meso-Substituted Dipyrromethanes from Vinylogous Aromatic Heterocycles and Their Utilization to the Synthesis of *meso*-Functionalized Porphyrins

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meso-Functionalized dipyrromethanes **6-10** were synthesized by acid-catalyzed addition of pyrrole to α-position of 2-alkenyl pyrroles. The regiochemistry of the reaction can be explained by either the formation of more stable carbocation intermediate or β-addition of α,β-unsaturated carbonyl compounds. The starting 2-alkenyl pyrroles were synthesized by Aldol condensation of 2-formylpyrrole with active methylene compounds such as nitromethane, diethylmalonate and malononitrile. Attempted '2+2' condensation of *meso*-diethylmalonyldipyrromethane, *meso*-(*p*-tolyl)dipyrromethane and *p*-tolualdehyde afforded three different porphyrins **12**, **13** and **14** in reasonable yields. On the other hand, *meso*-(nitromethyl)dipyrromethane with *p*-(*t*-butyl)benzaldehyde resulted in the formation of three different porphyrins such as 5,15-dicyano-10,20-diarylporphyrin (**16**), 5-cyano-15-formyl-10,20-diarylporphyrin (**17**) and 5,15-diformyl-10,20-diarylporphyrin (**18**) in low yields. Conversion of nitromethyl groups to nitrile and (or) formyl group was observed under the porphyrin forming conditions.

Key Words : *meso*-(Diethylmalonyl)-dipyrromethanes, Vinylpyrroles, 5,15-Dicyano-10,20-diarylporphyrin, 5-Cyano-15-formyl-10,20-diarylporphyrin

Introduction

The *meso*-substituted porphyrins have been widely used as key components in constructing porphyrin-based model systems and the design often requires incorporation of different substituents around the periphery of the mother macrocycles. The synthesis of asymmetrically substituted porphyrins at *meso*-positions is still challenging task due to the difficulties arising from separation and limited availability of suitable building blocks. A number of different synthetic routes have been developed to achieve this goal so far.[1-4] Most of the reported methods generally adopted acid-catalyzed condensation of *meso*-aryl dipyrromethanes with aldehydes in order to obtain asymmetrically substituted porphyrins.[5] We also reported that *meso*-substituted porphyrins can be synthesized by oxidative coupling of pentapyrrolic oligomers followed by treatment with acid.[6] Directly attached functional groups at the *meso*-position enable the construction of supramolecular architectures based on the non-covalent or covalent interactions. Thus, it is worthwhile to develop novel synthetic methods of *meso*-functionalized porphyrins.

In this article, we describe a new synthetic method of dipyrromethanes starting from vinyl substituted aromatic heterocycles including pyrrole, thiophene and furan. Also reported is the synthesis of porphyrinic macrocycles utilizing synthesized dipyrromethanes and unusual conversion of nitromethyl group to cyano or formyl group.

Experimental Section

Proton NMR spectra (400 MHz, Bruker DPX-400) were recorded using TMS as the internal standard. High and Low resolution FAB mass spectra were obtained on AUTO SPEC M-363 high-resolution mass spectrometer. Column chromatography was performed over silica gel (Merck, 230-400 mesh). Pyrrole was distilled at atmospheric pressure from CaH_2. Both CH_2Cl_2 and $CHCl_3$ (reagent grade) were distilled from K_2CO_3 to eliminate traces of acid. All other reagents were obtained from Aldrich and used as received unless noted otherwise.

2-(Dicyanoethen-1-yl)pyrrole (1). Pyrrole-2-carboxaldehyde (1.0 g, 10.5 mmol), NaOAc (0.88 g, 10.5 mmol), methylamine hydrochloride (0.71 g, 10.5 mmol) and malononitrile (0.66 mL, 10.5 mmol) were dissolved in methanol (20 mL). The mixture was stirred for 2 hr at 25°C and then was combined with brine (20 mL) and water (30 mL). The mixture was extracted with methylene chloride (20 mL × 3) and the organic layer was dried over anhydrous Na_2SO_4. Solvent was removed *in vacuo* and the remaining solid was purified by column chromatography on silica (CH_2Cl_2). The yellow compound was again recrystalized from hexanes/ethyl acetate. Yield: 1.43 g (95%); mp 127-128 °C; ^{1}H NMR ($CDCl_3$) δ 6.50-6.48 (m, 1H, pyrrole-H), 6.98 (m, 1H, pyrrole-H), 7.3 (m, 1H, pyrrole-H), 7.5 (s, 1H, pyrrole-H), 9.75 (br s, 1H, pyrrole-H).

