2,2-Dimethyl-5-nitroso-1,3-dioxan-5-yl benzoate, 2,2-dimethyl-5-nitroso-1,3-dioxan-5-yl 4-chlorobenzoate and 5-nitroso-1,3-dioxan-5-yl 4-chlorobenzoate

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The crystal structures of 2,2-dimethyl-5-nitroso-1,3-dioxan-5-yl benzoate, $C_{13}H_{15}NO_5$, (I), 2,2-dimethyl-5-nitroso-1,3-dioxan-5-yl 4-chlorobenzoate, $C_{13}H_{14}ClNO_5$, (II), and 5-nitroso-1,3-dioxan-5-yl 4-chlorobenzoate, $C_{11}H_{11}NO_5$, (III), have been determined in order to gain insight into the conformational preference of α-benzoyloxynitroso. Unfavourable 1,3-diaxial interactions force (I) and (II) to crystallize in the 2,5 twist-boat conformation, whereas compound (III), lacking this destabilizing interaction, crystallizes in the chair conformation.

Comment

α-Acyloxynitroso derivatives have elicited recent interest as a new class of HNO donors (Sha *et al.*, 2006). In 2004, we introduced α-acetoxynitroso derivatives as reactive dienophiles in (4+2)-cycloaddition reactions and the synthetic relevance of this new class of nitroso dienophiles has been demonstrated (Calvet *et al.*, 2004, 2005, 2007). The unprecedented behaviour of α-acetoxynitroso in the presence of a 1,3-diene led us to investigate the conformational preference of these compounds. This study was expected to trigger the development of more reactive/selective dienophiles. Moreover, the cycloaddition reaction of α-acetoxynitroso complexed with a metallic salt bearing enantiopure ligands was a very exciting development. Such an investigation required the rational design of a reactive dienophile, which cannot be accomplished without a detailed crystallographic study.

α-Benzoyloxynitroso derivatives (I) and (II) (see scheme) differ only by the nature of the aromatic *para* substituent [for

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(I), R^1 = H and R^2 = Me; for (II), R^1 = Cl and R^2 = Me]. The 1,3-dioxanyl ring crystallizes in the 2,5 twist-boat conformation (Figs. 1 and 2), with the N=O and the benzoyloxy substituents occupying the isoclinal positions (Freeman & Do, 2002). The puckering parameters for (I) are Q = 0.750 (1) Å, θ = 91.7 (1)° and φ = 337.0 (1)°, and for (II) are Q = 0.759 (1) Å, θ = 92.1 (1)° and φ = 334.4 (1)° for the atom sequence O1—C1—O2—C2—C3—C4 (Cremer & Pople, 1975). This twisted conformation occurs in the substituted 1,3-dioxanyl ring in order to relieve unfavourable 1,3-diaxial interaction (Rychnovsky *et al.*, 1993), as in the case of a related 1,3-dioxanyl ring [Cambridge Structural Database (CSD; Allen, 2002) refcode OCECUU (Kanoh *et al.*, 2000)]. These diaxial interactions [*e.g.* H5A···H4A = 2.24 Å in (I)] are magnified by the shorter length of the C—O bonds [1.4076 (16)–1.4428 (14) Å] compared with the corresponding cyclohexyl ring (see Tables 1 and 3). The N=O bond distance in (II) is slightly longer [0.020 (2) Å] than that observed in (I). This difference could be attributed to the electron-withdrawing character of the *p*-chlorobenzoyl group (Figs. 1 and 2). The distance between carbonyl atom O5 and atom N1 of the nitroso group is also shorter in (II) by 0.019 (2) Å.

