

**(3*R*,4*S*)-3-Phenyl-1-[(*R*)-1-phenylethyl]-4-[(*R*)-1-phenylethylimino-methyl]azetidin-2-one**Huub Kooijman,<sup>a\*</sup> Anthony L. Spek,<sup>a</sup> Henk Kleijn,<sup>b</sup> Hendrik L. van Maanen,<sup>b</sup> Johann T. B. H. Jastrzebski<sup>b</sup> and Gerard van Koten<sup>b</sup><sup>a</sup>Bijvoet Center for Biomolecular Research, Department of Crystal and Structural Chemistry, Utrecht University, Padualaan 8, 3584 CH Utrecht, The Netherlands, and <sup>b</sup>Debye Research Institute, Department of Metal-Mediated Synthesis, Utrecht University, Padualaan 8, 3584 CH Utrecht, The Netherlands  
Correspondence e-mail: h.kooijman@chem.uu.nl

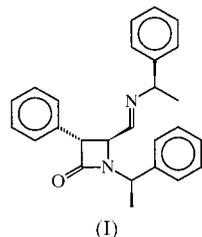
Received 10 December 1999

Accepted 17 January 2000

The configuration of the chiral ring atoms of the title compound, C<sub>26</sub>H<sub>26</sub>N<sub>2</sub>O, obtained in an enantioselective synthesis, has been established relative to the known *R* configuration of the  $\alpha$ -methylbenzyl moieties. The crystal packing involves a two-dimensional network of C—H $\cdots$  $\pi$  interactions between the aromatic rings.

**Comment**

Azetidin-2-ones are of interest as potential building blocks for the synthesis of antibiotic agents (Morin & Gorman, 1982). They can be prepared *via* zinc-mediated condensations of ester enolates with imines. During a study on 3-amino-substituted azetidin-2-ones it was established that the zinc-mediated condensation resulted in an exclusive *trans* arrangement of substituents on the newly formed four-membered ring. The enantioselective synthesis favoured the formation of the (3*R*,4*S*) configuration on the new chiral centres (van der Steen *et al.*, 1992). During a study on the enantioselective synthesis of 3-hydrocarbon-substituted azetidin-2-ones, the title compound, (I), was one of the compounds prepared (Kleijn *et al.*, 1992).

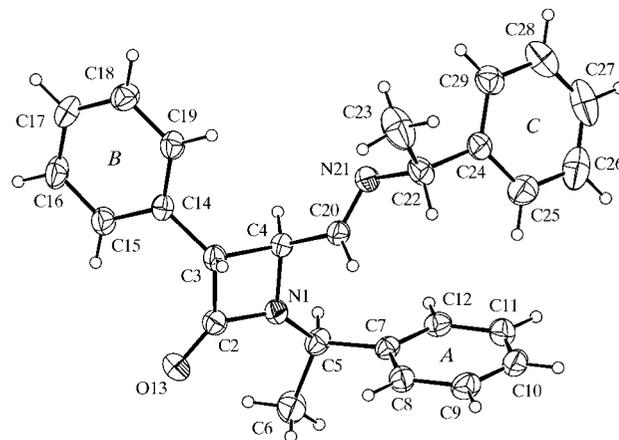


Compound (I) was obtained in a *trans* configuration with an enantiomeric excess of 64%. A crystal structure determination of the predominant diastereoisomer was undertaken to establish the absolute configurations of the atoms in the ring

fragment with respect to the known configuration of the (*R*)- $\alpha$ -methylbenzyl moieties. The absolute configurations of the newly formed chiral centres in the four-membered ring are *R* on C3 and *S* on C4. This shows that the enantioselective syntheses of the 3-amino- and the 3-hydrocarbon-substituted azetidin-2-ones favour the same absolute configurations in the newly formed four-membered ring.

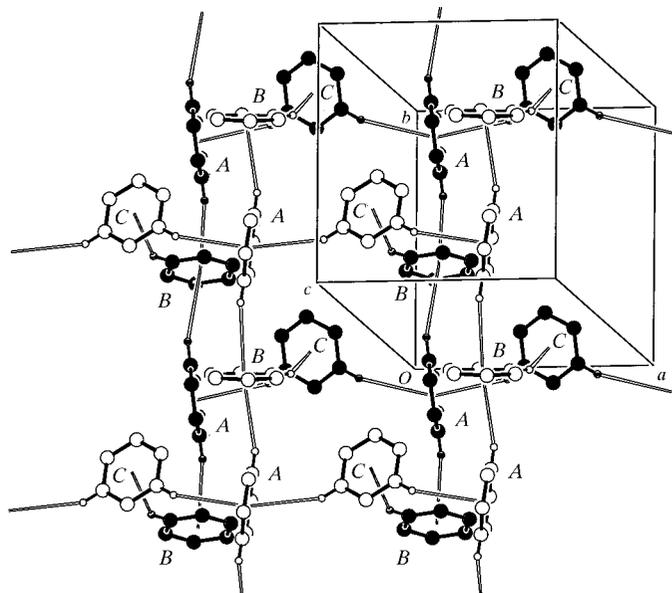
The bond lengths and angles in (I) are well within the range reported in similar structures [Cambridge Structural Database (CSD), October 1999 version; Allen & Kennard, 1993]. The central four-membered ring is slightly bent, as is illustrated by the puckering parameter  $q_2$  which amounts to 0.080 (2) Å (Cremer & Pople, 1975). The improper torsion angle N1—C2—C4—C3, another measure for the puckering of the four-membered ring, takes the value 171.2 (2)°, which is well within the range found in the CSD (160–180°).