2-(Diethoxycarbonylethen-1-yl)pyrrole (2). Pyrrole-2-carboxaldehyde (2 g, 21 mmol), sodium acetate (1.76 g, 20.9 mmol), methylamine hydrochloride (1.42 g, 21 mmol) and diethylmalonate (3.19 mL, 21 mmol) were treated identically as for the synthesis of **1**. Yield 4.9 g (98%), oil; ^{1}H NMR ($CDCl_3$) δ 1.26-1.36 (m, 6H, CH_3), 4.25-4.35 (m, 4H, CH_2), 6.31-6.33 (m, 1H, pyrrole-H), 6.31-6.33 (m, 1H, pyrrole-H), 7.08 (m, 1H, pyrrole-H), 7.67 (s, 1H, vinyl-H).

2-(2-*trans*-Nitrovinyl)pyrrole (3)[7]**.** Pyrrole-2-carboxalde-

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hyde (1.773 g, 18.6 mmol), sodium acetate (1.538 g, 18.8 mmol), methylamine hydrochloride (1.261 g, 18.7 mmol) and nitromethane (20 mL, 369.3 mmole) were treated identically as for the synthesis of **1**. Yield: 1.97 g (76%); mp 111-113 °C; ^{1}H NMR ($CDCl_3$) δ 6.39-6.41 (m, 1H, pyrrole-H), 6.80-6.81 (m, 1H, pyrrole-H), 7.10-7.11 (m, 1H, pyrrole-H), 7.40 (d, J = 13.4 Hz, 1H, vinyl-H), 7.95 (d, J = 13.4 Hz, 1H, vinyl-H).

2-(2-*trans*-Nitrovinyl)furan (4). Furfural (2 mL, 24.1 mmol), sodium acetate (1.998 g, 24.4 mmol), methylamine hydrochloride (1.629 g, 24.1 mmol) and nitromethane (20 mL, 369.3 mmol) were treated identically as for the synthesis of **1**. Yield: 3.30 g (98%); mp 73-74 °C; ^{1}H NMR ($CDCl_3$) δ 6.58 (q, 1H, furan-H), 6.89 (d, J = 3.5 Hz, 1H, furan-H), 7.53 (d, J = 13.3 Hz, 1H, vinyl-H), 7.59-7.60 (m, 1H, furan-H), 7.78 (d, J = 13.3 Hz, 1H, vinyl-H).

2-(2-*trans*-Nitrovinyl)thiophene (5). 2-Thiophene carboxaldehyde (1 mL, 10.7 mmol), sodium acetate (0.889 g, 10.8 mmol), methylamine hydrochloride (1.261 g, 10.7 mmol) and nitromethane (23 mL, 424.7 mmol) were treated identically as for the synthesis of **1**. Yield: 1.38 g (83%); mp 78-79 °C; ^{1}H NMR ($CDCl_3$) δ 7.14-7.16 (m, 1H, thiophene-H), 7.45-7.46 (m, 1H, thiophene-H), 7.48 (d, J = 13.4 Hz, 1H, vinyl-H), 7.57 (d, J = 5.0 Hz, 1H, thiophene-H), 8.15 (d, J = 13.4 Hz, 1H, vinyl-H).

5-(2-Diethylmalonyl)dipyrromethane (6). To the solution of **2** (0.88 g, 3.4 mmol) and pyrrole (9.4 mL) was added trifluoroacetic acid (1.3 mL, 5 equiv.). The mixture was stirred for 2.5 hr at 25 °C. Then aqueous NaOH solution (0.1 N, 5 mL) and water (30 mL) were added in order to quench the reaction and the mixture was extracted with CH_2Cl_2 (20 mL × 3). The organic layer was dried (Na_2SO_4) and solvent was removed *in vacuo*. Remaining dark solid was purified by column chromatography on silica (CH_2Cl_2). Yield: 0.2 g (20%); mp 126-130 °C; ^{1}H NMR ($CDCl_3$) δ 1.17-1.14 (m, 6H, CH_3), 4.15-4.07 (m, 5H, CH_2, CH), δ 4.88 (d, J = 6.9 Hz, 2H, vinyl-H), 5.96-5.97 (dd, J = 2.9, 5.9 Hz, 2H, pyrrole-H), 4.57 (q, J – 2.9 Hz, 2H, pyrrole-H), 6.67-6.68 (m, 2H, pyrrole-H), 8.72 (br s, 1H, NH).