(I) R^1 = H, R^2 = Me
(II) R^1 = Cl, R^2 = Me
(III) R^1 = H, R^2 = H
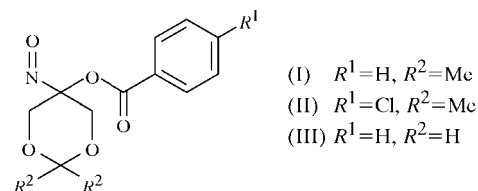
When the isopropylidene ketal unit of derivatives (I) and (II) is replaced by a methylene ketal group, the conformation of the 1,3-dioxanyl ring changes dramatically (Fig. 3). α-Benzoyloxynitroso (III) (R^1 = H and R^2 = H) crystallizes in a chair conformation, with the nitroso unit in an equatorial position and the benzoyloxy substituent in an axial position. For compound (III), the corresponding puckering parameters are Q = 0.571 (1) Å, θ = 3.4 (1)° and φ = 82 (2)°. That the sterically smaller NO substituent adopts the equatorial position could be rationalized in terms of dipole interaction
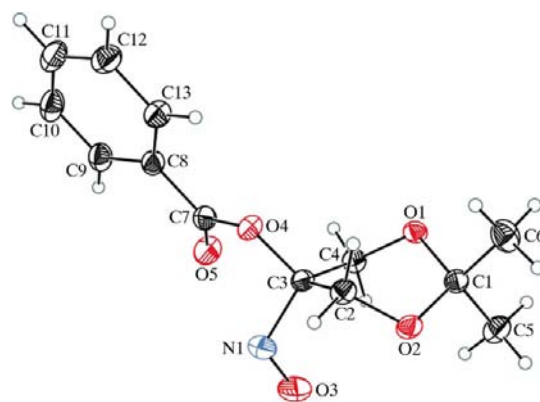
Figure 1
The molecular structure of (I), with displacement ellipsoids depicted at the 30% probability level. H atoms are shown as small spheres of arbitrary radii.

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(Abraham *et al.*, 1972) and/or a repulsive *gauche* effect (Eliel & Juaristi, 1978) between the lone pairs of the intracyclic O1 and O2 atoms and the lone pairs of the nitroso group. The nitroso bond length (Table 5) is intermediate between values observed for derivatives (I) and (II). In contrast, the N1—O5 distance is longer than the average of that in (I) and (II) by 0.178 (3) Å. The O4—C3—N1—O3 torsion angle is −19.51 (15)° for (III), similar to the reported value of −4.3 (1)° for the structure of 2,3,5,6-di-*O*-isopropylidene-1-*C*-nitroso-α-D-mannofuranosyl chloride (CSD refcode FADSOS; Felber *et al.*, 1986).

In each of (I), (II) and (III), there are weak intramolecular C—H···O hydrogen bonds (Tables 2, 4 and 6). These intramolecular hydrogen bonds affect the molecular conformation and stabilize the twist-boat conformation for (I) and (II). For compound (III), only one weak interaction appears, between C4—H4*B* and O5. We have also compared the three structures by superposition, maximizing the fit of atoms C3, O4 and C7 (Fig. 4). The figure shows clearly the exact superposition of (I) and (II). For (III), atom O3 is located 'outside' the six-membered ring, whereas in (I) and (II), atom O3 adopts a
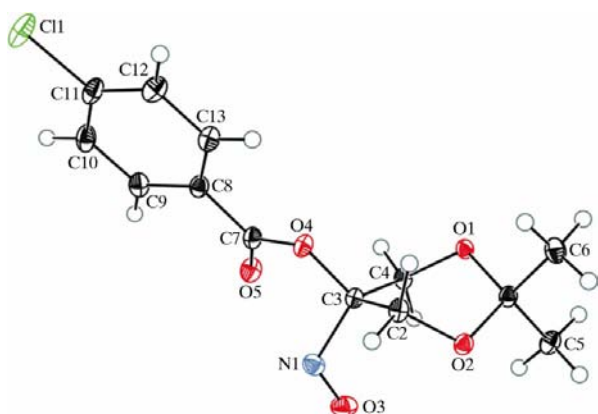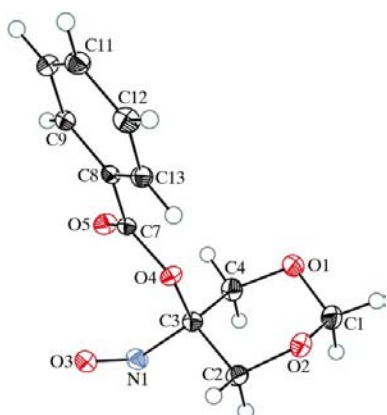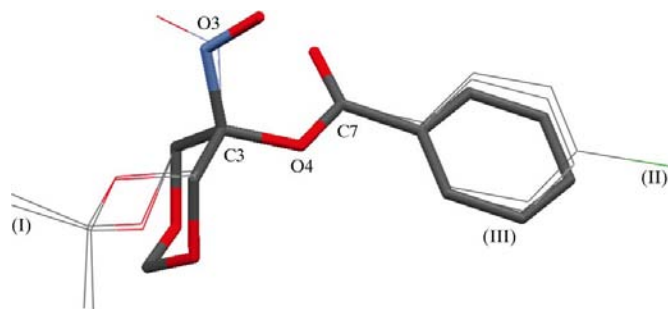

Figure 4
Superposition of the three structures (*Mercury*; Macrae *et al.*, 2006) using atoms C3, O4 and C7 as the common reference points. Compounds (I) and (II) are in wireframe and (III) in capped-stick style.

more 'inside' position. This allows the formation of an additional C—H···O hydrogen bond.

