Synthesis and crystal structure of 1,3-bis{[N,N-bis(2-hydroxyethyl)amino]methyl}-5-{[(4,6-dimethylpyridin-2-yl)amino]methyl}-2,4,6-triethylbenzene

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In the crystal structure of the title compound, C$_{30}$H$_{50}$N$_{4}$O$_{4}$, the two bis(hydroxyethyl)amino moieties and the 2,4-dimethylpyridinylamino unit of the molecule are located on one side of the central benzene ring, while the ethyl substituents are oriented in the opposite direction. The dihedral angle between the planes of the aromatic rings is 73.6 (1)$^\circ$. The conformation of the molecule is stabilized by intramolecular O—H···O (1.86–2.12 Å) and C—H···N (2.40, 2.54 Å) hydrogen bonds. Dimers of inversion-related molecules represent the basic supramolecular entities of the crystal structure. They are further connected via O—H···O hydrogen bonding into undulating layers extending parallel to the crystallographic bc plane. Interlayer interaction is accomplished by weak C—H···π contacts.

1. Chemical context

The 1,3,5-trisubstituted 2,4,6-trialkylbenzene scaffold has shown to be valuable for the construction of various artificial receptors (Hennrich & Anslyn, 2002). In the course of our research work, we have successfully used this molecular scaffold in the design of acyclic and macrocyclic receptors for neutral (Mazik, 2009, 2012; Lippe & Mazik, 2015; Lippe et al., 2015; Amrhein et al., 2016; Koch et al., 2016; Amrhein & Mazik, 2021; Köhler et al., 2020, 2021) and ionic substrates (Geffert et al., 2013; Stapf et al., 2015; Schulze et al., 2018). Our studies on the molecular recognition of carbohydrates have shown that the participation of different types of recognition groups in the complexation of the substrate favourably influences the binding process (Stapf et al., 2020a,b; Kaiser et al., 2019). Such a combination of two types of recognition units, namely heterocyclic and hydroxy groups, is realised in the triethylbenzene-based title compound 1 (see also Stapf et al., 2020a). The design of the receptors consisting of the aforementioned recognition units was inspired by the nature of the protein binding sites involved in the interactions stabilizing the crystalline protein–carbohydrate complexes (Quiocho, 1989). For example, 2-aminopyridine can be considered as a heterocyclic analogue of the asparagine/glutamine primary amide side chain. Furthermore, it should be noted that the formation of intramolecular interactions is also one of the factors influencing the binding properties of a receptor molecule (Rosien et al., 2013). Intramolecular interactions can also be observed in the crystal structure of 1.
2. Structural commentary

In the title molecule, the structure of which is shown in Fig. 1, the functionalized side arms are arranged on one side of the central benzene ring, while the ethyl substituents are oriented in the opposite direction. One of the bis(hydroxyethyl)amino moieties is disordered over two positions [s.o.f. 0.879 (2)/0.121 (2)]. The interplanar angle between the aromatic rings is 73.6 (1)°. Within the molecule, three hydroxy groups create a continuous pattern of O—H···O hydrogen bonds [d(H···O) 1.86–2.12 Å]. The amino nitrogen atoms N3 and N4 are involved in intramolecular C—H···N hydrogen bonding [d(H···N) 2.40, 2.54 Å]. The crystal structure contains four potentially solvent-accessible voids with a total volume of 110 Å³ per unit cell (Spek, 2015). The void volume of 27.5 Å³ and the maximum residual electron density of 0.55 e Å⁻³ indicate that the voids could be partially occupied by water molecules.

3. Supramolecular features

As depicted in Fig. 2 and Fig. 3, the crystal structure is constructed of inversion-symmetric molecular dimers held together by O—H···N and N—H···O hydrogen bonding [d(H···N) 1.89 (2) Å; d(H···O) 2.19 (2) Å; graph set R²(6) (Etter, 1990; Bernstein et al., 1995)]. These dimers are further assembled via O—H···O [d(H···O) 1.99 (2) Å] and C—H···O [d(H···O) 2.45 Å] bonds (Desiraju & Steiner, 1999).
Table 1
Hydrogen-bond geometry (Å, °).

| D—H · · · A | D—H | H—A | D···A | D—H···A |
|-------------|------|-----|-------|---------|
| O2A—H2A···O4' | 0.84 | 1.99 | 2.763 (18) | 152 |
| O1A—H1A···O2' | 0.84 | 1.99 | 2.832 (12) | 178 |
| C18A-H18D···O2A | 0.99 | 2.46 | 3.08 (2) | 120 |
| O2—H2···O3' | 0.87 (2) | 1.99 (2) | 2.828 (2) | 162 (3) |
| O1—H1···N2' | 0.87 (2) | 1.89 (2) | 2.7440 (19) | 167 (3) |
| N1—H1···O1' | 0.89 (2) | 2.19 (2) | 3.014 (2) | 152.0 (17) |
| C22—H22···N4 | 0.99 | 2.40 | 3.152 (2) | 132 |
| C18—H18···O2 | 0.99 | 2.39 | 3.106 (3) | 128 |
| C15—H15A···N3 | 0.99 | 2.54 | 3.282 (3) | 131 |
| C13—H13···O2Aiii | 0.98 | 2.33 | 3.220 (14) | 151 |
| C10—H10···O4'' | 0.95 | 2.45 | 3.365 (2) | 161 |
| O4—H4···O3 | 0.86 (2) | 2.12 (2) | 2.9200 (18) | 155 (3) |
| O3—H3···O1 | 0.87 (2) | 1.93 (2) | 2.727 (13) | 152 (3) |
| O3—H3···O1 | 0.87 (2) | 1.86 (2) | 2.7156 (19) | 172 (3) |

Symmetry codes: (i) -x, y + 1/2, z + 1/2; (ii) -x, -y + 1, -z; (iii) -x, y - 1/2, -z + 1/2; (iv) x, y, z - 1.

