

William T. A. Harrison,^{a*}
H. S. Yathirajan,^b A. Mithun,^c
B. Narayana^c and B. K. Sarojini^d^aDepartment of Chemistry, University of Aberdeen, Meston Walk, Aberdeen AB24 3UE, Scotland, ^bDepartment of Studies in Chemistry, University of Mysore, Manasagangotri, Mysore 570 006, India, ^cDepartment of Chemistry, Mangalore University, Mangalagangotri 574 199, India, and ^dDepartment of Chemistry, P. A. College of Engineering, Nadupadavu, Mangalore 574 153, IndiaCorrespondence e-mail:
w.harrison@abdn.ac.uk

Key indicators

Single-crystal X-ray study
 $T = 120$ K
Mean $\sigma(\text{C}-\text{C}) = 0.003$ Å
 R factor = 0.035
 wR factor = 0.081
Data-to-parameter ratio = 16.6For details of how these key indicators were automatically derived from the article, see <http://journals.iucr.org/e>.

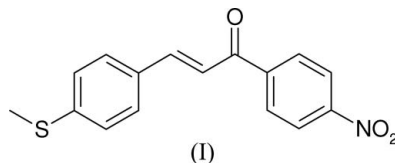
3-[4-(Methylsulfonyl)phenyl]-1-(4-nitrophenyl)-prop-2-en-1-one

The geometrical parameters for the title compound, $\text{C}_{16}\text{H}_{13}\text{NO}_2\text{S}$, are normal. The non-centrosymmetric crystal packing, which is consistent with the non-zero second harmonic generation response, may be influenced by a weak intermolecular $\text{C}-\text{H}\cdots\text{O}$ interaction.

Received 11 September 2006
Accepted 12 September 2006

Comment

The title compound, (I) (Fig. 1), was prepared as part of our ongoing studies (Harrison *et al.*, 2005, 2006) of the non-linear optical (NLO) properties and crystal structures of chalcone derivatives. It is known that substitution at either benzene ring of the chalcone skeleton substantially affects the optical response (Uchida *et al.*, 1998) and we are now exploring the role of the methylsulfonyl ($\text{H}_3\text{CS}-$) substituent (Butcher *et al.*, 2006) in this process.



The non-centrosymmetric polar space group of (I) is consistent with its significant second harmonic generation (SHG) response of 0.6 times that of urea (Watson *et al.*, 1993). The geometrical parameters for (I) fall within their expected ranges (Allen *et al.*, 1987). The molecule of (I) is distinctly twisted about the $\text{C}6-\text{C}7$ and the $\text{C}9-\text{C}10$ bonds (Table 1). The dihedral angle between the benzene ring mean planes ($\text{C}1-\text{C}6$ and $\text{C}10-\text{C}15$) in (I) is $45.84(4)^\circ$, which is significantly smaller than the equivalent value of $68.15(6)^\circ$ in 2-bromo-1-(4-methylphenyl)-3-[4-(methylsulfonyl)phenyl]prop-2-en-1-one (Butcher *et al.*, 2006). The nitro group in (I) is well ordered and makes a dihedral angle of $12.94(15)^\circ$ with respect to the $\text{C}10-\text{C}15$ benzene ring. The $\text{C}16$ methyl group is almost in the plane of the $\text{C}1-\text{C}6$ benzene ring [deviation = $0.049(4)$ Å].

A *PLATON* (Spek, 2003) analysis of the crystal structure of (I) indicates a possible intermolecular $\text{C}-\text{H}\cdots\text{O}$ interaction (Table 2) that might help to establish the crystal packing (Fig. 2). The $\text{C}-\text{H}\cdots\text{O}$ interaction forms extended chains of molecules propagating along [001]. Adjacent chains form pseudo-layers in (100), with all the molecules oriented in the same sense with respect to the polar axis.

Experimental

To a mixture of 4-(methylsulfonyl)benzaldehyde (1.52 g, 0.01 mol) and 4-nitroacetophenone (1.65 g, 0.01 mol) in ethanol (5 ml), a

solution of potassium hydroxide (5%, 5 ml) was added slowly with stirring. The mixture was stirred at room temperature for 24 h. The precipitated solid was filtered off, washed with water, dried and recrystallized from an acetone–toluene (1:1 v/v) solvent mixture (yield 86%; m.p. 409 K). Analysis for $C_{16}H_{13}NO_3S$ found (calculated) (%): C 64.15 (64.20), H 4.32 (4.38), N 4.66 (4.68).