In (I), no intermolecular C—H···O hydrogen-bond interactions are found. In the other two compounds, the packing of the molecules involves C—H···O hydrogen bonds utilizing atoms O2 and O3. Thus, molecules of (II) form dimers (Table 4). The molecules of (III) are linked into a two-dimensional framework by a combination of two C—H···O hydrogen bonds (Table 6). In the shorter of these, C10 acts as a hydrogen-bond donor to atom O2($x + \frac{1}{2}$, $-y + \frac{3}{2}$, $-z + 2$), thereby producing a chain running parallel to the [100] direction, generated by the 2_1 screw axis along ($x, \frac{1}{4}, 0$). In the second C—H···O hydrogen bond, atom C4 acts as a hydrogen-bond donor to O3($x + \frac{1}{2}$, $-y + \frac{5}{2}$, $-z + 2$), so producing a chain running parallel to the [001] direction, as generated by the 2_1 screw axis along ($-\frac{1}{4}, 0, z$). In addition, weak C—H···π hydrogen bonds are present in (I) and (II); for both compounds, atom C5 acts as a hydrogen-bond donor to the C8–C13 ring in an adjacent molecule (Tables 2 and 4).

Experimental

To a solution of 2,2-dimethyl-1,3-dioxan-5-one oxime (303 mg, 2.1 mmol) in CH_2Cl_2 (21 ml) was added iodobenzene dibenzoate (933 mg, 2.1 mmol) portionwise over a period of 45 min. The reaction mixture was stirred for 2 h at room temperature before being quenched with an aqueous saturated $NaHCO_3$ solution. The aqueous phase was extracted with CH_2Cl_2, dried over Na_2SO_3, filtered and concentrated. Flash chromatography (heptane/ethyl acetate, 9:1 to 7:3) afforded 396 mg (72%) of (I) as a bright-blue solid. Recrystallization from pentane/diethyl ether led to blue crystals suitable for X-ray diffraction. To a solution of 2,2-dimethyl-1,3-dioxan-5-one oxime (290 mg, 2.0 mmol) in CH_2Cl_2 (20 ml) was added iodobenzene di(*p*-chlorobenzoate) (1 g, 2.0 mmol) at 273 K. After 6 h at 273 K, the reaction mixture was hydrolyzed with an aqueous saturated $NaHCO_3$ solution. The aqueous phase was extracted with CH_2Cl_2, dried over Na_2SO_3, filtered and concentrated. Flash chromatography (heptane/ethyl acetate, 9:1) afforded 307 mg (57%) of (II) as a blue solid which was recrystallized from pentane/diethyl ether. To a solution of 1,3-dioxan-5-one oxime (502 mg, 4.3 mmol) in CH_2Cl_2 (43 ml) was added iodobenzene dibenzoate (1.91 g, 4.3 mmol) at 273 K. After 75 min at 273 K, the reaction mixture was hydrolyzed with an aqueous saturated $NaHCO_3$ solution. The aqueous phase was extracted with CH_2Cl_2, dried over Na_2SO_3, filtered and concentrated. Flash chromatography (heptane/ethyl acetate, 9:1) afforded 235 mg

Figure 2
The molecular structure of (II), with displacement ellipsoids depicted at the 50% probability level. H atoms are shown as small spheres of arbitrary radii.

Figure 3
The molecular structure of (III), with displacement ellipsoids depicted at the 50% probability level. H atoms are shown as small spheres of arbitrary radii.

(23%) of (III) as a blue solid which was recrystallized from pentane/diethyl ether. NMR (^{1}H and ^{13}C) and IR spectra were collected for the three compounds; the supplementary material contains these data.

