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Regioselective Bromination and Subsequent Suzuki Cross-Coupling of Highly Electron Deficient 5,10,15,20-Tetrakis(trifluoromethyl)porphyrin

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Abstract—5,10,15,20-Tetrakis(trifluoromethyl)porphyrin zinc complex **2** has been shown to undergo monobromination and regioselective dibromination to give β-bromoporphyrins **3a**–**c**. The free base β-bromoporphyrins **4a**,**b** are converted to aryl porphyrins through Suzuki cross-coupling reaction.

Introduction

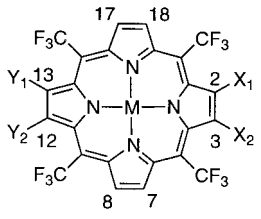
Porphyrins and metalloporphyrins are actively pursued in organic, material, bioinorganic and organometallic chemistry.[1,2] Electron withdrawing porphyrins have emerged as an important subclass especially for their oxidative robustness as ligands for metalloporphyrin oxidation catalysts.[3,4] Among the electron withdrawing groups, trifluoromethyl group is an ideal substituent since it possesses additional lipophilic property. CF_3 groups may be incorporated into a porphyrin at the *beta*- or *meso*- sites. β-Trifluoromethylated porphyrins have been synthesized in a multistepwise and low yielding route.[5] Since *meso*-substituted porphyrins can be synthesized by the acid catalyzed tetramerization of α-(hydroxymethyl)pyrrole,[6] a short synthetic pathway to *meso*-tetrakis(trifluoromethyl)porphyrin is available as reported by Therien.[7] Recently, β-octabromo*meso*-tetrakis-(trifluoromethyl)porphyrin has also been prepared by the bromination of *meso*-tetrakis(trifluoromethyl)porphyrinato nickel.[8] Further electronic and steric fine-tuning of bromoporphyrins by functional group conversion will allow access to other porphyrins. In this paper, we report the β-mono- and selective β-di-bromination of *meso*-trifluoromethylporphyrin and subsequent Suzuki cross-coupling to yield β-aryl porphyrins.

Results and Discussion

Synthesis of bromotrifluoromethylporphyrins

5,10,15,20-Tetrakis(trifluoromethyl)porphyrin [$H_2(TCF_3P)$] (**1**) was synthesized according to the literature method.[7] Initial attempts to brominate the free base porphyrin **1** using *N*-bromosuccinimide (NBS) and tetrabutylammonium tribromide did not result in any bromoporphyrins. Attempts were then made on the bromination of the more electron rich metalloporphyrin **2**. **2** was prepared in quantitative yield by metallating **1** with excess $Zn(OAc)_2{\cdot}2H_2O$ in $CHCl_3$/MeOH. We found that **2** did react with NBS in refluxing $CHCl_3$ to yield bromoporphyrins (Fig. 1, Scheme 1). However, **2** was easily demetallated by the acid generated during bromination. No significant improvement was made when the base K_2CO_3 or $Zn(OAc)_2$ was added to the reaction mixture.

As synthesis of the highly electron deficient zinc porphyrin in refluxing MeOH did not result in any demetallated porphyrins,[9] **2** was then brominated with 1.1, 4.3,



	M = H_2	M = Zn
$X_1 = X_2 = Y_1 = Y_2 = H$,	**1**	**2**
$X_1 = Br$, $X_2 = Y_1 = Y_2 = H$,	**4a**	**3a**
$X_1 = X_2 = Br$, $Y_1 = Y_2 = H$,	**4b**	**3b**
$X_1 = X_2 = Y_1 = Y_2 = Br$,	**4c**	**3c**

Figure 1. Numbering system of porphyrins

Keywords: tetrakis(trifluoromethyl) porphyrin; monobromination; Suzuki cross-coupling.

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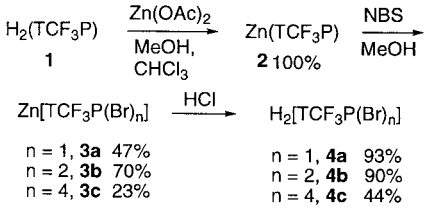


Scheme 1. Bromination of porphyrins

6.7 equiv. of NBS respectively in refluxing MeOH to yield $Zn[TCF_3P(Br)_n]$, n=1, 2, 4, (**3a**–**c**) (Scheme 1) with reduced extent of demetallation of **2**. **3a** was obtained in 47 or 78% yield based on recovered starting material. **3b** was isolated in 70% yield. However, only 23% yield of **3c** was obtained. If a large excess of NBS was used in order to obtain further bromination, a colorless solution resulted. Ring opening of the porphyrin might have occurred. The low yield of **3c** might be due to decomposition under the reaction conditions. As demetallation of **3c** by HCl gave the corresponding **4c** in only 44% yield (see below), **3c** may be easily decomposed in acidic conditions and this is thought to account for the low yield obtained in bromination.