5-(Nitromethyl)dipyrromethane (7). The mixture of **3** (0.588 g, 4.04 mmol), indium(III) chloride (0.091 g, 0.411 mmol) and pyrrole (10 mL, 144.1 mmol) was stirred for 4 hr at 25 °C. Then the mixture was combined with water (5 mL) and brine (20 mL). The mixture was extracted with CH_2Cl_2 (30 mL × 3) and the organic layer was dried. Solvent was removed *in vacuo* and the resulting dark blue oil was purified by column chromatography on silica (CH_2Cl_2/EtOAc – 95/5). Yield: 0.5 g (60%); ^{1}H NMR ($CDCl_3$) δ 4.83 (d, J – 7.6 Hz, 2H, CH_2), 5.01 (t, J = 7.6 Hz, 1H, *meso*-H), 6.10 (s, 2H, pyrrole-H), 6.17-6.19 (m, 2H, pyrrole-H), 6.70-6.72 (m, 2H, pyrrole-H), 7.98 (br s, 2H, NH).

5-(Nitromethyl)-10-oxadipyrromethane (8). The mixture of **4** (0.51 g, 3.64 mmol), indium(III) chloride (0.081 g, 0.366 mmol) and pyrrole (6 mL, 84.0 mmol) was stirred for 2 hr at room temperature. Then water (5 mL) was added and the organic layer was dried *in vacuo*. The resulting yellow viscous oil was separated by column chromatography on silica (CH_2Cl_2/Hexanes = 9/1). Yield: 0.2 g (27%); ^{1}H NMR ($CDCl_3$) δ 4.77-4.93 (m, 2H, CH_2), 4.95 (t, J = 7.6 Hz, 1H, *meso*-H), 6.08-6.10 (m, 1H, pyrrole-H), 6.16 (dd, J = 2.9, 5.9 Hz, 1H, pyrrole-H), 6.19 (d, J = 3.2 Hz, 1H, furan-H), 6.32-6.34 (m, 1H, furan-H), 6.71-6.74 (m, 1H, pyrrole-H), 7.39-7.40 (m, 1H, furan-H), 8.24 (bs, 1H, NH).

5-(Nitromethyl)-10-thiadipyrromethane (9). Compound **5** (0.21 g, 1.33 mmol), indium(III) chloride (0.031 g, 0.14 mmol) and pyrrole (4 mL, 57.65 mmol) was treated identically as for the synthesis of **8**. Column chromatography on silica (CH_2Cl_2). Yield: 0.093 g (32%); ^{1}H NMR ($CDCl_3$) δ 4.79-4.95 (m, 2H, CH_2), 5.19 (t, J = 7.8 Hz, 1H, *meso*-H), 6.10 (s, 1H, pyrrole-H), 6.15-6.17 (m, 1H, pyrrole-H), 6.69-6.70 (m, 1H, pyrrole-H), 6.92-6.93 (m, 1H, thiophene-H), 6.95-6.97 (m, 1H, thiophene-H), 7.23-7.25 (m, 1H, thiophene-H), 8.01 (bs, 1H, NH).

2-[Bis-(pyrrol-2-yl)-methyl]pyrrole (10). To the mixture of **1** (0.09 g, 0.62 mmol) and pyrrole (2 mL, 30.8 mmol) was added TFA (241 μL, 3.13 mmol). The mixture was heated for 5 hr at 60 °C, and then the reaction was quenched by addition of aqueous NaOH (0.1 N, 30 mL). The mixture was extracted with CH_2Cl_2 (30 mL × 3) and the organic layer was dried (Na_2SO_4). Solvent was removed *in vacuo* and the remaining solid was purified by column chromatography on silica (EtOAc/Hexanes = 1/1). Yield: 0.067 g (51%); mp 133-134 °C; ^{1}H NMR ($CDCl_3$) δ 5.56 (s, 1H, *meso*-H), 6.06 (m, 3H, pyrrole-H), 6.18 (q, 3H, J = 3.0 Hz, pyrrole-H), 6.69-6.70 (m, 3H, pyrrole-H), 7.98 (br s, 3H, NH); EI MS calcd for $C_{13}H_{13}N_3$ 211.11, Found 211.12.