Crystal data

| | |
|----------------------------------|---|
| $C_{16}H_{13}NO_3S$ | $Z = 8$ |
| $M_r = 299.33$ | $D_x = 1.448 \text{ Mg m}^{-3}$ |
| Orthorhombic, <i>Aba2</i> | Mo $K\alpha$ radiation |
| $a = 13.7388 (4) \text{ \AA}$ | $\mu = 0.25 \text{ mm}^{-1}$ |
| $b = 33.5802 (8) \text{ \AA}$ | $T = 120 (2) \text{ K}$ |
| $c = 5.9538 (2) \text{ \AA}$ | Plate, yellow |
| $V = 2746.80 (14) \text{ \AA}^3$ | $0.28 \times 0.24 \times 0.03 \text{ mm}$ |

Data collection

| | |
|---|--|
| Nonius KappaCCD diffractometer | 27858 measured reflections |
| ω and φ scans | 3173 independent reflections |
| Absorption correction: multi-scan | 2811 reflections with $I > 2\sigma(I)$ |
| (<i>SADABS</i> ; Bruker, 2003) | $R_{\text{int}} = 0.063$ |
| $T_{\text{min}} = 0.936$, $T_{\text{max}} = 0.993$ | $\theta_{\text{max}} = 27.6^\circ$ |

Refinement

| | |
|---------------------------------|--|
| Refinement on F^2 | $w = 1/[\sigma^2(F_o^2) + (0.0338P)^2 + 1.763P]$ |
| $R[F^2 > 2\sigma(F^2)] = 0.035$ | where $P = (F_o^2 + 2F_c^2)/3$ |
| $wR(F^2) = 0.081$ | $(\Delta/\sigma)_{\text{max}} = 0.001$ |
| $S = 1.06$ | $\Delta\rho_{\text{max}} = 0.29 \text{ e \AA}^{-3}$ |
| 3173 reflections | $\Delta\rho_{\text{min}} = -0.21 \text{ e \AA}^{-3}$ |
| 191 parameters | Absolute structure: Flack (1983), |
| H-atom parameters constrained | 1416 Friedel pairs |
| | Flack parameter: 0.04 (8) |

Table 1

Selected torsion angles ($^\circ$).

| | | | |
|-------------|----------|---------------|----------|
| C5–C6–C7–C8 | 10.3 (3) | O1–C9–C10–C15 | 21.2 (3) |
| C7–C8–C9–O1 | 11.4 (3) | | |

Table 2

Hydrogen-bond geometry (\AA , $^\circ$).

| $D-H\cdots A$ | $D-H$ | $H\cdots A$ | $D\cdots A$ | $D-H\cdots A$ |
|----------------------------------|-------|-------------|-------------|---------------|
| C11–H11 \cdots O1 ¹ | 0.95 | 2.60 | 3.278 (3) | 129 |

Symmetry code: (i) $x, y, z + 1$.

A handful of reflections weakly violated the $h00$ ($h \neq 2n$) systematic absence condition for the space group *Aba2*. Attempts to develop a model in lower-symmetry space groups were not successful. The H atoms were positioned geometrically ($C-H = 0.95\text{--}0.98 \text{ \AA}$) and refined as riding, with $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{carrier})$ or $1.5U_{\text{eq}}(\text{methyl})$. The methyl group was allowed to rotate but not to tip to best fit the electron density.

Data collection: *COLLECT* (Nonius, 1998); cell refinement: *SCALEPACK* (Otwinowski & Minor, 1997); data reduction: *SCALEPACK* and *DENZO* (Otwinowski & Minor, 1997), and *SORTAV* (Blessing, 1995); program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *ORTEP-3* (Farrugia, 1997); software used to prepare material for publication: *SHELXL97*.

