

# New optically active hexaaza triphenolic macrocycles: synthesis, molecular structure and crystal packing features

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**3 + 3 Condensed optically active hexaaza triphenolic macrocycles 1 and 2 are synthesised and characterised; molecular and close packing structures of macrocycle 2 are discussed.**

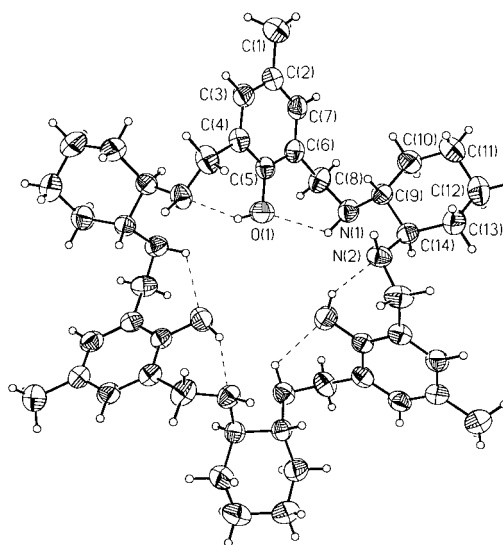
Synthesis and study of new ligands with phenolic groups is an area of active research interest because of their use as models for biological metal-binding sites, their ability to form metal complexes with interesting magnetic exchange, redox and catalytic properties.<sup>1</sup> 2,6-Diformyl-4-methylphenol **A** is a useful source to synthesise such ligands and oxo-bridged macrocyclic complexes with diamines in the presence of template metal salts.<sup>1</sup> Although 2 + 2 condensed macrocyclic dinuclear complexes are the favoured products, a few 3 + 3 and 4 + 4 multinuclear macrocyclic complexes have been reported,<sup>3</sup> but the free ligands have not been isolated. Preformed ligands are required to investigate host-guest interactions, to synthesise complexes of metals inert to template reactions and complexes of heteronuclear metals. So far only 2 + 2 condensed metal-free macrocycles have been isolated ( $H^+$  as a template ion) from **A**.<sup>4</sup> For the first time we report the synthesis and structural characterisation of a new template-free, 3 + 3 condensed and optically active hexamine triphenolic Schiff base macrocycle **1** derived from **A** and *trans*-(*R,R*)-1,2-cyclohexyldiamine **B**,<sup>5</sup> and its reduced analogue hexamine triphenolic macrocycle **2**. Macrocycles **1** and **2** have the potential to bind three metal ions through oxo-bridges.

The reaction of **A** and **B** in methanol in equimolar ratio using the high dilution technique affords a 3 + 3 Schiff-base macrocycle **1** as yellow solid in high yield. The molecular ion peak at  $m/z$  727 of **1** indicates the condensation of three units of **A** and three units of **B**. The macrocycle **2**, the reduced analogue of macrocycle **1** was obtained by the reduction of **1** with  $NaBH_4$  in methanol<sup>6</sup> and was identified by its molecular ion peak at  $m/z$  739. Compounds **1** and **2** are also characterised by IR, NMR and CHN analysis.‡ The molecular structure of **2** was confirmed from its crystal structure (crystals of **1** were not suitable for X-ray structure determination).