The synthesis and structure of **3b** were unexpected. When **2** was treated with 4.3 equiv. of NBS in refluxing MeOH in order to synthesize **3c**,[10] a green compound was obtained as the only isolated product. In its ^{1}H NMR spectrum, a multiplet at δ 9.59–9.62 ppm was observed which was inconsistent with the expected singlet of **3c**.[1] The mass spectrum showed a molecular ion at 804 which corresponded to a dibromoporphyrin with the characteristic isotope pattern.

The structure of **3b** was finally shown by X-ray crystallography to be [2,3-dibromo-5,10,15,20-tetrakis(trifluoromethyl)-porphyrinato] zinc(II). **3b** has a saddle geometry.[11] The bromine atoms pointed upward and the two pyrrolic carbons, C(2) and C(3), deviated 1.25 and 1.20 Å from the porphyrin mean plane respectively. Large derivations of C(2) and C(3) were mainly steric in origin. The corresponding deviation of pyrrolic carbons of $Zn[TPFPP(Br)_8]$ (TPFPP=tetrakispentafluorophenylporphyrination dianion) was 0.89 Å on the average.[12] The steric interactions between bromine atoms and the *meso*-trifluoromethyl group are therefore larger than that of bromine and the pentafluorophenyl group. The bond length of C(2) and C(3) was 1.379(16) Å which was longer than the other pyrrolic carbon bonds. The central zinc sat 0.24 Å above in the basal plane of a square pyramid in which water was acted as an axial ligand and the four nitrogens

Table 1. Calculated charge on β-carbons of **3a**

Position	Charge
C(2)	−0.17
C(3)	−0.11
C(7)	−0.09
C(8)	−0.15
C(12)	−0.13
C(13)	−0.13
C(17)	−0.15
C(18)	−0.09

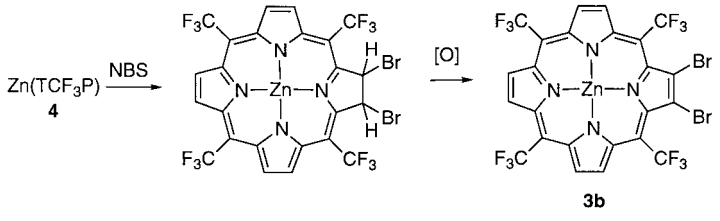
of **3b** formed the equatorial base. The bond length of Zn to coordinated water was 2.154(8) Å which was shorter than the 2.20 Å observed in $Zn(tpp)(H_2O)$.[13] Therefore, the porphyrin was more electron deficient and interacted more strongly with the ligated H_2O.

Free base $H_2(tpp)$ has been brominated regioselectively on the antipodal positions.[10] However, in reactions of a tetraarylporphyrin involving the use of less than four equivalents of NBS, the corresponding 7,8-, 7,17- and 7,18-dibromoporphyrins were isolated.[10] This is in contrast to our result in which only one regioisomer was isolated in high yield.

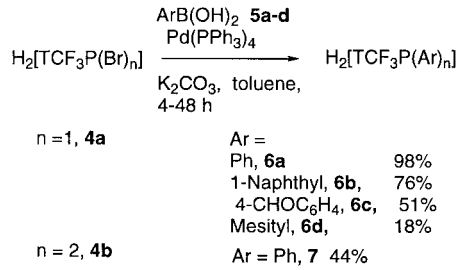
Two possible reaction pathways may lead to the 2,3-dibromination of **2** (Scheme 2). The first pathway is through the conventional electrophilic aromatic substitution of **2** or **3a** to yield **3b**. Alternatively, **2** is brominated to form a chlorin intermediate which is then oxidized to **3b**. Such an intermediate has also been proposed in the bromination of $H_2(tpp)$.[10]

In order to verify the proposed reaction pathways, semiempirical calculations were performed using PM3 model for the charge distribution of **3a**. It was found that all the charges on β-carbons do not differ very much (Fig. 1 and Table 1). It seems, however, unlikely to substitute the H atom selectively by another Br atom through the directing effect of Br at C(2) due to steric hindrance. Moreover, when **3a** was reacted with 1.1 equiv. of NBS in refluxing MeOH, an inseparable mixture of polybrominated porphyrins was obtained. Furthermore, the double bond character of porphyrin and metalloporphyrin has also been shown in the dihydroxylation by OsO_4[14] and cyclopropanation with ethyl diazoacetate.[15] Therefore, the chlorin pathway is the favored pathway.

