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Extension of N-Confused Porphyrin by an *o*-Xylene Fragment

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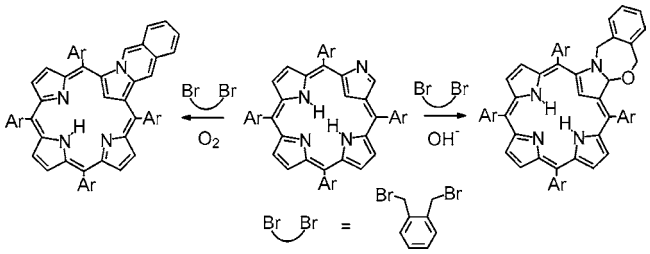
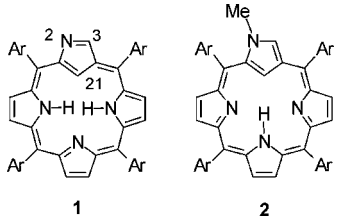
ABSTRACT



A simple method of modification of N-confused porphyrin is provided by reactions of 5,10,15,20-tetraaryl-2-aza-21-carbaporphyrin with α,α′-dibromoxylene. The *N*-bromoxylene-substituted monomer formed in a first step of alkylation can be converted to the products with the extended structure on the N-confused pyrrole for which formation of organometallic silver(III) complexes has been shown.

"Inverted" or "N-confused" porphyrin **1** (NCP, Figure 1) was the first synthesized isomer of the regular porphyrin that retained its basic skeleton.[1−3] Structurally similar to the regular porphyrin, the "N-confused" isomer possesses many distinct features that can be exploited in designing new compounds and materials. The properties of the macrocycle can be fine-tuned by substituting either the periphery[4] or the core[5,6] of the porphyrinoid, so as to modify the coordination chemistry of the ligand[1,7,8] as well as its redox or optical behavior. The unusual reactivity of the inverted pyrrole is largely a consequence of placing the nitrogen atom on the macrocyclic periphery. This simple N-confusion step brings each member of the pyrrole ring into an "unnatural" position, resulting in an unorthodox chemical behavior at each of the three reactive sites (2-N, 3-C, and 21-C). The external nitrogen (2-N) is a primary target of electrophilic attack on the porphyrin free base **1**[4a] giving the methylation product



1 **2**

Figure 1. Inverted porphyrin **1** (NCP) and its 2-methylated derivative **2**.

(1) Chmielewski, P. J.; Latos-Grażyński, L.; Rachlewicz, K.; Glowiak, T. *Angew. Chem., Int. Ed. Engl.* **1994**, *33*, 779.
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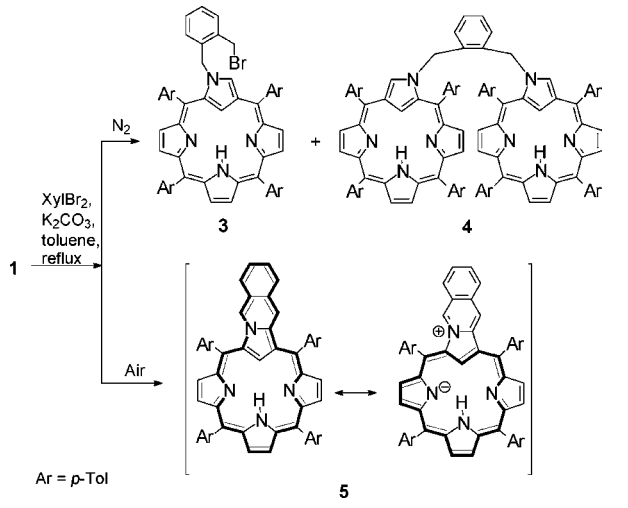
2. Substitution at position 3-C is catalyzed by acids.[4d,h] For nickel(II) complex, internal carbon atom 21-C is the most susceptible position for electrophilic attack, although deprotonation of 2-NH results in the formation of 2-substituted products.[5,6a−c]

In the present paper, a reaction of **1** with 1,2-di(bromomethyl)benzene ($XylBr_2$) is shown to give the products involving both "external" positions of the *confused* pyrrole in the NCP free base (Scheme 1).