5,15-Bis(diethylmalonyl)-10,20-di(*p*-tolyl)porphyrin (12) and 5-Diethylmalonyl-10,15,20-tri(*p*-tolyl)porphyrin (13) and 5,10,15,20-Tetra(*p*-tolyl)porphyrin (14). Compound **6** (0.1 g, 0.33 mmol), 5-(*p*-tolyl)dipyrromethane (78 mg, 0.33 mmol), *p*-tolualdehyde (77 μL, 0.66 mmol) were dissolved in CH_2Cl_2 (33 mL) with stirring and then BF_3(OEt) (42 mL, 0.33 mmol) was added. The whole mixture was stirred for 40 min at 0 °C and DDQ (0.22 g, 0.999 mmol) was added. The mixture was stirred for 1 hr and was combined with water. The mixture was extracted with CH_2Cl_2 (30mL × 3) and the organic layer was dried (Na_2SO_4). Solvent was removed *in vacuo* and the remaining solid was separated by column chromatography on silica (CH_2Cl_2). Three different products **12**, **13** and **14** were isolated. Spectroscopic data for (**12**); Yield: 16 mg (12%); ^{1}H NMR ($CDCl_3$) δ -2.7 (s, 2H, NH), 1.13 (t, J – 7.1 Hz, 12H, CH_3), 2.72 (s, 6H, tolyl-CH_3), 4.25-4.3 (m, 8H, CH_2), 7.26 (s, 2H, CH), 7.55 (d, J = 7.7 Hz, 4H, β-pyrrole), 8.04 (d, J – 7.8 Hz, 4H, β-pyrrole), 8.9 (d, J – 4.9 Hz, 4H, Ar-H), 9.47 (d, J – 5.0 Hz, 4H, Ar-H); ^{13}C NMR ($CDCl_3$) δ 13.97, 21.54, 57.98, 62.24, 76.69, 77.01, 77.21, 77.33, 109.58, 120.43, 127.31, 128.59, 132.56, 134.25, 137.54, 139.33, 169.96; FAB-MS clacd for $C_{48}H_{46}N_4O_8$ 806.33, found 807.3 (MH^+). For (**13**); Yield: 60 mg (25%); ^{1}H NMR ($CDCl_3$) δ -2.73 (s, 2H, NH), 1.14 (t, J – 7.1 Hz, 6H, CH_3), 2.7 (s, 6H, tolyl-CH_3), 4.29 (m, 4H, CH_2), 7.3 (s, 1H, CH), 7.55 (d, J = 7.8 Hz, 6H, Ar-H), 8.07 (d, J – 7.8 Hz, 6H, Ar-H), 8.81 (q, J – 4.8 Hz, 4H, β-

pyrrole), 8.94 (d, J = 5.0 Hz, 2H, β-pyrrole), 9.5 (d, J = 5.0 Hz, 2H, β-pyrrole); ^{13}C NMR ($CDCl_3$) δ 13.98, 21.50, 21.53, 58.15, 62.19, 76.69, 77.00, 77.21, 77.32, 108.38, 120.28, 121.29, 127.34, 127.48, 128.49, 129.67, 131.04, 132.42, 134.41, 134.46, 137.41, 138.84, 139.32; FAB-MS clacd for $C_{48}H_{42}N_4O_4$ 738.32, found 739.2 (MH^+). For (**14**); Yield: 17 mg (15%); ^{1}H NMR ($CDCl_3$) δ-2.8 (s, 2H, NH), 2.7 (s, 6H, tolyl-CH_3), 7.55 (d, J = 7.79 Hz, 4H, β-pyrrole), 8.09 (d, J = 7.85 Hz, 4H, β-pyrrole), 8.85 (s, 4H, Ar-H).