Figure 4
Packing diagram of the title compound viewed down the c axis. Oxygen atoms are displayed as red, nitrogen atoms as blue circles. Hydrogen-bonding interactions are shown as dashed lines.

4. Database survey

A search in the Cambridge Structural Database (CSD, Version 5.43, update November 2021; Groom et al., 2016) for 2,4,6-triethylbenzene derivatives bearing the (4,6-dimethylpyridin-2-yl)aminomethyl unit gave eight hits. In the crystal structures of the monohydrate and the methanol solvate of [1-{[(4,6-dimethylpyridin-2-yl)amino]methyl}-2,4,6-triethylbenzene (TUGVEX; Mazik et al., 2008), three water molecules are accommodated in the binding pocket created by the heterocyclic units (one phenanthrolinyl and two pyridinyl groups) of the host molecule. This host–water aggregate is stabilized by O—H···O, N—H···O and O—H···N hydrogen bonds. In a similar way, two water molecules and one ethanol molecule are accommodated in the binding pocket of 1,3-bis[[4-(1,10-phenanthroline-2-yl)carbonyl]amino]methyl]-2,4,6-triethylbenzene (ROKJEH; Mazik et al., 2009), containing one pyridinyl and two phenanthrolinyl groups.

5. Synthesis and crystallization

A mixture of diethanolamine (0.18 mL, 0.20 g, 1.88 mmol), THF (10 mL) and potassium carbonate (86 mg, 0.62 mmol) was stirred at room temperature for 30 minutes. After that, a solution of 1,3-bis(bromomethyl)-5-[(4,6-dimethylpyridin-2-yl)carbonyl]amino]methyl]-2,4,6-triethylbenzene in 10 mL of THF/CH3CN (1:1) was added dropwise and the resulting mixture was stirred at room temperature and under light exclusion (the progress of the reaction was monitored by TLC). After filtration, the solvents were removed under reduced pressure and the residual yellow oil was treated with a THF/water mixture. Then the THF was evaporated and the resulting oil was separated from the water. The oil was again dissolved in THF and dried over MgSO4. By addition of n-hexane, the product was precipitated as a white solid (58% yield, 95 mg, 0.18 mmol). Analysis data: m.p. = 408 K; 1H NMR (500 MHz, CDCl3) δ 1.14 (t, J = 7.5 Hz, 3H, CH3), 1.19 (t, J = 7.5 Hz, 6H, CH3), 2.29 (s, 3H, CH3), 2.35 (s, 3H, CH3), 2.63 (t, J = 7.5 Hz, 8H, CH2), 2.80 (q, J = 7.5 Hz, 4H, CH2), 3.26 (q, J = 7.5 Hz, 2H, CH2), 3.50 (t, J = 5.0 Hz, 8H, CH2), 3.77 (s, 4H, CH2), 4.22 (d, J = 4.0 Hz, 2H, CH2), 4.60 (br, 1H, NH), 6.17 (s, 1H, ArH), 6.38 (s, 1H, ArH); 13C NMR (126 MHz, CDCl3) δ 15.7, 16.5, 21.2, 21.3, 22.9, 23.8, 40.8, 52.3, 55.2, 59.7, 102.7, 114.1, 136.1, 132.6, 143.5, 145.8, 149.7, 156.2, 158.0; MS (ESI): m/z calculated for C30H50N4O4: 531.4 [M + H]+, found 531.4; Rp = 0.50 (Al2O3, CHCl3/CH3OH 7:1). Crystals of the title compound suitable for X-ray analysis were obtained as dimers of 1:1 host–guest complexes held together by O—H···N and N—H···O hydrogen bonds. In the case of the ethanol solvate of 1,3,5-tris[(4,6-dimethylpyridin-2-yl)aminomethyl]-2,4,6-triethylbenzene (RAJZAE; Mazik et al., 2004), dimers of host–guest units stabilized by O—H···Npyr and N—H···O bonds represent the basic supramolecular aggregates. The latter compound is also capable of forming crystalline complexes with methyl β-d-glucopyranoside (LAJZOP; Köhler et al., 2020). This crystal structure (acetonylitrile tetrasolvate monohydrate) contains two structurally different 2:1 receptor-carbohydrate complexes in which the sugar substrate is located in a cavity formed by the functionalized side arms of a pair of receptor molecules.

In the crystal structure of 1-{[(4,6-dimethylpyridin-2-yl)amino]methyl}-2,4,6-triethylbenzene (CADTAG, CADTEK; Stapf et al., 2020a), the host molecules reveal similar geometries with an alternating arrangement of the substituents above and below the plane of the central benzene ring. The crystals of these solvates are composed of inversion-symmetric

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colourless blocks by diffusion of n-hexane into a solution of the compound in THF.

6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. Carbon-bound hydrogen atoms and protons of the minor (12%) positions of the disordered OH groups (H1A, H2A) were positioned geometrically and allowed to ride on their respective parent atoms, with C—H = 0.95 Å (aromatic) and 0.99 Å (methylene) and Uiso(H) = 1.2 Ueq(C), and O—H = 0.84 Å (OH) and C—H = 0.98 Å (methyl) and Uiso(H) = 1.5 Ueq(C,O), respectively. The protons of the N—H and O—H (undisordered or the main positions) were located from the residual electron density map and refined with Uiso(H) bound to the parent atom (1.2, for NH and 1.5 for OH) with distance restraints for the OH bonds (SADI). The refinement of the disordered N(CH2CH2OH)2 group was performed using geometry (SAME) and Uij (SIMU, RIGU) restraints implemented in SHELXL (Sheldrick, 2015). The refined proportion of the two positions is 88:12%. The maximum residual peak of 0.55 e Å⁻³ is located inside a 27.5 Å³ void and can be refined as a partially occupied water molecule (~6%); however, due to the low occupancy, it was not included in the final refinement.