Attempted further bromination of $Cu(TCF_3P)$ by Br_2 in refluxing CCl_4 was unsuccessful and a complex mixture was formed. Recently, however, $Ni(TCF_3P)$ has been reported to undergo octabromination successfully.[8]



Scheme 2. Proposed mechanism for the formation of **3b**



Scheme 3. Synthesis of arylporphyrins

Synthesis of $H_2[TCF_3P(Br)_n]$

The free base porphyrins **4a–c** were obtained by acid treatment of **3a–c** with 35% HCl and subsequent neutralization (Scheme 3). **3a–b** were easily demetallated in high yields of about 90% while **4c** was obtained in only 44% yield. The low yield of **4c** may be due to its acid lability.

Suzuki cross-coupling of $H_2[TCF_3P(Br)_n]$

4a and **4b** underwent smooth Suzuki cross-coupling[16] with arylboronic acids **5a–d** to give mostly good yields of arylporphyrins **6a–d** and **7** (Scheme 3). **4a** was coupled with phenylboronic acid catalyzed by $Pd(PPh_3)_4$ in 4 h to yield 6a in 98% yield. It was more reactive than H_2[tpp(Br)] in the Suzuki cross-coupling reaction, in which 28 h was required.[17] The higher reactivity could be assigned to the electron deficiency of **4a** which facilitates the oxidative addition of the porphyrin–bromine bond by the palladium catalyst.

The 4-formylphenyl boronic acid (**5c**) produced the versatile porphyrin aldehyde **6c**, which could be converted into porphyrin dimers using the Rothemun–Adler reaction.[18] Even the extremely sterically bulky naphthylboronic acid (**5b**) and mesitylboronic acid (**5d**) cross-coupled to **6b** and **6d** respectively, though **6d** was obtained in poor yield.

Conclusion

Regioselective 2-mono-, 2,3-di-, and 2,3,12,13-tetra-brominations of $Zn(TCF_3P)$ **2** were successfully performed. Various 2-aryl-substituted electron deficient porphyrins **6a–d** and **7** were synthesized by Suzuki cross-coupling of 2-bromo-5,10,15,20-tetrakis(trifluoromethyl)porphyrin **5a** with aryl boronic acids.

Experimental

All materials were obtained from commercial suppliers and used without further purification unless otherwise specified. Toluene was distilled from sodium. Thin layer chromatography was performed on precoated silica gel plates. Column chromatography was performed on silica gel (70–230 mesh and 230–400 mesh) or neutral aluminum oxide (activity I, 70–230 mesh).

^{1}H NMR spectra were recorded at 250 MHz. Chemical shifts were referenced with the residual solvent protons in $CDCl_3$ (δ 7.24 ppm) or with tetramethylsilane (δ 0.00 ppm) as the internal standard. Chemical shifts (δ) were reported as part per million (ppm) in δ scale down-field from TMS. ^{13}C NMR spectra were recorded at 62.9 MHz. Chemical shifts were referenced to the residual solvent peak of $CDCl_3$ (δ 77.0 ppm).

Mass spectra were recorded in electron ionization, fast atom bombardment, or electrospray mode. Fast atom bombardment spectra were obtained using 3-nitrobenzyl alcohol (NBA) as the matrix. Electrospray ionization spectra were obtained with a solvent mixture of acetone with 3% of acetic acid.

IR spectra were obtained with samples prepared either as neat film on KBr plates or as a KBr disk. Elemental analyses were performed by the Medac Ltd, Department of Chemistry, Brunel University, U.K. Semi-empirical calculations were performed on Spartan 4.1 program using RHF/PM3 model for on a Silicon Graphics Indigo workstation.

