CHEMISTRY LETTERS, pp. 2233-2236 1994.

Synthesis of Sterically Overcrowded Deca- and Undecaphenylporphyrins via Mixed Condensation of 3,4-Diphenylpyrrole with Benzaldehyde and Formaldehyde

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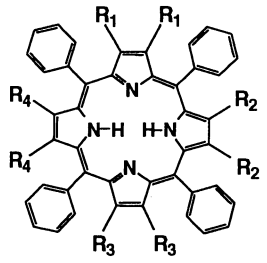
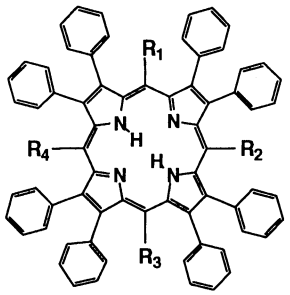
Sterically overcrowded unsymmetrical porphyrins bearing ten and eleven phenyl groups are synthesized using mixed condensation of diphenylpyrrole with benzaldehyde and formaldehyde and characterized by FAB-MS, UV-VIS, and NMR spectra.

Synthesis and properties of nonplanar 2,3,5,7,8,10,12,13,15,17,18,20-dodecaphenylporphyrin (H_2DPP, **1**) have recently been reported by Smith et al.[1] and Takeda et al.[2] H_2DPP has a unique nonplanar macrocycle of saddle type distortion,[2-4] and its reactive properties such as metalation rate[5] and redox behavior[6] are shown to be significantly different from those of planar 5,10,15,20-tetraphenylporphyrin (H_2TPP, **2**). Quite recently, we have reported the synthesis of a series of sterically-overcrowded porphyrins,[7] 2,3,5,10,15,20-hexaphenylporphyrin (H_2HPP, **3**), 2,3,5,10,12,13,15,20-octaphenylporphyrin (H_2(*trans*-OPP), **4**), 2,3,5,7,8,10,15,20-octaphenylporphyrin (H_2(*cis*-OPP), **5**), and 2,3,5,7,8,10,12,13,15,20-decaphenylporphyrin (H_2DecPP, **6**). These porphyrins are constructed based on the H_2TPP skeleton by introducing phenyl groups at the β-pyrrole positions. The UV-VIS and NMR spectral properties indicate that the degree of macrocyclic nonplanarity in these porphyrins is increased with the number of phenyl substituents.