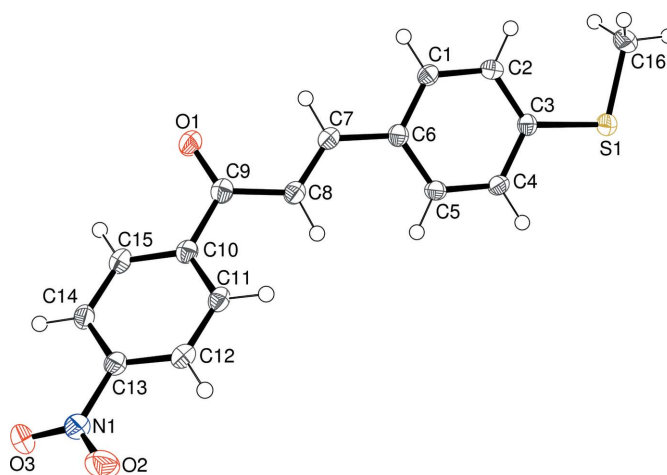


Figure 1

Molecular structure of (I) showing 50% displacement ellipsoids (arbitrary spheres for the H atoms).

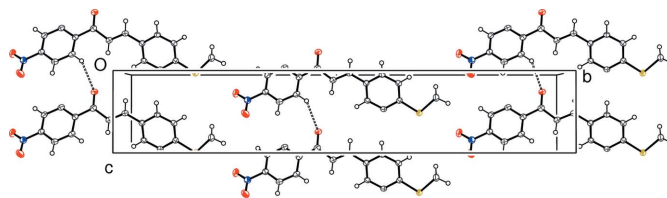


Figure 2

Part of a (100) sheet of molecules in (I) with $C-H\cdots O$ interactions shown as dashed lines.

We thank the EPSRC National Crystallography Service (University of Southampton) for the data collection. BKS thanks AICTE, Government of India, New Delhi, for financial assistance under the 'Career Award for Young Teachers' scheme.

References

- Allen, F. H., Kennard, O., Watson, D. G., Brammer, L., Orpen, A. G. & Taylor, R. (1987). *J. Chem. Soc. Perkin Trans. 2* pp. S1–19.
- Blessing, R. H. (1995). *Acta Cryst.* **A51**, 33–38.
- Bruker (2003). *SADABS*. Bruker AXS Inc., Madison, Wisconsin, USA.
- Butcher, R. J., Yathirajan, H. S., Anilkumar, H. G., Sarojini, B. K. & Narayana, B. (2006). *Acta Cryst.* **E62**, o1659–o1661.
- Farrugia, L. J. (1997). *J. Appl. Cryst.* **30**, 565.
- Flack, H. D. (1983). *Acta Cryst.* **A39**, 876–881.
- Harrison, W. T. A., Yathirajan, H. S., Sarojini, B. K., Narayana, B. & Anilkumar, H. G. (2005). *Acta Cryst.* **C61**, o728–o730.
- Harrison, W. T. A., Yathirajan, H. S., Sarojini, B. K., Narayana, B. & Vijaya Raj, K. K. (2006). *Acta Cryst.* **E62**, o1578–o1579.
- Nonius (1998). *COLLECT*. Nonius BV, Delft, The Netherlands.
- Otwinowski, Z. & Minor, W. (1997). *Methods in Enzymology*, Vol. 276, *Macromolecular Crystallography*, Part A, edited by C. W. Carter Jr & R. M. Sweet, pp. 307–326. New York: Academic Press.
- Sheldrick, G. M. (1997). *SHELXS97* and *SHELXL97*. University of Göttingen, Germany.
- Spek, A. L. (2003). *J. Appl. Cryst.* **36**, 7–13.
- Uchida, T., Kozawa, K., Sakai, T., Aoki, M., Yoguchi, H., Abduryim, A. & Watanabe, Y. (1998). *Mol. Cryst. Liq. Cryst.* **315**, 135–140.
- Watson, G. J. R., Turner, A. B. & Allen, S. (1993). *Organic Materials for Non-linear Optics III*, edited by G. J. Ashwell & D. Bloor. RSC Special Publication No. 137, pp 112–117. Cambridge: Royal Society of Chemistry.

supporting information

Acta Cryst. (2006). E62, o4508–o4509 [https://doi.org/10.1107/S160053680603710X]

