Free-base tripyrrins†

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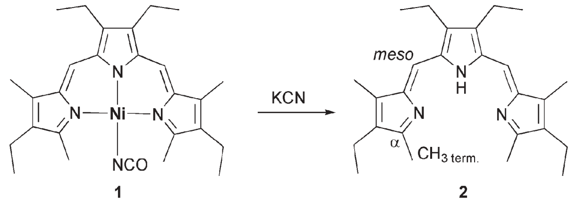
The hitherto unavailable free-base tripyrrins HTrpy have been prepared by cyanide promoted demetallation of a nickel(II) tripyrrin and by acid-induced condensation of a diformylpyrrole and an alkylpyrrole with a sterically shielded α-position.

Metal chelates of the tripyrrin ligand[1] show a rich and multifacetted coordination chemistry including 1D and 3D polymeric coordination compounds,[2] unusual coordination geometries[3] and unexpected palladium(II) chelates.[4] The chemistry of the tripyrrins has been hampered, however, by the pronounced sensitivity of these tripyrrolic moieties against nucleophiles. For this reason the synthesis of tripyrrin ligands had to be carried out in a strongly acidic media, and the metalation processes consisted basically of competition reactions between the binding of excess protons and the transition-metal ions at low pH. These conditions rendered the preparation of many metallotripyrrins, especially those with labile complex fragments such as TrpyCd, TrpyFe or TrpyMn, almost impossible. Although highly desirable, tripyrrins have not been isolated as the free bases so far, but were obtained either oxygenated in the *meso*-[5] or α-position,[6] or in impure form as fully protonated dications.[7] We report here about successful preparations of free-base tripyrrins.

The first hint to a possible preparation of free-base tripyrrins came from the serendipitous observation that an attempted ligand exchange on **1** with excess cyanide did not yield the desired cyano derivative, but resulted in a colour change from dark green to intense red (Scheme 1). From the resulting mixture a single compound **2** could be isolated, which decomposed rapidly and in an unspecific fashion in aerated as well as in deaerated solutions, but remained stable in the solid state. If the treatment of **1** with cyanide is carried out with sonication in the biphasic system diethyl ether/water the solution stability of the red product is markedly enhanced, and the new compound **2** can easily be isolated after phase separation and drying as a red powder in 90% yield. Similar cyanide promoted reactions are well-established as demetalation procedures in porphyrin chemistry.[8] We therefore expected, that **2** is indeed the hitherto elusive free-base tripyrrin. This expectation was confirmed by the results from a microanalysis and by the observation of a M^+ ion at *m*/*z* 389 in EI mass spectra.

^1H NMR spectroscopy of the new compound proves the diamagnetic nature of the tripyrrin. Besides the signals for the methyl and ethyl substituents, which are present in the expected range, splitting pattern and number, the *meso* situated protons and the NH proton produce characteristic singlets at 6.50 and 12.84 ppm, respectively. In addition, the NH proton was also detected in the IR spectrum of **2** by a band for the NH stretching vibration at 3243 cm^{-1}. Fig. 1 shows an overlay of the optical spectra of the paramagnetic nickel(II) chelate **1** and the free-base tripyrrin **2**. The major bands of the nickel chelate **1** at 353 and 678 nm are blue-shifted by about 20 nm to 330 and 660 nm, respectively, for the free-base **2**, and a new, broad and intense band with a shoulder now appears between 450 and 600 nm. These spectra are markedly different and qualitatively reflect the colour change observed upon demetalation. First experiments towards the remetalation of **2** have been successful and prove the suitability of the new compound for the preparation of *e.g.* Mn^{II} or Cd^{II} complexes. These results point to a broader application of tripyrrin ligands in coordination chemistry and will be published elsewhere in due course.

In a different attempt we investigated the shielding of the sensitive α-position of the tripyrrins by large *tert*-butyl substituents (Scheme 2). Therefore the di(*tert*-butyl) derivative **5** was prepared from *tert*-butylpyrrole **4** and diformylpyrrole **3** in the typical fashion for tripyrrins, *i.e.* by boiling the starting material in trifluoroacetic acid for 10 h. **5** is relatively robust as the protonated



Scheme 1 Preparation of free-base tripyrrin HTryp **2** by cyanide promoted demetalation of nickel chelate **1**.

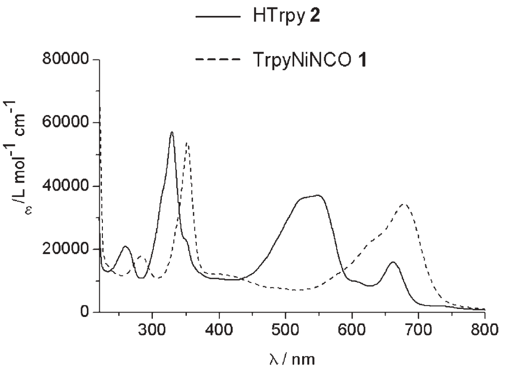


Fig. 1 UV/Vis spectra of TrpyNiNCO **1** and free-base tripyrrin HTrpy **2** in dichloromethane.