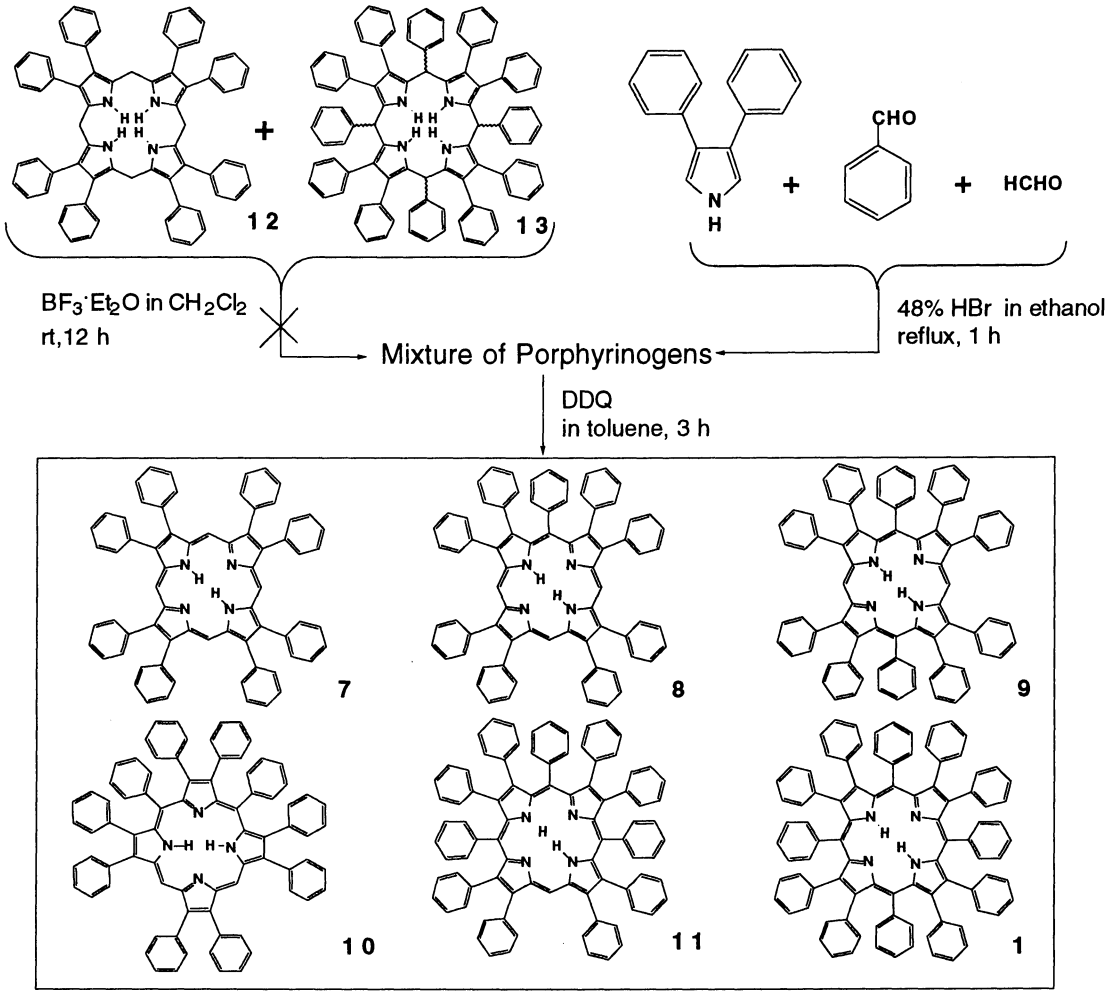
R_1	R_2	R_3	R_4	
H	H	H	H	H_2TPP (2)
Ph	H	H	H	H_2HPP (3)
Ph	H	Ph	H	H_2(*trans*-OPP) (4)
Ph	Ph	H	H	H_2(*cis*-OPP) (5)
Ph	Ph	Ph	H	H_2DecPP (6)
Ph	Ph	Ph	Ph	H_2DPP (1)



R_1	R_2	R_3	R_4	
H	H	H	H	H_2OPP (7)
Ph	H	H	H	H_2NPP (8)
Ph	H	Ph	H	H_2(*trans*-DecPP) (9)
Ph	Ph	H	H	H_2(*cis*-DecPP) (10)
Ph	Ph	Ph	H	H_2UPP (11)
Ph	Ph	Ph	Ph	H_2DPP (1)

In this letter, we report the synthesis and characterization of another series of phenyl-substituted porphyrins, which are constructed based on the planar 2,3,7,8,12,13,17,18-octaphenylporphyrin (H_2OPP, **7**)[8, 9] skeleton by introducing phenyl groups at the *meso*-positions. The newly synthesized porphyrins include 2,3,5,7,8,12,13,15,17,18-decaphenylporphyrin (H_2(*trans*-DecPP), **9**), 2,3,5,7,8,10,12,13,17,18-decaphenylporphyrin (H_2(*cis*-DecPP), **10**), and 2,3,5,7,8,10,12,13,15,17,18-undecaphenylporphyrin (H_2UPP, **11**). However, 2,3,5,7,8,12,13,17,18-nonaphenylporphyrin (H_2NPP, **8**), a member of this series of porphyrins, has not been isolated and characterized.

Scheme 1.



Following the porphyrinogen exchange method,[10] we first tried to prepare the new porphyrins **8-11** by allowing an equimolar mixture of octaphenylporphyrinogen **12**[9] and dodecaphenylporphyrinogen **13** to reach exchange equilibrium in CH_2Cl_2. However, the porphyrinogen exchange did not occur even after 20 h, and the starting porphyrinogens were recovered almost quantitatively. No exchange reactivity indicates the stable nature of octa- and dodecaphenylporphyrinogen macrocycles which is probably caused by the eight phenyl groups at the β-pyrrole positions and is contrasted to the system involving *meso*-tetraarylporphyrinogens.[10]

We have then attempted to synthesize the new compounds using the mixed condensation method shown in Scheme 1. Thus, a mixture of 3,4-diphenylpyrrole (1 equiv), benzaldehyde (0.5 equiv), and formaldehyde (0.5 equiv) was refluxed in ethanol in the presence of HBr for 1 h.[9,11] The porphyrinogens resulted were oxidized to the corresponding porphyrins with 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ) in refluxing toluene for 3 h.