3-[4-(Methylsulfonyl)phenyl]-1-(4-nitrophenyl)prop-2-en-1-one

William T. A. Harrison, H. S. Yathirajan, A. Mithun, B. Narayana and B. K. Sarojini

3-[4-(Methylsulfonyl)phenyl]-1-(4-nitrophenyl)prop-2-en-1-one

Crystal data

$C_{16}H_{13}NO_3S$

$M_r = 299.33$

Orthorhombic, *Aba2*

Hall symbol: A 2 -2ac

$a = 13.7388$ (4) Å

$b = 33.5802$ (8) Å

$c = 5.9538$ (2) Å

$V = 2746.80$ (14) Å³

$Z = 8$

$F(000) = 1248$

$D_x = 1.448$ Mg m⁻³

Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å

Cell parameters from 6217 reflections

$\theta = 2.9$ – 27.5°

$\mu = 0.25$ mm⁻¹

$T = 120$ K

Plate, yellow

$0.28 \times 0.24 \times 0.03$ mm

Data collection

Nonius KappaCCD

diffractometer

Radiation source: fine-focus sealed tube

Graphite monochromator

ω and ϕ scans

Absorption correction: multi-scan

(SADABS; Bruker, 2003)

$T_{\min} = 0.936$, $T_{\max} = 0.993$

27858 measured reflections

3173 independent reflections

2811 reflections with $I > 2\sigma(I)$

$R_{\text{int}} = 0.063$

$\theta_{\max} = 27.6^\circ$, $\theta_{\min} = 3.0^\circ$

$h = -17 \rightarrow 17$

$k = -43 \rightarrow 43$

$l = -7 \rightarrow 7$

Refinement

Refinement on F^2

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)] = 0.035$

$wR(F^2) = 0.081$

$S = 1.06$

3173 reflections

191 parameters

1 restraint

Primary atom site location: structure-invariant

direct methods

Secondary atom site location: none

Hydrogen site location: inferred from neighbouring sites

H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0338P)^2 + 1.763P]$

where $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{\max} = 0.001$

$\Delta\rho_{\max} = 0.29$ e Å⁻³

$\Delta\rho_{\min} = -0.21$ e Å⁻³

Absolute structure: Flack (1983), 1416 Friedel

pairs

Absolute structure parameter: 0.04 (8)

Special details

Geometry. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

Refinement. Refinement of F^2 against ALL reflections. The weighted R -factor wR and goodness of fit S are based on F^2 , conventional R -factors R are based on F , with F set to zero for negative F^2 . The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating R -factors(gt) *etc.* and is not relevant to the choice of reflections for refinement. R -factors based on F^2 are statistically about twice as large as those based on F , and R -factors based on ALL data will be even larger.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (\AA^2)

