Synthesis of unsymmetrically substituted *meso*-phenylporphyrins by Suzuki cross coupling reactions

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Unsymmetrically substituted tetraphenylporphyrins, including A_2B_2 and $AA'B_2$ types can be synthesised by bromination of 5,15-diphenylporphyrins followed by palladium catalysed Suzuki coupling to arylboronic acids and esters. Unsymmetrically substituted triphenylporphyrins are also accessed *via* partial debromination *in situ*.

Introduction

Synthetic routes to unsymmetrically substituted *meso*-arylporphyrins are of great interest due to the potential of such compounds for use in photodynamic therapy,[1,2] optoelectronic devices[3,4,5] and the construction of photoactive bioconjugates.[6] We have recently reported methods for synthesising such compounds, which do not involve "mixed" condensations, thus leading to single unsymmetrically substituted products. Two of these methods rely upon palladium catalysed Heck and Stille couplings on halogenated *meso*-arylporphyrins.[7,8] We have now expanded this methodolgy to include Suzuki couplings[9] on *meso*-brominated, symmetrically and unsymmetrically substituted 5,15-diphenylporphyrins (DPPs). Several examples of Suzuki couplings on porphyrins have previously been reported, however these have involved coupling of arylboronic acids to porphyrins halogenated at either the β positions[10–13] or on a *meso*-phenyl ring.[14] An example of Suzuki type couplings in which the porphyrin represents the arylboronic acid coupling partner has also been reported.[15] Suzuki couplings between arylboronic acids and *meso*-halogenated 5,15-diphenylporphyrins had not, however, been reported. It was decided, therefore, to conduct a detailed study of the viability of this type of reaction for fabrication of unsymmetrically substituted *meso*-tetraphenylporphyrins. During the course of our studies a communication was published reporting this type of reaction on symmetrically substituted DPPs,[16] however, in this case it was only possible to use inert alkyl substituents on the starting DPPs. The method reported here allows more useful, and unsymmetrically, substituted DPPs to be employed. We have also investigated the effect of substitution on the arylboronic acids in relation to two significant reactions, which compete with bis-coupling. These are, firstly, the deboronylation of the arylboronic acid, previously reported by Suzuki,[17] but also the unreported debromination of the bis-brominated DPP. The latter process gives access to unsymmetrically substituted *meso*-triarylporphyrins in yields of up to 24%. Conditions for minimising these side reactions are reported which, unlike those previously communicated, utilise low boiling solvents and do not require degassing by freeze–thaw cycles, making bis-coupling much more facile and widely applicable.

Results and discussion

In previous studies we have investigated various palladium catalysed coupling reactions on DPPs substituted at the *meso*-positions with iodo[7] and/or bromo[8] groups; this has allowed the independent introduction of ethynyl and vinyl substituents at these positions. Porphyrin substrates of this type had not, however, been subjected to Suzuki couplings with arylboronic acids. A study was undertaken, therefore, to determine how facile and widely applicable such a reaction would be, for the synthesis of unsymmetrically substituted *meso*-arylporphyrins. Initial investigations involved determining which of the many combinations of solvent and base reported for Suzuki couplings[9] would be most convenient and applicable. Coupling of 5,15-dibromo-10,20-diphenylporphyrin (Scheme 1: **1**; R = R^1 = H)[18] with 4-methoxybenzeneboronic acid (Scheme 1: **2**; R^2 = 4-OMe) was tested with a variety of solvent and base combinations. The previously reported requirement for zinc chelation of the porphyrin[18] was also examined. At reflux temperatures, lower boiling solvents, such as THF, required the use of stronger bases in order to obtain acceptable yields of the desired coupled products. Higher boiling solvents, such as toluene and DMF, in combination with weaker bases, gave products, but also in many cases led to unacceptably low yields. The combination of higher boiling solvents and weaker bases gave significant amounts of porphyrin debromination for all arylboronic acids tested, producing mixtures of bis- and mono-coupled products. Trace amounts of the corresponding, fully debrominated, DPP were also detected. Conditions for bis-coupling were optimised using THF as solvent and potassium phosphate as base. These conditions gave good yields (74–78%) of the tetraaryl A_2B_2 product (Scheme 1: **4**; R = R^1 = H, R^2 = 4-OMe) (Table 1), the major by-product being the corresponding triaryl A_2B product (Scheme 1: **12**; R = R^1 = H, R^2 = 4-OMe). Use of the zinc chelate of 5,15-dibromo-10,20-diphenylporphyrin resulted in no coupling due to efficient transmetallation with palladium, a phenomenon not encountered with the analogous metal free porphyrin. Optimised conditions were then applied to a wider range of arylboronic acids, bearing electron releasing and withdrawing groups, and also the sterically hindered 2,4,6-trimethylbenzeneboronic acid. Sterically unencumbered (Scheme 1: **2**; R^2 = H or 4-Me), electron