Scheme 1



Refluxing **1** with 3 equiv of $XylBr_2$ in the presence of K_2CO_3 (dry toluene, N_2, 6 h) results in the formation of an olive alkylation product **3** (55%). It is accompanied by a grass-green dimeric derivative **4** (13%). Their molar ratio is rather insensitive to the excess of the alkylating agent. The spectral characteristics of both products are similar and resemble that of **2**.[4a] The ^{1}H NMR spectra of **3** and **4** show significant weakening of the aromatic character of the macrocyclic systems with respect to that of **1**. NMR reveals the symmetry of **4** presenting only one set of signals for both macrocyclic fragments. Also the optical spectra of **3** and **4** (Figure 2) resemble that of 2-methylated derivative of NCP.[4a]

In the presence of air, the major product of reaction of **1** with $XylBr_2$ is a purple-red isoquinolincarbaporphyrin **5**.[4g] The reaction does not require application of a proton scavenger.[9] Formation of **3** precedes that of **5** since the latter product can be obtained by a 2 h reflux of the former in a

(7) (a) Chmielewski, P. J.; Latos-Grażyński, L. *Inorg. Chem.* **1997**, *36*, 840. (b) Chmielewski, P. J.; Latos-Grażyński, L.; Schmidt, I. *Inorg. Chem.* **2000**, *39*, 5475. (c) Furuta, H.; Ogawa, T.; Uwatoko, Y.; Araki, K. *Inorg. Chem.* **1999**, *38*, 2676. (d) Ogawa, T.; Furuta, H.; Takahashi, M.; Morino, A.; Uno, H. *J. Organomet. Chem.* **2000**, *661*, 551. (e) Furuta, H.; Kubo, N.; Maeda, H.; Ishizuka, T.; Osuka, A.; Nanami, H.; Ogawa, T. *Inorg. Chem.* **2000**, *39*, 5424, (f) Chen, W.-C.; Hung, C.-H. *Inorg. Chem.* **2001**, *40*, 5070. (g) Srinivasan, A.; Furuta, H.; Osuka, A. *Chem. Commun.* **2001**, 1666.

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(9) Without a proton scavenger, the formation of a certain amount of a directly 3,3′-linked N-confused bisporphyrin is observed, likely due to liberation of HBr, which is an effective catalyst of the dimerization. See ref 4h.

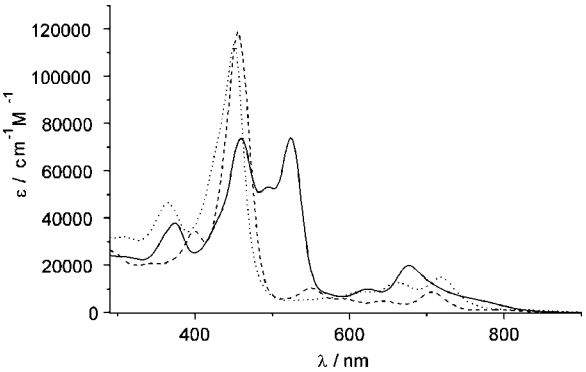
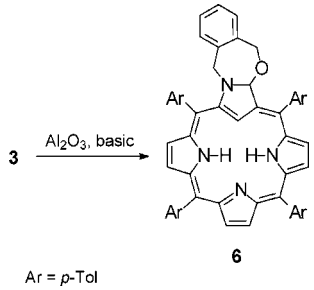


Figure 2. Optical spectra (CH_2Cl_2) of **3** (dotted line), **5** (solid line), and **6** (dashed line).

toluene solution. Clearly, the overall conversion of **3** into **5** involves substitution at the α position of the *confused* pyrrole followed by abstraction of two hydrogen atoms, thus leading to the formation of a new heteroaromatic ring. The aromaticity of the isoquinoline fragment is revealed by NMR spectroscopy. The six-membered heterocyclic ring is represented by two singlets at 8.78 and 7.16 ppm in the ^{1}H NMR spectrum of **5** ($CDCl_3$, 298 K), while the external benzoprotons give rise to multiplets in the 7.2−7.4 ppm region. The upfield shift of the internal 21-CH (−1.06 ppm) and NH (0.68 ppm) indicate the aromatic character of the macrocycle. The optical spectrum of **5** (Figure 2) is markedly distinct from those of other 2-substituted derivatives of **1**. The split Soret band may reflect the contribution of the *confused* pyrrole extension into the aromatic system of the macrocycle.

The reactive character of the benzylic bromomethyl group in **3** allows another type of extension of the *confused* pyrrole. The facile conversion of **3** into **6** (Scheme 2) resulted in an