| | x | y | z | $U_{\text{iso}}^*/U_{\text{eq}}$ |
|------|--------------|---------------|--------------|----------------------------------|
| C1 | 0.33886 (12) | 0.58404 (5) | 0.0329 (4) | 0.0197 (4) |
| H1 | 0.3126 | 0.5828 | -0.1146 | 0.024* |
| C2 | 0.34598 (13) | 0.62074 (6) | 0.1380 (3) | 0.0209 (4) |
| H2 | 0.3246 | 0.6442 | 0.0633 | 0.025* |
| C3 | 0.38469 (12) | 0.62311 (6) | 0.3537 (3) | 0.0187 (4) |
| C4 | 0.41536 (13) | 0.58797 (5) | 0.4603 (3) | 0.0201 (4) |
| H4 | 0.4422 | 0.5892 | 0.6072 | 0.024* |
| C5 | 0.40679 (13) | 0.55163 (6) | 0.3533 (4) | 0.0207 (4) |
| H5 | 0.4271 | 0.5281 | 0.4288 | 0.025* |
| C6 | 0.36880 (14) | 0.54878 (6) | 0.1360 (4) | 0.0201 (4) |
| C7 | 0.36326 (12) | 0.51127 (5) | 0.0127 (4) | 0.0215 (4) |
| H7 | 0.3467 | 0.5129 | -0.1420 | 0.026* |
| C8 | 0.37921 (13) | 0.47485 (6) | 0.0965 (3) | 0.0222 (4) |
| H8 | 0.3892 | 0.4717 | 0.2534 | 0.027* |
| C9 | 0.38153 (13) | 0.43940 (6) | -0.0505 (4) | 0.0229 (4) |
| C10 | 0.38089 (13) | 0.39913 (6) | 0.0592 (3) | 0.0208 (4) |
| C11 | 0.34357 (13) | 0.39365 (6) | 0.2756 (3) | 0.0218 (4) |
| H11 | 0.3219 | 0.4160 | 0.3597 | 0.026* |
| C12 | 0.33801 (13) | 0.35585 (6) | 0.3683 (3) | 0.0231 (4) |
| H12 | 0.3103 | 0.3518 | 0.5128 | 0.028* |
| C13 | 0.37387 (15) | 0.32407 (6) | 0.2449 (4) | 0.0227 (4) |
| C14 | 0.41321 (13) | 0.32839 (5) | 0.0330 (4) | 0.0229 (4) |
| H14 | 0.4383 | 0.3061 | -0.0464 | 0.028* |
| C15 | 0.41513 (13) | 0.36617 (6) | -0.0604 (3) | 0.0230 (4) |
| H15 | 0.4401 | 0.3697 | -0.2078 | 0.028* |
| C16 | 0.34877 (16) | 0.70446 (6) | 0.3191 (4) | 0.0304 (5) |
| H16A | 0.3535 | 0.7308 | 0.3888 | 0.046* |
| H16B | 0.2804 | 0.6984 | 0.2866 | 0.046* |
| H16C | 0.3862 | 0.7042 | 0.1790 | 0.046* |
| N1 | 0.36971 (13) | 0.28424 (5) | 0.3491 (3) | 0.0287 (4) |
| O1 | 0.38403 (11) | 0.44190 (4) | -0.2549 (3) | 0.0295 (3) |
| O2 | 0.31977 (12) | 0.28024 (4) | 0.5189 (3) | 0.0416 (4) |
| O3 | 0.41585 (12) | 0.25723 (4) | 0.2606 (3) | 0.0373 (4) |
| S1 | 0.39700 (3) | 0.667528 (13) | 0.50812 (10) | 0.02260 (12) |

Atomic displacement parameters (\AA^2)

| | U^{11} | U^{22} | U^{33} | U^{12} | U^{13} | U^{23} |
|----|------------|-------------|-------------|-------------|-------------|------------|
| C1 | 0.0198 (8) | 0.0229 (9) | 0.0163 (9) | -0.0008 (6) | 0.0022 (8) | 0.0003 (9) |
| C2 | 0.0199 (9) | 0.0219 (10) | 0.0209 (10) | 0.0015 (7) | -0.0007 (8) | 0.0037 (8) |

