7-Phenyl-1-oxa-4-thiaspiro[4.5]decan-7-ol stereoisomers

Masood Parvez,[a]* Govindaraji Senthil[b] and Veejendra K. Yadav[b]

[a]Department of Chemistry, The University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada T2N 1N4, and [b]Department of Chemistry, Indian Institute of Technology, Kanpur, India

Correspondence e-mail: parvez@ucalgary.ca

The stereoisomers of 7-phenyl-1-oxa-4-thiaspiro[4.5]decan-7-ol, $C_{14}H_{18}O_2S$, have the same stereochemistry at the C atom bearing an OH group, *i.e.* axial OH and equatorial phenyl groups. However, the acetal S and O atoms are axial and equatorial, respectively, in one isomer and reversed in the second. Furthermore, the crystals of one isomer are composed of hydrogen-bonded molecules involving the hydroxyl H atom and the O atom of the five-membered heterocyclic ring, with an O···O distance of 2.962 (3) Å, forming a polymeric chain along the *b* axis. The asymmetric unit of the other isomer is composed of two molecules, wherein hydroxyl H atoms and the O atoms of the five-membered heterocyclic rings display intramolecular O—H···O hydrogen bonds with O···O separations of 2.820 (2) and 2.834 (2) Å.

Comment

The most recent theory of products distribution relies upon the ground state relative abundance of the conformational isomers and argues against the transition state structure (Gung & Francis, 1993; Tomoda, 1999). 1-Oxa-4-thiaspiro[4.5]decan-7-one, (I), would be expected to exist as an equilibrium mixture of (I*a*) and (I*b*). Isomer (I*b*) is 0.92 kcal mol^{-1} (1 kcal = 4.1868 J) more stable than isomer (I*a*), as determined from energy calculations using the program *GAUSSIAN*94 (Frisch *et al.*, 1995). This small energy difference would correlate to (II*a*):(II*b*) = 1:1 on reaction with a nucleophile. Due to very similar geometry and the high steric resistance arising from the acetal function to axial attack, the conformers (I*a*) and (I*b*) would be expected to undergo predominantly equatorial attack at equal rates. In order to investigate the validity of this prediction, we reacted (I) with phenylmagnesium bromide, PhMgBr, to obtain the two title products, (II*a*) and (II*b*). The stereochemical characterization of these products from spectrometric data was difficult. We therefore resorted to single-crystal X-ray determination for

the structural characterization of these compounds. In this paper, we describe the crystal structures of (II*a*) and (II*b*).

The structure of (II*a*) (Fig. 1) is composed of molecules having intermolecular interactions between the hydroxyl H atom and the O atom of the five-membered heterocyclic ring, with an O2···O1 distance of 2.962 (3) Å, forming a polymeric chain along the *b* axis (Fig. 2). The acetal S and O atoms are axial and equatorial, respectively, and the heterocyclic ring adopts an O-envelope conformation, with O1 0.509 (4) Å out of the plane formed by the rest of the atoms of the ring; the maximum deviation of any atom from this plane is 0.014 (2) Å. The six-membered C3–C8 ring adopts a classical chair conformation, with puckering parameters (Cremer & Pople, 1975) $Q = 0.542$ (3) Å, $\theta = 5.1$ (3) and $\varphi = 259$ (4)°, while the phenyl ring (C9–C14) is essentially planar [maximum deviation 0.006 (2) Å].
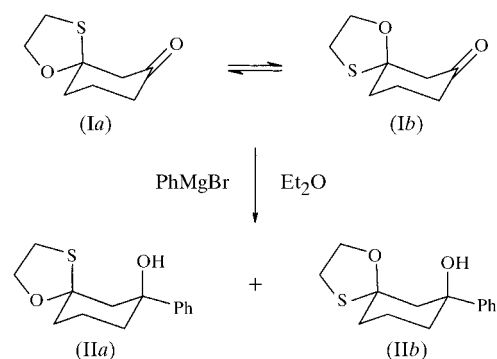
The asymmetric unit of (II*b*) (Fig. 3), on the other hand, is composed of two independent molecules separated by normal van der Waals distances. The hydroxyl H atoms and the O atoms of the five-membered heterocyclic rings in the two molecules display intramolecular interactions with O···O distances of 2.834 (2) and 2.820 (2) Å, unlike the intermolecular hydrogen-bonding pattern observed in (II*a*). The acetal S and O atoms in (II*b*) have been reversed from (II*a*) and are equatorial and axial, respectively. Atoms S1, C1 and C2 of the heterocyclic rings are disordered, resulting in S1/C1/C2/O1/C3 and S1'/C1'/C2'/O1/C3 rings in one molecule, and S1A/C1A/C2A/O1A/C3A and S1A'/C1A'/C2A'/O1/C3 rings in the second. These rings adopt C2-, C2'-, C2A- and C2A'-envelope conformations, respectively, with these atoms 0.557 (17), 0.44 (5), 0.559 (13) and 0.39 (5) Å, respectively, out of the planes formed by the rest of the atoms of the rings. This
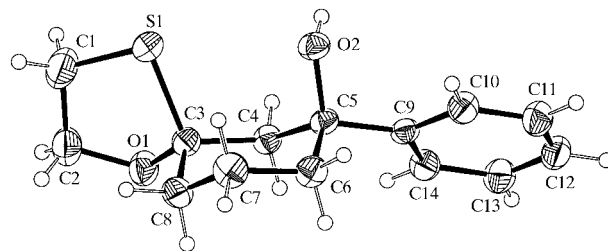