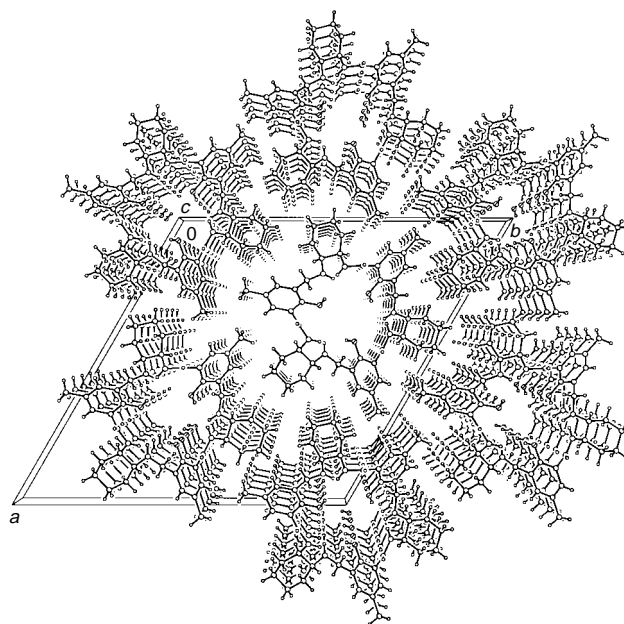
The X-ray structure of **2**§ was performed on single crystals grown by slow evaporation from benzene. It crystallises in space group *R*3 (no.146) wherein the molecular three-fold symmetry coincides with the crystallographic three-fold axis. The macrocyclic cavity is defined by 27 atoms in which six N-atoms and 21 C-atoms are present. The three phenolic-OH groups projected inside the cavity generate three equivalent  $N_2O_2$  sub-cavities. The geometry of these sub-cavities appears suitable for metal complexation as the two N and two O atoms provide appropriate coordination sites. The macrocycle is stabilised by intra-molecular (O-H...N, N-H...O, N-H...N) hydrogen bonding with H...acceptor distances lying in the range 2.02–2.29 Å. An ORTEP drawing of **2** with intramolecular hydrogen bonding is shown in Fig. 1.

The macrocycle has an internal hydrophilic cavity capable of forming hydrogen bonds and has an external hydrophobic periphery. The molecules are extended in the *ab* plane with the mean plane of the molecule perpendicular to the *c*-axis. It can be seen from the packing diagram (Fig. 2) that each molecule is surrounded by six molecules leading to a trigonal network

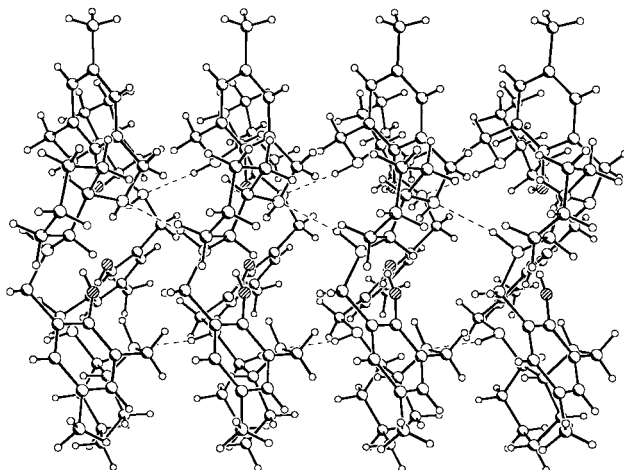
structure. The organisation of the molecules in the *ab* plane is governed by the hydrophobic interaction between the methyl groups of moiety **A** and methylene groups of moiety **B** and is not assisted by any other observable interactions. The two  $CH_3...CH_3$  and cyclohexyl  $CH_2...CH_2$  close packing C–C distances are 3.96 and 4.00 Å, respectively. The stacking in the *c*-axis is maintained by inter-molecular N–H...N hydrogen bonding [ $N(2)–H(2)...N(1)$ ]:  $D = 3.22$  Å,  $d = 2.23$  Å,  $\theta =$



**Fig. 1** An ORTEP diagram of macrocycle **2**; thermal ellipsoids are shown at the 50% probability level



**Fig. 2** Stacks viewed down the *c*-axis of macrocycle **2**



**Fig. 3** The intermolecular hydrogen bonds between the molecules viewed down the *Y*-axis of macrocycle **2**

167.32°) and supported by weak C–H···O interactions (H···O, 2.9 Å) leading to a channel like structure. The aromatic rings of the moiety **A** in the stacks are separated by 5.143 Å as shown in Fig. 3. The three-dimensional trigonal assembly of the macrocycle is maintained by hydrophobic interactions in the *ab* plane and hydrogen bonding along the *c*-axis. Although carry-over of the molecular symmetry into the crystal is not very common, the non-centrosymmetric trigonal networking of molecules as shown in Fig. 3 is reported to have important applications in NLO and an example of such arrangements due to intermolecular hydrogen bonding has been reported recently.<sup>7</sup>

The X-ray structure of macrocycle **2** suggests an analogous structure for macrocycle **1**. The successful synthesis of **1** and **2** results from the stability of the 27-membered macrocycle possibly due to its optimum ring size and the intramolecular hydrogen bonding interactions.