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Synthesis and crystal structure of 1,3-bis[[N,N-bis(2-hydroxyethyl)amino]-methyl]-5-[[4,6-dimethylpyridin-2-yl]amino]methyl]-2,4,6-triethylbenzene

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Computing details

Data collection: APEX2 (Bruker, 2008); cell refinement: SAINT (Bruker, 2008); data reduction: SAINT (Bruker, 2008); program(s) used to solve structure: SHELXS97 (Sheldrick, 2008); program(s) used to refine structure: SHELXL2018/3 (Sheldrick, 2015); molecular graphics: ORTEP-3 for Windows (Farrugia, 2012); software used to prepare material for publication: SHELXTL (Sheldrick, 2008).

2-[[3-[[Bis(2-hydroxyethyl)amino]methyl]-5-[[4,6-dimethylpyridin-2-yl]amino]methyl]-2,4,6-triethylphenyl]methyl][2-hydroxyethyl]amino]ethan-1-ol

Crystal data
\[ C_{30}H_{50}N_{4}O_{4} \]  
\[ M_r = 530.74 \]  
Monoclinic, \( P2_1/c \)  
\[ a = 14.2508 (3) \text{ Å} \]  
\[ b = 15.3046 (4) \text{ Å} \]  
\[ c = 15.2593 (3) \text{ Å} \]  
\[ \beta = 113.3107 (13) \text{°} \]  
\[ V = 3056.43 (12) \text{ Å}^3 \]  
\[ Z = 4 \]  

Data collection

Bruker Kappa APEX2 with CCD area detector diffractometer  
Radiation source: fine-focus sealed X-Ray tube  
phi and \( \omega \) scans  
22458 measured reflections  
6881 independent reflections  
4968 reflections with \( I > 2 \sigma (I) \)  
\( R_{int} = 0.031 \)  
\( \theta_{max} = 27.4 \text{°}, \theta_{min} = 3.1 \text{°} \)  
\( h = -18 \rightarrow 17 \)  
\( k = -19 \rightarrow 12 \)  
\( l = -19 \rightarrow 19 \)  

Refinement

Refinement on \( F^2 \)  
Least-squares matrix: full  
\( R[F^2] = 0.049 \)  
\( wR[F^2] = 0.144 \)  
\( S = 1.03 \)  
6881 reflections  
431 parameters  
290 restraints  
Primary atom site location: structure-invariant direct methods  
Secondary atom site location: difference Fourier map  
Hydrogen site location: mixed  
\( H \) atoms treated by a mixture of independent and constrained refinement  
\( \Delta \rho_{max} = 0.55 \text{ e Å}^{-3} \)  
\( \Delta \rho_{min} = -0.26 \text{ e Å}^{-3} \)  

