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Synthesis of Carbon-carbon Linked Porphyrinoligomers by Utilization of Heck-type Coupling of Natural Tetrapyrroles

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Abstract: The Heck type cross-coupling reaction of zinc(II)-monobromodeuteroporphyrin-dimethylester and di- or trivinylbenzene provided C-C-linked di- and trimeric porphyrins in high yields. The reaction was carried out with palladium(II)-acetate in DMF under phase-transfer conditions.
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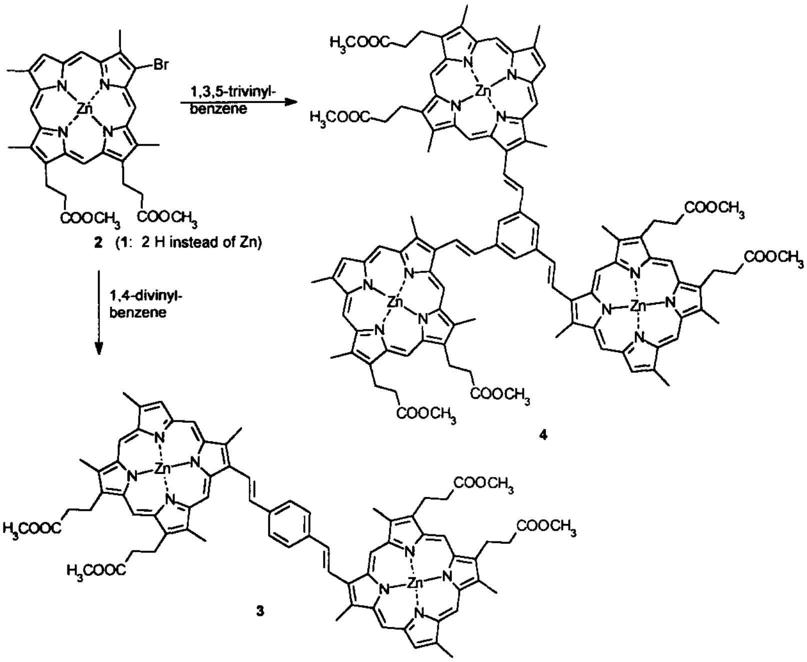
The development of new synthetic routes to oligomeric porphyrins has attracted considerable interest, due to possible insights into the mechanisms of photosynthesis[1] and conceivable applications in photodynamic therapy (PDT)[2] of these compounds. In particular, palladium(0)-catalyzed coupling reactions have been shown to be very powerful in the functionalization and linking of porphyrins[3]. Preliminary studies showed that the coupling reaction of zinc(II)-3,8-dibromodeuteroporphyrin-dimethylester with styrene proceeds very well under phase tranfer conditions[4] (which have never been applied to porphyrins so far) using 5 mol per cent palladium(II)-acetate in DMF as catalyst[5]. The resulting zinc(II)-3,8-distyryl-deuteroporphyrin-dimethylester was separated in 87% yield (only the *trans*-configurated product was formed).



Scheme 1. Synthesis of the vinylbenzene-bridged zinc-deuteroporphyrin-dimer **3** and -trimer **4**

The same reaction conditions proved to be also extremely useful for the formation of porphyrin oligomers. The 3-/8-monobromo-deuteroporphyrin-dimethylester **1a**, **b**[6] represents a suitable and easily obtainable starting material proceeding from natural tetrapyrroles. Metalation with zinc(II)-acetate in a mixture of dichloromethane and methanol (1:1) yielded the zinc complex **2**. The coupling reaction of 1,4-divinylbenzene with a two-fold quantity of **2** resulted in the formation of the novel dimeric porphyrin **3**. The reaction was carried out under similar conditions to those described above (10 mol % palladiumacetate; 85 °C; 8 h). Compound **3** was isolated in 76 % yield after chromatography on silica gel. The structure of **3** was confirmed by FAB-MS and NMR spectroscopy[7]. The UV/VIS spectra of **3**[7] exhibit a red-shifted soret band compared to compound **2** which probably reveals an unhindered conjugation between the porphyrin- and divinylbenzene units.