Further studies on the host–guest properties of **1** and **2** with metal ions, solvent molecules, organic guest molecules and variations in crystal packing pattern by changing the substituents on the macrocycle in different solvents are in progress.

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## Notes and References

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‡ **1**: yield 80%. IR:  $\nu/\text{cm}^{-1}$  1639 (C=N);  $^1\text{H NMR}$  ( $\text{CDCl}_3$ )  $\delta$  8.66 (s, HC=N), 8.2 (s, HC=N), 7.56 (s, Ar-H), 6.89 (s, Ar-H), 3.3 (m, =N–CH), 2.08 (s, Ar-CH<sub>3</sub>), 1.86–1.46 (m, CH<sub>2</sub>CH<sub>2</sub>).  $^{13}\text{C NMR}$  ( $\text{CDCl}_3$ )  $\delta$  19.92, 24.45, 33.26, 33.48, 73.49, 75.45, 118.78, 122.99, 126.89, 129.56, 134.20, 156.15, 159.32, 163.46; FABMS: Calc. for  $\text{C}_{45}\text{H}_{54}\text{N}_6\text{O}_3$   $m/z$  727. Found 727 ( $\text{M}^+$ ). Anal. Calc. C, 74.35; H, 7.49; N, 11.57. Found: C, 74.23; H, 7.46; N, 11.93%.  $[\alpha]_{\text{D}}^{27} = -239$  (c 1,  $\text{CH}_2\text{Cl}_2$ ).

**2**: yield 70%. IR:  $\nu/\text{cm}^{-1}$  1612 (NH);  $^1\text{H NMR}$  ( $\text{CDCl}_3$ )  $\delta$  6.8 (s, Ar-H), 5.00 (br, NH), 3.6–3.9 (q, HNCH<sub>2</sub>), 2.1 (s, Ar-CH<sub>3</sub>), 2.45–1.2 (m, CH<sub>2</sub>CH<sub>2</sub>);  $^{13}\text{C NMR}$  ( $\text{CDCl}_3$ )  $\delta$  20.52, 25.00, 31.24, 47.74, 60.47, 125.17, 127.21, 128.24, 154.18; FABMS: Calc. for  $\text{C}_{45}\text{H}_{66}\text{N}_6\text{O}_3$   $m/z$  739. Found: 739 ( $\text{M}^+$ ). Anal. Calc. C, 73.13; H, 9.00; N, 11.38. Found: C, 73.44; H, 8.99; N, 11.30%.  $[\alpha]_{\text{D}}^{27} = -189$  (c 1,  $\text{CH}_2\text{Cl}_2$ ).

§ *Crystal structure determination of 2*:  $\text{C}_{45}\text{H}_{66}\text{N}_6\text{O}_3$ ,  $M = 739$ , trigonal, space group  $R\bar{3}$  (no.146),  $a = 26.499(4)$ ,  $b = 26.499(4)$ ,  $c = 5.1433(10)$  Å,  $\alpha = \beta = 90^\circ$ ,  $\gamma = 120.0^\circ$   $U = 3127.7(9)$  Å<sup>3</sup>,  $T = 293(2)$  K,  $Z = 3$ ,  $\mu = 0.07$  mm<sup>-1</sup>; 1367 independent reflections out of 3641 collected with  $1.52 < \theta < 24.94$ , 173 parameters one restraint,  $R_{\text{int}} = 0.0229$ . Refinement method: full-matrix least squares on  $F^2$ , Final  $R$  indices  $[I > 2\sigma(I)]$ :  $R_1(\text{observed}) = 0.0449$ ,  $wR_2 = 0.1073$ .  $R(\text{all data})$ :  $R_1 = 0.0535$ ,  $wR_2 = 0.1211$ . The absolute configuration of macrocycle **2** could not be determined from the X-ray data. CCDC 182/867.

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