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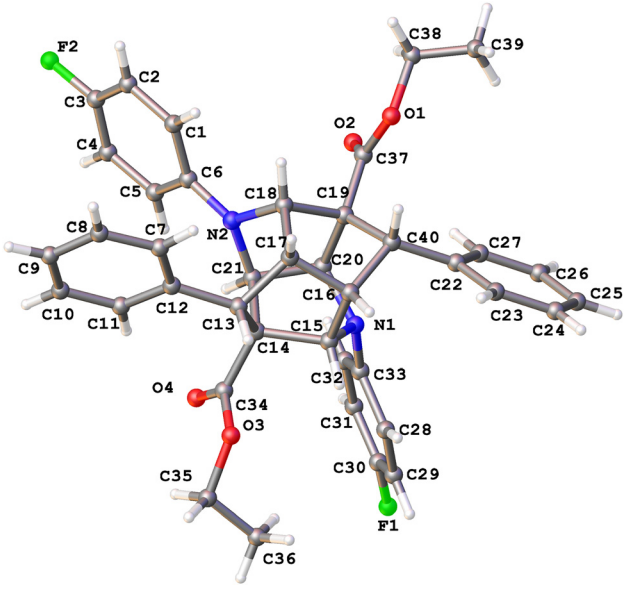
Crystal structure of diethyl 1,9-bis(4-fluorophenyl)-4,6-diphenylhexahydro-3*H*-2,7,3,5-(epimethanetriyliminomethanetriyl) cyclopenta [*b*]pyridine-3,7(2*H*)-dicarboxylate, $C_{40}H_{36}F_2N_2O_4$



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Abstract

$C_{40}H_{36}F_2N_2O_4$, monoclinic, $P2_1/c$ (no. 14), a = 9.8180(16) Å, b = 19.355(3) Å, c = 17.930(3) Å, β = 102.353(3)°, V = 3328.3(9) Å^3, Z = 4, $R_{gt}(F)$ = 0.0564, $wR_{ref}(F^2)$ = 0.1866, T = 296(2) K.

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Table 1: Data collection and handling.

Crystal:	Colourless block
Size:	0.18 × 0.16 × 0.15 mm
Wavelength:	Mo *K*α radiation (0.71073 Å)
μ:	0.09 mm^{-1}
Diffractometer, scan mode:	Bruker APEX-II, φ and ω
θ_{max}, completeness:	27.5°, >99 %
$N(hkl)_{measured}$, $N(hkl)_{unique}$, R_{int}:	20,489, 7585, 0.034
Criterion for I_{obs}, $N(hkl)_{gt}$:	$I_{obs} > 2\sigma(I_{obs})$, 4295
$N(param)_{refined}$:	473
Programs:	Bruker [1], SHELX [2,3]

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.

1 Source of material

A 100 mL round bottom flask was sequentially charged with 50 mL of 1,2-dichloroethane, 30 mmol of 4-fluoroaniline, 30 mmol of ethyl propionate, 30 mmol of cinnamaldehyde, 12 mmol of piperazine and 0.24 mmol of *p*-toluenesulfonic acid. The reaction mixture was slowly heated to reflux for 12 h. At the end of the reaction the mixture was cooled, to room temperature. Then 200 mL of water were slowly added, with ethyl acetate was extracted three times (3 × 100 mL), the organic layer was separated, and saturated aqueous sodium chloride was washed twice (2 × 100 mL), and the organic layers were combined. The organic layer was dried over anhydrous sodium sulfate, filtered, distilled under reduced pressure, and separated by silica gel column chromatography (ethyl acetate:petroleum ether = 1:50) to give 1, a white powdered solid. An amount of 1 g of 1 was added to the mixed solution of methanol/tetrahydrofuran, added to a 30 mL quartz tube, and irradiated by 410 nm UV light for 72 h. The product was separated by column chromatography,

