

2,3-Diaryl-3-hydroxypropionic acid intermediates in the synthesis of *threo* forms of 1,2-diaryl-1,3-propanediols

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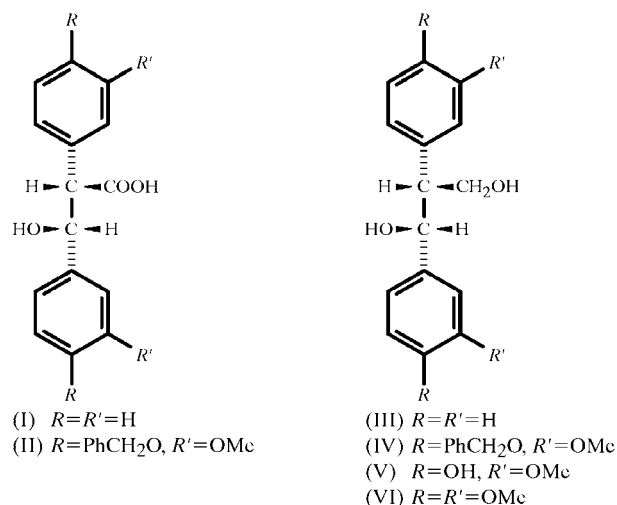
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Racemic *threo*-3-hydroxy-2,3-diphenylpropionic acid, C₁₅H₁₄O₃, (I), crystallizes from ethyl acetate as a conglomerate of separate (+)- and (−)-crystals. The geometries of (I) and its methyl ester are compared. Reduction of (I) gives *threo*-1,2-diphenyl-1,3-propanediol. The synthesis of *threo* forms of 1,2-diaryl-1,3-propanediols *via* 2,3-diaryl-3-hydroxypropionic acids is discussed.

Comment

The stereochemistries of the *threo*, (I), and *erythro* forms of 3-hydroxy-2,3-diphenylpropionic acid were elucidated by Zimmerman & Traxler (1957). Reaction of benzaldehyde with α -lithiated phenylacetic acid gives a mixture of the diastereomers in high yield (Lundquist & Stomberg, 1987). The *threo* isomer (I) predominates in the product and could be obtained in the pure state by fractional crystallization from ethyl acetate. The crystal structure of (I) reported in this paper confirms its steric assignment. 2,3-Bis(4-benzyloxy-3-methoxyphenyl)-3-hydroxypropionic acid has been prepared in an analogous synthesis (Berndtsson *et al.*, 1980). The *threo* form, (II), predominates in the reaction product. Reduction of (I) gives the *threo* form of 1,2-diphenyl-1,3-propanediol, (III) (Lundquist & Stomberg, 1987). Analogously, reduction of (II) gives the *threo* form of a 1,2-diaryl-1,3-propanediol, (IV) (Berndtsson *et al.*, 1980). Removal of the benzyl groups by catalytic hydrogenation gives the *threo* form of 1,2-bis(4-hydroxy-3-methoxyphenyl)-1,3-propanediol, (V) (Berndtsson *et al.*, 1980). This compound is an appropriate model compound for *threo* forms of lignin structures of the 1,2-diaryl-1,3-propanediol type. The results described above suggest that the synthetic method involving an α -lithiated carboxylic acid intermediate is generally applicable to the synthesis of *threo* forms of lignin models of the 1,2-diaryl-1,3-propanediol type. *Threo* selectivity was also observed in a synthesis of 1,2-diaryl-

1,3-propanediols involving an intermediate methyl ester of a 2,3-diaryl-3-hydroxypropionic acid (Nakatsubo & Higuchi, 1975). Hydroboration of (*E*)-2,3-bis(3,4-dimethoxyphenyl)-propenoic acid gives the *threo* form of the 1,2-diaryl-1,3-propanediol lignin model 1,2-bis(3,4-dimethoxyphenyl)-1,3-propanediol, (VI) (Li *et al.*, 1997). This exemplifies an additional synthetic method for the preparation of *threo* forms of this type of lignin model. It is noteworthy that ¹H NMR data for the CH₂ group in the diacetate of (VI) calculated based on substituent effects (Ede & Ralph, 1996) deviate significantly from experimental data (Li *et al.*, 1993). This discrepancy may be related to the vicinity of the aromatic groups in this type of compounds.



