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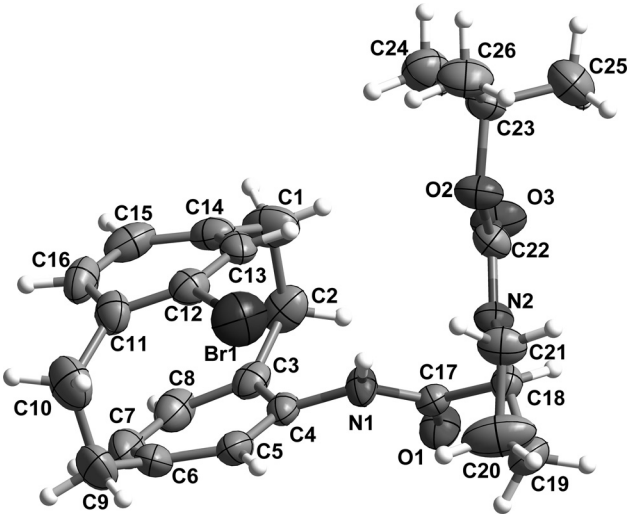
The crystal structure of *tert*-butyl 2-(4-(12-bromo [2.2]paracyclophanyl)carbamoyl)pyrrolidine-1-carboxylate, $C_{26}H_{31}BrN_2O_3$



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Abstract

$C_{26}H_{31}BrN_2O_3$, orthorhombic, $P2_12_12_1$ (no. 19), a = 11.01(1) Å, b = 13.227(12) Å, c = 16.458(14) Å, V = 2397(4) Å^3, Z = 4, $R_{gt}(F)$ = 0.0367, $wR_{ref}(F^2)$ = 0.0775, T = 298(2) K.

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The molecular structure is shown in the figure. Table 1 contains crystallographic data and Table 2 contains the list of the atoms including atomic coordinates and displacement parameters.

Table 1: Data collection and handling.

Crystal:	Colorless block
Size:	0.20 × 0.15 × 0.10 mm
Wavelength:	Mo $K\alpha$ radiation (0.71073 Å)
μ:	1.75 mm^{-1}
Diffractometer, scan mode:	Bruker Smart Apex II, φ and ω
θ_{max}, completeness:	27.7°, >99%
$N(hkl)_{measured}$, $N(hkl)_{unique}$, R_{int}:	17,705, 5536, 0.035
Criterion for I_{obs}, $N(hkl)_{gt}$:	$I_{obs} > 2\sigma(I_{obs})$, 3657
$N(\text{param})_{refined}$:	302
Programs:	Bruker [1], Olex2 [2], SHELX [3, 4], Diamond [5]

Source of materials

4-Amino-12-bromine [2.2] paracyclophane was synthesized according to published procedures [6]. *L*-proline protected by tert-butyloxycarbonyl (10 mmol) and 1,3-dicyclohexyl carbodiimide (10 mmol) were dissolved in dry CH_2Cl_2 (50 mL) and stirred at room temperature for 5 min. Then racemic 4-amino-12-bromine[2.2]paracyclophane (10 mmol) in CH_2Cl_2 (20 mL) was added to the above solution and reacted 12 h at room temperature. The mixture was filtered under reduced pressure and the filtrate was rotatably dried to obtain the diastereoisomer products, which were separated by column chromatography with petroleum ether and ethyl acetate as mobile phase at room temperature. Colorless crystal of title compound was obtained by slow evaporation of chromatogram liquid.

Experimental details

The structure was solved by Direct Methods with the SHELX [3]. All H-atoms were positioned geometrically and refined using a riding model with d(C–H) = 0.93 Å, U_{iso} = 1.2U_{eq} (C) for aromatic, 0.97 Å, U_{iso} = 1.2U_{eq} (C) for CH_2, 0.98 Å, U_{iso} = 1.2U_{eq} (C) for CH, 0.96 Å, U_{iso} = 1.5U_{eq} (C) for CH_3 atoms and d(N–H) = 0.86 Å, U_{iso} = 1.2U_{eq} (N) for NH. A CH_2 group of the 5-membered ring is

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Table 2: Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2).