Preparation of [5,10,15,20-tetrakis(trifluoromethyl)-porphyrinato] zinc(II) [Zn(TCF$_3$P)] (2).[7] **1** (200 mg, 0.34 mmol) was stirred at room temperature in 2:1 $CHCl_3$/MeOH (113 mL) with $Zn(OAc)_2{\cdot}2H_2O$ (753 mg, 3.4 mmol) for 3 h. After rotary evaporation to dryness, the violet crude product was chromatographed through a silica gel column (200–300 mesh) with hexanes to CH_2Cl_2 as the eluent. The violet band was collected and a purple crystalline solid (228 mg, 0.34 mmol, 100%) was obtained after rotary evaporated to dryness. R_f=0.15 (CH_2Cl_2/hexanes=1:1); ^{1}H NMR ($CDCl_3$) δ −1.06 (s, 2H, coordinated H_2O), 9.66–9.69 (s, 8 H); ^{1}H NMR ($CDCl_3$/D_2O) δ 4.78 (H_2O in D_2O), 9.71 (s, 8 H); ^{13}C NMR ($CDCl_3$, 62.9 MHz) δ 107.3 (q, $^2J_{CF}$=29.6 Hz), 127.9 (q, $^1J_{CF}$=276.1 Hz), 133.7, 147.2; UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 411 (4.13), 561 (2.94), 596 (3.17); EIMS: *m/z* 644 (M^+); HRMS (ESIMS): Calcd for $C_{24}H_8F_{12}N_4Zn$: *m/z* 643.9849. Found: *m/z* 643.9844.

Preparation of [2-bromo-5,10,15,20-tetrakis(trifluoromethyl)-porphyrinato] zinc(II) {Zn[TCF$_3$P(Br)]} (3a). To the refluxing solution of **2** (200 mg, 0.30 mmol) in MeOH (50 mL), NBS (59 mg, 0.33 mmol) in MeOH (50 mL) was added dropwise for 45 min. The solution gradually turned from violet to green in color and was refluxed for a further 45 min. After removal of solvent by rotary evaporation, the product was chromatographed on a silica gel column (230–400 mesh) and using toluene/hexanes (3:2) to (4:1) as the gradient eluent. The first violet band, R_f=0.29 (toluene/hexanes=2:1), (81 mg, 0.12 mmol, 40%) yielded **2**. The second dark green band yielded a dark green solid (102 mg, 0.14 mmol, 47%) as **3a**. R_f=0.19 (toluene/hexanes=2:1); ^{1}H NMR ($CDCl_3$) δ 9.59–9.65 (m, 7 H); UV–visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 419 (5.15), 567 (3.90), 611 (4.21); FABMS: *m/z* (relative intensity) 725.45 (M^++2, 85), 723.50 (M^+, 100); HRMS (ESIMS): Calcd for $C_{24}H_7BrF_{12}N_4Zn$: *m/z* 721.8954. Found: *m/z* 721.9053. The third dark green band was obtained as a dark green solid (31 mg, 0.038 mmol, 12%) **3b**. R_f=0.10 (toluene/hexanes=2:1).

Preparation of [2,3-dibromo-5,10,15,20-tetrakis(trifluoromethyl)-porphyrinato] zinc(II) {Zn[TCF$_3$P(Br)$_2$]} (3b). *N*-Bromosuccinimide (NBS) (30 mg, 0.046 mmol) in MeOH (10 mL) was added dropwise to a refluxing solution of **2** (36 mg, 0.20 mmol) in MeOH (6 mL) for 1 h. Then the solution was refluxed for another 1 h. After removal of the solvent, the reaction mixture was purified by column chromatography using a solvent mixture of toluene/hexane (3:1) as the eluent on silica gel (230–400 mesh). A dark green band was obtained to produce a dark green solid (26 mg, 0.032 mmol, 70%) after rotary evaporation and recrystallization from CH_2Cl_2/MeOH as **3b**. R_f=0.25 (toluene/hexane=3:1); mp d 230°C; ^{1}H NMR ($CDCl_3$) δ=9.59–9.62 (m, 6 H, β-pyrrolic protons). UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 428 (4.83), 583 (3.60), 630 (4.03).EIMS: *m/z* (relative intensity) 806 (M^++6, 40), 804 (M^++4, 100), 802 (M^++2, 90), 800 (M^+, 34). Anal. Calcd for $C_{24}H_6Br_2F_{12}N_4Zn{\cdot}CH_3OH$: C, 35.94; H, 1.21; N, 6.71. Found: C, 36.33; H, 1.40; N, 6.79. Crystals for X-ray diffraction analysis were grown from hexane/CH_2Cl_2 by slow evaporation.