A perspective drawing and the atom-numbering of (I) are shown in Fig. 1. The compound crystallizes as a conglomerate of (+)- and (−)-crystals, but the absolute configuration could not be determined and the configuration with *R* on C7 and *S* on C8 was adopted. A search of the Cambridge Structural Database (CSD; Version 5.27 of November 2005, plus three updates; Allen, 2002) for related compounds [search fragment: Ar-CHOH-CH(COO)-Ar'; Ar and Ar' are aromatic groups] gave just two hits, one of them (CSD refcode NEWSUD; Ahn

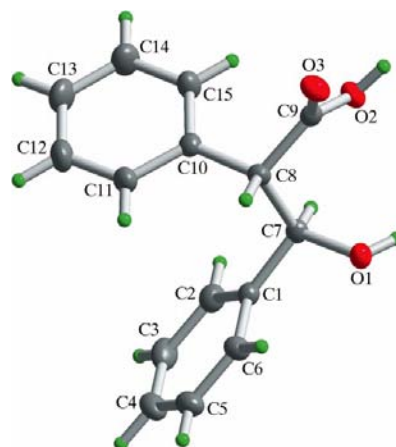


Figure 1

A perspective drawing of (I), showing the atom numbering. Atomic displacement ellipsoids are shown at the 30% probability level.

et al., 1998) with a bulky binaphthalene substituent. The second was the methyl ester of (I), which exists as *rac*-(*R,S*) crystals (YUYKAE; Kolev *et al.*, 1995). Geometric details of (I) and its methyl ester are given in Table 1. Disregarding the differently oriented carboxyl and methoxycarboxyl groups, the overall geometries are quite similar (Fig. 2).

There are both strong O—H...O (Fig. 3) and weak C—H...O hydrogen bonds present in the crystal structure of (I) (Table 2). On the first-level graph-set, as defined by Bernstein *et al.* (1995) and Grell *et al.* (1999), *C*(6) chains, formed by hydrogen bonds *a* and *b*, a *C*(7) chain formed by hydrogen bonds *c*, and an *S*(6) string formed by the intramolecular hydrogen bond *d* were identified. On the second-level graph-set, *R*₂²(12) (*a,b*), *R*₂²(13) (*a,c*) and *R*₂²(9) (*b,c*) rings, and *C*₂²(6)

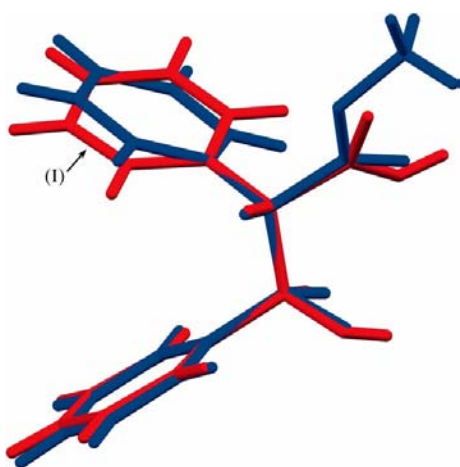


Figure 2

A projection of the overlayed structures of (I) and (±)-*threo*-3-hydroxy-2,3-diphenylpropanoic acid methyl ester (Kolev *et al.*, 1995).

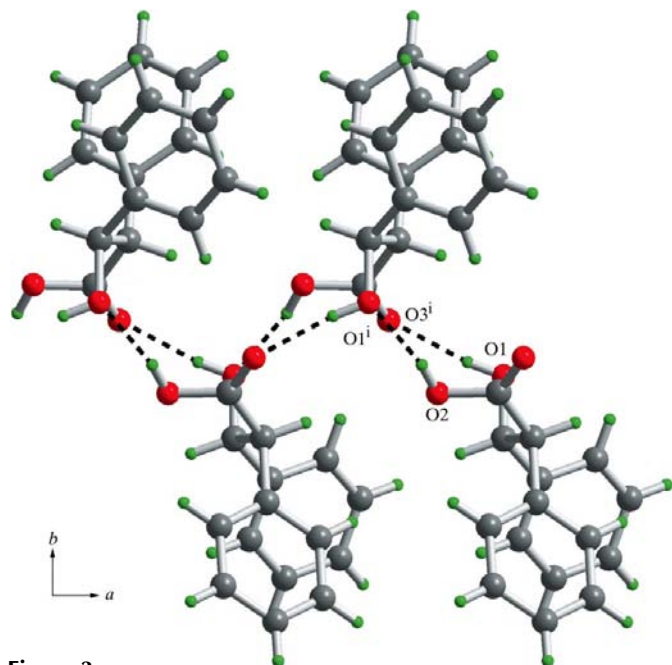


Figure 3

The hydrogen-bonding scheme, viewed along the *c* axis. For symmetry codes, see Table 2.

(*a,b*), *C*₂¹(7) (*a,c*) and *C*₂²(13) (*b,c*) chains, could be recognized. The assignments of graph-set descriptors were performed using *PLUTO* as described by Motherwell *et al.* (1999).

Experimental

threo-3-Hydroxy-2,3-diphenylpropionic acid, (I), was prepared according to the method of Lundquist & Stomberg (1987). Crystals were obtained from ethyl acetate (m.p. 451–454 K).