| | | | | | | |
|-----|-------------|-------------|-------------|--------------|--------------|--------------|
| C3 | 0.0163 (8) | 0.0199 (9) | 0.0200 (9) | 0.0006 (7) | 0.0021 (7) | -0.0015 (8) |
| C4 | 0.0210 (8) | 0.0229 (9) | 0.0165 (11) | 0.0006 (7) | -0.0006 (7) | 0.0003 (8) |
| C5 | 0.0215 (9) | 0.0217 (10) | 0.0187 (10) | 0.0034 (7) | 0.0006 (8) | 0.0025 (8) |
| C6 | 0.0191 (9) | 0.0209 (10) | 0.0202 (10) | 0.0002 (7) | 0.0016 (8) | -0.0012 (8) |
| C7 | 0.0212 (8) | 0.0256 (9) | 0.0176 (8) | -0.0002 (7) | -0.0003 (9) | -0.0015 (10) |
| C8 | 0.0229 (10) | 0.0238 (10) | 0.0199 (10) | -0.0002 (8) | -0.0011 (8) | -0.0022 (8) |
| C9 | 0.0186 (9) | 0.0259 (10) | 0.0243 (11) | -0.0009 (7) | -0.0009 (7) | -0.0035 (8) |
| C10 | 0.0175 (9) | 0.0233 (9) | 0.0217 (12) | -0.0020 (7) | -0.0030 (7) | -0.0024 (8) |
| C11 | 0.0185 (9) | 0.0265 (10) | 0.0204 (10) | 0.0013 (7) | -0.0016 (8) | -0.0053 (8) |
| C12 | 0.0222 (9) | 0.0286 (11) | 0.0186 (10) | -0.0009 (8) | -0.0003 (8) | -0.0012 (8) |
| C13 | 0.0242 (9) | 0.0227 (10) | 0.0213 (10) | -0.0017 (8) | -0.0042 (8) | -0.0014 (8) |
| C14 | 0.0242 (9) | 0.0223 (9) | 0.0223 (11) | 0.0014 (7) | -0.0029 (9) | -0.0051 (9) |
| C15 | 0.0218 (9) | 0.0275 (11) | 0.0197 (10) | -0.0020 (8) | 0.0013 (7) | -0.0038 (8) |
| C16 | 0.0391 (12) | 0.0203 (10) | 0.0319 (13) | 0.0037 (9) | -0.0054 (10) | 0.0007 (9) |
| N1 | 0.0340 (9) | 0.0258 (10) | 0.0262 (10) | -0.0005 (7) | -0.0052 (8) | 0.0000 (8) |
| O1 | 0.0413 (9) | 0.0276 (8) | 0.0197 (8) | -0.0001 (6) | 0.0023 (7) | -0.0022 (6) |
| O2 | 0.0547 (9) | 0.0352 (8) | 0.0350 (8) | 0.0026 (7) | 0.0094 (10) | 0.0107 (9) |
| O3 | 0.0524 (9) | 0.0210 (8) | 0.0385 (9) | 0.0061 (7) | -0.0038 (8) | -0.0040 (7) |
| S1 | 0.0248 (2) | 0.0203 (2) | 0.0227 (2) | 0.00036 (18) | -0.0015 (2) | -0.0021 (2) |

Geometric parameters (Å, °)

| | | | |
|----------|-------------|-------------|-------------|
| C1—C2 | 1.386 (3) | C10—C15 | 1.398 (3) |
| C1—C6 | 1.395 (3) | C10—C11 | 1.399 (3) |
| C1—H1 | 0.9500 | C11—C12 | 1.386 (3) |
| C2—C3 | 1.392 (3) | C11—H11 | 0.9500 |
| C2—H2 | 0.9500 | C12—C13 | 1.386 (3) |
| C3—C4 | 1.405 (3) | C12—H12 | 0.9500 |
| C3—S1 | 1.760 (2) | C13—C14 | 1.380 (3) |
| C4—C5 | 1.382 (3) | C13—N1 | 1.475 (3) |
| C4—H4 | 0.9500 | C14—C15 | 1.386 (3) |
| C5—C6 | 1.398 (3) | C14—H14 | 0.9500 |
| C5—H5 | 0.9500 | C15—H15 | 0.9500 |
| C6—C7 | 1.460 (3) | C16—S1 | 1.801 (2) |
| C7—C8 | 1.339 (3) | C16—H16A | 0.9800 |
| C7—H7 | 0.9500 | C16—H16B | 0.9800 |
| C8—C9 | 1.478 (3) | C16—H16C | 0.9800 |
| C8—H8 | 0.9500 | N1—O3 | 1.225 (2) |
| C9—O1 | 1.220 (2) | N1—O2 | 1.229 (3) |
| C9—C10 | 1.502 (3) | | |
| C2—C1—C6 | 122.4 (2) | C15—C10—C9 | 119.33 (17) |
| C2—C1—H1 | 118.8 | C11—C10—C9 | 121.39 (17) |
| C6—C1—H1 | 118.8 | C12—C11—C10 | 120.48 (18) |
| C1—C2—C3 | 119.60 (19) | C12—C11—H11 | 119.8 |
| C1—C2—H2 | 120.2 | C10—C11—H11 | 119.8 |
| C3—C2—H2 | 120.2 | C13—C12—C11 | 118.31 (19) |
| C2—C3—C4 | 118.92 (18) | C13—C12—H12 | 120.8 |