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

Atom	*x*	*y*	*z*	U_{iso}*/U_{eq}
F1	0.6963 (2)	0.97589 (9)	0.47231 (12)	0.1322 (7)
C1	0.6467 (2)	0.49669 (13)	0.19420 (14)	0.0768 (7)
H1	0.562781	0.474591	0.194619	0.092*
O1	0.22769 (16)	0.61826 (10)	0.14321 (8)	0.0840 (5)
O2	0.41076 (18)	0.68466 (10)	0.13638 (9)	0.0828 (5)
F2	0.93853 (17)	0.47412 (9)	0.10501 (10)	0.1121 (6)
C2	0.7306 (3)	0.47082 (15)	0.14912 (16)	0.0869 (8)
H2	0.702761	0.432216	0.118800	0.104*
O3	0.68921 (16)	0.64025 (9)	0.54550 (8)	0.0784 (5)
C3	0.8522 (3)	0.50090 (15)	0.14866 (14)	0.0770 (7)
N1	0.46538 (16)	0.72575 (8)	0.36222 (8)	0.0477 (4)
N2	0.59973 (16)	0.57907 (9)	0.28714 (9)	0.0540 (4)
O4	0.82344 (16)	0.67755 (9)	0.46835 (8)	0.0726 (5)
C4	0.8935 (3)	0.55757 (17)	0.19074 (17)	0.0977 (10)
H4	0.978888	0.578119	0.190126	0.117*
C5	0.8071 (3)	0.58497 (15)	0.23509 (15)	0.0846 (8)
H5	0.834204	0.625064	0.262903	0.102*
C6	0.6825 (2)	0.55447 (10)	0.23906 (11)	0.0502 (5)
C7	0.6023 (3)	0.42589 (13)	0.40095 (15)	0.0741 (7)
H7	0.506494	0.419474	0.385721	0.089*
C8	0.6885 (3)	0.36920 (13)	0.40570 (16)	0.0830 (7)
H8	0.649528	0.325738	0.393760	0.100*
C9	0.8263 (3)	0.37527 (14)	0.42702 (18)	0.0897 (8)
H9	0.889780	0.345286	0.412287	0.108*
C17	0.4186 (2)	0.55270 (11)	0.35957 (12)	0.0532 (5)
H17	0.362804	0.510689	0.359300	0.064*
C16	0.3433 (2)	0.61699 (10)	0.37881 (11)	0.0510 (5)
H16	0.281579	0.606945	0.413771	0.061*
C15	0.46274 (19)	0.66781 (10)	0.41420 (11)	0.0477 (5)
H15	0.456343	0.683123	0.465440	0.057*
C14	0.60060 (19)	0.62616 (10)	0.41450 (10)	0.0472 (5)
C13	0.5535 (2)	0.55083 (10)	0.42098 (12)	0.0538 (5)
H13	0.525529	0.547136	0.470127	0.065*
C20	0.5046 (2)	0.69105 (10)	0.29770 (11)	0.0491 (5)
H20	0.530858	0.723768	0.261509	0.059*
C19	0.3840 (2)	0.64179 (11)	0.25869 (11)	0.0511 (5)
C18	0.45101 (19)	0.56865 (11)	0.27905 (11)	0.0523 (5)
H18	0.413455	0.533521	0.240800	0.063*
C21	0.6262 (2)	0.64104 (10)	0.33267 (11)	0.0489 (5)
H21	0.718442	0.660852	0.333591	0.059*
C22	0.1754 (2)	0.70690 (12)	0.30082 (11)	0.0542 (5)
C12	0.6522 (2)	0.49109 (11)	0.41773 (12)	0.0573 (5)
C26	0.1030 (3)	0.82274 (14)	0.25998 (14)	0.0767 (7)
H26	0.113357	0.861676	0.231320	0.092*
C25	0.0051 (3)	0.82207 (14)	0.30448 (15)	0.0766 (7)
H25	−0.051169	0.860493	0.306016	0.092*