Figure 1
An *ORTEP*II (Johnson, 1976) drawing of (II*a*), with displacement ellipsoids plotted at the 30% probability level and H atoms drawn as small spheres of arbitrary radii.

organic compounds

is also in contrast with the heterocyclic ring conformation in (IIa), which adopts an O-envelope conformation. The separation between the disordered fractions of atoms ranges between 0.035 and 0.843 Å for S1/S1′ and C2A/C2A′, respectively. The six-membered C3–C8 and C3A–C8A rings in (IIb) adopt a classical chair conformation, with puckering para-
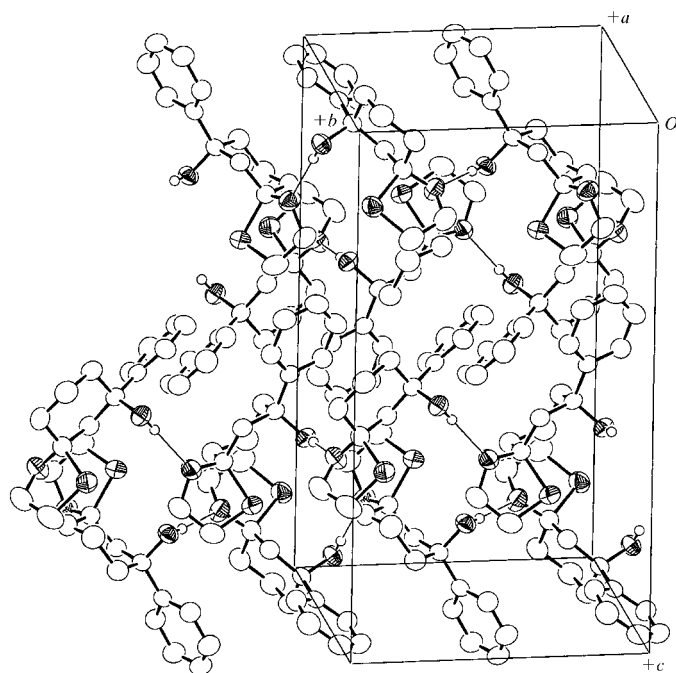