Preparation of [2,3,12,13-tetrabromo-5,10,15,20-tetrakis-(trifluoro-methyl)porphyrinato] zinc(II) {Zn[TCF$_3$P(Br)$_4$]} (3c). To the refluxing solution of **2** (50 mg, 0.076 mmol) in MeOH (15 mL), NBS (91 mg, 0.51 mmol) in MeOH (15 mL) was added dropwise. The solution was then refluxed for a further 50 min. The solution turned from violet to green gradually during reflux. After removal of solvent by rotary evaporation, the product was separated by column chromatography using silica gel (230–400 mesh) using toluene/hexanes (2:1) as the eluent. The last very slow moving green band was collected and a green solid (17 mg, 0.18 mmol, 23%) was obtained. R_f= 0.05 (toluene:hexanes=4:1); ^{1}H NMR ($CDCl_3$) δ 9.46 (s, 4H); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 377 (4.31) 436 (4.94), 613 (3.59), 669 (4.34); FABMS: *m/z* (relative intensity) 961 (M^+); HRMS (ESIMS): Calcd for $(C_{24}H_4Br_4F_{12}N_4Zn)^+$: *m/z* 961.6201. Found: *m/z* 961.6183.

Preparation of β-bromo-5,10,15,20-tetrakis(trifluoromethyl)porphyrin {H$_2$[TCF$_3$P(Br)$_n$]}. General procedure. The preparation of [2-bromo-5,10,15,20-tetrakis(trifluoromethyl)porphyrin {H_2[$TCF_3P(Br)$]} **(4a)** was described as a typical example for the synthesis of $H_2[TCF_3P(Br)_n]$.

To the green solution of **3a** (130 mg, 0.18 mmol) in $CHCl_3$ (50 mL), 37% HCl (5 mL) was added and stirred at rt for 5 min. Then saturated $NaHCO_3$ was added until no gas evolved. The solution turned from green to reddish brown in color. The product was then extracted from $CHCl_3/H_2O$. The organic extract was then dried over $MgSO_4$, filtered and rotary evaporated to dryness. It was then chromatographed on silica gel (70–210 mesh) using hexane as the eluent. A brown solid (111 mg, 0.17 mmol, 93%) was obtained after rotary evaporation of the brown solution together with MeOH. R_f=0.25 (hexane); ^{1}H NMR ($CDCl_3$, 250 MHz) δ −1.64 (br s, 2 H), 9.36–9.45 (m, 3 H), 9.56 (br s, 4 H); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 408 (4.80), 522 (3.61), 561 (3.78), 600 (3.51), 660 (3.60); ESIMS: *m/z* (relative intensity) 663 [$(M+H)^+$+2, 100], 663 [$(M+H)^+$, 93]. Anal. Calcd for $C_{24}H_9BrF_{12}N_4{\cdot}0.5C_6H_{14}$: C, 46.04; H, 2.29; N, 7.95. Found: C, 45.66; H, 2.16; N, 7.84.

Preparation of 2,3-dibromo-5,10,15,20-tetrakis(trifluoromethyl)-porphyrin {H$_2$[TCF$_3$P(Br)$_2$]} (4b). 4b was synthesized from **3b** (26 mg, 0.032 mmol). Green solid (21 mg, 0.029 mmol, 90%) was obtained and was further purified by recrystallization from CH_2Cl_2/EtOH. R_f=0.07 (hexane); mp 233–234°C; ^{1}H NMR ($CDCl_3$) δ=−2.39 (br s, 2H, N–H protons), 9.29 (br s, 2H, β-pyrrolic protons), 9.61 (br s, 4H, β-pyrrolic protons); ^{13}C NMR (62.9 MHz) δ 107.36 (q, $^2J_{CF}$=30.8 Hz), 109.00 (q, $^2J_{CF}$=33.3 Hz), 119.72, 126.23 (q, $^1J_{CF}$=276.7 Hz), 126.95 (q, $^1J_{CF}$= 276.1 Hz), 129.43, 131.02, 135.43, 137.01, 138.17, 150.21, 154.86; UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 413 (5.04), 579 (4.20), 613 (3.95), 670 (3.42); EIMS: *m/z* (relative intensity) 742 (M^++4, 38), 740 (M^++2, 100), 738 (M^+, 47); Anal. Calcd for $C_{24}H_8Br_2F_{12}N_4$0.5EtOH: C, 39.35; H, 1.45; N, 7.34. Found: C, 39.54; H, 1.29; N, 7.52.