Table 1

Entry	R	R^1	R^2	Yield (%)
4	H	H	4-OCH_3	74
5	H	H	4-CH_3	72
6	H	H	H	75
7	H	H	4-$C(O)CH_3$	77
8	H	H	3-CHO	78
9	4-CH_3	4-CH_3	4-OCH_3	73
10	4-$C(O)OCH_3$	4-$C(O)OCH_3$	4-OCH_3	77
11	4-$C(O)OCH_3$	4-NO_2	4-OCH_3	78
12	H	H	2,4,6-Me	24

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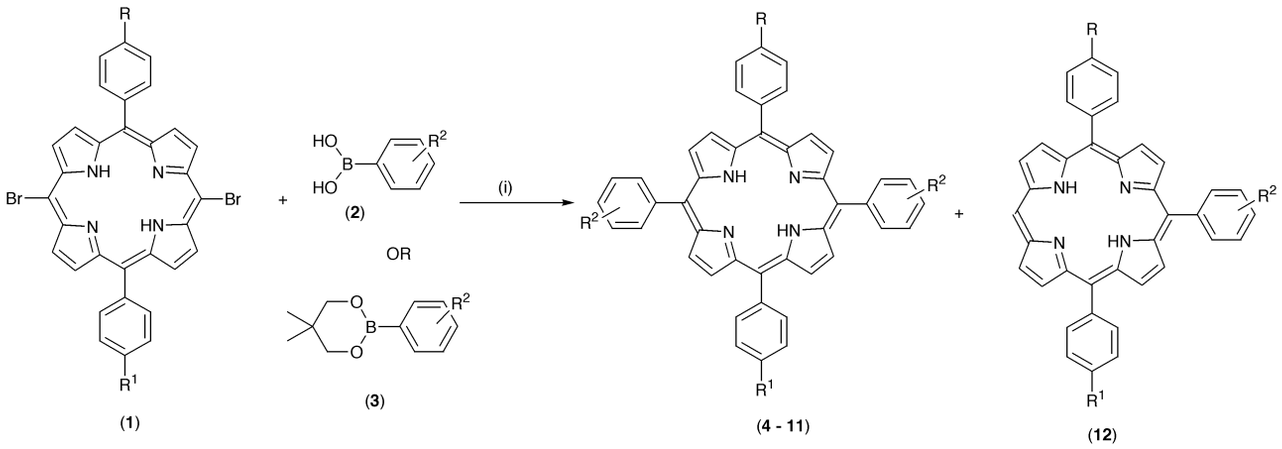

Scheme 1 *Reagents and conditions*: (i) K_3PO_4, $Pd(PPh_3)_4$, THF reflux, 7 h.

