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# 2,3,5,6-Tetra(pyrazin-2-yl)pyrazine: a novel bis-bidentate, bis-tridentate chelator

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## ABSTRACT

Novel 10-nitrogen ligand, 2,3,5,6-tetra(pyrazin-2-yl)pyrazine, has been synthesized in four steps. This compound shows different conformations and the crystal structure of one of them has been established. This structure is sustained by non-classical H-bonds and π···π interactions among heteroaromatic rings.

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Recent interest in polybasic ligands bearing pyridine or pyrazine moieties such as 2,3,5,6-tetra(pyrid-2-yl)pyrazine (**1**, *tppz*)[1] and tetrapyrido[3,2-*a*:2′,3′-*c*: 3″,2″-*h*:2‴,3‴-*j*]phenazine (**2**, *tpphz*)[2] is devoted to their ability to form a plethora of coordination modes with metallic centers (Fig. 1). Many other syntheses of bridging ligands with multidentate binding sites are also described.[3]

These molecules can coordinate to form transition metal arrays[4] and dendrimers[5] with implications for the development of numerous applications, such as photoelectrochemical cells, photoconversion and light-harvesting devices, and organic/inorganic light-emitting diodes. One could imagine an analogous structure to **1** with the replacement of the pyridine units by pyrazines. In this case the final structure should be 2,3,4,5-tetra(pyrazin-2-yl)-pyrazine (**3**, *tpzpz*). This compound will have 10 nitrogen atoms: six in a potential bis-tridentate binding system and four in a bis-bidentate binding system, significantly increasing the amount of coordination modes, compared to the seven modes shown by **1**.[6]

To put this idea into practice 1,2-di(pyrazin-2-yl)ethene-1,2-diol (**7**) was prepared in 73% yield by benzoin coupling of pyrazine-2-carbaldehyde (**6**) in water with 10 mol % potassium cyanide[7] (Scheme 1). An increase in the catalyst loading in this reaction led to invariably lower yields. Intermediates **5** and **6** are well-known compounds and were prepared by classical methodologies in 93%[8] and 68%[9] yields from the commercially available pyrazine-2-carboxylic acid (**4**). *Tpzpz* (**3**) was obtained in 37% yield following a modification of the procedure successfully implemented by Goodwin and Lions[10] in their syntheses of compound **1**. Thus, we submitted compound **7** to condensation with ammonium acetate in pyridine at 80 °C.

Attempts to perform this reaction in molten ammonium acetate or in other solvents such as DMSO, 2,6-lutidine, and DMF failed or resulted in very low yields of the desired ligand. Also, this reaction gave poorer yields at higher temperatures, with sonication, or with microwave heating.

All compounds were fully characterized by $^1$H NMR, $^{13}$C NMR, IR, elemental analyses, and HRMS. As anticipated, the pyrazine moieties gave very similar and characteristic patterns in $^1$H NMR: three groups of signals ranging from $\delta$ 8.40 to $\delta$ 8.73, $\delta$ 8.50 to $\delta$ 8.77, and $\delta$ 9.12 to $\delta$ 9.30. We noted by $^1$H NMR and HMQC experiments, at least three coexisting atropisomeric conformations for **3** in DMSO-$d_6$, DMF-$d_7$, or $D_2O$/TFA-*d* solution.[11] High-temperature $^1$H NMR at 120 °C showed significant reduction of the number and complexity of lines, but unfortunately this temperature was insufficient for the complete coalescence of each group of signals. HRMS showed a mass/charge ratio of 393.1341 for the $[M+1]^+$ ion ($m/z = 393.1327$ calculated for $C_{20}H_{13}N_{10}$).