Compound (I)

Crystal data

$C_{13}H_{15}NO_5$
$M_r = 265.26$
Monoclinic, $P2_1/n$
$a = 6.2809 (5)$ Å
$b = 21.9393 (19)$ Å
$c = 9.6452 (9)$ Å
$\beta = 100.495 (2)°$

$V = 1306.9 (2)$ Å^3
$Z = 4$
Mo $K\alpha$ radiation
$\mu = 0.10$ mm^{-1}
$T = 273 (2)$ K
$0.32 \times 0.24 \times 0.09$ mm

Data collection

Bruker SMART APEXII area-detector diffractometer
Absorption correction: ψ scan (*SADABS*; Bruker, 2000)
$T_{min} = 0.98$, $T_{max} = 0.99$

21059 measured reflections
3401 independent reflections
2914 reflections with $I > 2\sigma(I)$
$R_{int} = 0.022$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.050$
$wR(F^2) = 0.150$
$S = 1.12$
3401 reflections

173 parameters
H-atom parameters constrained
$\Delta\rho_{max} = 0.60$ e Å^{-3}
$\Delta\rho_{min} = -0.41$ e Å^{-3}

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

C1—O1	1.4286 (15)	O2—C2	1.4076 (16)
C1—O2	1.4360 (15)	N1—O3	1.1901 (19)
C1—C5	1.509 (2)	C7—O5	1.2001 (18)
C1—C6	1.513 (2)	N1—O5	2.6573 (19)
O1—C4	1.4232 (16)		
O4—C3—N1—O3	160.35 (14)		

Table 2
Hydrogen-bond geometry (Å, °) for (I).

Cg is the centroid of the C8–C13 ring.

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
C4—H4A$\cdots$O3	0.97	2.34	2.7593 (19)	105
C4—H4B$\cdots$O5	0.97	2.57	3.0016 (17)	107
C5—H5C$\cdots Cg^i$	0.97	2.69	3.6482 (18)	173

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

Compound (II)

Crystal data

$C_{13}H_{14}ClNO_5$
$M_r = 299.70$
Monoclinic, $C2/c$
$a = 21.716 (3)$ Å
$b = 6.1950 (8)$ Å
$c = 20.398 (2)$ Å
$\beta = 96.927 (2)°$

$V = 2724.2 (6)$ Å^3
$Z = 8$
Mo $K\alpha$ radiation
$\mu = 0.30$ mm^{-1}
$T = 100 (1)$ K
$0.21 \times 0.17 \times 0.15$ mm

Data collection

Bruker SMART APEXII area-detector diffractometer
Absorption correction: ψ scan (*SADABS*; Bruker, 2000)
$T_{min} = 0.93$, $T_{max} = 0.96$

26111 measured reflections
3819 independent reflections
3425 reflections with $I > 2\sigma(I)$
$R_{int} = 0.021$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.037$
$wR(F^2) = 0.110$
$S = 1.09$
3819 reflections

181 parameters
H-atom parameters constrained
$\Delta\rho_{max} = 1.09$ e Å^{-3}
$\Delta\rho_{min} = -0.54$ e Å^{-3}

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

C1—O1	1.4344 (14)	N1—O3	1.2101 (15)
C1—O2	1.4428 (14)	C4—O1	1.4296 (14)
C1—C6	1.5154 (16)	C7—O5	1.2090 (14)
C1—C5	1.5160 (17)	N1—O5	2.6381 (14)
O2—C2	1.4131 (15)		
O4—C3—N1—O3	159.81 (10)		

Table 4
Hydrogen-bond geometry (Å, °) for (II).

Cg is the centroid of the C8–C13 ring.

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
C4—H4B$\cdots$O3	0.97	2.35	2.7716 (15)	106
C4—H4B$\cdots$O5^i	0.97	2.58	3.4507 (16)	149
C5—H5B$\cdots Cg^{ii}$	0.97	2.78	3.7156 (14)	164

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

Compound (III)

Crystal data

$C_{11}H_{11}NO_5$
$M_r = 237.21$
Orthorhombic, $P2_12_12_1$
$a = 9.3969 (5)$ Å
$b = 9.4328 (5)$ Å
$c = 12.2133 (7)$ Å
$V = 1082.58 (10)$ Å^3

$Z = 4$
Mo $K\alpha$ radiation
$\mu = 0.12$ mm^{-1}
$T = 100 (1)$ K
$0.21 \times 0.16 \times 0.14$ mm

Data collection

Bruker SMART APEXII area-detector diffractometer
Absorption correction: ψ scan (*SADABS*; Bruker, 2000)
$T_{min} = 0.96$, $T_{max} = 0.99$

16965 measured reflections
2327 independent reflections
2041 reflections with $I > 2\sigma(I)$
$R_{int} = 0.029$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.034$
$wR(F^2) = 0.091$
$S = 1.03$
2327 reflections
154 parameters

H-atom parameters constrained
$\Delta\rho_{max} = 0.36$ e Å^{-3}
$\Delta\rho_{min} = -0.17$ e Å^{-3}

Table 5
Selected geometric parameters (Å, °) for (III).