rich (Scheme 1: **2**; R^2 = 4-OMe) and sterically hindered (Scheme 1: **2**; R^2 = 2,4,6-Me) boronic acid gave good yields (>70%) of bis-coupled A_2B_2 tetraphenylporphyrins (Table 1). In the case of two electron deficient arylboronic acids, 3-formyl (Scheme 1: **2**; R^2 = 3-CHO) and 4-acetyl (Scheme 1: **2**; R^2 = C(O)Me) and the sterically hindered 2,4,6-trimethylbenzeneboronic acid however, products were heavily contaminated with the corresponding benzene derivatives, resulting from extensive deboronylation. Analysis indicated the by-products, other than the A_2B_2 tetraphenylporphyrins, were a mono-coupled product and DPP, resulting from debromination of the porphyrin component. Deboronylation was also found to be problematic in cases where the resulting benzene derivative coeluted with the desired porphyrin product. To address the latter problem the relevant boronic acids were converted to the corresponding cyclic neopentyl glycol† esters (Scheme 1: **3**; R^2 = 3-CHO or 4-C(O)Me or 2,4,6-Me). The coupling reactions using the neopentyl esters, as opposed to boronic acids, for the electron deficient benzeneboronic neopentyl esters, suppressed deboronylation, thus allowing purification of the desired porphyrin product in good yields.

Previous experiments were restricted to DPPs without substituents on the phenyl groups, however, as we were interested in these reactions as part of an ongoing program to develop combinatorial methods in porphyrin chemistry;[19] we decided to explore how many points of potential diversification could be introduced onto a *meso*-arylporphyrin using this method. Initially, we investigated if the reaction conditions would tolerate the presence of the synthetically versatile, but hydrolytically sensitive, methoxycarbonyl group. 5,15-Bis-(4-methoxycarbonylphenyl)porphyrin was brominated[18] at the available 10 and 20 positions (Scheme 1: **1**; R = R^1 = 4-C(O)OMe) and then subjected to Suzuki cross coupling with 4-methoxybenzeneboronic acid, under our optimised conditions. The desired product 5,15-bis(4-methoxyphenyl)-10,20-bis(4-methoxycarbonylphenyl)porphyrin (Scheme 1: **10**; R = R^1 = 4-C(O)OMe, R^2 = 4-OMe) was obtained in 77% yield (Table 1). It was next decided to attempt the synthesis of a highly unsymmetrically substituted $AA'B_2$ type porphyrin, anticipating that this could give access to a core porphyrin with three independently reactive points of diversification, for use in our combinatorial studies. 5-(4-Nitrophenyl)-15-(4-methoxycarbonylphenyl)porphyrin was brominated[18] (Scheme 1: **1**; R = 4-NO_2, R^1 = 4-C(O)OMe) and cross coupled with 4-methoxybenzeneboronic acid to give 5,15-bis(4-methoxyphenyl)-10-(4-nitrophenyl)-20-(4-methoxycarbonylphenyl)porphyrin (Scheme 1: **11**; R = 4-NO_2, R^1 = 4-C(O)OMe, R^2 = 4-OMe) in 78% yield (Table 1). Finally, it was determined if *meso*-triarylporphyrins could be obtained in acceptable yields by *in situ* debromination of the porphyrin. Consequently 5,15-dibromo-10,20-diphenylporphyrin was treated with 2,4,6-trimethylbenzeneboronic acid using optimised conditions. In this way, 5-(2,4,6-trimethylphenyl)-10,20-diphenylporphyrin (Scheme 1: **12**; R = R^1 = H, R^2 = 2,4,6-trimethyl) was obtained in 24% yield.

In summary, an optimised method is described for obtaining unsymmetrically substituted *meso*-tetraarylporphyrins of the A_2B_2 and $AA'B_2$ types by Suzuki cross coupling reactions. Using the same conditions A_2B *meso*-triarylporphyrins can also be accessed as a major by-product in yields up to 24%. Problems of product contamination due to deboronylation, encountered with electron deficient boronic acids, can be overcome with the use of boronic esters. Finally, a core structure bearing three useful functional groups, which can be reacted independently to generate combinatorial diversity, has been synthesised using this route.