10,20-Di(4-*tert*-butylphenyl)-5,15-dicyanoporphyrin (16), 10,20-Di(4-*tert*-butylphenyl)-5-cyano-15-formylporphyrin (17) and 10,20-Di(*p*-*tert*-butylphenyl)-5,15-diformylporphyrin (18). Compound **7** (0.18 g, 0.88 mmol), 4-*tert*-butylbenzaldehyde (150 μL, 0.9 mmol), NH_4Cl (0.49 g, 9.2 mmol) were dissolved in CH_3CN (88 mL) and BF_3·$(OEt)_2$ (22 μL, 0.17 mmol) was added with stirring at 0 °C. The solution was stirred for 30 min and then triethyl amine (24 μL, 0.17 mmol) and DDQ (0.649 g, 2.9 mmol) were added successively and stirred for 1 hr. The reaction mixture was combined with water (50 mL) and extracted with CH_2Cl_2 (50 mL × 3). The organic layer was dried (Na_2SO_4) and solvent was removed *in vacuo*. Remaining solid was separated by column chromatography on silica (CH_2Cl_2/hexanes = 2/1). Three porphyrin components were isolated and characterized. (**16**) Yield: 3 mg (1%); ^{1}H NMR ($CDCl_3$) δ-2.69 (s, 2H, NH), 1.64 (s, 18H, *tert*-butyl-H), 7.85 (d, J = 8.0 Hz, 4H, Ar-H), 8.12 (d, J = 8.0 Hz, 4H, Ar-H), 9.10 (d, J = 4.8 Hz, 4H, pyrrole-H), 9.66 (d, J = 4.8 Hz, 4H, pyrrole-H); IR (CN): 2217; UV-Vis. (CH_2Cl_2) λ_{max} (ε): 421 (87714), 523 (3305), 563 (5333), 605 (1019), 661 (4362); FAB MS Calcd. for $C_{42}H_{36}N_6$ (624.30), Found (625.1) (MH^+); (**17**) Yield: 4 mg (1%); ^{1}H NMR ($CDCl_3$) δ-2.59 (s, 2H, NH), 1.64 (s, 18H, *tert*-butyl-H), 7.83 (d, J = 8.2 Hz, 4H, Ar-H), 8.11 (d, J = 8.2 Hz, 4H, Ar-H), 9.03 (d, J = 4.5 Hz, 2H, pyrrole-H), 9.09 (d, J = 4.8 Hz, 2H, pyrrole-H), 9.60 (d, J = 4.8 Hz, 2H, pyrrole-H), 10.04 (br s, 2H, pyrrole-H), 12.60 (s, 1H, CHO); IR (CN): 2217, (CHO): 1674; UV-Vis. (CH_2Cl_2) λ_{max} (ε): 423 (94271), 528 (2902), 573 (5791), 671 (4585); FAB MS Calcd. for $C_{42}H_{37}N_5O$ (627.30), Found (628.20) (MH^+); ^{1}H NMR ($CDCl_3$ · TFA-*d*) δ 1.66 (s, 18H, *tert*-butyl-H), 8.10 (d, J = 8.0 Hz, 4H, Ar-H), 8.40 (d, J = 8.0 Hz, 4H, Ar-H), 8.77 (d, J = 4.9 Hz, 2H, pyrrole-H), 8.92 (d, J = 4.8 Hz, 2H, pyrrole-H), 9.53 (d, J = 4.8 Hz, 2H, pyrrole-H), 9.67 (d, J = 4.9 Hz, 2H, pyrrole-H), 12.39 (s, 1H, CHO); (**18**) Yield: 11 mg (4%); ^{1}H NMR ($CDCl_3$) δ -2.43 (s, 2H, NH), 1.64 (s, 18H, *tert*-butyl-H), 7.80 (d, J = 8.2 Hz, 4H, Ar-H), 8.07 (d, J = 8.2 Hz, 4H, Ar-H), 8.98 (d, J = 4.9 Hz, 4H, pyrrole-H), 9.95 (d, J = 4.9 Hz, 4H, pyrrole-H), 12.48 (s, 2H, CHO); IR (CHO): 1672; UV-Vis. (CH_2Cl_2) λ_{max} ($\varepsilon \times 10^4$): 427 (14.97), 539 (0.33), 585 (1.26), 684 (1.12); ^{13}C NMR: 31.679, 35.009, 110.957, 123.896, 124.060, 129.181, 134.289, 138.232, 151.382, 194.949; FAB MS Calcd. for $C_{42}H_{38}N_4O_2$ 630.30, Found 631.30 (MH^+).

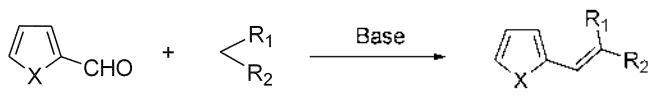
Results and Discussion

The synthesis of dipyrromethane from vinyl pyrroles has been reported previously.[8] However, the reported methods generally adopted multi-substituted pyrroles, strongly acidic reaction conditions and elevated temperature. Our approaches, on the other hand, are milder and versatile to access various dipyrroemthane analogues bearing any combination of pyrroles, furans and thiophenes. Aldol reaction of 2-formylpyrrole with active methylene compounds such as malononitrile or ethyl cyanoacetate has been well documented[9] and in some cases, the alkenyl pyrroles have been applied as a protecting group for 2-formylpyrrole due to their relative stability in acidic media. On the other hand, acid-catalyzed condensation of alkenyl pyrroles with pyrrole has not been studied well to the best of our knowledge. Attempted Aldol-type reaction of 2-formylpyrrole, 2-formylfuran or 2-formyl thiophene with active methylene compounds gave corresponding 2-alkenyl derivatives in high yields as shown in Scheme 1. Typical reaction was treatment of 2-formylpyrrole and malononitrile with sodium acetate/methylammonium chloride in methanol.