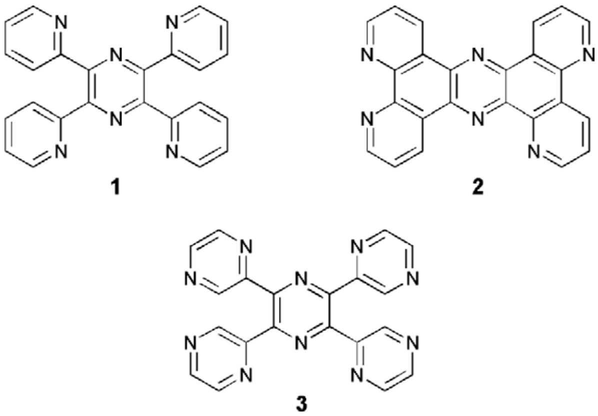

**Figure 1.** Structures of 2,3,5,6-tetra(pyrid-2-yl)pyrazine (**1**, *tppz*), tetrapyrido[3,2-*a*:2′,3′-*c*:3″,2″-*h*:2‴,3‴-*j*]phenazine (**2**, *tpphz*), and 2,3,4,5-tetra(pyrazin-2-yl)pyrazine (**3**, *tpzpz*).

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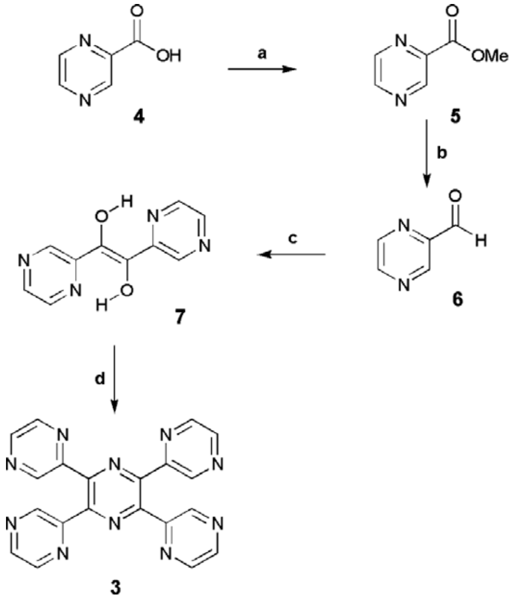

**Scheme 1.** Reagents and conditions: (a) dry MeOH, $H_2SO_4$, rt, 72 h, 93%; (b) $LiAlH_4$, dry THF, −82 °C, 1.5 h, 68%; (c) KCN, water, rt, 1 h, 73%; and (d) $NH_4OAc$, pyridine, 80 °C, 1 h, 37%.

The numbering scheme and molecular structure of *tpzpz* (**3**) are shown in Figure 2. It belongs to the $P2_1/c$ space group, and its conformation is quite similar to that of *tppz* (**1**), although it is less distorted.[11] C1–C2–C3–N2 and C2–C1–C7–N4 dihedral angles are, respectively, 34.8(1) and 42.8(1)° for *tpzpz* (**3**) and 50 and 53° for *tppz* (**3**).[11] These lower dihedral angles lead to a closer distance between nitrogens N2 and N4. Therefore, the N2–N4 distance for *tpzpz* (**3**) is 2.96 Å, and for *tppz* (**1**) it is 3.24 Å.[11]

X-ray diffraction data also show intermolecular interactions in the solid. The crystalline structure of *tpzpz* (**3**) is stabilized by two C–H···N non-classical H-bonds.[12] These weak hydrogen bonds have lengths within the 2.50–2.61 Å range, as shown in Figure 3. Angles for C10–H10···N3 and C5–H5···N4 are 146 and 141 degrees, respectively. These values are in accordance with the literature for similar cases.[12a,12b] The smallest centroid–centroid distance ($R_{cen}$) presented among pyrazine rings was 3,88 Å. This π···π interaction shows solid body azimuthal angle (θ) of 32.3° and Euler angle yaw (γ) of 19.7°. These values suggest crystal structure stabilization occurring also by π···π interactions among heteroaromatic rings.[13] The lattice grows in the [1 0 0] direction and [1 0 1] diagonal plane. This leads to 2D self-arrangement. *Tpzpz* (**3**) molecules also stack in the [0 1 0] direction.