| | | | |
|---------------|--------------|-----------------|--------------|
| C2—C3—S1 | 124.52 (16) | C11—C12—H12 | 120.8 |
| C4—C3—S1 | 116.55 (15) | C14—C13—C12 | 122.88 (18) |
| C5—C4—C3 | 120.52 (18) | C14—C13—N1 | 119.64 (17) |
| C5—C4—H4 | 119.7 | C12—C13—N1 | 117.48 (19) |
| C3—C4—H4 | 119.7 | C13—C14—C15 | 118.07 (19) |
| C4—C5—C6 | 121.26 (18) | C13—C14—H14 | 121.0 |
| C4—C5—H5 | 119.4 | C15—C14—H14 | 121.0 |
| C6—C5—H5 | 119.4 | C14—C15—C10 | 120.96 (19) |
| C1—C6—C5 | 117.31 (19) | C14—C15—H15 | 119.5 |
| C1—C6—C7 | 119.72 (19) | C10—C15—H15 | 119.5 |
| C5—C6—C7 | 122.93 (18) | S1—C16—H16A | 109.5 |
| C8—C7—C6 | 126.3 (2) | S1—C16—H16B | 109.5 |
| C8—C7—H7 | 116.8 | H16A—C16—H16B | 109.5 |
| C6—C7—H7 | 116.8 | S1—C16—H16C | 109.5 |
| C7—C8—C9 | 121.26 (19) | H16A—C16—H16C | 109.5 |
| C7—C8—H8 | 119.4 | H16B—C16—H16C | 109.5 |
| C9—C8—H8 | 119.4 | O3—N1—O2 | 124.16 (18) |
| O1—C9—C8 | 122.38 (19) | O3—N1—C13 | 118.04 (19) |
| O1—C9—C10 | 119.72 (18) | O2—N1—C13 | 117.80 (17) |
| C8—C9—C10 | 117.90 (17) | C3—S1—C16 | 102.82 (10) |
| C15—C10—C11 | 119.24 (17) | | |
| | | | |
| C6—C1—C2—C3 | 0.3 (3) | C8—C9—C10—C11 | 23.6 (3) |
| C1—C2—C3—C4 | -0.3 (3) | C15—C10—C11—C12 | -1.8 (3) |
| C1—C2—C3—S1 | -179.35 (14) | C9—C10—C11—C12 | 175.91 (16) |
| C2—C3—C4—C5 | -0.3 (3) | C10—C11—C12—C13 | 2.6 (3) |
| S1—C3—C4—C5 | 178.83 (14) | C11—C12—C13—C14 | -1.1 (3) |
| C3—C4—C5—C6 | 0.9 (3) | C11—C12—C13—N1 | 178.38 (16) |
| C2—C1—C6—C5 | 0.2 (3) | C12—C13—C14—C15 | -1.1 (3) |
| C2—C1—C6—C7 | -177.38 (16) | N1—C13—C14—C15 | 179.42 (16) |
| C4—C5—C6—C1 | -0.8 (3) | C13—C14—C15—C10 | 1.9 (3) |
| C4—C5—C6—C7 | 176.70 (17) | C11—C10—C15—C14 | -0.5 (3) |
| C1—C6—C7—C8 | -172.30 (18) | C9—C10—C15—C14 | -178.24 (17) |
| C5—C6—C7—C8 | 10.3 (3) | C14—C13—N1—O3 | 12.0 (3) |
| C6—C7—C8—C9 | -173.50 (18) | C12—C13—N1—O3 | -167.51 (18) |
| C7—C8—C9—O1 | 11.4 (3) | C14—C13—N1—O2 | -167.74 (19) |
| C7—C8—C9—C10 | -168.69 (17) | C12—C13—N1—O2 | 12.8 (3) |
| O1—C9—C10—C15 | 21.2 (3) | C2—C3—S1—C16 | 0.09 (18) |
| C8—C9—C10—C15 | -158.66 (17) | C4—C3—S1—C16 | -179.01 (14) |
| O1—C9—C10—C11 | -156.5 (2) | | |

Hydrogen-bond geometry (\AA , $^\circ$)

| $D-H\cdots A$ | $D-H$ | $H\cdots A$ | $D\cdots A$ | $D-H\cdots A$ |
|----------------------------------|-------|-------------|-------------|---------------|
| C11—H11 \cdots O1 ⁱ | 0.95 | 2.60 | 3.278 (3) | 129 |

Symmetry code: (i) $x, y, z+1$.