Since pyrroles have been recognized as a C-nucleophile[10] in some cases, we attempted to synthesize dipyrromethanes by nucleophilic addition of pyrrole to the alkenylpyrrole derivatives as shown in Scheme 2. For preliminary studies, we directed our attention to the synthesis of simple 2-(nitrovinyl)pyrrole. When 2-formylpyrrole was treated with nitromethane in the presence of sodium acetate at room temperature, *trans*-2-(nitrovinyl)pyrrole **3** was formed in 76% yield. The reaction gave even higher yields of corresponding vinyl derivatives **4** or **5**, when 2-furfural or 2-formylthiophene were treated under the same conditions. Inspired by these results, we examined the reaction with malononitrile or diethyl malonate with 2-formylpyrrole and observed the formation of corresponding alkenylpyrroles **1** and **2** in 95% and 98% yields, respectively.

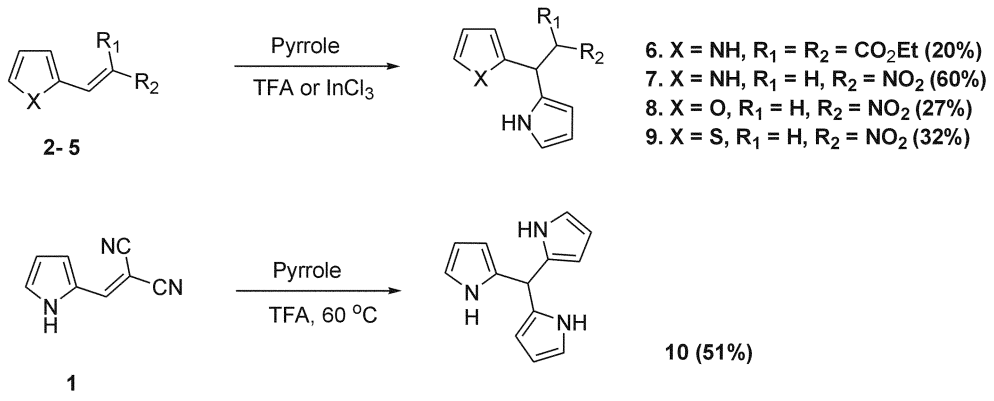
Desired dipyrromethane derivatives then were prepared by condensation of the 2-alkenylpyrroles with pyrrole in neat excess pyrrole presence (Scheme 2). These results were comparable with conventional methods such as pyrrole-aldehyde condensation and 2-(α-hydroxymethyl)pyrrole-pyrrole condensation.[11]

Several different acids including TFA, BF_3, $TiCl_4$, $ZnCl_2$, $InCl_3$, and p-TSA were examined in order to optimize the reactions. When **3** or **5** were treated with catalytic amount of trifluoroacetic acid in neat excess pyrrole, only trace amount



1. X = NH, R_1 = R_2 = CN (95%)
2. X = NH, R_1 = R_2 = CO_2Et (98%)
3. X = NH, R_1 = H, R_2 = NO_2 (76%)
4. X = O, R_1 = H, R_2 = NO_2 (98%)
5. X = S, R_1 = H, R_2 = NO_2 (83%)

