	2097(3)	1.0	79(2)
O-4(3)	7059(3)	6647(4)	624(3)	1.0	55(1)
O-5(3)	6411(4)	4391(4)	476(2)	1.0	58(1)
O-6(3)	6287(4)	4798(4)	−736(2)	1.0	65(1)
C-7(3)	6740(13)	4264(13)	2486(5)	1.0	130(6)
C-8(3)	6327(13)	4045(11)	3095(5)	1.0	121(6)
C-9(3)	6615(9)	4918(9)	−1324(3)	1.0	92(4)
C-0(3)	5980(10)	4267(10)	−1742(5)	1.0	107(4)
C-1(4)	2724(5)	2322(5)	105(3)	1.0	45(1)
C-2(4)	3204(5)	2482(5)	1681(3)	1.0	44(1)
C-3(4)	4048(5)	3293(5)	1670(3)	1.0	46(1)
C-4(4)	4534(5)	3299(6)	1122(3)	1.0	51(2)
C-5(4)	4013(5)	3135(5)	560(3)	1.0	46(1)

Table 4 (Continued)

Atom	x	y	z		U_{eq}
C-6(4)	4454(6)	3078(6)	2(3)	1.0	54(2)
O-2(4)	2667(4)	2490(3)	2153(2)	1.0	50(1)
O-3(4)	4488(4)	3356(4)	2214(2)	1.0	57(1)
O-4(4)	5286(3)	4088(4)	1110(2)	1.0	52(1)
O-5(4)	3239(4)	2339(3)	629(2)	1.0	50(1)
O-6(4)	4761(6)	2506(5)	85(4)	1.0	89(2)
C-7(4)	2585(7)	1981(8)	2658(4)	1.0	75(3)
C-8(4)	1850(6)	1822(8)	3034(4)	1.0	73(3)
C-9(4)	5258(11)	2503(9)	−398(6)	1.0	103(4)
C-0(4)	5462(13)	1807(11)	−333(11)	1.0	150(8)
C-1(5)	375(5)	3055(5)	445(4)	1.0	51(2)
C-2(5)	348(5)	2760(5)	1099(4)	1.0	50(2)
C-3(5)	1252(5)	2999(5)	1298(3)	1.0	44(1)
C-4(5)	1633(5)	2661(4)	846(3)	1.0	41(1)
C-5(5)	1614(5)	2979(5)	214(3)	1.0	50(2)
C-6(5)	1946(5)	2618(4)	−255(3)	1.0	49(2)
O-2(5)	22(3)	3164(4)	1481(3)	1.0	57(1)
O-3(5)	1186(3)	2630(3)	1871(2)	1.0	49(1)
O-4(5)	2479(3)	2944(3)	1040(2)	1.0	43(1)
O-5(5)	748(3)	2717(3)	71(2)	1.0	49(1)
O-6(5)	1523(4)	1731(3)	−203(3)	1.0	62(1)
C-7(5)	−789(8)	2630(11)	1754(6)	1.0	119(6)
C-8(5)	−1465(10)	2594(21)	1323(12)	1.0	236(16)
C-9(5)	1837(7)	1334(5)	−0593(5)	1.0	70(2)
C-0(5)	1279(11)	385(6)	−0525(8)	1.0	116(5)
C-1(6)	574(6)	5876(6)	−0328(4)	1.0	53(2)
C-2(6)	140(6)	5549(6)	275(4)	1.0	58(2)
C-3(6)	487(6)	5045(6)	570(4)	1.0	56(2)
C-4(6)	415(5)	4352(5)	141(3)	1.0	48(2)
C-5(6)	830(6)	4734(5)	−457(3)	1.0	51(2)
C-6(6)	671(6)	4047(5)	−916(3)	1.0	64(2)
O-2(6)	263(4)	6246(5)	621(3)	1.0	66(1)
O-3(6)	31(5)	4672(5)	1102(3)	1.0	73(2)
O-4(6)	812(3)	3940(3)	433(2)	1.0	46(1)
O-5(6)	447(4)	5203(3)	−697(2)	1.0	52(1)
O-6(6)	1217(5)	4414(4)	−1436(2)	1.0	71(2)
C-7(6)	−453(9)	6125(9)	961(7)	1.0	106(5)
C-8(6)	−289(8)	6941(8)	1238(5)	1.0	85(3)
C-9(6)	1984(8)	4396(9)	−1392(6)	1.0	96(4)
C-0(6)	2568(10)	4791(10)	−1901(7)	1.0	119(5)
C-1(7)	3441(6)	8687(6)	−848(4)	1.0	54(2)
C-2(7)	2842(6)	8778(5)	−408(4)	1.0	54(2)
C-3(7)	2304(6)	7939(5)	−100(4)	1.0	49(2)
C-4(7)	1820(5)	7244(5)	−568(4)	1.0	50(2)
C-5(7)	2421(5)	7221(5)	−1034(3)	1.0	46(1)
C-6(7)	1924(5)	6673(5)	−1565(3)	1.0	54(2)
O-2(7)	3342(4)	9411(4)	21(3)	1.0	62(1)
O-3(7)	1700(4)	7984(4)	289(3)	1.0	66(1)
O-4(7)	1443(3)	6465(3)	−229(2)	1.0	47(1)
O-5(7)	2955(4)	8073(3)	−1270(2)	1.0	52(1)
O-6(7)	2486(5)	6623(6)	−1983(3)	1.0	82(2)
C-7(7)	3027(8)	9953(6)	194(5)	1.0	72(2)
C-8(7)	3592(10)	10553(7)	677(6)	1.0	98(4)
C-9(7)	2575(18)	6960(20)	−2534(6)	1.0	183(11)
C-0(7)	3039(13)	6708(13)	−2979(6)	1.0	123(6)
C-1(M)	9506(18)	10474(11)	412(8)	1.0	175(12)

Table 4 (Continued)

Atom	x	y	z		U_{eq}
O-1(M)	8966(10)	10548(11)	914(10)	1.0	207(9)
C-2(M)	4569(40)	5403(48)	−558(16)	1.0	353(25)
O-2(M)	4111(44)	4605(47)	−266(30)	1.0	568(36)
O-1(W)	8117(33)	6309(13)	3115(14)	1.0	399(26)
O-2(W)	1012(14)	4970(13)	−2568(10)	1.0	220(9)

4. Supplementary data

Full crystallographic details, excluding structure factors, have been deposited with the Cambridge Crystallographic Data Center. These data may be obtained on request, from The Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (Tel.: +44-1223-336408; fax: +44-1223-336033; e-mail: deposit@ccdc.cam.ac.uk.1 or www: http://www.ccdc.cam.ac.uk).

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