It has been known that H_2OPP **7** is sparingly soluble in most organic solvents.[8,9] This compound was isolated by filtration using a fine sintered glass frit.[9] The TLC ($SiO_2/CHCl_3$) of the filtrate showed the presence of four different porphyrins. The chromatographic separation on silica gel using solvents with a gradient from CH_2Cl_2 to $CHCl_3$ (containing 0.75% ethanol) afforded H_2(*trans*-DecPP) **9**, H_2(*cis*-DecPP) **10**, H_2UPP **11**, and H_2DPP **1** in the order of elution. The most polar porphyrin with the lowest R_F values was easily identified

as H_2DPP **1** by UV-VIS spectrum in comparison with an authentic sample. Three other porphyrins were identified after isolation by FAB-MS and NMR spectroscopy.[12] The FAB-MS spectra showed that both the porphyrins from the first and second fractions have the parent peaks at *m/z* 1071, indicative of decaphenylporphyrins, while the porphyrin from the third fraction has the parent peak at *m/z* 1147 in consistent with H_2UPP **11**. The ^{1}H NMR spectra, showing three and five different types of phenyl groups in H_2(*trans*-DecPP) **9** and H_2(*cis*-DecPP) **10**, respectively, clearly distinguished between the *trans*- and *cis*-isomers in decaphenylporphyrins.

The yields after recrystallization (heptane/CH_2Cl_2) are shown in Table 1. The total porphyrin yield by the present method amounts to 44%, which is much higher than that by the mixed condensation of benzaldehyde with pyrrole and 3,4-diphenylpyrrole.[7] In this method, H_2NPP **8** could not be isolated from the reaction mixture. H_2NPP **8** must be sintered in the insoluble isolated fraction of H_2OPP **7**.

Table 1. Isolated yield, Selected ^{1}H NMR and UV-VIS data for the phenyl substituted porphyrins.

Porphyrin	Yield(%)	^{1}H NMR/δ [a]		UV-VIS
		NH	*meso*-H	λ_{max}/nm (CH_2Cl_2)
H_2OPP (**7**)	9.0 [b]	-3.03 [c]	10.32 [c]	423, 515, 551, 583, 635
H_2NPP (**8**)		-	-	-
H_2(*trans*-DecPP) (**9**)	1.8	[d]	10.16	429, 521, 553, 588, 640 (sh)
H_2(*cis*-DecPP) (**10**)	11.9	-1.99	9.91	439, 531, 568 (sh), 606, 666
H_2UPP (**11**)	12.6	-1.10	9.63	452, 546, 587, 618(sh), 686
H_2DPP (**1**)	8.6	-0.90	-	468, 564, 617, 722
total yield	43.9			

[a] NMR spectra were recorded in $CDCl_3$ at 400 MHz at 27 °C with Me_4Si internal reference. [b] Total yield of the undissolved porphyrin (H_2OPP and H_2NPP) based on the molecular weight of H_2OPP. [c] Chemical shift of *p*-isopropylphenyl derivatives. (H_2OPP is insoluble in $CDCl_3$). [d] Accurate chemical shift value was not obtained due to the poor solubility.

Spectral data for the new series of phenyl-substituted porphyrins are summarized in Table 1. The NH and *meso*-H chemical shifts are much affected by introduction of the phenyl groups; the NH resonances are shifted to lower fields whereas the *meso*-H resonances shifted to higher fields as the number of phenyl rings is increased. The UV-VIS spectral data show that both the Soret and Q bands are shifted to longer wavelengths with increase in the phenyl substituents. In the light of the correlation between the spectral shifts and the macrocyclic nonplanarity,[7] it appears well established that the nonplanarity of porphyrin macrocycle increases with the number of the phenyl substituents, i.e., in the order of H_2OPP **7** < H_2(*trans*-DecPP) **9** < H_2(*cis*-DecPP) **10** < H_2UPP **11** < H_2DPP **1**.