Scheme 1



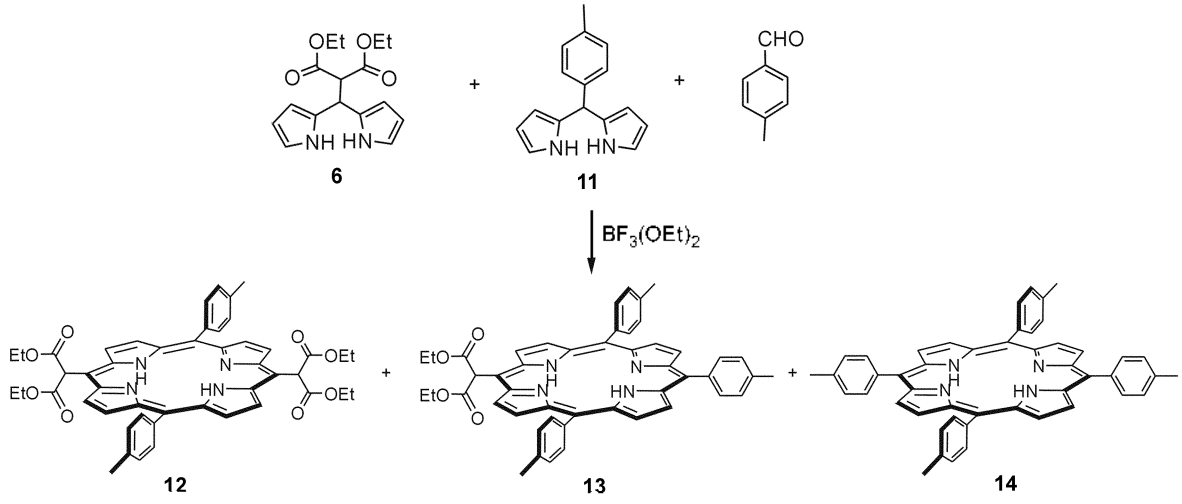
Scheme 2

of the desired product was isolated. On the other hand, applying $InCl_3$ as catalyst afforded good yield of the desired products in both cases. Eeven better yields (82-84%) were achieved when the pyrrolic nitrogen was protected with *t*-Boc or benzene sulfonyl group in the case of **3**. Similar addition of pyrrole to the electron deficient olefins in the presence of $InCl_3$ has been reported previously.[12] Interestingly, the condensation of **1** with pyrrole affored only tripyrrylmethane **10** in 51% yield. The formation of **10** could be explained by rapid elimination of malononitrile group from the initially formed dipyrromethane followed by nucleophilic attack of pyrrole to the resulting 2,2'-dipyrrylmethyl cationic intermediate.[13] The methylene protons in compound **8** and **9** are diastereotopic in nature and clean separation of signals were observed in proton NMR spectra.

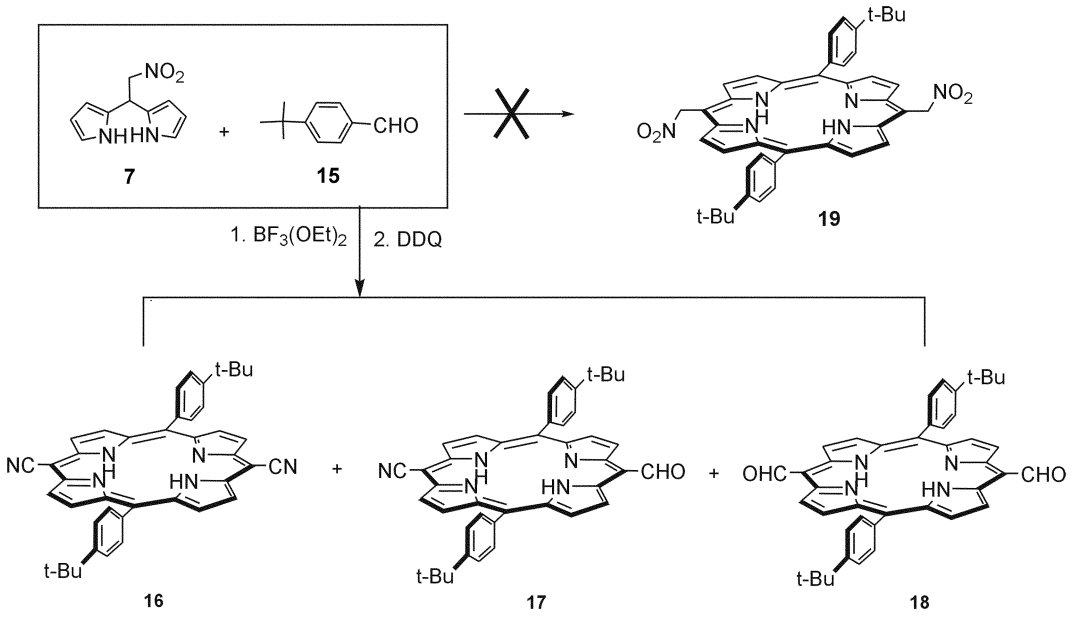
Since various dipyrromethanes are in hand, we attempted to synthesize porphyrins by '2+2' condensation as shown in Scheme 3. The condensation of dipyrromethanes **6**, **11** with *p*-tolualdehyde in the presence of $BF_3(OEt)_2$ as standard manner[14] afforded three different porphyrins **12**, **13** and **14** in 12%, 25% and 15% yields, respectively. The resonance line of the α-protons on the *meso*-positions in **12** and **13** appeared at 7.30 ppm as sharp singlet indicating strong influence of the diamagnetic ring current.