Supporting information

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**Special details**

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

**Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)**

|       | x     | y     | z     | Uiso (Å²) | Occ. (<1) |
|-------|-------|-------|-------|-----------|-----------|
| O3    | 0.06213 (10) | 0.37633 (9) | 0.20622 (9) | 0.0317 (3) |
| H3    | 0.0307 (19) | 0.4220 (14) | 0.1746 (17) | 0.066 (8)* |
| O4    | 0.14319 (11) | 0.36916 (9) | 0.41431 (9) | 0.0344 (3) |
| H4    | 0.133 (2) | 0.3843 (18) | 0.3569 (14) | 0.075 (9)* |
| N1    | 0.27113 (11) | 0.44288 (9) | -0.07113 (9) | 0.0208 (3) |
| H1N   | 0.2143 (16) | 0.4558 (13) | -0.0622 (13) | 0.031 (5)* |
| N2    | 0.15327 (11) | 0.43433 (8) | -0.22623 (9) | 0.0228 (3) |
| N4    | 0.27759 (10) | 0.34248 (8) | 0.32090 (9) | 0.0205 (3) |
| C1    | 0.35480 (12) | 0.49260 (10) | 0.09155 (10) | 0.0187 (3) |
| C2    | 0.31562 (12) | 0.57360 (10) | 0.10358 (11) | 0.0194 (3) |
| C3    | 0.30179 (12) | 0.59065 (9) | 0.18829 (11) | 0.0181 (3) |
| C4    | 0.32351 (11) | 0.52609 (10) | 0.25834 (10) | 0.0173 (3) |
| C5    | 0.35813 (12) | 0.44317 (9) | 0.24358 (10) | 0.0174 (3) |
| C6    | 0.37449 (11) | 0.42637 (10) | 0.16047 (10) | 0.0177 (3) |
| C7    | 0.36773 (12) | 0.47485 (11) | -0.00056 (11) | 0.0221 (3) |
| H7A   | 0.387939 | 0.529168 | -0.023767 | 0.027* |
| H7B   | 0.421962 | 0.430698 | 0.010295 | 0.027* |
| C8    | 0.25215 (12) | 0.43984 (9) | -0.16689 (11) | 0.0193 (3) |
| C9    | 0.12935 (14) | 0.42942 (11) | -0.32090 (12) | 0.0267 (4) |
| C10   | 0.20380 (14) | 0.43045 (11) | -0.35800 (12) | 0.0275 (4) |
| H10   | 0.185041 | 0.427754 | -0.425011 | 0.033* |
| C11   | 0.30622 (14) | 0.43547 (11) | -0.29619 (12) | 0.0273 (4) |
| C12   | 0.33091 (13) | 0.43981 (10) | -0.19916 (11) | 0.0233 (3) |
| H12   | 0.400235 | 0.442732 | -0.155317 | 0.028* |
| C13   | 0.01792 (15) | 0.42276 (15) | -0.38339 (14) | 0.0410 (5) |
| H13A  | 0.009330 | 0.414806 | -0.449864 | 0.062* |
| H13B  | -0.016851 | 0.476413 | -0.377828 | 0.062* |
| H13C  | -0.011639 | 0.372699 | -0.363317 | 0.062* |
| C14   | 0.38925 (17) | 0.43524 (14) | -0.33408 (15) | 0.0413 (5) |
| H14A  | 0.396002 | 0.376396 | -0.356233 | 0.062* |
| H14B  | 0.454117 | 0.452731 | -0.283249 | 0.062* |
| H14C  | 0.371554 | 0.476451 | -0.387372 | 0.062* |
| C15   | 0.28910 (15) | 0.64292 (11) | 0.02668 (12) | 0.0301 (4) |
| H15A  | 0.232164 | 0.678992 | 0.028352 | 0.036* |
| H15B  | 0.265364 | 0.614087 | -0.036485 | 0.036* |
| C16   | 0.37980 (19) | 0.70256 (13) | 0.03842 (16) | 0.0468 (6) |
| H16A  | 0.435285 | 0.667612 | 0.033810 | 0.070* |
| H16B  | 0.403792 | 0.731212 | 0.100914 | 0.070* |
| H16C  | 0.358268 | 0.746977 | -0.011954 | 0.070* |
| Atom | x | y | z | U11 | U22 | U33 | U12 | U13 | U23 |
|------|---|---|---|-----|-----|-----|-----|-----|-----|
| C17  | 0.25925 (12) | 0.67846 (10) | 0.20094 (12) | 0.0220 (3) |
| H17A | 0.275654    | 0.688014    | 0.269611    | 0.026*   |
| H17B | 0.292937    | 0.725243    | 0.179147    | 0.026*   |
| H17C | 0.295174    | 0.699548    | 0.267252    | 0.026*   |
| H17D | 0.268160    | 0.722174    | 0.157027    | 0.026*   |
| N3   | 0.14881 (13) | 0.68479 (11) | 0.14808 (13) | 0.0210 (4) |
| C18  | 0.09000 (15) | 0.61856 (13) | 0.17436 (13) | 0.0257 (4) |
| H18A | 0.067231    | 0.643267    | 0.222641    | 0.031*   |
| H18B | 0.134482    | 0.567761    | 0.203334    | 0.031*   |
| C19  | −0.0016 (2)  | 0.5886 (3)   | 0.0894 (3)   | 0.0291 (8) |
| H19A | −0.050599   | 0.637513    | 0.064946    | 0.035*   |
| H19B | 0.019809    | 0.569992    | 0.037941    | 0.035*   |
| O1   | −0.04980 (13)| 0.51746 (9)  | 0.11566 (11)| 0.0291 (4) |
| H1   | −0.0746 (19) | 0.5386 (16)  | 0.1552 (16)  | 0.044*   |
| C20  | 0.11081 (16) | 0.77397 (12) | 0.14305 (16)| 0.0307 (5) |
| H20A | 0.035285    | 0.772108    | 0.111954    | 0.037*   |
| H20B | 0.135047    | 0.808013    | 0.100913    | 0.037*   |
| C21  | 0.1402 (2)   | 0.82323 (15) | 0.2360 (2)   | 0.0441 (6) |
| H21A | 0.215140    | 0.831891    | 0.264051    | 0.053*   |
| H21B | 0.107765    | 0.881661    | 0.222582    | 0.053*   |
| O2   | 0.11150 (16) | 0.78077 (12) | 0.30323 (13)| 0.0529 (5) |
| H2   | 0.0511 (16)  | 0.801 (2)    | 0.292 (2)    | 0.088 (12)* |
| N3A  | 0.1503 (6)   | 0.6654 (8)   | 0.1793 (8)   | 0.028 (3) |
| C18A | 0.0841 (8)   | 0.6365 (8)   | 0.0834 (7)   | 0.022 (2) |
| H18C | 0.119291    | 0.590229    | 0.062551    | 0.026*   |
| H18D | 0.071014    | 0.686176    | 0.038571    | 0.026*   |
| C19A | −0.0162 (11)| 0.6017 (19)  | 0.0800 (16)  | 0.025 (4) |
| H19C | −0.061027   | 0.650470    | 0.081917    | 0.030*   |
| H19D | −0.051601   | 0.568134    | 0.020504    | 0.030*   |
| O1A  | 0.0064 (10)  | 0.5463 (9)   | 0.1615 (10)  | 0.051 (3) |
| H1A  | −0.040111   | 0.550860    | 0.181942    | 0.076*   |
| C20A | 0.1121 (12)  | 0.7331 (9)   | 0.2246 (10)  | 0.050 (3) |
| H20C | 0.152433    | 0.732286    | 0.294424    | 0.060*   |
| H20D | 0.039976    | 0.720561    | 0.213106    | 0.060*   |
| C21A | 0.1192 (18)  | 0.8226 (10)  | 0.1859 (13)  | 0.066 (5) |
| H21C | 0.106339    | 0.867512    | 0.226497    | 0.079*   |
| H21D | 0.189389    | 0.831435    | 0.189293    | 0.079*   |
| O2A  | 0.0491 (14)  | 0.8342 (12)  | 0.0907 (11)  | 0.087 (5) |
| H2A  | −0.010553   | 0.825947    | 0.087201    | 0.130*   |
| C22  | 0.31398 (13) | 0.54528 (10) | 0.35242 (11)| 0.0229 (3) |
| H22A | 0.299154    | 0.490307    | 0.378670    | 0.027*   |
| H22B | 0.256090    | 0.585763    | 0.340778    | 0.027*   |
| C23  | 0.41152 (14)| 0.58586 (11) | 0.42515 (11)| 0.0261 (4) |
| H23A | 0.469352    | 0.546753    | 0.435284    | 0.039*   |
| H23B | 0.404018    | 0.594612    | 0.485670    | 0.039*   |
| H23C | 0.423840    | 0.642269    | 0.401207    | 0.039*   |
| C24  | 0.37421 (12)| 0.37309 (10)| 0.31879 (11)| 0.0205 (3) |
| H24A | 0.410543    | 0.322946    | 0.305591    | 0.025*   |
**H24B** 0.417870 0.396841 0.382251 0.025*  
**C25** 0.21403 (13) 0.29319 (11) 0.23560 (11) 0.0246 (4)  
**H25A** 0.182595 0.243188 0.255098 0.029*  
**H25B** 0.19565 (15) 0.28872 (12) 0.42530 (13) 0.032 (4)  
**C27** 0.29400 (14) 0.29730 (11) 0.41001 (12) 0.0264 (4)  
**H27A** 0.344684 0.330023 0.463986 0.032*  
**H27B** 0.322171 0.238398 0.408799 0.032*  
**C29** 0.41588 (13) 0.33905 (10) 0.14462 (12) 0.0246 (4)  
**H29A** 0.389151 0.326780 0.075312 0.029*  
**H29B** 0.391172 0.292370 0.175083 0.029*  
**C30** 0.555528 0.279991 0.172831 0.050*  
**H30A** 0.557266 0.382886 0.154862 0.050*  