Due to the lack of classic hydrogen bond donors, the packing is determined by weaker interactions. No C—H $\cdots$ O or C—H $\cdots$ N interactions are present, not even for those C—H groups neighbouring electronegative moieties. The only directional interactions in the structure appear to be C—H $\cdots$  $\pi$  hydrogen bonds. In ring A (atoms C7—C12), the atoms C8 and C11, positioned *para* with respect to each other, donate a C—H $\cdots$  $\pi$  bond to the B rings (atoms C14—C19) of the molecules at ( $\frac{1}{2} + x, \frac{1}{2} - y, 1 - z$ ) and ( $\frac{1}{2} + x, \frac{3}{2} - y, 1 - z$ ) (geometric details are given in Table 2), thus creating an infinite string of edge-face  $\pi$ -systems (Hunter, 1994) running in the [010] direction. This string of aromatic rings intersects with a similar string of C—H $\cdots$  $\pi$  bonded ring systems, consisting of ring C (atoms C24—C29) and ring A, where the latter now acts as the acceptor. This string, which runs in the [100] direction, contains alternating intra- and intermolecular C—H $\cdots$  $\pi$  interactions. The two intersecting strings create a two-dimensional network with base vectors [100] and [010]. The two symmetry-related two-dimensional C—H $\cdots$  $\pi$  networks that are located at approximately  $z = 0.85$  and  $z = 0.65$  are joined by a C—H $\cdots$  $\pi$  interaction between C17 of ring B and ring C, creating a 'bilayer' of C—H $\cdots$  $\pi$  bonded

**Figure 1**

Displacement ellipsoid plot of (I) drawn at the 30% probability level (PLATON; Spek, 1999). H atoms have an arbitrary radius. Ring labels A, B and C refer to  $\pi$ -systems accepting C—H $\cdots$  $\pi$  bonds.

aromatic rings (Fig. 2). Rings *A* and *B* accept C—H... $\pi$  donations from other phenyl rings on both sides of their  $\pi$ -systems. In contrast, ring *C* receives a C—H... $\pi$  interaction from another phenyl ring on only one side of its  $\pi$ -system. The other side of ring *C* receives a C—H... $\pi$  bond from the methyl group, C6 (geometric details are included in Table 2; this interaction is not drawn in Fig. 2).



**Figure 2**  
Packing diagram for (I), showing the bilayer of C—H... $\pi$  bonded aromatic rings. Only the aromatic C atoms and those H atoms involved in the interactions are shown. Atoms belonging to the rings in the back layer are drawn as black spheres, atoms belonging to rings in the front layer are drawn as white spheres. Ring labels *A*, *B* and *C* refer to the ring classification defined in Fig. 1. The Me... $\pi$  interaction has been omitted for clarity.

## Experimental

Details of the synthesis of (I) are given elsewhere (Kleijn *et al.*, 1992). Light-yellow crystals were obtained from a solution in diethyl ether (m.p. 360 K).

### Crystal data

$C_{26}H_{26}N_2O$   
 $M_r = 382.49$   
 Orthorhombic,  $P2_12_12_1$   
 $a = 9.4958$  (10) Å  
 $b = 10.1947$  (8) Å  
 $c = 22.124$  (2) Å  
 $V = 2141.7$  (3) Å<sup>3</sup>  
 $Z = 4$   
 $D_x = 1.186$  Mg m<sup>-3</sup>

Mo  $K\alpha$  radiation  
 Cell parameters from 25 reflections  
 $\theta = 11.48$ – $13.98^\circ$   
 $\mu = 0.072$  mm<sup>-1</sup>  
 $T = 293$  K  
 Block, light yellow  
 $0.4 \times 0.4 \times 0.2$  mm

### Data collection

Enraf–Nonius CAD-4T diffractometer  
 $\omega/2\theta$  scans  
 5566 measured reflections  
 2783 independent reflections  
 2033 reflections with  $I > 2\sigma(I)$   
 $R_{int} = 0.027$

$\theta_{max} = 27.46^\circ$   
 $h = 0 \rightarrow 12$   
 $k = 0 \rightarrow 13$   
 $l = -28 \rightarrow 28$   
 3 standard reflections  
 frequency: 60 min  
 intensity decay: 1%

### Refinement

Refinement on  $F^2$   
 $R(F) = 0.040$   
 $wR(F^2) = 0.106$   
 $S = 1.018$   
 2783 reflections  
 265 parameters  
 H-atom parameters constrained  
 $w = 1/[\sigma^2(F_o^2) + (0.0551P)^2 + 0.1317P]$   
 where  $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{max} = 0.001$   
 $\Delta\rho_{max} = 0.17$  e Å<sup>-3</sup>  
 $\Delta\rho_{min} = -0.16$  e Å<sup>-3</sup>  
 Extinction correction:  
 SHELXL97-2 (Sheldrick, 1997)  
 Extinction coefficient: 0.0114 (16)  
 Absolute structure: see below

**Table 1**

Selected geometric parameters (Å, °).