However, it should be noted that the nonplanarity of the porphyrin ring is affected also by the position of phenyl substitution. For example, H_2DecPP **6**[7], a member of the previously reported series of phenyl-substituted porphyrins, shows UV-VIS (λ_{max} 454 nm) and NMR (δ_{NH} -1.30 ppm) spectra which are more similar to those of H_2UPP **11**. The spectral shifts in H_2DecPP **6** with respect to the planar H_2OPP and/or H_2TPP are much greater than those in H_2(*cis*-DecPP) **10** and H_2(*trans*-DecPP) **9** with the same number of the phenyl substituents. Our contention is that the steric interaction between the adjacent phenyl groups at the *meso*-

and β-positions is most effective in producing the macrocyclic distortion. Including previously reported porphyrins,[7] H_2HPP **3**, H_2(*trans*-OPP) **4**, H_2(*cis*-OPP) **5**, and H_2DecPP **6**, we have obtained eleven phenyl-substituted porphyrins differing in the number and positions of phenyl substituents. Further studies on the structure-property relationship using these porphyrins are underway, details of which will be reported elsewhere.

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12) **H_2(*cis*-DecPP) (10):** ^{1}H NMR ($CDCl_3$) δ -1.99 (2H, s, internal NH), 6.46 (4H, m, PhH_o), 6.58 (4H, m, PhH_m), 6.64 (2H, m, PhH_p), 6.68 (4H, m, PhH_m), 6.80 (2H, m, PhH_p), 6.92 (6H, m, $PhH_{m,p}$), 6.99 (4H, m, PhH_o), 7.41 (6H, m, $PhH_{m,p}$), 7.49 (2H, m, *meso*-PhH_p), 7.52 (4H, m, PhH_o), 7.53 (4H, m, *meso*-PhH_m), 7.64 (4H, m, PhH_o), 7.88 (4H, m, *meso*-PhH_o), 9.91 (2H, s, *meso*-H); FAB-MS (matrix: *m*-nitrobenzyl alcohol) *m/z* 1071 (M^+). **H_2(*trans*-DecPP) (9):** FAB-MS (matrix: *m*-nitrobenzyl alcohol) *m/z* 1071 (M^+). Owing to a poor solubility of H_2(*trans*-DecPP) in $CDCl_3$, accurate NMR data are obtained with the zinc(II) complex which is more soluble than the free base. **Zn(*trans*-DecPP) (9-Zn):** ^{1}H NMR ($CDCl_3$) δ 6.55 (4H, m, *meso*-PhH_m), 6.73 (2H, t, *meso*-PhH_p), 6.93 (12H, m, β-$PhH_{m,p}$), 7.01 (8H, m, β-PhH_o), 7.28-7.37 (20H, m, β-$PhH_{o,m,p}$), 7.62 (4H, m, *meso*-PhH_o), 10.13 (2H, s, *meso*-H). **H_2UPP (11):** ^{1}H NMR ($CDCl_3$) δ -1.10 (2H, s, internal NH), 6.53 (4H, m, PhH_o), 6.62 (12H, PhH_p, $PhH_{o,m,p}$), 6.68 (8H, m, PhH_m, *meso*-PhH_m), 6.77 (3H, m, *meso*-$PhH_{m,p}$), 6.81 (2H, m, *meso*-PhH_p), 6.88 (4H, m, PhH_m), 6.90 (2H, m, PhH_p), 6.99 (4H, m, PhH_o), 7.41 (2H, m, PhH_p), 7.46 (4H, m, PhH_m), 7.48 (4H, m, *meso*-PhH_o), 7.64 (4H, m, PhH_o), 7.88 (2H, m, *meso*-PhH_o), 9.63 (1H, s, *meso*-H); FAB-MS (matrix: *m*-nitrobenzyl alcohol) *m/z* 1147 (M^+).

(Received August 15, 1994)