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**Atomic displacement parameters (Å²)**

|   | U¹¹ | U¹² | U¹³ | U²² | U²³ | U³³ |
|---|-----|-----|-----|-----|-----|-----|
| O3 | 0.0266 (7) | 0.0379 (7) | 0.0313 (7) | 0.0018 (6) | 0.0122 (6) | 0.0082 (6) |
| O4 | 0.0409 (8) | 0.0418 (8) | 0.0244 (7) | 0.0039 (6) | 0.0170 (6) | 0.0003 (6) |
| N1 | 0.0216 (7) | 0.0258 (7) | 0.0169 (7) | -0.0023 (6) | 0.0096 (6) | -0.0033 (5) |
| N2 | 0.0267 (8) | 0.0207 (7) | 0.0218 (7) | 0.0009 (5) | 0.0103 (6) | 0.0008 (5) |
| N4 | 0.0258 (7) | 0.0192 (6) | 0.0153 (6) | -0.0026 (5) | 0.0068 (6) | 0.0014 (5) |
| C1 | 0.0180 (7) | 0.0219 (7) | 0.0168 (7) | -0.0045 (6) | 0.0077 (6) | -0.0025 (6) |
| C2 | 0.0188 (8) | 0.0188 (7) | 0.0194 (8) | -0.0033 (6) | 0.0063 (6) | 0.0013 (6) |
| C3 | 0.0167 (7) | 0.0153 (7) | 0.0221 (8) | -0.0014 (6) | 0.0075 (6) | -0.0011 (6) |
| C4 | 0.0169 (7) | 0.0172 (7) | 0.0188 (7) | -0.0023 (6) | 0.0084 (6) | -0.0027 (6) |
| C5 | 0.0178 (7) | 0.0169 (7) | 0.0168 (7) | -0.0005 (6) | 0.0062 (6) | 0.0000 (6) |
| C6 | 0.0167 (7) | 0.0182 (7) | 0.0183 (7) | -0.0008 (6) | 0.0069 (6) | -0.0036 (6) |
| C7 | 0.0215 (8) | 0.0286 (8) | 0.0180 (8) | -0.0041 (7) | 0.0096 (7) | -0.0028 (6) |
| C8 | 0.0261 (8) | 0.0147 (7) | 0.0185 (7) | 0.0000 (6) | 0.0104 (7) | 0.0001 (6) |
| C9 | 0.0325 (10) | 0.0221 (8) | 0.0232 (8) | -0.0002 (7) | 0.0088 (7) | -0.0002 (6) |
| C10 | 0.0395 (10) | 0.0268 (9) | 0.0174 (8) | -0.0027 (7) | 0.0127 (8) | -0.0005 (6) |
| C11 | 0.0360 (10) | 0.0255 (8) | 0.0261 (9) | -0.0049 (7) | 0.0184 (8) | -0.0036 (7) |
| C12 | 0.0246 (9) | 0.0254 (8) | 0.0210 (8) | -0.0029 (7) | 0.0101 (7) | -0.0038 (6) |
| C13 | 0.0350 (11) | 0.0513 (12) | 0.0294 (10) | 0.0004 (9) | 0.0047 (9) | 0.0011 (9) |
| C14 | 0.0483 (13) | 0.0514 (12) | 0.0367 (11) | -0.0127 (10) | 0.0301 (10) | -0.0116 (9) |
| C15 | 0.0458 (11) | 0.0221 (8) | 0.0234 (8) | -0.0009 (8) | 0.0145 (8) | 0.0052 (7) |
| C16 | 0.0773 (17) | 0.0288 (10) | 0.0509 (13) | -0.0146 (10) | 0.0429 (13) | -0.0012 (9) |
| C17 | 0.0218 (8) | 0.0189 (7) | 0.0255 (8) | 0.0010 (6) | 0.0093 (7) | -0.0014 (6) |
| C18 | 0.0249 (10) | 0.0268 (10) | 0.0260 (10) | 0.0008 (8) | 0.0109 (8) | 0.0009 (8) |
C19 0.0286 (13) 0.0305 (17) 0.0260 (13) 0.0004 (12) 0.0085 (10) 0.0001 (10)
O1 0.0237 (8) 0.0311 (8) 0.0342 (8) 0.0008 (6) 0.0130 (7) −0.0026 (6)
C20 0.0276 (11) 0.0183 (9) 0.0487 (13) 0.0081 (8) 0.0178 (10) 0.0071 (9)
C21 0.0336 (14) 0.0276 (11) 0.0711 (18) 0.0065 (10) 0.0207 (14) −0.0135 (12)
O2 0.0628 (13) 0.0487 (10) 0.0471 (10) 0.00246 (9) 0.0218 (10) −0.0080 (8)
N3A 0.025 (5) 0.018 (5) 0.035 (5) −0.001 (4) 0.006 (4) −0.002 (4)
C18A 0.013 (4) 0.020 (5) 0.027 (5) 0.003 (4) 0.002 (4) −0.004 (4)
C19A 0.019 (6) 0.021 (7) 0.033 (7) −0.005 (5) 0.008 (5) −0.014 (5)
O1A 0.026 (6) 0.069 (8) 0.053 (7) 0.011 (6) 0.011 (5) 0.021 (6)
C20A 0.046 (6) 0.042 (5) 0.054 (6) 0.008 (5) 0.010 (5) −0.012 (5)
C21A 0.060 (8) 0.047 (7) 0.077 (8) 0.007 (6) 0.013 (7) 0.004 (6)
O2A 0.077 (10) 0.096 (11) 0.080 (8) 0.027 (8) 0.023 (7) 0.017 (7)
C22 0.0326 (9) 0.0182 (7) 0.0236 (8) −0.00005 (7) 0.0174 (7) −0.0018 (6)
C23 0.0374 (10) 0.0228 (8) 0.0195 (8) 0.0007 (7) 0.0126 (7) −0.0035 (6)
C24 0.0243 (8) 0.0183 (7) 0.0173 (7) 0.0015 (6) 0.0066 (7) 0.0012 (6)
C25 0.0284 (9) 0.0214 (8) 0.0227 (8) −0.0037 (7) 0.0088 (7) −0.0026 (6)
C26 0.0259 (9) 0.0329 (9) 0.0197 (8) −0.0065 (7) 0.0077 (7) −0.0001 (7)
C27 0.0341 (10) 0.0245 (8) 0.0195 (8) −0.00002 (7) 0.0094 (7) 0.0060 (6)
C28 0.0398 (11) 0.0338 (10) 0.0249 (9) −0.0032 (8) 0.0153 (8) 0.0042 (7)
C29 0.0306 (9) 0.0212 (8) 0.0230 (8) 0.0032 (7) 0.0118 (7) −0.0040 (6)
C30 0.0323 (10) 0.0331 (9) 0.0348 (10) 0.0130 (8) 0.0128 (8) −0.0021 (8)