C24	−0.0093 (2)	0.76401 (14)	0.34690 (14)	0.0714 (7)
H24	−0.076096	0.763119	0.376693	0.086*
C23	0.0748 (2)	0.70753 (13)	0.34516 (12)	0.0615 (6)
H23	0.064398	0.668860	0.374222	0.074*
C27	0.1860 (2)	0.76533 (13)	0.25795 (12)	0.0650 (6)
H27	0.250714	0.766017	0.226917	0.078*
C32	0.6160 (2)	0.82532 (11)	0.35302 (13)	0.0594 (6)
H32	0.636321	0.807797	0.308344	0.071*
C31	0.6716 (3)	0.88846 (12)	0.38108 (15)	0.0729 (7)
H31	0.728432	0.913232	0.355312	0.087*
C30	0.6425 (3)	0.91342 (12)	0.44591 (16)	0.0773 (7)
C29	0.5599 (3)	0.87847 (13)	0.48522 (15)	0.0797 (7)
H29	0.542306	0.896424	0.530331	0.096*
C28	0.5035 (2)	0.81682 (12)	0.45754 (12)	0.0640 (6)
H28	0.445575	0.793381	0.483801	0.077*
C37	0.3442 (2)	0.65226 (12)	0.17306 (12)	0.0594 (6)
C36	0.7391 (4)	0.7320 (2)	0.6354 (2)	0.171 (2)
H36A	0.804493	0.748746	0.679328	0.256*
H36B	0.649624	0.725914	0.647965	0.256*
H36C	0.731292	0.764866	0.594538	0.256*
C38A[a]	0.1756 (9)	0.6113 (5)	0.0635 (4)	0.0664 (15)
H38A[a]	0.128871	0.567260	0.051306	0.080*
H38B[a]	0.249765	0.615422	0.035666	0.080*
C39A[a]	0.0740 (12)	0.6708 (5)	0.0456 (4)	0.129 (3)
H39A[a]	0.051118	0.678473	−0.008512	0.194*
H39B[a]	0.115586	0.711697	0.070938	0.194*
H39C[a]	−0.009363	0.659859	0.063107	0.194*
C38B[b]	0.1742 (13)	0.6432 (7)	0.0555 (6)	0.0665 (16)
H38C[b]	0.188204	0.692503	0.051094	0.080*
H38D[b]	0.224898	0.619266	0.022386	0.080*
C39B[b]	0.0296 (10)	0.6268 (9)	0.0350 (5)	0.114 (4)
H39D[b]	−0.007007	0.640663	−0.016849	0.171*
H39E[b]	0.017365	0.577878	0.039682	0.171*
H39F[b]	−0.019139	0.650733	0.068241	0.171*
C35	0.7862 (3)	0.66785 (16)	0.61212 (14)	0.0878 (9)
H35A	0.796102	0.635055	0.653840	0.105*
H35B	0.877080	0.674027	0.599958	0.105*
C11B[c]	0.7794 (10)	0.4905 (5)	0.4714 (8)	0.075 (2)
H11B[c]	0.806562	0.527787	0.503928	0.090*
C10B[c]	0.8633 (10)	0.4324 (5)	0.4743 (8)	0.078 (2)
H10B[c]	0.948072	0.431634	0.509432	0.094*
C10A[d]	0.8846 (4)	0.4425 (2)	0.4297 (3)	0.0815 (14)
H10A[d]	0.979747	0.448273	0.433165	0.098*
C11A[d]	0.7983 (4)	0.4992 (2)	0.4271 (3)	0.0709 (13)
H11A[d]	0.836696	0.543352	0.431570	0.085*
C34	0.7183 (2)	0.65120 (11)	0.47714 (11)	0.0506 (5)
C33	0.53043 (19)	0.78798 (10)	0.39067 (10)	0.0457 (5)
C40	0.2629 (2)	0.64276 (11)	0.30082 (11)	0.0526 (5)
H40	0.198989	0.605594	0.278819	0.063*