Figure 2
The unit-cell packing of (IIa), showing the intermolecular hydrogen bonds forming a polymeric chain along the b axis. Only those H atoms involved in hydrogen bonding are shown.
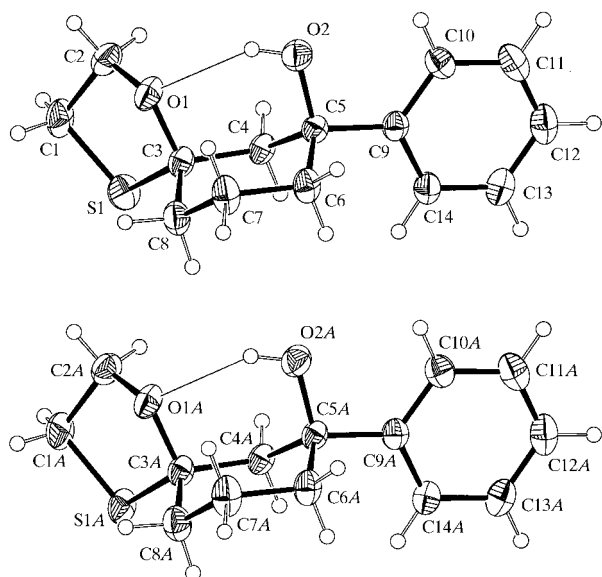

Figure 3
An *ORTEP*II (Johnson, 1976) drawing of the two molecules in the asymmetric unit of (IIb), with displacement ellipsoids plotted at the 30% probability level and H atoms drawn as small spheres of arbitrary radii. Intramolecular hydrogen bonds have been plotted with thin lines and the minor fractions of the disordered atoms have been omitted.

meters Q = 0.552 (3) and 0.550 (3) Å, θ = 5.2 (3) and 4.1 (3)°, and φ = 248 (4) and 259 (4)°, respectively. The phenyl rings (C9–C14 and C9A–C14A) are essentially planar.

The bond distances and angles in the two structures are normal and agree well with the corresponding values reported for similar compounds in the Cambridge Structural Database (Allen & Kennard, 1993). The S—Csp^3 bond distances of 1.853 (3) and 1.794 (4) Å in (IIa), although significantly different from each other, are in excellent agreement with the corresponding bond distances in the two molecules of (IIb). Similar inequivalent S—C bond distances have been reported in the crystal structures of cyclohexanespiro-2′-(1′,3′-oxa-thiolan-5-one 3′-oxide) (Frechina *et al.*, 1992), (+)-(3S,4R)-6-phenyl-1-oxa-4-thiaspiro[4.5]decan-8-one (Sonoda *et al.*, 1992), two derivatives of an oxathiaspirodecene (Parvez *et al.*, 1997), 2-(7-ethylidene-6-methyl-1-oxa-4-thiaspiro[4.5]dec-7-yl)ethanol (Parvez *et al.*, 1998), two derivatives of 1-oxa-4-thiaspirodecane (Parvez *et al.*, 2001a) and some Diels–Alder adducts of a 1-oxa-4-thia-6-vinylspirodec-6-ene (Parvez *et al.*, 2001b).

Experimental

The two title stereoisomers, (IIa) and (IIb), were prepared according to the literature protocol of Mertes (1961). Condensation of mercaptoethanol and cyclohexane-1,3-dione in benzene at reflux furnished a mixture of the acetals (Ia) and (Ib). This mixture was reacted further with PhMgBr in Et$_2$O to obtain a mixture of the desired compounds (IIa) and (IIb) in quantitative yield.

Compound (IIa)

Crystal data

C$_{14}$H$_{18}$O$_2$S	Cu $K\alpha$ radiation
M_r = 250.34	Cell parameters from 25
Orthorhombic, $Pbca$	reflections
a = 12.313 (2) Å	θ = 20–30°
b = 10.674 (5) Å	μ = 2.13 mm^{-1}
c = 19.535 (2) Å	T = 293 (2) K
V = 2568 (1) Å^3	Needle, colourless
Z = 8	0.52 × 0.18 × 0.10 mm
D_x = 1.295 Mg m^{-3}	

Data collection

Enraf–Nonius CAD-4 diffract-ometer	1529 reflections with $I > 2\sigma(I)$
$\omega/2\theta$ scans	θ_{max} = 68°
Absorption correction: empirical *via* ψ scan (3 reflections; North *et al.*, 1968)	h = 0 → 14
	k = 0 → 10
	l = −23 → 0
T_{min} = 0.40, T_{max} = 0.82	3 standard reflections
2199 measured reflections	every 200 reflections
2199 independent reflections	intensity decay: <0.1%