Experimental

2,2-Dimethylpropane-1,3-diol and 2,4,6-trimethylbenzeneboronic acid were purchased from Avocado Research Chemicals Ltd, UK. All other reagents were purchased from Lancaster Synthesis Ltd, UK. THF was distilled from sodium and benzophenone. TLC was performed with Merck aluminium plates coated with silica gel 60 F_{254}. Chromatography was performed using Fluorochem Silica Gel 35–70 μ, 60 Å. All purified compounds were found to contain only one component by TLC analysis. Melting points were recorded on a Gallenkamp melting point instrument and are uncorrected. UV spectra were measured in dichloromethane on an Agilent 8453E UV–visible spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on either JEOL JNM-LA400 or JEOL JNM-GX270 NMR spectrometers. Chemical shifts δ are quoted in ppm relative to the $SiMe_4$ signal as internal standard. Coupling constants are given in Hz. Low resolution mass spectra were recorded on a Shimadzu GCMS-QP5050 mass spectrometer. Accurate mass spectra were carried out at the EPSRC National Mass Spectrometry Service Centre, University of Wales, Swansea.

General procedure for Suzuki coupling reactions

To a stirred slurry of K_3PO_4 (20 eq.) in anhydrous THF was added porphyrin (1 eq.), benzeneboronic acid or benzeneboronic acid neopentyl glycol cyclic ester (10 eq.) and $Pd(PPh_3)_4$ (0.1 eq.). The reaction was kept under reflux at 85 °C for 7 hours and protected from light. After completion, the solvent was evaporated and the residue was dissolved in CH_2Cl_2. This mixture was washed with saturated $NaHCO_3$, H_2O, and brine

† The IUPAC name for neopentyl glycol is 2,2-dimethylpropane-1,3-diol.

then dried by Na_2SO_4. The organic solvent was evaporated and the crude product was purified by flash chromatography to produce a purple solid.

5,15-Bis(4-methoxyphenyl)-10,20-diphenylporphyrin (4). Following the general procedure 5,15-dibromo-10,20-diphenylporphyrin (31 mg, 0.05 mmol), K_3PO_4 (212 mg, 1 mmol), 4-methoxybenzeneboronic acid (76 mg, 0.5 mmol) and $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol) in THF (20 ml) gave a purple solid (25 mg, 74%); column chromatography (silica, 50% hexane in dichloromethane, R_f = 0.23); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 420 (5.8), 516 (4.5), 553 (4.3), 594 (4.2) and 649 (4.2); δ_H (400 MHz, $CDCl_3$) −2.77 (2H, br s, NH), 4.09 (6H, s, OCH_3), 7.27–7.30 (4H, m, 5,15-Ar-3,5H), 7.76–7.78 (6H, m, 10,20-Ar-3,4,5H), 8.11–8.14 (4H, m, 5,15-Ar-2,6H), 8.21–8.23 (4H, m, 10,20-Ar-2,6H) and 8.83–8.88 (8H, m, β-pyrrole H); δ_C (100 MHz, $CDCl_3$) 55.7, 112.3, 120.0, 120.1, 126.8, 127.8, 131.0, 134.6, 135.7, 142.3 and 159.5; HRMS (EI) calc. for $C_{46}H_{34}N_4O_2$ 674.2682, found 674.2672.