Scheme 2



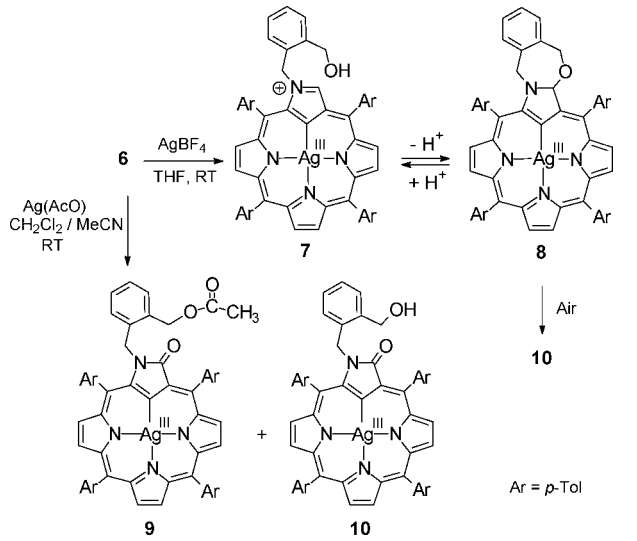
increase of macrocyclic aromaticity, with ^{1}H NMR signals at −4.62 ppm for 21-CH and −2.36 and −2.71 ppm for two internal NH ($CDCl_3$, 213 K). The stronger ring current effect (relative to that observed in **3**) is clearly due to the alteration of the macrocyclic delocalization path caused by breaking of the conjugation on its perimeter since carbon 3 adopts an sp^3 hybridization. Both methylene groups of the seven-

membered oxazole ring are diastereotopic due to formation of a rigid cyclic structure. Significantly, there is a ^{1}H NMR singlet of 3-H at 8.06 ppm showing throughspace interactions with both CH_2 groups in the NOESY map and a correlation with 21-C in the HMBC experiment. The chemical shift of the asymmetric carbon 3 (99.2 ppm, $CDCl_3$, 298K) is in line with the strongly deshielding influences of two heteroatoms and aromatic macrocyclic ring.

The ^{1}H NMR-controlled titration of **5** with trifluoroacetic acid (TFA) reveals the presence of two basic sites inside the macrocycle. In the case of **6**, stepwise addition of TFA results in an initial formation of a monocation with three NH protons within the macrocyclic crevice, followed by a reversible dissociation of the 3-C−O bond. This cleavage can be inferred from the absence of diastereotopic differentiation of the methylene protons in the dication at room temperature.

The macrocyclic interior of **6** is potentially trianionic, and thus the formation of a stable organometalic silver(III) complex analogous to those of NCP **1** or other carbaporphyrinoids is expected.[7c,10] Application of silver(I) tetrafluoroborate yields a diamagnetic cationic species **7** in which the external heterocyclic ring is broken (Scheme 3). Addition

Scheme 3



of a base (i.e., wet K_2CO_3) leads to the restoration of the exocyclic structure in **8** with four diastereotopic methylene signals in the ^{1}H NMR spectrum.

With the less acidic silver(I) acetate as a metal source, two similar complexes **9** and **10** can be separated (Scheme 3), both characterized by the presence of an N-substituted lactam functionality.[4e] In the presence of air, a conversion of **8** into **10** takes place in solution.

(10) (a) Furuta, H.; Maeda, H.; Osuka, A. *J. Am. Chem. Soc.* **2000**, *122*, 803. (b) Maeda, H.; Osuka, A.; Ishikawa, Y.; Aritome, I.; Hisaeda, Y.; Furuta, H. *Org. Lett.* **2003**, *5*, 1293. (c) Muckey, M. A.; Szczepura, L. F.; Ferrence, G. M.; Lash, T. D. *Inorg. Chem.* **2002**, *41*, 4840. (d) Lash, T. D.; Colby, D. A.; Szczepura, L. F. *Inorg. Chem.* **2004**, *43*, 5258. (e) Lash, T. D.; Rasmussen, J. M.; Bergman, K. M.; Colby, D. A. *Org. Lett.* **2004**, *6*, 549. (f) Pawlicki, M.; Latos-Grażyński, L. *Chem. Eur. J.* **2003**, *9*, 4650.

The ^{1}H NMR spectra of both **7** and **8** are characterized by the position of the 3-H singlet. This signal is strongly shifted downfield in **7** (9.27 ppm, 298 K, $CDCl_3$), as it is in the case of the silver(III) complex of **1**.[7c] On the other hand, the chemical shift of 3-H in **8** (7.68 ppm) is similar to that observed for this proton in **6**. Obviously, this signal is missing in the ^{1}H NMR spectra of **9** and **10**. The amide carbon 3-C (169.2 ppm for **9**, 169.7 ppm for **10**, $CDCl_3$, 298 K) correlates with protons of one of the methylene groups (5.32 ppm for **9**, 5.40 ppm for **10**) in the ^{1}H−^{13}C HMBC map. The acetate moiety in **9** can be identified by the presence of another carbonyl signal (170.3 ppm), which shows scalar coupling to the methyl protons at 2.11 ppm and the methylene protons at 4.71 ppm. The benzylic hydroxymethylene fragment in the ^{1}H NMR spectrum of **10** is represented by a doublet of CH_2 protons at 4.36 ppm and the −OH triplet at 1.75 ppm (Figure 3, CD_2Cl_2, 298 K). The