[a]Occupancy: 0.584 (11), [b]Occupancy: 0.416 (11), [c]Occupancy: 0.300 (8), [d]Occupancy: 0.700 (8).

and the elution solvent was petroleum ether and ethyl acetate 20:1. Finally, the obtained solution was evaporated to dryness *in vacuo* and recrystallized from methanol and dichloromethane to obtain the title compound.

2 Experimental details

All hydrogen atoms were placed in the calculated positions and all the non-hydrogen atoms were refined anisotropically.

3 Comment

In recent years, cage compounds, as an important class of three-dimensional polyhedral structure compounds, have been a hot topic of research due to their wide applications in antitumor, immunity enhancement and antiviral [4,5]. Photochemical reactions have been widely used in various synthetic reactions [6, 7]. In particular, six-membered rings with symmetrical double bond structure are often used as raw materials for photoreaction. A cage compound (systematic name: diethyl 1,9-bis(4-fluorophenyl)-4,6-diphenylhexahydro-3*H*-2,7,3,5-(epimethanetriyliminomethanetriyl) cyclopenta[*b*] pyridine-3,7(2*H*)-dicarboxylate) of the title structure is shown in the figure. Stereochemically the compound is the product of common enantiometric forms. It can formally be considered as resulting from the attack of one dihydropyridine molecule on the far side of the dihydropyridine ring of the second molecule (i.e., the side that does not face the aryl moiety) [8,9].

In the molecules forming the title crystal structure, several important bond angle data are involved as follows: C18–N2–C6 = 126.95(19) Å, C33–N1–C20 = 120.12(18) Å, C16–C40–C22 = 116.5(2) Å. The bond lengths and angles are in the expected ranges [10,11].

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

References

1. BRUKER. SAINT. *Version 8.23B.*; Bruker AXS Inc.: Madison, Wisconsin, USA, 2013.
2. Sheldrick G. M. Crystal structure refinement with SHELXL. *Acta Crystallogr.* 2015, *C71*, 3–8.
3. Sheldrick G. M. A short history of *SHELX*. *Acta Crystallogr.* 2008, *A64*, 112–122.
4. Simeonova L., Gegova G., Galabov A. S. Prophylactic and therapeutic combination effects of rimantadine and oseltamivir against influenza virus A (H_3N_2) infection in mice. *Antiviral Res.* 2012, *95*, 172–181.
5. Liu J., Obando D., Liao V., Lifa T., Codd R. The many faces of the adamantyl group in drug design. *Eur. J. Med. Chem.* 2011, *46*, 1949–1963.
6. Han Y., Jin Y., Jiang M., Yang H., Fu H. Photocatalyst-free visible-light photoredox dearomatization of phenol derivatives containing ketoximes: an easy access to spiropyrrolines. *Org. Lett.* 2019, *21*, 1799–1803.
7. Mishiro K., Kimura T., Furuyama T., Kunishima M. Phototriggered active alkyne generation from cyclopropenones with visible light-responsive photocatalysts. *Org. Lett.* 2019, *21*, 4101–4105.
8. Hilgeroth A., Baumeister U. The first functionalized 6,12-diazatetrakishomocubanes. *Angew. Chem. Int. Ed.* 2000, *39*, 576–578.
9. Shao H. Q., Lu Y. M., Lin Q. W., Wang Y. C., Xie Y. S. Crystal structure of diethyl 3,9-bis(4-fluorophenyl)-6,12-diphenyl-3,9-diazapentacyclo [6.4.0.$0^{2,7}$.$0^{4,11}$]dodecane-1,5-dicarboxylate, $C_{40}H_{36}F_2N_2O_4$. *Z. Kristallogr. N. Cryst. Struct.* 2021, *2*, 385–386.
10. Wang Y.-X., Geng S.-Q., Qin J.-R., Zhang W.-L., Zhong Q.-D. Crystal structure of dimethyl 1,4,6,9-tetraphenylhexahydro-3*H*-2,7,3,5-(epimethanetriyliminomethanetriyl)cyclopenta[*b*]pyridine-3,7(2*H*)-dicarboxylate, $C_{38}H_{34}N_2O_4$. *Z. Kristallogr. N. Cryst. Struct.* 2022, *237*, 463–465.
11. Fan S., Zhang Q., Lv X.-D., Jin Y.-Y., Yang Z.-Y. Crystal structure of diethyl 4,6-diphenyl-1,9-di-*p*-tolylhexahydro-3*H*-2,7,3,5-(epimethanetriyliminomethanetriyl)cyclopenta[b]pyridine-3,5(2*H*)-dicarboxylate, $C_{42}H_{42}N_2O_4$. *Z. Kristallogr. N. Cryst. Struct.* 2022, *237*, 455–457.