O13—C2	1.211 (3)	N21—C22	1.486 (3)
N1—C2	1.362 (3)	C2—C3	1.538 (3)
N1—C4	1.476 (3)	C3—C4	1.560 (3)
N21—C20	1.250 (3)		
C2—N1—C4	94.93 (18)	C2—C3—C4	84.99 (14)
C20—N21—C22	116.5 (2)	N1—C4—C3	87.16 (15)
N1—C2—C3	92.26 (18)	N21—C20—C4	121.01 (18)

**Table 2**

Geometric details of the C—H... $\pi$  interactions (Å, °).

Cg1, Cg2 and Cg3 represent the centres of gravity of rings *A*, *B* and *C*, respectively.

<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>
C6—H62...Cg3 <sup>i</sup>	0.96	3.00	3.741 (3)	135
C8—H81...Cg2 <sup>ii</sup>	0.93	2.89	3.757 (3)	156
C11—H111...Cg2 <sup>i</sup>	0.93	2.94	3.801 (3)	155
C17—H171...Cg3 <sup>iii</sup>	0.93	2.98	3.753 (3)	141
C25—H251...Cg1	0.93	3.14	3.890 (3)	139
C29—H291...Cg1 <sup>iv</sup>	0.93	3.07	3.929 (3)	155

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

H atoms were introduced at calculated positions and included in the refinement riding on their carrier atoms. Methyl moieties were refined as rigid groups, allowing for rotation around the C—C bonds while maintaining tetrahedral geometry at the methyl C atoms. The isotropic displacement parameters of the H atoms were set to a fixed value related to the equivalent isotropic displacement parameter of the carrier atom by a factor of 1.5 for the methyl H atoms and a factor of 1.2 for all other H atoms. For 2104 Friedel pairs, the intensities of both members were measured, *i.e.* 76% of the total number of Friedel pairs with  $\theta < \theta_{max}$ . Due to the lack of anomalous scatterers, the absolute configuration could not be established reliably, as is illustrated by the value of  $-0.3$  (19) obtained for the Flack  $x$  parameter (Flack, 1983) derived during a structure-factor calculation using all data (meaning that only the symmetry-related intensities were averaged and not the Friedel pairs). The absolute structure was therefore set in accordance with the known configuration of the (*R*)- $\alpha$ -methylbenzyl moieties. Since there is no significant dispersion, the final refinement cycles were carried out using a data set in which the Friedel-related reflections were also averaged.

Data collection: locally modified *CAD-4 Software* (Enraf–Nonius, 1989); cell refinement: *SET4* (de Boer & Duisenberg, 1984); data reduction: *HELENA* (Spek, 1997); program(s) used to solve structure: *SHELXS86* (Sheldrick, 1985); program(s) used to refine structure: *SHELXL97-2* (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 1999); software used to prepare material for publication: *PLATON*.

This work was supported in part (ALS) by the Council for the Chemical Sciences of the Netherlands Organization for Scientific Research (CW-NWO)

Supplementary data for this paper are available from the IUCr electronic archives (Reference: LN1096). Services for accessing these data are described at the back of the journal.

## References

- Allen, F. H. & Kennard, O. (1993). *Chem. Des. Autom. News*, **8**, 31–37.
- Boer, J. L. de & Duisenberg, A. J. M. (1984). *Acta Cryst.* **A40**, C-410.
- 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.
- Flack, H. D. (1983). *Acta Cryst.* **A39**, 876–881.
- Hunter, C. A. (1994). *Chem. Soc. Rev.* **23**, 101–109.
- Kleijn, H., van Maanen, H. L., Jastrzebski, J. T. B. H. & van Koten, G. (1992). *Recl. Trav. Chim. Pays-Bas*, **111**, 497–498.
- Morin, R. B. & Gorman, M. (1982). Editors. *Chemistry and Biology of  $\beta$ -Lactam Antibiotics*, Vols. 1–3. London: Academic Press.
- Sheldrick, G. M. (1985). *SHELXS86*. University of Göttingen, Germany.
- Sheldrick, G. M. (1997). *SHELXL97-2*. University of Göttingen, Germany.
- Spek, A. L. (1997). *HELENA*. University of Utrecht, The Netherlands.
- Spek, A. L. (1999). *PLATON*. University of Utrecht, The Netherlands. <http://www.cryst.chem.uu.nl/PLATON>.
- Steen, F. H. van der, Kleijn, H., Britovsek, G. J. P., Jastrzebski, J. T. B. H. & van Koten, G. (1992). *J. Org. Chem.* **57**, 3906–3916.