Preparation of 2,3,12,13-tetrabromo-5,10,15,20-tetrakis-(trifluoromethyl)-porphyrin {H$_2$[TCF$_3$P(Br)$_4$]} (4c). 4c was synthesized from **3c** (53 mg, 0.056 mmol). A green solid (22 mg, 0.024 mmol, 44%) was obtained and further purified by recrystallization from CH_2Cl_2/EtOH. R_f=0.13 (hexanes); ^{1}H NMR ($CDCl_3$) δ −2.21 (br s, 2H), 9.45 (s, 4H); UV–visible (CH_2Cl_2), λ_{max}, nm (abs) 418 (0.537), 610 (0.092); ESIMS *m/z* (relative intensity) 901 [$(M+H)^+$+4, 71]; 899 [$(M+H)^+$+2, 100]; 897 [$(M+H)^+$, 65]; Anal. Calcd for $C_{24}H_6Br_4F_{12}N_4$EtOH: C, 33.08; H, 1.28; N, 5.94. Found: C, 33.21; H, 1.46; N, 6.10.

Preparation of β-aryl-5,10,15,20-tetrakis(trifluoromethyl)porphyrin {H$_2$[TCF$_3$P(Ar)$_n$]}. General procedure. The preparation of 2-phenyl-5,10,15,20-tetrakis(trifluoromethyl)porphyrin {H_2[$TCF_3P(Ph)$]} (**6a**) was described as a typical example for the synthesis of $H_2[TCF_3P(Ar)_n]$ by Suzuki cross-coupling.

A Teflon screw-head stoppered flask (50 mL) was charged with **4a** (40 mg, 0.060 mmol), [$Pd(PPh_3)_4$] (3.5 mg, 10 mol%), toluene (10 mL), anhydrous K_2CO_3 (67 mg, 0.48 mmol), and phenylboronic acid (**5a**) (29 mg, 0.24 mmol). The brown suspension was degassed by the freeze–pump–thaw method (3 cycles), and then was heated at 90–100°C under N_2 for 4 h. After removal of the solvent, the crude product was purified by column chromatography on silica gel (70–230 mesh) using hexane to hexane/CH_2Cl_2 (20:1) as the gradient eluent. The brown band was collected and evaporated to give a brown solid which was further recrystallized from CH_2Cl_2–MeOH to yield pure brown crystals (39 mg, 0.059 mmol, 98% yield). R_f=0.06 (hexane); mp 206–207°C; ^{1}H NMR ($CDCl_3$) δ −1.75 (br s, 2H, N–H protons), 7.62–7.72 (m, 3H, *m,p*-phenyl protons), 8.00 (d, 2H, *J*=7.0 Hz, *o*-phenyl protons), 9.30 (m, 1H, β-pyrrolic proton), 9.44 (m, 1H, β-pyrrolic proton), 9.53 (m, 5H, β-pyrrolic protons); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 409 (5.08), 517 (3.99), 554 (3.97), 602 (3.73), 660 (4.04); EIMS: 658 (M^+); Anal. Calcd for $C_{30}H_{14}F_{12}N_4{\cdot}0.5H_2O$: C, 53.96; H, 2.27; N, 8.51. Found C, 53.76; H, 2.24; N, 8.19.

Preparation of 2-(2′-naphthyl)-5,10,15,20-tetrakis(trifluoro-methyl)porphyrin {H$_2$[TCF$_3$P(2′-naphthyl)]} (6b). **4a** (40 mg, 0.060 mmol) was reacted with 2-naphthylboronic acid (**5b**) (41 mg, 0.24 mmol) and K_2CO_3 (67 mg, 0.48)

catalyzed by $Pd(PPh_3)_4$ (3.5 mg, 3.0×10^{-3} mmol) in toluene (10 mL) at 90–100°C for 2 h. A purple solid (32 mg, 0.046 mmol, 76%) was obtained. R_f=0.11 (hexane); ^{1}H NMR ($CDCl_3$) δ −1.58 (br s, 2 H), 7.51–7.82 (m, 4 H,), 8.13–8.16 (m, 4 H), 9.38 (m, 1 H), 9.47–9.58 (m, 6 H); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 408 (5.34), 517 (4.24), 554 (4.21), 602 (3.97), 659 (4.28); ESIMS: *m/z* 709 [$(M+H)^+$]; Anal. Calcd for $C_{34}H_{16}F_{12}N_4$: C, 57.64; H, 2.28; N, 7.91. Found C, 57.38; H, 2.57; N, 7.55.