C1—O2	1.4094 (17)	N1—O3	1.2042 (15)
C1—O1	1.4104 (17)	C4—O1	1.4233 (17)
O2—C2	1.4256 (16)	C7—O5	1.2098 (16)
C2—C3	1.5312 (18)	N1—O5	2.8248 (15)
C3—C4	1.5290 (17)		
O4—C3—N1—O3	−19.51 (15)		

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Table 6
Hydrogen-bond geometry (Å, °) for (III).

$D-\mathrm{H}\cdots A$	$D-\mathrm{H}$	$\mathrm{H}\cdots A$	$D\cdots A$	$D-\mathrm{H}\cdots A$
C4—H4B⋯O5	0.97	2.41	2.9825 (17)	117
C4—H4B⋯O3^{i}	0.97	2.54	3.4569 (17)	157
C10—H10⋯O2^{ii}	0.93	2.58	3.2872 (17)	133
C13—H13⋯O4	0.93	2.40	2.7235 (15)	100

Symmetry codes: (i) $x + \frac{1}{2}, -y + \frac{5}{2}, -z + 2$; (ii) $x + \frac{1}{2}, -y + \frac{3}{2}, -z + 2$.

H atoms were positioned geometrically and treated as riding. Refinement of the Flack parameter (Flack & Schwarzenbach, 1988) for (III) was suppressed by the MERG 4 command in *SHELXL97* (Sheldrick, 1997).

For all three compounds, data collection: *SMART* (Bruker, 2001); cell refinement: *SMART*; data reduction: *SAINT* (Bruker, 2001); program(s) used to solve structure: *SHELXTL* (Bruker, 2001); program(s) used to refine structure: *SHELXTL*; molecular graphics: *ORTEP-3.2* (Brueggemann & Schmid, 1990); software used to prepare material for publication: *SHELXTL*.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: GA3047). Services for accessing these data are described at the back of the journal.

References

Abraham, R. J., Banks, H. D., Eliel, E. L., Hofer, O. & Kaloustian, M. K. (1972). *J. Am. Chem. Soc.* **94**, 1913–1918.
Allen, F. H. (2002). *Acta Cryst.* B**58**, 380–388.
Brueggemann, R. & Schmid, G. (1990). *ORTEP-3.2*. PC Version. University of Ulm, Germany.
Bruker (2000). *SADABS*. Version 2.03. Bruker AXS Inc., Madison, Wisconsin, USA.
Bruker (2001). *SMART* (Version 5.624), *SAINT* (Version 6.04) and *SHELXTL* (Version 5.10). Bruker AXS Inc., Madison, Wisconsin, USA.
Calvet, G., Blanchard, N. & Kouklovsky, C. (2007). *Org. Lett.* **9**, 1485–1488.
Calvet, G., Dussaussois, M., Blanchard, N. & Kouklovsky, C. (2004). *Org. Lett.* **6**, 2449–2551.
Calvet, G., Guillot, R., Blanchard, N. & Kouklovsky, C. (2005). *Org. Biomol. Chem.* **3**, 4395–4401.
Cremer, D. & Pople, J. A. (1975). *J. Am. Chem. Soc.* **97**, 1354–1358.
Eliel, E. L. & Juaristi, E. (1978). *J. Am. Chem. Soc.* **100**, 6114–6119.
Felber, H., Kresze, G., Prewo, R. & Vasella, A. (1986). *Helv. Chim. Acta*, **69**, 1137–1146.
Flack, H. D. & Schwarzenbach, D. (1988). *Acta Cryst.* A**44**, 499–506.
Freeman, F. & Do, K. U. (2002). *J. Mol. Struct.* **577**, 43–54.
Kanoh, N., Ishihara, J., Yamamoto, Y. & Murai, A. (2000). *Synthesis*, pp. 1878–1893.
Macrae, C. F., Edgington, P. R., McCabe, P., Pidcock, E., Shields, G. P., Taylor, R., Towler, M. & van de Streek, J. (2006). *J. Appl. Cryst.* **39**, 453–457.
Rychnovsky, S. D., Yang, G. & Powers, J. P. (1993). *J. Org. Chem.* **58**, 5251–5255.
Sha, X., Isbell, S., Patel, R. P., Day, C. S. & King, S. B. (2006). *J. Am. Chem. Soc.* **128**, 9687–9692.
Sheldrick, G. M. (1997). *SHELXL97*. University of Göttingen, Germany.