5,15-Bis(4-methylphenyl)-10,20-diphenylporphyrin (5). Following the general procedure 5,15-dibromo-10,20-diphenylporphyrin (31 mg, 0.05 mmol), K_3PO_4 (212 mg, 1 mmol), 4-methylbenzeneboronic acid (68 mg, 0.5 mmol) and $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol) in THF (20 ml) gave a purple solid (23 mg, 74%); column chromatography (silica, 30% hexane in dichloromethane; R_f = 0.88); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 418 (5.7), 515 (4.2), 550 (3.9), 590 (3.7) and 647 (3.5); δ_H (400 MHz, $CDCl_3$) −2.77 (2H, br s, NH), 2.69 (6H, s, CH_3), 7.53–7.55 (4H, d, J = 7.8, 5,15-Ar-3,5H), 7.71–7.78 (6H, m, 10,20-Ar-3,4,5H), 8.08–8.10 (4H, m, 10,20-Ar-2,6H), 8.18–8.23 (4H, m, 5,15-Ar-2,6H) and 8.82–8.87 (8H, m, β-pyrrole H); δ_C (67.8 MHz, $CDCl_3$) 21.6, 120.0, 120.3, 126.7, 126.8, 127.5, 127.7, 131.1, 134.6, 134.7, 137.4, 139.3 and 142.3; HRMS (EI) calc. for $C_{46}H_{34}N_4$ 642.2783, found 642.2784.

5,10,15,20-Tetraphenylporphyrin (6). Following the general procedure 5,15-dibromo-10,20-diphenylporphyrin (31 mg, 0.05 mmol), K_3PO_4 (212 mg, 1 mmol), benzeneboronic acid (61 mg, 0.5 mmol) and $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol) in THF (20 ml) gave a purple solid (23 mg, 75%); column chromatography (silica, 40% hexane in dichloromethane; R_f = 0.75); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 417 (5.7), 514 (4.3), 549 (4.0), 589 (3.7) and 645(3.6); δ_H (400 MHz, $CDCl_3$) −2.77 (2H, br s, NH), 7.74–7.77 (12H, m, 5,10,15,20-Ar-3,4,5H), 8.20–8.23 (8H, m, 5,10,15,20-Ar-2,6H) and 8.85 (8H, m, β-pyrrole H); δ_C (100 MHz, $CDCl_3$) 120.2, 126.8, 127.8, 131.4, 134.7 and 142.3; HRMS (EI) calc. for $C_{44}H_{30}N_4$ 614.2470, found 614.2470.

5,15-Bis(4-acetylphenyl)-10,20-diphenylporphyrin (7). Following the general procedure 5,15-dibromo-10,20-diphenylporphyrin (31 mg, 0.05 mmol), K_3PO_4 (212 mg, 1 mmol), 4-acetylbenzeneboronic acid neopentyl glycol cyclic ester (116 mg, 0.5 mmol) and $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol) in THF (20 ml) gave a purple solid (27 mg, 77%); column chromatography (silica, dichloromethane; R_f = 0.36); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 419 (5.5), 515 (4.1), 551 (3.8), 590 (3.6) and 645 (3.5); δ_H (400 MHz, $CDCl_3$) −2.79 (2H, br s, NH), 2.89 (6H, s, $C(O)CH_3$), 7.73–7.80 (6H, m, 10,20-Ar-3,4,5H), 8.20–8.22 (4H, m, 5,15-Ar-3,5H), 8.31–8.38 (8H, m, 5,10,15,20-Ar-2,6H), 8.79–8.80 (4H, d, J = 4.8, β-pyrrole H) and 8.87–8.88 (4H, d, J = 4.8, β-pyrrole H); δ_C (100 MHz, $CDCl_3$) 27.0, 118.9, 120.7, 126.7, 126.8, 127.9, 131.7, 134.6, 134.8, 136.4, 141.9, 147.2 and 198.3; HRMS (EI) calc. for $C_{48}H_{34}N_4O_2$ 698.2682, found 698.2680.