Atom	*x*	*y*	*z*	U_{iso}*/U_{eq}
Br1	0.76167 (4)	0.87996 (3)	0.22192 (3)	0.07424 (18)
O1	0.4379 (2)	1.26682 (16)	0.16071 (15)	0.0495 (6)
O2	0.3263 (2)	1.02571 (18)	0.05528 (15)	0.0568 (7)
O3	0.3703 (2)	0.87087 (16)	0.10886 (13)	0.0465 (6)
N1	0.5625 (2)	1.13180 (19)	0.17696 (16)	0.0393 (7)
H1	0.5616	1.0673	0.1837	0.047*
N2	0.3660 (2)	1.00455 (17)	0.18860 (16)	0.0366 (6)
C1	0.6514 (4)	1.1138 (3)	−0.0233 (2)	0.0710 (12)
H1A	0.5747	1.0782	−0.0186	0.085*
H1B	0.6682	1.1234	−0.0806	0.085*
C2	0.6395 (4)	1.2196 (3)	0.0185 (2)	0.0555 (10)
H2A	0.6675	1.2711	−0.0190	0.067*
H2B	0.5544	1.2326	0.0297	0.067*
C3	0.7093 (3)	1.2287 (2)	0.0957 (2)	0.0411 (9)
C4	0.6781 (3)	1.1765 (2)	0.1665 (2)	0.0367 (8)
C5	0.7656 (3)	1.1500 (2)	0.2228 (2)	0.0441 (8)
H5	0.7429	1.1152	0.2695	0.053*
C6	0.8860 (3)	1.1744 (3)	0.2108 (2)	0.0509 (9)
C7	0.9103 (4)	1.2458 (3)	0.1505 (3)	0.0599 (12)
H7	0.9867	1.2756	0.1480	0.072*
C8	0.8239 (4)	1.2726 (3)	0.0950 (3)	0.0543 (11)
H8	0.8421	1.3212	0.0560	0.065*
C9	0.9824 (4)	1.1090 (4)	0.2487 (3)	0.0742 (12)
H9A	0.9565	1.0901	0.3030	0.089*
H9B	1.0564	1.1483	0.2539	0.089*
C10	1.0110 (4)	1.0099 (3)	0.1989 (3)	0.0732 (13)
H10A	1.0947	1.0122	0.1806	0.088*
H10B	1.0024	0.9519	0.2345	0.088*
C11	0.9294 (3)	0.9964 (3)	0.1265 (2)	0.0473 (9)
C12	0.8144 (3)	0.9567 (2)	0.1299 (2)	0.0417 (8)
C13	0.7263 (3)	0.9820 (2)	0.0744 (2)	0.0430 (9)
H13	0.6497	0.9527	0.0781	0.052*
C14	0.7502 (4)	1.0503 (2)	0.0135 (2)	0.0473 (9)
C15	0.8711 (4)	1.0716 (3)	−0.0014 (2)	0.0548 (11)
H15	0.8933	1.1046	−0.0490	0.066*
C16	0.9582 (3)	1.0443 (3)	0.0537 (3)	0.0526 (10)
H16	1.0391	1.0582	0.0421	0.063*
C17	0.4534 (3)	1.1784 (2)	0.17765 (19)	0.0352 (8)
C18	0.3495 (3)	1.1118 (2)	0.20681 (18)	0.0353 (7)
H18	0.2731	1.1354	0.1828	0.042*
C19	0.3389 (3)	1.1128 (3)	0.2997 (2)	0.0498 (9)
H19A[a]	0.3810	1.1707	0.3223	0.060*
H19B[a]	0.2544	1.1154	0.3162	0.060*
H19C[b]	0.4151	1.1341	0.3238	0.060*
H19D[b]	0.2758	1.1594	0.3165	0.060*
C21	0.3716 (4)	0.9406 (2)	0.2608 (2)	0.0510 (9)
H21A[a]	0.4361	0.8909	0.2563	0.061*
H21B[a]	0.2951	0.9060	0.2699	0.061*
H21C[b]	0.4550	0.9261	0.2758	0.061*
H21D[b]	0.3287	0.8774	0.2523	0.061*
C22	0.3503 (3)	0.9713 (2)	0.1118 (2)	0.0390 (8)
C23	0.3431 (3)	0.8117 (3)	0.0361 (2)	0.0434 (9)
C24	0.4163 (4)	0.8472 (3)	−0.0355 (2)	0.0621 (11)
H24A	0.3886	0.9129	−0.0520	0.093*
H24B	0.4067	0.8004	−0.0796	0.093*
H24C	0.5005	0.8509	−0.0206	0.093*
C25	0.2092 (3)	0.8168 (3)	0.0196 (3)	0.0718 (13)
H25A	0.1652	0.7986	0.0677	0.108*
H25B	0.1890	0.7708	−0.0235	0.108*
H25C	0.1877	0.8844	0.0038	0.108*
C26	0.3812 (4)	0.7062 (3)	0.0620 (2)	0.0649 (12)
H26A	0.4640	0.7075	0.0803	0.097*
H26B	0.3739	0.6609	0.0167	0.097*
H26C	0.3297	0.6835	0.1054	0.097*
C20[a]	0.3974 (8)	1.0152 (4)	0.3275 (3)	0.055 (2)
H20A[a]	0.4842	1.0239	0.3347	0.065*
H20B[a]	0.3624	0.9926	0.3784	0.065*
C20A[b]	0.308 (3)	1.0062 (13)	0.3266 (11)	0.051 (7)
H20C[b]	0.2206	0.9951	0.3266	0.061*
H20D[b]	0.3397	0.9920	0.3803	0.061*

[a]Occupancy: 0.786 (16). [b]Occupancy: 0.214 (16).

disordered and treated with a split operation, with site occupancies of 0.786 for C20 and 0.214 for C20A. As a result, the H atoms on C19 and C21 were split automatically. The absolute structure was established by refinement of the Flack parameter (−0.007(5) from 1210 selected quotients) using Parsons' method [7].