Crystal data

*C*₁₅H₁₄O₃
M_r = 242.26
 Orthorhombic, *P*2₁2₁2₁
a = 5.8107 (2) Å
b = 13.6635 (3) Å
c = 15.4507 (5) Å
V = 1226.70 (6) Å³

Z = 4
D_x = 1.312 Mg m^{−3}
 Mo *K*α radiation
 μ = 0.09 mm^{−1}
T = 296 (2) K
 Needle, colourless
 0.35 × 0.09 × 0.09 mm

Data collection

Siemens SMART CCD area-detector diffractometer
 ω scans
 Absorption correction: multi-scan (*SADABS*; Sheldrick, 2003)
*T*_{min} = 0.832, *T*_{max} = 0.992

9335 measured reflections
 1325 independent reflections
 1133 reflections with *I* > 2σ(*I*)
*R*_{int} = 0.046
 θ_{max} = 25.4°

Refinement

Refinement on *F*²
R [*F*² > 2σ(*F*²)] = 0.035
wR (*F*²) = 0.089
S = 1.00
 1325 reflections
 166 parameters
 H-atom parameters constrained

w = 1/[σ²(*F*_o²) + (0.0499*P*)² + 0.2342*P*]
 where *P* = (*F*_o² + 2*F*_c²)/3
 (Δ/σ)_{max} < 0.001
 Δρ_{max} = 0.14 e Å^{−3}
 Δρ_{min} = −0.13 e Å^{−3}
 Extinction correction: *SHELXTL*
 Extinction coefficient: 0.045 (5)

Table 1

Selected geometrical parameters (Å, °) for (I) and its methyl ester (YUYKAE; Kolev *et al.*, 1995).

	(I)	YUYKAE
Bond		
C1—C7	1.506 (3)	1.514 (3)
O1—C7	1.442 (3)	1.427 (3)
C7—C8	1.553 (3)	1.530 (3)
C8—C10	1.521 (3)	1.515 (3)
C8—C9	1.513 (3)	1.515 (3)
O2—C9	1.323 (3)	1.326 (3)
O3—C9	1.213 (3)	1.205 (2)
Angle		
C1—C7—C8	111.8 (2)	110.0 (2)
C1—C7—O1	109.60 (19)	112.2 (2)
O1—C7—C8	107.99 (18)	106.8 (2)
C7—C8—C10	113.03 (18)	112.8 (2)
C7—C8—C9	110.33 (19)	112.7 (2)
C9—C8—C10	111.91 (19)	108.9 (2)
C8—C9—O2	113.2 (2)	110.3 (2)
C8—C9—O3	124.4 (2)	126.5 (2)
O2—C9—O3	122.3 (2)	123.1 (2)
Torsion angle		
C1—C7—C8—C10	−58.7 (3)	−63.4 (2)
C1—C7—C8—C9	175.2 (2)	172.7 (2)
O1—C7—C8—C10	−179.3 (2)	175.8 (2)
O2—C9—C8—C7	40.8 (3)	−149.3 (3)
O3—C9—C8—C7	−139.3 (2)	34.7 (3)
O2—C9—C8—C10	−86.0 (3)	84.7 (3)
O3—C9—C8—C10	93.9 (3)	−91.3 (3)
Dihedral angle between aromatic rings	42.0 (1)	53.0 (1)

Table 2

Hydrogen-bonding geometry (Å, °).

Label	<i>D</i> —H... <i>A</i>	<i>D</i> —H	H... <i>A</i>	<i>D</i> ... <i>A</i>	<i>D</i> —H... <i>A</i>
<i>a</i>	O1—H1...O3 ⁱ	0.82	1.93	2.746 (2)	173
<i>b</i>	O2—H2A...O1 ⁱ	0.82	1.87	2.667 (2)	164
<i>c</i>	C6—H6...O3 ⁱⁱ	0.93	2.54	3.458 (3)	169
<i>d</i>	C15—H15...O2	0.93	2.52	3.147 (3)	125

Symmetry codes: (i) $x - \frac{1}{2}, -y + \frac{1}{2}, -z + 1$; (ii) $x + \frac{1}{2}, -y + \frac{1}{2}, -z + 1$.

C-bound H atoms were constrained to an ideal geometry using an appropriate riding model, with $U_{\text{iso}}(\text{H})$ values fixed at $1.2U_{\text{eq}}(\text{C})$ ($\text{C}—\text{H} = 0.93$ and 0.98 Å). For the hydroxy groups, the O—H distances (0.82 Å) and C—O—H angles (109.5°) were kept fixed, while the torsion angles were allowed to refine with the starting positions based on a circular Fourier synthesis; for these H atoms, $U_{\text{iso}}(\text{H})$ values were fixed at $1.5U_{\text{eq}}(\text{O})$.

Data collection: *SMART* (Bruker, 2003); cell refinement: *SAINT* (Bruker, 2003); data reduction: *SAINT* and *SADABS* (Sheldrick, 2003); program(s) used to solve structure: *SHELXTL* (Bruker, 2003); program(s) used to refine structure: *SHELXTL*; molecular graphics: *DIAMOND* (Brandenburg, 2006); software used to prepare material for publication: *SHELXTL*.

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: SK3072). Services for accessing these data are described at the back of the journal.

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