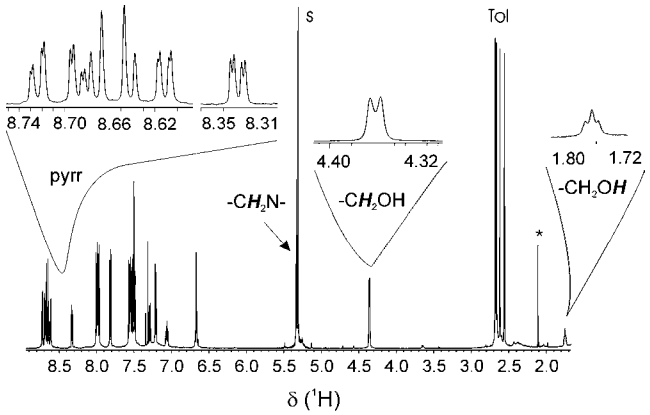
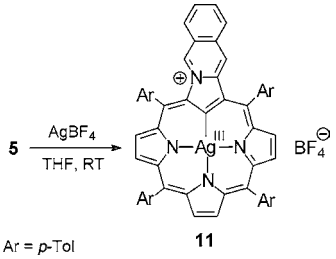


Figure 3. ^{1}H NMR spectrum of **10** (500 MHz, CD_2Cl_2, 298 K). Assignments: pyrr, β-pyrrole; Tol, methyl protons of *meso*-tolyl substituents; s, residual solvent signal; *, solvent impurity.

splitting of the β-pyrrole signals in the ^{1}H NMR caused by the ^{1}H−^{107,109}Ag heteronuclear coupling unequivocally indicates the coordination of a silver ion in the macrocyclic interior of **8**, **9**, or **10** (Figure 3, inset).

Although **5** can be at most dianionic as a ligand,[11] having only two removable protons within the macrocyclic crevice, its metalation with $AgBF_4$ proceeds readily, leading to a green cationic diamagnetic silver(III) complex **11** (Scheme 4). The complex is stable in the solid state and in solution.

Scheme 4



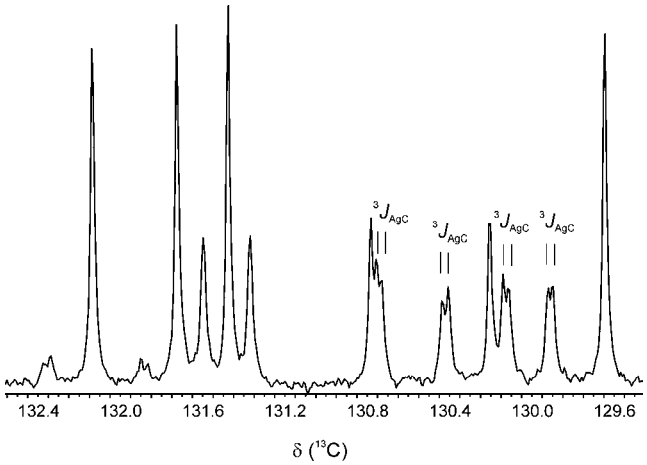


Figure 4. Fragment of the ^{13}C NMR spectrum of **11** (126 MHz, $CDCl_3$, 298 K) showing heteronuclear couplings between silver and some of the β-pyrrole carbons ($^3J_{AgC}$).

The structure of the ligand remains unaltered as long as the integrity and aromaticity of the isoquinoline system are concerned. The absence of any upfield signals in ^{1}H NMR indicates deprotonation of the macrocyclic interior. Coordination to the silver ion can be inferred again on the basis of a heteronuclear coupling between β-pyrrole protons or carbons and the silver nucleus ($^4J_{AgH} = 0.9-1.1$ Hz; $^3J_{AgC} = 2.9-3.3$ Hz, Figure 4), while the signal in the ^{11}B NMR spectrum of **11** (−1.5 ppm, $CDCl_3$, 298 K) confirms the presence of the tetrafluoroborate anion.

In conclusion, we have shown that a bromoxylene group can be readily attached to the external nitrogen of the *confused* pyrrole. Its reactivity is promising since it can be exploited in covalent linking of the porphyrin moiety to the various objects. The facile formation of a heteroaromatic ring results in extension of the aromatic system on the macrocyclic perimeter, strongly affecting spectral properties of the porphyrinoid. Despite the dianionic character of the ligand, the tendency of the 2-N-substituted derivatives of NCP to stabilize trivalent silver, typical for the other carbaporphyrinoids, is preserved.

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Supporting Information Available: Spectral data, detailed descriptions of syntheses, and characterization of the compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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(11) Neutral nickel(II) complex of **5** has been reported as a product of a Diels−Alder cycloaddition with (NCP)Ni^{II} acting as a dienophile. See ref 4g.