Comment

The planar chiral ligands are widely used in asymmetric catalysis. Because of the unique skeleton structure, easy to construct a planar chiral environment to achieve better stereoscopic control, [2.2]paracyclophane derivatives play an important role in this field. Among them, 4,12-disubstitution [2.2]paracyclophane is a typical intermediate for building planar chiral ligands. And many excellent catalysts based on 4,12-disubstitution [2.2]paracyclophane derivatives have been reported [8]. Growth and characterization of single crystal are very important for the chiral resolution, structure identification, structure-activity relationship and mechanism study of these ligands. We have luckily obtained the single crystal of the title compound in the course of the resolution of 4-amino-12-bromine [2.2] paracyclophane.

The structure of the title compound is illustrated in the figure, its absolute configuration of the [2.2] paracyclophane moiety is established as (Sp) by comparison with the known conguration of the L-proline moiety residues. The single crystal structure verifies that all bond lengths are in normal ranges. The dihedral angles of the two planes that across $C_4/C_5/C_7/C_8$ and $C_{12}/C_{13}/C_{15}/C_{16}$ is up

to 2.75(9)° which is between the similar structures 4-bromo-12-camphanoyloxy[2.2]paracyclophane and 4-bromo-12-(*t*-butylsulfinyl)tricyclo-[2.2]paracyclophane [9, 10]. However, the side with substituents C_4/C_5 and C_{12}/C_{13} is significantly closer to each other than the other side which is unusual to the similar structures [9, 10]. This may be the case due to the involvement of substituents in intermolecular and intramolecular interactions such as hydrogen or halogen bonds. The presence of hydrogen bonds [C21–H21···O1^{i} symmetry code *i*: $1 - x$, $-1/2 + y$, $1/2 - z$] or potential weak interactions between bromine atom and acyl oxygen atom from another molecule [O1^{i}···Br1 = 3.285 (7) symmetry code *i*: $1 - x$, $-1/2 + y$, $1/2 - z$], results in the formation of a chain structure along the (010) direction. The 1D structures are further connected by non-classical hydrogen bonds between C–H donors and the acyl oxygen atom [C15–H15···O1^{ii} symmetry code *ii*: $1/2 + x$, $5/2 - y$, $-z$] forming a 3D structure.

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Conflict of interest statement: The authors declare no conflicts of interest regarding this article.

References

1. Bruker. Sadabs, Saint *and* Smart; Bruker AXS Inc.: Madison, Wisconsin, USA, 2008.
2. Dolomanov O. V., Bourhis L. J., Gildea R. J., Howard J. A. K., Puschmann H. Olex2: a complete structure solution, refinement and analysis program. *J. Appl. Crystallogr.* 2009, *42*, 339–341.
3. Sheldrick G. M. A short history of Shelx. *Acta Crystallogr.* 2008, *A64*, 112–122.
4. Sheldrick G. M. Crystal structure refinement with Shelxl. *Acta Crystallogr.* 2015, *C71*, 3–8.
5. Brandenburg K. Diamond. *Visual Crystal Structure Information System. Ver. 4.0*; Crystal Impact: Bonn, Germany, 2015.
6. Ma Q. S., Ma Y. D., Liu X., Duan W. Z., Qu B., Song C. Planar chiral imidazolium salts based on [2.2] paracyclophane in the asymmetric rhodium-catalyzed 1,2-addition of arylboronic acids to aldehydes. *Tetrahedron: Asymmetry* 2010, *21*, 292–298.
7. Parsons S., Flack H. D., Wagner T. Use of intensity quotients and differences in absolute structure refinement. *Acta Crystallogr.* 2013, *B69*, 249–259.
8. Paradies J. [2.2]Paracyclophane derivatives: synthesis and application in catalysis. *Synthesis* 2011, *23*, 3749–3766.
9. Zhuravsky R., Starikova Z., Vorontsov E., Rozenberg V. Novel strategy for the synthesis of chiral pseudo-ortho-substituted hydroxy [2.2] paracyclophane-based ligands from the resolved 4-bromo-12-hydroxy [2.2] paracyclophane as a parent compound. *Tetrahedron: Asymmetry* 2008, *19*, 216–222.
10. Enders D., Ludwig M., Raabe G. Synthesis and application of the first planar chiral strong bronsted acid organocatalysts. *Chirality* 2012, *24*, 215–222.