5,15-Bis(3-formylphenyl)-10,20-diphenylporphyrin (8). Following the general procedure 5,15-dibromo-10,20-diphenylporphyrin (31 mg, 0.05 mmol), K_3PO_4 (212 mg, 1 mmol), 3-formylbenzeneboronic acid neopentyl glycol cyclic ester (109 mg, 0.5 mmol) and $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol) in THF (20 ml) gave a purple solid (26 mg, 78%); column chromatography (silica, 20% hexane in dichloromethane; R_f = 0.35); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 419 (5.8), 514 (4.2), 550 (3.8), 591 (3.7) and 642 (3.4); δ_H (400 MHz, $CDCl_3$) −2.78 (2H, br s, NH), 7.76–7.80 (6H, m, 10,20-Ar-3,4,5H), 7.93–7.97 (2H, t, J = 7.6, 5,15-Ar-5H), 8.21–8.23 (4H, m, 10,20-Ar-2,6H), 8.32–8.35 (2H, m, 5,15-Ar-6H), 8.48–8.50 (2H, m, 5,15-Ar-4H), 8.71 (2H, br s, 5,15-Ar-2H), 8.76–8.77 (4H, d, J = 4.8, β-pyrrole H), 8.88–8.89 (4H, d, J = 4.8, β-pyrrole H) and 10.32 (2H, s, CHO); δ_C (100 MHz, $CDCl_3$) 118.4, 120.8, 126.8, 127.6, 127.9, 128.9, 134.6, 135.0, 135.2, 139.8, 141.9, 143.2 and 192.6; HRMS (EI) calc. for $C_{46}H_{30}N_4O_2$ 670.2369, found 670.2358.

5,15-Bis(4-methoxyphenyl)-10,20-(4-methylphenyl)porphyrin (9). Following the general procedure 5,15-dibromo-10,20-bis-(4-methylphenyl)porphyrin (20 mg, 0.031 mmol), K_3PO_4 (131 mg, 0.62 mmol), 4-methoxybenzeneboronic acid (47 mg, 0.31 mmol) and $Pd(PPh_3)_4$ (3.6 mg, 0.0031 mmol) in THF (15 ml) gave a purple solid (16 mg, 73%); column chromatography (silica, dichloromethane; R_f = 0.91); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 421 (5.7), 517 (4.2), 554 (4.0), 592 (3.7) and 649 (3.7); δ_H (400 MHz, $CDCl_3$) −2.77 (2H, br s, NH), 2.71 (6H, s, CH_3), 4.10 (6H, s, OCH_3), 7.28–7.30 (4H, m, 5,15-Ar-3,5H), 7.55–7.57 (4H, m, 10,20-Ar-3,5H), 8.09–8.14 (8H, m, 5,10,15,20-Ar-2,6H) and 8.86 (8H, s, β-pyrrole H); δ_C (67.8 MHz, $CDCl_3$) 21.6, 53.5, 112.2, 127.4, 127.6, 130.9, 134.6, 135.6, 137.4, 139.3 and 164.0; HRMS (EI) calc. for $C_{48}H_{38}N_4O_2$ 702.2995, found 702.2993.

5,15-Bis(4-methoxyphenyl)-10,20-bis(4-methoxycarbonylphenyl)porphyrin (10). Following the general procedure 5,15-dibromo-10,20-bis(4-methoxycarbonylphenyl)porphyrin (28 mg, 0.038 mmol), K_3PO_4 (161 mg, 0.76 mmol), 4-methoxybenzeneboronic acid (58 mg, 0.38 mmol) and $Pd(PPh_3)_4$ (4.4 mg, 0.0038 mmol) in THF (15 ml) gave a purple solid (23 mg, 77%); column chromatography (silica, dichloromethane; R_f = 0.17); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 420 (5.8), 517 (4.5), 553 (4.2), 592 (4.0) and 649 (3.9); δ_H (400 MHz, $CDCl_3$) −2.79 (2H, br s, NH), 2.50 (6H, s, $C(O)OCH_3$), 4.10 (6H, s, OCH_3), 7.29–7.31 (4H, m, 5,15-Ar-3,5H), 7.49–7.51 (4H, m, 10,20-Ar-3,5H), 8.11–8.13 (4H, m, 5,15-Ar-2,6H), 8.21–8.23 (4H, m, 10,20-Ar-2,6H) and 8.85–8.89 (8H, m, β-pyrrole H); δ_C (100 MHz, $CDCl_3$) 21.4, 55.6, 112.3, 118.9, 119.9, 120.1, 131.1, 134.5, 135.4, 135.6, 139.8, 150.6, 159.5 and 169.6; HRMS (EI) calc. for $C_{50}H_{38}N_4O_6$ 790.2791, found 790.2789.