Geometric parameters (Å, º)

O3—C26 1.436 (2) C18—C19 1.502 (4)
O3—H3 0.867 (16) C18—H18A 0.9900
O4—C28 1.415 (2) C18—H18B 0.9900
O4—H4 0.863 (16) C19—O1 1.427 (3)
N1—C8 1.3775 (19) C19—H19A 0.9900
N1—C7 1.456 (2) C19—H19B 0.9900
N1—H1N 0.89 (2) O1—H1 0.873 (16)
N2—C8 1.343 (2) C20—C21 1.512 (3)
N2—C9 1.349 (2) C20—H20A 0.9900
N4—C27 1.4595 (19) C20—H20B 0.9900
N4—C25 1.466 (2) C21—O2 1.404 (3)
N4—C24 1.467 (2) C21—H21A 0.9900
C1—C2 1.401 (2) C21—H21B 0.9900
C1—C6 1.407 (2) O2—H2 0.865 (17)
C1—C7 1.513 (2) N3A—C18A 1.461 (9)
C2—C3 1.407 (2) N3A—C20A 1.466 (9)
C2—C15 1.515 (2) C18A—C19A 1.507 (10)
C3—C4 1.397 (2) C18A—H18C 0.9900
C3—C17 1.518 (2) C18A—H18D 0.9900
C4—C5 1.412 (2) C19A—O1A 1.433 (10)
C4—C22 1.523 (2) C19A—H19C 0.9900
C5—C6 1.4010 (19) C19A—H19D 0.9900
C5—C24 1.521 (2) O1A—H1A 0.8400
C6—C29 1.518 (2) C20A—C21A 1.511 (10)
C2—C3—C17 119.29 (13)  C20A—N3A—C17 110.8 (8)
C3—C4—C5  119.95 (13)  N3A—C18A—C19A 111.7 (11)
C3—C4—C22 120.61 (13)  N3A—C18A—H18C 109.3
C5—C4—C22 119.40 (13)  C19A—C18A—H18C 109.3
C6—C5—C4  120.22 (13)  N3A—C18A—H18D 109.3
C6—C5—C24 121.63 (13)  C19A—C18A—H18D 109.3
C4—C5—C24 118.13 (12)  H18C—C18A—H18D 107.9
C5—C6—C1  119.28 (13)  O1A—C19A—C18A 107.1 (10)
C5—C6—C29 121.33 (13)  O1A—C19A—H19C 110.3
N1—C7—C1  108.68 (12)  O1A—C19A—H19D 110.3
N1—C7—H7A 110.0  C19A—C18A—C19A 111.7 (11)
N1—C7—H7B 110.0  C19A—C18A—H19C 110.3
H7A—C7—H7B 108.3  C19A—C18A—H19D 110.3
C1—C7—H7B 110.0  C18A—C19A—C19A 111.7 (11)
C1—C7—H7A 110.0  C18A—C19A—H19C 110.3
N2—C8—N1  115.51 (13)  C18A—C19A—H19D 110.3
N2—C8—C12 122.62 (14)  H19C—C19A—H19D 108.5
N1—C8—C12 121.84 (15)  C19A—O1A—H1A 109.5
N2—C9—C10 121.94 (16)  C4—C22—C23 111.64 (13)
N2—C9—C13 115.99 (15)  C4—C22—H22A 109.3
C10—C9—C13 122.07 (16)  C4—C22—H22B 109.3
C9—C10—C11 119.35 (15)  C4—C22—H22C 109.3
C9—C10—H10 120.3  O2A—C21A—C20A 111.2 (12)
C11—C10—H10 120.3  O2A—C21A—H21C 109.0
C12—C11—C10 118.68 (16)  O2A—C21A—H21D 109.0
C12—C11—C8 118.68 (16)  C21A—C20A—H20C 109.4
C11—C12—C8 118.68 (16)  C21A—C20A—H20D 109.4
C11—C12—H12 120.7  N3A—C20A—H20C 109.4
C8—C12—H12 120.7  N3A—C20A—H20D 109.4
C9—C13—H13A 109.5  C21A—C20A—H20D 108.0
C11—C14—H14A 109.5  C21A—O2A—H2A 109.5
C11—C14—H14B 109.5  O2A—C21A—H21D 112.8 (12)
H13A—C13—H13B 109.5  C4—C22—H21C 109.0
H13A—C13—H13C 109.5  O2A—C21A—H21D 112.8 (12)
H13B—C13—H13C 109.5  C4—C22—H21C 109.0
C11—C14—H14C 109.5  O2A—C21A—H21D 112.8 (12)
C11—C14—H14B 109.5  C4—C22—H21C 109.0
C14—C13—H13A 109.5  H22A—C22—H22B 108.0
C14—C13—H13B 109.5  C22—C23—H23A 109.5
C14—C13—H13C 109.5  C22—C23—H23B 109.5
C11—C14—H14C 109.5  C22—C23—H23C 109.5
C11—C14—H14B 109.5  H23A—C23—H23C 109.5
H14A—C14—H14B 109.5  H23B—C23—H23C 109.5
C11—C14—H14C 109.5  N4—C24—C5 112.30 (13)
C11—C14—H14B 109.5  N4—C24—H24A 109.1
H14A—C14—H14C 109.5  N4—C24—H24B 109.1
C2—C15—C16 112.70 (16)  C5—C24—H24A 109.1
C2—C15—H15A 109.1  H24A—C24—H24B 107.9
C16—C15—H15A 109.1  N4—C25—C26 113.08 (14)
C2—C15—H15B 109.1  N4—C25—H25A 109.0
C16—C15—H15B 109.1  C26—C25—H25A 109.0
| Bond | Angle (°) |  | Bond | Angle (°) |  |
|------|----------|---|------|----------|---|
| H15A—C15—H15B | 107.8 | | N4—C25—H25B | 109.0 |
| C15—C16—H16A | 109.5 | | C26—C25—H25B | 109.0 |
| C15—C16—H16B | 109.5 | | H25A—C25—H25B | 107.8 |
| H16A—C16—H16B | 109.5 | | O3—C26—C25 | 108.92 (13) |
| C15—C16—H16C | 109.5 | | O3—C26—H26A | 109.9 |
| H16A—C16—H16C | 109.5 | | C25—C26—H26A | 109.9 |