Refinement

Refinement on F^2	$w = 1/[\sigma^2(F_o^2) + (0.082P)^2$
$R[F^2 > 2\sigma(F^2)]$ = 0.052	$+ 0.255P]$
$wR(F^2)$ = 0.150	where $P = (F_o^2 + 2F_c^2)/3$
S = 1.03	$(\Delta/\sigma)_{max} < 0.01$
2199 reflections	$\Delta\rho_{max}$ = 0.32 e Å^{-3}
155 parameters	$\Delta\rho_{min}$ = −0.25 e Å^{-3}
H-atom parameters constrained	

Table 1
Selected geometric parameters (Å, °) for (IIa).

S1—C1	1.794 (4)	O1—C3	1.424 (3)
S1—C3	1.853 (3)	O2—C5	1.430 (3)
O1—C2	1.420 (4)		
C1—S1—C3	92.00 (16)	C2—O1—C3	110.6 (2)

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

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
O2—H2$\cdots$O1^i	0.82	2.14	2.962 (3)	175

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

Compound (IIb)

Crystal data

$C_{14}H_{18}O_2S$
$M_r = 250.34$
Monoclinic, $C2/c$
$a = 22.136$ (8) Å
$b = 10.144$ (2) Å
$c = 24.923$ (6) Å
$\beta = 114.17$ (2)°
$V = 5106$ (2) Å^3
$Z = 16$

$D_x = 1.303$ Mg m^{-3}
Cu $K\alpha$ radiation
Cell parameters from 25
    reflections
$\theta = 20$–$30°$
$\mu = 2.15$ mm^{-1}
$T = 293$ (2) K
Block, colourless
$0.41 \times 0.33 \times 0.31$ mm

Data collection

Enraf–Nonius CAD-4 diffract-
    ometer
$\omega/2\theta$ scans
Absorption correction: empirical
    via ψ scan (3 reflections; North et
    $al.$, 1968)
    $T_{min} = 0.43$, $T_{max} = 0.51$
4577 measured reflections
4459 independent reflections

2869 reflections with $I > 2\sigma(I)$
$R_{int} = 0.022$
$\theta_{max} = 68°$
$h = -25 \rightarrow 0$
$k = -10 \rightarrow 0$
$l = -27 \rightarrow 29$
3 standard reflections
    every 200 reflections
    intensity decay: 1.1%

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.044$
$wR(F^2) = 0.124$
$S = 1.03$
4459 reflections
365 parameters
H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.057P)^2$
    $+ 2.16P]$
    where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.01$
$\Delta\rho_{max} = 0.16$ e Å^{-3}
$\Delta\rho_{min} = -0.18$ e Å^{-3}

Table 3
Selected geometric parameters (Å, °) for (IIb).

S1—C1	1.757 (15)	S1A—C1A	1.741 (10)
S1—C3	1.854 (3)	S1A—C3A	1.852 (3)
C2—O1	1.383 (5)	C2A—O1A	1.397 (4)
O1—C3	1.426 (3)	O1A—C3A	1.423 (3)
O2—C5	1.435 (3)	O2A—C5A	1.428 (3)
C1—S1—C3	92.7 (4)	C1A—S1A—C3A	93.3 (3)
C2—O1—C3	111.9 (3)	C2A—O1A—C3A	112.2 (3)

The asymmetric unit of (IIb) is composed of two independent molecules, which are related by pseudo-centres of symmetry located at −0.375, −0.126, 0.000 and −0.125, 0.624, 0.000. The cell constants and space group were verified on a Nonius KappaCCD instrument.

Table 4
Hydrogen-bonding geometry (Å, °) for (IIb).