5,15-Bis(4-methoxyphenyl)-10-(4-nitrophenyl)-20-(4-methoxycarbonylphenyl)porphyrin (11). Following the general procedure 5,15-dibromo-10-(4-nitrophenyl)-20-(4-methoxycarbonylphenyl)-porphyrin (24 mg, 0.033 mmol), K_3PO_4 (141 mg, 0.66 mmol), 4-methoxybenzeneboronic acid (50 mg, 0.33 mmol) and Pd-$(PPh_3)_4$ (3.8 mg, 0.0033 mmol) in THF (15 ml) gave a purple solid (20 mg, 78%); column chromatography (silica, dichloromethane; R_f = 0.54); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 422 (5.6), 518 (4.3), 552 (4.0), 592 (3.7) and 649 (3.6); δ_H (400 MHz, $CDCl_3$) −2.78 (2H, br s, NH), 2.50 (3H, s, $C(O)OCH_3$), 4.10 (6H, s, OCH_3), 7.27–7.31 (4H, m, 5,15-Ar-3,5H), 7.48–7.52 (2H, m, 20-Ar-3,5H), 8.09–8.13 (4H, m, 5,15-Ar-2,6H), 8.20–8.23 (2H, m, 10-Ar-3,5H), 8.37–8.40 (2H, m, 20-Ar-2,6H), 8.61–8.64 (2H, m, 10-Ar-2,6H), 8.72–8.73 (2H, br d, J = 5.8, β-pyrrole H) and 8.87–8.92 (6H, m, β-pyrrole H); δ_C (100 MHz, $CDCl_3$) 55.6, 112.4, 116.7, 120.0, 120.6, 121.9, 131.2, 131.9, 134.2, 135.2, 135.4, 135.6, 139.6, 147.7, 149.3, 150.7, 159.6 and 169.6; HRMS (EI) calc. for $C_{48}H_{35}N_5O_6$ 777.2587, found 777.2578.

General method for synthesis of benzeneboronic acid neopentyl glycol cyclic esters[20]

benzeneboronic acid (1 eq.) and 2,2-dimethylpropane-1,3-diol (1.1 eq.) in anhydrous THF (5 ml $mmol^{-1}$) was stirred for 10 min at room temperature. The solvent was evaporated and the residue was dissolved in CH_2Cl_2, washed with water, dried by Na_2SO_4 and concentrated *in vacuo*. A small amount of hexane was added and the mixture was sonicated to produce a suspension. This suspension was evaporated to produce a solid.

4-Acetylbenzeneboronic acid neopentyl glycol cyclic ester (2, R = 4-C(O)CH$_3$). 4-Acetylbenzeneboronic acid (164 mg, 1 mmol) and 2,2-dimethylpropane-1,3-diol (120 mg, 1.1 mmol) in THF (5 ml) gave a brown solid (176 mg, 76%); mp 88 °C; δ_H (400 MHz, $CDCl_3$) 1.03 (6H, s, $C(CH_3)_2(OCH_2)_2$), 2.61 (3H, s, $C(O)CH_3$), 3.79 (4H, s, $C(CH_3)_2(OCH_2)_2$) and 7.89–7.91 (4H, m, Ar); δ_C (100 MHz, $CDCl_3$) 22.0, 26.8, 32.0, 72.5, 127.3, 134.1, 138.7 and 198.7; HRMS (ES) calc. for $C_{13}H_{18}BO_3$ 233.1349, found 233.1349.