On the other hand, porphyrin forming reaction of dipyrromethane **7** with *p*-(*t*-butyl)benzaldehyde **15** unexpectedly gave three different porphyrins **16**, **17** and **18** in 1%, 1% and 4% yields, respectively, as shown in Scheme 4. However, desired porphyrin **19** was not isolated. We examined various oxidants and acid catalysts in order to isolate porphyrin **19**, but isolated porphyrin components were porphyrin **16**, **17**, and **18** with similar yields as those shown in Scheme 4. The formation of porphyrin products was not influenced by change of solvent or reaction temperature. Oxidative conversion of nitromethyl group to formyl or carboxyl group has been documented as Nef reaction.[15] This partial oxidative conversion can be explained by considering a nucleophilic attack of water to the carbon center of the oxime (–C=N-) or nitrile oxide (-CNO) intermediate. But conversion of nitromethyl group to cyano group is rather unusual especially in acidic condition.

Although the formation of porphyrin **16** is not easy to explain mechanistically at this point, the inherent electron-rich nature of the porphyrin ring might play crucial role in forcing dehydration of oxime-intermediate instead of nucleophilic attack of water. The reaction is useful for direct access to the *meso*-cyano substituted porphyrins in spite of



Scheme 3



Scheme 4

lower overall yields of porphyrins.

All the spectroscopic data were well matched with the proposed structures. For example, porphyrin **16** and **17** showed typical vibrational absorption at 2217 cm $^{-1}$ indicating the existence of -CN group. Porphyrin **17** showed both typical carbonyl stretching at 1674 cm $^{-1}$ and –CN stretching vibration including typical C-H stretching vibration of aldehyde. The combined resonance lines of **16** and those of **18** were well matched with the resonance lines of porphyrin **17**. This observation indicates the independent nature of the *meso*-substituents. The UV-vis. absorption spectra taken in methylene chloride displayed quite different $Q_x(0,0)$ bands at 661 nm, 671 nm and 684 nm respectively, to be compared with those of the TPP (649 nm). The Soret band of these three porphyrins appeared at 421 nm, 423 nm and 427 nm respectively, which were similar with that of TPP (421 nm). The effect of direct *meso*-substitution of unsaturated group conjugated with overall macrocyclic π-system on spectral properties usually shifted the Q-bands to longer wavelength. The enhanced absorption at longest wavelength of porphyrins **16**, **17** and **18**, was typical trend in the porphyrins bearing electron-withdrawing substituents diametrically at *meso*-position.[16] The *meso*-formyl substituents somewhat interact with porphyrin π-system more efficiently compared with those of cyano-substituent.

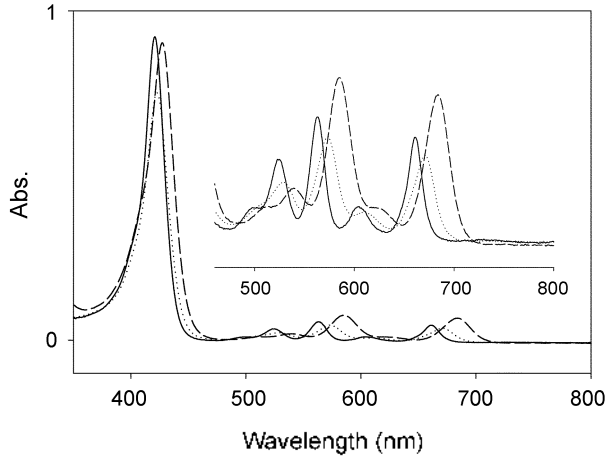


Figure 1. UV-vis spectra of porphyrin **16** (—, 1.1×10^{-5} M), **17** (·····, 8.0×10^{-6} M) and **18** (– – –, 6.0×10^{-6} M) in CH_2Cl_2.

In conclusion, we have demonstrated a useful synthesis of *meso*-substituted dipyrromethanes with good yields under mild conditions. The synthesized dipyrromethanes could be good building blocks for the convenient access to the *meso*-functionalized porphyrins. The porphyrin systems synthesized with these studies will provide variety of access to the family of direct *meso*-functionalized porphyrins.

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