| H16B—C16—H16C | 109.5 | | O3—C26—H26B | 109.9 |
| N3—C17—C3 | 112.70 (14) | | C25—C26—H26B | 109.9 |
| N3A—C17—C3 | 106.9 (5) | | H26A—C26—H26B | 108.3 |
| N3—C17—H17A | 109.1 | | N4—C27—C28 | 111.58 (14) |
| N3—C17—H17A | 109.1 | | N4—C27—H27A | 109.3 |
| N3—C17—H17B | 109.1 | | C28—C27—H27A | 109.3 |
| N3—C17—H17B | 109.1 | | N4—C27—H27B | 109.3 |
| H17A—C17—H17B | 107.8 | | C28—C27—H27B | 109.3 |
| N3A—C17—H17C | 110.3 | | H27A—C27—H27B | 108.0 |
| C3—C17—H17C | 110.3 | | O4—C28—C27 | 112.57 (14) |
| N3A—C17—H17D | 110.3 | | O4—C28—H28A | 109.1 |
| C3—C17—H17D | 110.3 | | C27—C28—H28A | 109.1 |
| H17C—C17—H17D | 108.6 | | O4—C28—H28B | 109.1 |
| C20—N3—C17 | 112.80 (16) | | C27—C28—H28B | 109.1 |
| C20—N3—C18 | 114.82 (16) | | H28A—C28—H28B | 107.8 |
| C17—N3—C18 | 114.22 (15) | | C6—C29—C30 | 112.38 (14) |
| N3—C18—C19 | 111.71 (17) | | C6—C29—H29A | 109.1 |
| N3—C18—H18A | 109.3 | | C30—C29—H29A | 109.1 |
| C19—C18—H18A | 109.3 | | C30—C29—H29B | 109.1 |
| C19—C18—H18B | 109.3 | | H29A—C29—H29B | 107.9 |
| H18A—C18—H18B | 107.9 | | C29—C30—H30A | 109.5 |
| O1—C19—C18 | 109.9 (2) | | C29—C30—H30B | 109.5 |
| O1—C19—H19A | 109.7 | | H30A—C30—H30B | 109.5 |
| C18—C19—H19A | 109.7 | | C29—C30—H30C | 109.5 |
| O1—C19—H19B | 109.7 | | H30A—C30—H30C | 109.5 |
| C18—C19—H19B | 109.7 | | H30B—C30—H30C | 109.5 |
| C6—C1—C2—C3 | 3.9 (2) | | N2—C8—C12—C11 | 1.1 (2) |
| C7—C1—C2—C3 | 179.11 (14) | | N1—C8—C12—C11 | 179.13 (15) |
| C6—C1—C2—C15 | −176.63 (15) | | C1—C2—C15—C16 | −88.89 (19) |
| C7—C1—C2—C15 | −1.5 (2) | | C3—C2—C15—C16 | 90.55 (19) |
| C1—C2—C3—C4 | −2.3 (2) | | C4—C3—C17—N3 | −99.98 (17) |
| C15—C2—C3—C4 | 178.26 (15) | | C2—C3—C17—N3 | 77.67 (18) |
| C1—C2—C3—C17 | −179.95 (14) | | C4—C3—C17—N3A | −77.6 (6) |
| C15—C2—C3—C17 | 0.6 (2) | | C2—C3—C17—N3A | 100.1 (6) |
| C2—C3—C4—C5 | −0.8 (2) | | C3—C17—N3—C20 | −167.61 (15) |
| C17—C3—C4—C5 | 176.79 (14) | | C3—C17—N3—C18 | 58.88 (19) |
| C2—C3—C4—C22 | 176.88 (14) | | C20—N3—C18—C19 | 83.7 (3) |
| C17—C3—C4—C22 | −5.5 (2) | | C17—N3—C18—C19 | −143.8 (2) |
| C3—C4—C5—C6 | 2.4 (2) | | N3—C18—C19—O1 | 173.3 (2) |
| C22—C4—C5—C6 | −175.35 (14) | | C17—N3—C20—C21 | −52.4 (2) |
C3—C4—C5—C24 −176.09 (14) C18—N3—C20—C21 80.8 (2)
C22—C4—C5—C24 6.2 (2) N3—C20—C21—O2 −56.8 (3)
C4—C5—C6—C1 −0.8 (2) C3—C17—N3A—C18A −61.6 (11)
C24—C5—C6—C29 −4.1 (2) C17—N3A—C18A—C19A 163.7 (14)
C2—C1—C6—C5 −2.4 (2) N3A—C18A—C19A—O1A −45 (3)
C7—C1—C6—C29 179.35 (14) C3—C17—N3A—C20A 157.2 (8)
C8—N1—C7—C1 165.06 (14) C20A—N3A—C21A—C22A −77.9 (15)
C9—N2—C8—N1 −85.21 (17) C22—C4—C5—C24 −85.93 (18)
C6—C1—C7—N1 90.00 (17) C5—C4—C22—C23 91.81 (17)
C2—C1—C7—C12 −177.49 (14) C27—N4—C24—C5 −108.97 (16)
C7—C1—C7—C12 4.2 (2) C4—C5—C24—N4 69.50 (18)
C2—C1—C7—N1 −85.21 (17) C13—C9—C10—C12 −179.07 (16)
C6—C1—C7—N1 90.00 (17) C11—C10—C11—C12 −0.4 (2)
C2—C1—C7—N1 −85.21 (17) C27—N4—C25—C26 132.61 (15)
C7—C1—C7—C12 20.8 (2) C24—N4—C25—C26 −98.70 (15)
C2—C1—C7—N1 90.00 (17) C9—C10—C11—C12 −179.00 (16)
C7—N1—C8—N2 −178.75 (14) C13—C9—C10—C11 −0.6 (2)
C9—N2—C8—C12 −161.06 (14) C14—C11—C12—C8 −0.6 (2)
C7—N1—C8—N2 −178.75 (14) C13—C9—C10—C11 −0.6 (2)
C2—C1—C7—N1 −85.21 (17) C14—C11—C12—C8 −179.97 (15)
C7—N1—C8—C12 20.8 (2) C10—C11—C12—C8 −179.97 (15)
C9—N2—C8—N1 −161.06 (14) C13—C9—C10—C11 −179.07 (17)
C10—C11—C12—C8 −0.6 (2) C14—C11—C12—C8 −179.97 (15)
C11—C10—C11—C12 −179.00 (16) C9—C10—C11—C12 −0.4 (2)