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
O2—H2$\cdots$O1	0.82	2.12	2.834 (2)	145
O2A—H2A1$\cdots$O1A	0.82	2.11	2.820 (2)	145

The corresponding atoms S1, C1 and C2 of the heterocyclic rings in both the molecules of (IIb) were disordered, with inequivalent site-occupancy factors; the major fractions were 0.717 (18) and 0.794 (16) in the two molecules. Atoms O1 and C3 did not seem to be affected by this disorder. For both (IIa) and (IIb), most of the H atoms were located from difference Fourier syntheses and all were included in the refinements at geometrically idealized positions, with C—H distances of 0.93 and 0.97 Å, and an O—H distance of 0.82 Å, utilizing a riding model. In order to avoid collisions with the cryogenic system, reflections with $k > 10$ could not be collected for both crystals.

For both compounds, data collection: CAD-4 $Software$ (Enraf–Nonius, 1989); data reduction: $TEXSAN$ (Molecular Structure Corporation, 1994); program(s) used to solve structure: $SAPI$91 (Fan, 1991); program(s) used to refine structure: $SHELXL$97 (Sheldrick, 1997); molecular graphics: $TEXSAN$; software used to prepare material for publication: $SHELXL$97.

References

Allen, F. H. & Kennard, O. (1993). $Chem. Des. Autom. News$, **8**, 1, 31–37.
Cremer, D. & Pople, J. A. (1975). $J. Am. Chem. Soc.$ **97**, 1354–1358.
Enraf–Nonius (1989). CAD-4 $Software$. Version 5.0. Enraf–Nonius, Delft, The Netherlands.
Fan, H.-F. (1991). $SAPI$91. Rigaku Corporation, Tokyo, Japan.
Frechina, J. V., Sanz, V., Cervilla, A., Ramirez, J. A., Ghilardi, C. A. & Orlandini, A. (1992). $Acta Cryst.$ C**48**, 1523–1525.
Frisch, M. J., Trucks, G. W., Schlegel, H. B., Gill, P. M. W., Johnson, B. G., Robb, M. A., Cheeseman, J. R., Keith, T. A., Petersson, G. A., Montgomery, J. A., Raghavachari, K., Al-Laham, M. A., Zakrzewski, V. G., Ortiz, J. V., Foresman, J. B., Cioslowski, J., Stefanov, B. B., Nanayakkara, A., Challalcombe, M., Peng, C. Y., Ayala, P. Y., Chen, W., Wong, M. W., Andrews, J. L., Replogle, E. S., Gomperts, R., Martin, R. L., Fox, D. L., Binkley, J. S., Defrees, D. J., Baker, J., Stewart, J. P., Head-Gordon, M., Gonzalez, C. & Pople, J. A. (1995). $GAUSSIAN$94. Revision A1. Gaussian Inc., Pittsburgh, Pennsylvania, USA.
Gung, B. W. & Francis, M. B. (1993). $J. Org. Chem.$ **58**, 6177–6179.
Johnson, C. K. (1976). $ORTEP$II. Report ORNL-5138. Oak Ridge National Laboratory, Tennessee, USA.
Mertes, M. P. (1961). $J. Org. Chem.$ **26**, 5236–5237.
Molecular Structure Corporation (1994). $TEXSAN$. Version 1.6f. MSC, 3200 Research Forest Drive, The Woodlands, TX 77381, USA.
North, A. C. T., Phillips, D. C. & Mathews, F. S. (1968). $Acta Cryst.$ A**24**, 351–359.
Parvez, M., Jeyaraj, D. A. & Yadav, V. K. (1997). $Acta Cryst.$ C**53**, 1961–1963.
Parvez, M., Yadav, V. K. & Jeyaraj, D. A. (1998). $Acta Cryst.$ C**54**, 1679–1681.
Parvez, M., Yadav, V. K. & Senthil, G. (2001a). $Acta Cryst.$ C**57**, 79–81.
Parvez, M., Yadav, V. K. & Senthil, G. (2001b). $Acta Cryst.$ C**57**, 82–85.
Sheldrick, G. M. (1997). $SHELXL$97. University of Göttingen, Germany.
Sonoda, S., Houchigai, H., Asaoka, M. & Takei, H. (1992). $Tetrahedron Lett.$ **33**, 3145–3146.
Tomoda, S. (1999). $Chem. Rev.$ **99**, 1243–1263.