In summary, a novel bis-bidentate/bis-tridentate chelator containing 10 nitrogen atoms was synthesized. *Tpzpz* (**3**) is not planar, but it is less distorted than its analogue, *tppz* (**1**), suggesting a

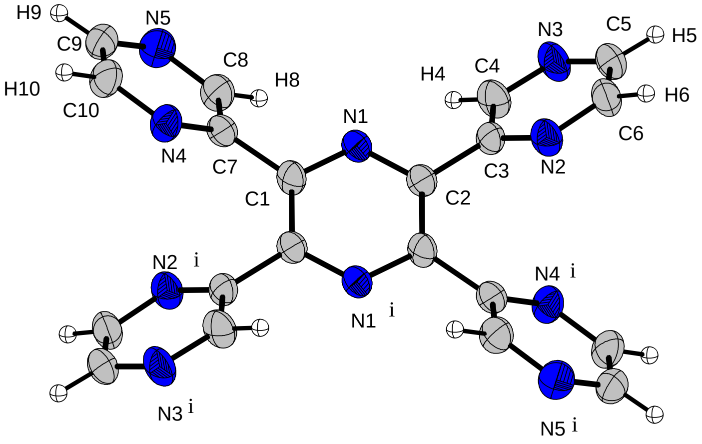

**Figure 2.** *ORTEP* drawing of *tpzpz* (**3**) with thermal parameters at a level of 50% probability.

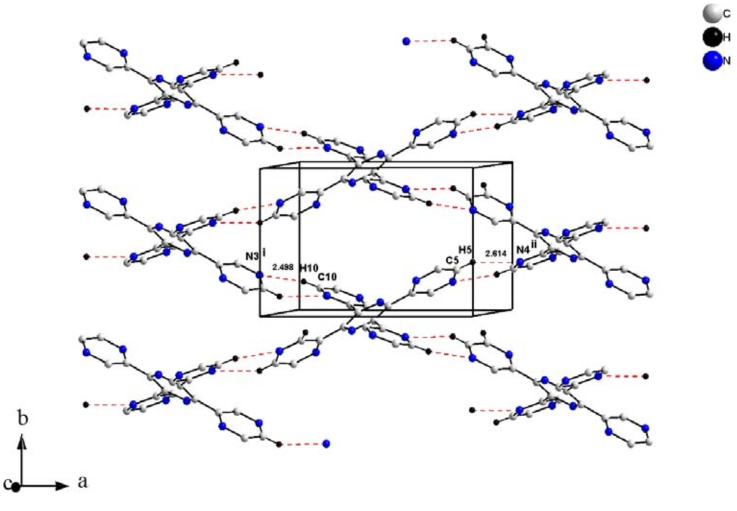

**Figure 3.** 2D lattice of *tpzpz* (**3**) via C–H···N non-classical H-bonds. Symmetry code (i) = −1 + *x*, ½ − *y*, −½ + *z* and (ii) = 1 + *x*, ½ − *y*, ½ + *z*.

greater ability to form transition metal arrays. *Tpzpz* (**3**) shows four non-classical H-bonds per molecule stabilizing the crystal structure. In addition, *tpzpz* (**3**) molecules mount in the [0 1 0] direction showing $\pi\cdots\pi$ stacking in the crystal.

Further studies on this ligand are ongoing and will include a careful evaluation of photophysical and electrochemical properties of the self-assembly of ligand-transition metals bridged supramolecular structures.

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## Supplementary data

Details of the syntheses of compounds **3**, **5**, **6**, and **7**, crystallographic information, supplementary figures, XRD, NMR spectra, and MS for compound **3** and NMR spectra and MS for compound **7** are available in this supplementary material. The crystal structure for **3** has been deposited at the CCDC and allocated the deposition number 690110. Supplementary data associated with this Letter can be found, in the online version, at doi:10.1016/j.tetlet.2009.04.098.

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