Hydrogen-bond geometry (Å, °)

| D—H···A | D—H | H···A | D···A | D—H···A |
|---------|------|-------|-------|---------|
| O2A—H2A···O4i | 0.84 | 1.99 | 2.763 (18) | 152 |
| O1A—H1A···N2ii | 0.84 | 1.99 | 2.832 (12) | 178 |
| C18A—H18D···O2A | 0.99 | 2.46 | 3.08 (2) | 120 |
| O2—H2···O3i | 0.87 (2) | 1.99 (2) | 2.828 (2) | 162 (3) |
| O1—H1···N2ii | 0.87 (2) | 1.89 (2) | 2.7449 (19) | 167 (3) |
| N1—H1N···O1ii | 0.89 (2) | 2.19 (2) | 3.014 (2) | 152.0 (17) |
| C22—H22A···N4 | 0.99 | 2.40 | 3.152 (2) | 132 |
| C18—H18A···O2 | 0.99 | 2.39 | 3.106 (3) | 128 |
| C15—H15A···N3 | 0.99 | 2.54 | 3.282 (3) | 131 |
| C13—H13A···O2Aiii | 0.98 | 2.33 | 3.220 (14) | 151 |
| C10—H10···O4iv | 0.95 | 2.45 | 3.365 (2) | 161 |
| O4—H4···O3 | 0.86 (2) | 2.12 (2) | 2.9200 (18) | 155 (3) |
| O3—H3···O1A | 0.87 (2) | 1.93 (2) | 2.727 (13) | 152 (3) |
| O3—H3···O1 | 0.87 (2) | 1.86 (2) | 2.7156 (19) | 172 (3) |

Symmetry codes: (i) −x, y+1/2, −z+1/2; (ii) −x, −y+1, −z; (iii) −x, y−1/2, −z−1/2; (iv) x, y, z−1.