Preparation of 2-(4′-formylphenyl)-5,10,15,20-tetrakis-(trifluoromethyl)porphyrin {H_2[TCF_3P(4-C_6H_4CHO)]} (6c). 4a (40 mg, 0.060 mmol) was reacted with 4-formylphenylboronic acid (**5c**) (36 mg, 0.24 mmol) and K_2CO_3 (67 mg, 0.48) catalyzed by $Pd(PPh_3)_4$ (3.5 mg, 3.0×10^{-3} mmol) in toluene (10 mL) at 90–100°C for 19 h. A purple solid (21 mg, 0.031 mmol, 51%) was obtained. R_f=0.43 (hexane/$CHCl_3$=2:1); ^{1}H NMR ($CDCl_3$) δ −1.78 (bs, 2H), 8.15–8.23 (m, 4H, 1,4-substituted phenyl protons with hindered rotation), 9.29–9.32 (m, 1H), 9.44–9.57 (m, 6H), 10.24 (s, 1H); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 411 (5.30), 518 (4.16), 556 (4.18), 602 (3.96), 660 (4.21); ESIMS: *m/z* 687 [$(M+H)^+$]; HRMS (ESIMS): Calcd for $(C_{31}H_{14}F_{12}N_4O+H)^+$: *m/z* 687.1054. Found: *m/z* 687.0970.

Preparation of 2-mesityl-5,10,15,20-tetrakis(trifluoromethyl)porphyrin {H_2[TCF_3P(mesityl)]} (6d). 4a (40 mg, 0.060 mmol) was reacted with mesitylboronic acid (**5d**) (39 mg, 0.24 mmol) and K_2CO_3 (67 mg, 0.48) catalyzed by $Pd(PPh_3)_4$ (3.5 mg, 3.0×10^{-3} mmol) in toluene (10 mL) at 90–100°C for 4 days. A purple solid (7.0 mg, 0.010 mmol, 18%) was obtained. R_f=0.15 (hexanes); ^{1}H NMR ($CDCl_3$) δ −1.53 (br s, 2H), 2.15 (s, 6H), 2.52 (s, 3H), 7.19 (s, 2H), 9.24–9.25 (m, 1H,), 9.25–9.56 (m, 6H); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 407 (5.04), 517 (3.93), 553 (3.93), 602 (3.63), 657 (4.00); ESIMS: *m/z* 701 [$(M+H)^+$]; HRMS (ESIMS): Calcd for $(C_{33}H_{21}F_{12}N_4+H)^+$: *m/z* 701.1569. Found: *m/z* 701.1585.

Preparation of 2,3-diphenyl-5,10,15,20-tetrakis(trifluoromethyl)-porphyrin {H_2[$TCF_3P(Ph)_2$]} (7). 4b (39 mg, 0.053 mmol) was reacted with phenylboronic acid (**5a**) (51 mg, 0.42 mmol) and K_2CO_3 (116 mg, 0.84) catalyzed by $Pd(PPh_3)_4$ (6 mg, 5.3×10^{-3} mmol) in toluene (10 mL) at 90–100°C for 9 h. A purple solid (17 mg, 0.023 mmol, 44%) was obtained. R_f=0.07 (hexane); ^{1}H NMR ($CDCl_3$) δ −1.75 (br s, 2H), 7.27–7.33 (m, 10H,), 9.40–9.43 (m, 2H), 9.47 (s, 2H), 9.50–9.55 (m, 2H); UV-visible (CH_2Cl_2), λ_{max}, nm (log ϵ) 412 (5.03), 524 (3.85), 564 (4.03), 612 (3.69), 668 (3.88); FABMS: *m/z* 736 [$(M+H)^+$]; Anal. Calcd for $C_{36}H_{18}F_{12}N_4\cdot2.5H_2O$: C, 55.44; H, 2.97; N, 7.19. Found C, 55.42; H, 2.95; N, 6.79.

Supplementary information available

X-Ray crystallographic data for compound **3b** has been deposited at Cambridge Crystallographic Data Centre.

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