3-Formylbenzeneboronic acid neopentyl glycol cyclic ester (2, R = 3-CHO). 3-Formylbenzeneboronic acid (150 mg, 1 mmol) and 2,2-dimethylpropane-1,3-diol (120 mg, 1.1 mmol) in THF (5 ml) gave a white solid (141 mg, 65%); mp 39 °C; δ_H (400 MHz, $CDCl_3$) 1.04 (6H, s, $C(CH_3)_2(OCH_2)_2$), 3.80 (4H, s, $C(CH_3)_2(OCH_2)_2$), 7.49–7.53 (1H, t, J = 7.3, Ar-5H), 7.94–7.97 (1H, m, Ar-6H), 8.05–8.07 (1H, m, Ar-4H), 8.30 (1H, s, Ar-2H) and 10.04 (1H, s, CHO); δ_C (100 MHz, $CDCl_3$) 21.9, 32.0, 53.5, 72.5, 128.4, 130.9, 135.8, 136.5, 140.0 and 193.0; HRMS (ES) calc. for $C_{12}H_{16}BO_3$ 219.1192, found 219.1190.

2,4,6-Trimethylbenzeneboronic acid neopentyl glycol cyclic ester (2, R = 2,4,6-Me). 2,4,6-Trimethylbenzeneboronic acid (164 mg, 1 mmol) and 2,2-dimethylpropane-1,3-diol (120 mg, 1.1 mmol) in THF (5 ml) gave a yellow solid (200 mg, 86%); mp 47 °C (Lit.[21] 39–40 °C); δ_H (400 MHz, $CDCl_3$) 1.02 (6H, s, $C(CH_3)_2(OCH_2)_2$), 2.16 (3H, s, Ar-4-CH_3), 2.28 (6H, s, Ar-2,6-CH_3), 3.70 (4H, s, $C(CH_3)_2(OCH_2)_2$) and 6.70 (2H, s, Ar-3,5H); δ_C (100 MHz, $CDCl_3$) 21.2, 22.2, 22.3, 31.7, 72.3, 127.3, 138.1 and 140.7; HRMS (ES) calc. for $C_{14}H_{22}BO_2$ 233.1713, found 233.1716.

Investigations of by-product in Suzuki cross coupling: 5-(2,4,6-trimethylphenyl)-10,20-diphenylporphyrin (12). Following the general procedure 5,15-diphenyl-10,20-dibromoporphyrin (31 mg, 0.05 mmol), K_3PO_4 (212 mg, 1 mmol), 2,4,6-trimethylbenzeneboronic acid (82 mg, 0.5 mmol) and $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol) in THF (20 ml) gave the main by-product (7 mg, 24%) as a purple solid; column chromatography (silica, 50% hexane in dichloromethane; R_f = 0.69); mp >350 °C (decomp.); $\lambda_{max}(CH_2Cl_2)$/nm (log (ε/dm^3 mol^{-1} cm^{-1})) 412 (5.9), 508 (4.6), 541 (4.1), 583 (4.1) and 638 (3.9); δ_H (400 MHz, $CDCl_3$) −2.90 (2H, br s, NH), 1.82 (6H, s, Ar-2,6-CH_3), 2.63 (3H, s, Ar-4-CH_3), 7.28 (2H, s, 5-Ar-3,5H), 7.76–7.79 (6H, m, 10,20-Ar-3,4,5H), 8.23–8.27 (4H, m, 10,20-Ar-2,6H), 8.74–8.75 (2H, d, J = 4.8, β-pyrrole H), 8.85–8.87 (2H, d, J = 4.8, β-pyrrole H), 9.00–9.01 (2H, d, J = 4.5, β-pyrrole H), 9.32–9.33 (2H, d, J = 4.5, β-pyrrole H) and 10.20 (1H, s, *meso* H); HRMS (EI) calc. for $C_{41}H_{32}N_4$ 580.2627, found 580.2626.

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