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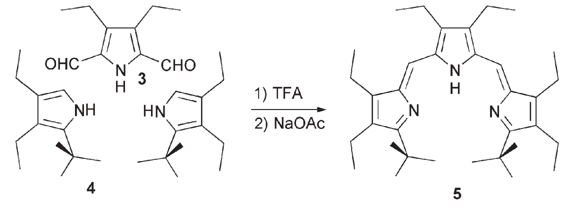

Scheme 2 Trifluoroacetic acid promoted condensation of dialdehyde **3** with *tert*-butylpyrrole **4** and formation of the sterically shielded tripyrrin **5**.

dication. Treatment of this initially formed **5**·2HOAc^{F} with a solution of sodium acetate in methanol does not, as usually observed, result in the immediate decomposition of the tripyrrole, but in the formation of the sterically blocked free-base tripyrrin as a red solution. From this solution pure **5** was obtained by silica chromatography and crystallization from *n*-hexane as shiny green-metallic cubes. All attempts to coordinate **5** to transition-metal ions were not successful. Upon prolonged heating in the presence of palladium acetate only a gradual decomposition was observed. The green cubes of **5** were subjected to a X-ray diffraction study.[9] **5** crystallizes as monoclinic crystals in space group $P2_1/c$. Two enantiomers are present in the unit cell. The molecular structure of one enantiomer and selected molecular data are summarized in Fig. 2.

The X-ray crystallographic analysis reveals that tripyrrin **5** displays a severely non-planar distortion with the C1 and C16 atoms of the *tert*-butyl termini being situated 1.7325 and 1.7952 Å above and below the mean tripyrrin plane, respectively. As a consequence of this helical twist the stereoelectronic orientation of the N-donor electron pairs becomes unfavourable for cooperative metal ion binding. The *tert*-butyl substituents are too bulky to allow a planar conformation of the tripyrrin. In addition, the spacial segments for the prospective binding of a metal ions coligands are blocked to a large extent. It could be argued, that **5** and other tripyrrins may move one of the terminal C_4N rings away from the binding cavity by *E*/*Z* isomerization or rotation and serve as mono- or bidentate ligands. Such a behaviour is known *e.g.* for bis(arylimino)isoindoline (BAI) ligands,[10] but has not been observed for tripyrrins and related tripyrroles[11] so far.

The structural characteristic of **5** is only partially reflected in the spectroscopic data in solution. The optical spectra of **2** and **5** show only minor differences as do the ^{1}H NMR spectra with the exception of the intense singlet at 1.35 ppm for the *tert*-butyl protons of **5**. The ethyl group protons split into the simple A_2X_3 system pattern without diastereotopic splitting even at low temperature, and as before the *meso*-situated protons and the NH proton produce characteristic singlets at 6.65 and 11.70 ppm, respectively. These feature are in agreement with a very rapid helix inversion process of **5** in solution.

The fact, that **5** displays by far the highest resistance of all tripyrrins against nucleophilic attack and degradation points to the terminal α positions and/or the methyl termini as the primary reactive sites. With respect to the literature[5,6] the *meso* positions appear vulnerable only in those cases, where an additional one-electron oxidant such as Cu^{II} is present.

In summary we have reported the syntheses, spectroscopic details and a structural characterization for the first free-base tripyrrins, thereby filling a blank entry in the systematic exploration of open-chain oligopyrroles.[12] Especially the advent of the free-base **2** now allows studies towards the coordination chemistry of more labile ions like Mn^{II}, Fe^{II} and the like, which have always been of major importance in the exploration of novel porphyrinoids.[13]

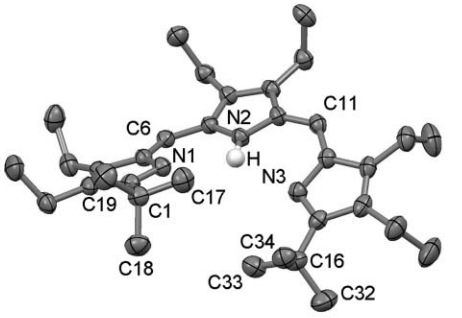

Fig. 2 Molecular structure of **5**. Selected bond lengths, distances (Å) and angles (°): N1–C2 1.311(2), N1–C5 1.416(2), N2–C7 1.373(2), N2–C10 1.369(2), N3–C12 1.410(2), N3–C15 1.310(2), C2–C3 1.488(3), C3–C4 1.352(3), C4–C5 1.457(3), C5–C6 1.344(2), C6–C7 1.429(3), C7–C8 1.395(2), C8–C9 1.403(2), C9–C10 1.402(2), C10–C11 1.432(3), C11–C12 1.345(3), C12–C13 1.464(3), C13–C14 1.353(3), C14–C15 1.488(3), C1–C16 5.364(3); C5–C6–C7 129.25(18), C10–C11–C12 127.22(18). Hydrogen atoms bound to carbon omitted for clarity. Ellipsoids are set at 50% probability.

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9 *Crystal data* for $C_{34}H_{51}N_3$ **5**: green cubes, M = 501.78, monoclinic, space group $P2_1/c$, a = 11.1869(9), b = 24.340(2), c = 11.6741(11) Å, β = 93.714(10)°, V = 3172.1(5) Å^3, Z = 4, D_c = 1.051 g cm^{-3}, μ = 0.061 mm^{-1}, $F(000)$ = 1104, 24891 reflections collected ($1.94 < \theta < 26.04°$) at 193(2) K, 6006 independent (R_{int} = 0.1174), that are used in the structure refinement; R_1 = 0.0377 [$I > 2\sigma(I)$], wR_2 = 0.0682 (all data), GOF = 0.690 for 351 parameters, largest difference peak, hole = 0.110, −0.131 e Å^{-3}. CCDC 626329. For crystallographic data in CIF or other electronic format see DOI: 10.1039/b615935d.
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