A centrally linked trimeric porphyrin **4** was achieved by the coupling reaction of **2** with 1,3,5-trivinylbenzene. The trimer **4** was prepared under similar reaction conditions using 3 moles of the porphyrin **2** and 1 mole of benzene derivative. The structure of the dark purple trimer **4** was confirmed by NMR spectroscopy in $[D_6]$DMSO[8] and FAB-MS. The UV/VIS spectra of **4**[8] expose a less red-shifted soret band compared with **3** indicating less conjugation among the porphyrin and the benzene core.

The shown synthetic strategy represents a flexible attempt which will be suitable for the synthesis of a great variety of porphyrin oligomers. The yields achieved are very good compared to other syntheses in this field. Further research on the applications of palladium(0)-catalyzed coupling reactions on derivatives of natural tetrapyrroles is currently being carried out.

References and Notes

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5. The conditions of the coupling reaction: 1 mmol bromoporphyrin was heated at 85 °C with 1 mmol alkene, 1 mmol tetra-n-butyl-ammonium bromide, 5 mmol potassium carbonate, 1 mmol lithium chloride 0.05 mmol palladium(II)-acetate in 10 ml DMF for 8 to 15 h.
6. Synthesis of the regioisomers **1a**, **1b** see: R. Bonnett, I. H. Campion-Smith, A. N. Kozyrev, A. F. Mironov, *J. Chem. Research* **1990**, 138-139. To our surprise, repeated crystallisation from dichloromethane : hexane (5:1) yielded in regioisomerically pure bromodeuteroporphyrin **1**, which could not yet be assigned as either the 3- or 8- regioisomer. (In all schemes, we tentatively present those regioisomers substituted at C-8.)
7. ^{1}H-NMR (300 MHz, $[D_6]$DMSO, TMS): δ = 3.30-3.33 (m, 8H, $13^2/17^2$-CH_2), 3.60-3.95 (m, 36H, $CH_{3\,Pyr}$, $COOCH_3$), 4.38-4.40 (m, 8H, $13^1/17^1$-CH_2), 8.01 (d, J = 16.3 Hz, 2H, AB-CH_{vinyl}), 8.36-8.38 (m, 4H, H_{Ar}), 9.17-9.23 (m, 4H, AB-CH_{vinyl}, $3^1/8^1$-$H_{\beta\text{-}Pyr}$), 10.09-10.13 (m, 4H, $H_{meso\text{-}Pyr}$), 10.25 (s, 2H, $H_{meso\text{-}Pyr}$), 10.48-10.50 (s, 2H, $H_{meso\text{-}Pyr}$); UV/VIS (CH_2Cl_2): λ_{max} (lg ε)= 595 (4.771), 549 (4.603), 413 (5.161).
8. ^{1}H-NMR (300 MHz, $[D_6]$DMSO, TMS): δ = 3.23-3.43 (m, 12H, $13^2/17^2$-CH_2), 3.51-4.10 (m, 54H, $CH_{3\,Pyr}$, $OOCH_3$), 4.26-4.50 (m, 12H, $13^1/17^1$-CH_2), 8.30 (d, J = 16.5 Hz, 3H, AB-CH_{vinyl}), 8.98 (s, 3H, H_{ar}), 9.27 (s, 3H, $3^1/8^1$-$H_{\beta\text{-}Pyr}$), 9.57 (d, 3H, AB-CH_{vinyl}), 10.11-10.16 (m, 6H, $H_{meso\text{-}Pyr}$), 10.32 (s, 3H, $H_{meso\text{-}Pyr}$), 10.65-10.69 (m, 3H, $H_{meso\text{-}Pyr}$); UV/VIS (CH_2Cl_2): λ_{max} (lg ε)= 589 (4.873), 547 (4.809), 510 (4.243), 413 (5.598).

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