Synthesis and characterization of monosubstituted hexapyrrolylbenzene derivatives

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Abstract
Six new monosubstituted hexapyrrolylbenzene derivatives **3a**–**c**, **4a**–**c** have been synthesized based on the multiple nucleophilic substitution reaction of appropriate 1-pentafluorophenyl-1*H*-pyrrole derivatives **1a**–**c**, **2a**–**c** with the sodium salt of pyrrole in dry DMF.

Keywords: Propeller-shaped hexapyrrolylbenzenes, S_NAr reaction, π-conjugation

Introduction

It is well known that oligomers and polymers with extended π-conjugation serve as important active components of electronic and opto-electronic devices.[1] Currently a growing interest has been directed towards the design of molecular wires and rods, since such structures may serve as building blocks for nanoscale chemical entities that are geometrically and dimensionally confined. They may act as connectors in molecular and supramolecular electronic and photonic devices. The interest in chemically functionalized conductive materials continues to expand and currently encompasses electronic and opto-electronic devices, energy storage systems, bio-electrochemical sensors etc. Detecting single molecule properties,[2,3] however, leads to completely new functional concept, and benzene-based compounds are particularly well-suited subjects for this developing technology. In these compounds is a synergism through which spectroscopic techniques are improved and in the course greater understanding of structure-property relationships is gained.[4] The study of stereochemistry of molecules is a relatively mature field.[5]

Highly symmetrical, propeller-shaped, hexasubstituted benzenes have received considerable interest due to their intriguing properties as sterically congested polycyclic aromatic compounds.[6] Any aromaticity disscusion will soon rise the awareness that benzene chemistry is

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a starting point for polymer chemistry and in turn, that π-conjugated polymers contribute tremendously to theories of π-bonding structures.[7,8] While the electronic design of conjugated polymers will appear to be an important concern below, it should be mentioned that benzene-based polymers should be looked at not only from the point of view of extended π-conjugation. Other important aspects of introducing benzene-based units into polymers are the high chemical and thermal stability of the building block and their easy chemical functionalization[9] with all of the additional properties brought in by adding an appropriate group.

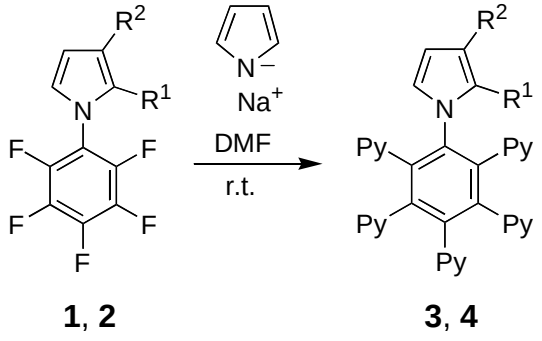
Pyrroles are very often used as a conducting interface because the substitution chemistry of the monomer is well defined and chemical and electrochemical polymerization is easy and the resulting polymers form robust and even films.

Monosubstituted hexapyrrolylbenzenes[6,10] are unknown. Electrophilic substitution reactions of hexapyrrolylbenzene such as Vilsmeyer-Haack formylation and electrophilic acylation failed to lead to the formation of monosubstituted derivatives **3a**–**c, 4a**–**c**.

Results and Discussion

The 2-substituted products **1a**–**c** could be selectively converted with high yields into the 3-substutited products **2a**–**c** by treatment with trifluoromethanesulphonic acid.[11] We now tried new synthetic route to **3a**–**c, 4a**–**c** starting from monosubstituted derivatives of 1-pentafluorophenyl-1*H*-pyrrole **1a**–**c** and **2a**–**c** by S_NAr reaction with pyrrole sodium salt. The one-pot synthesis of compounds **3a**–**c, 4a**–**c** is based on the multiple nucleophilic substitution of the penta-fluorophenyl group with 7.0 equivalents of pyrrolyl sodium salt in DMF (Scheme 1).

Since it is known that the rate of an S_NAr reaction increases by the use of a more polar aprotic solvent, we performed the reaction of sodium salt of pyrrole with **1a-c** and **2a-c** in dry DMF at ambient temperature.



1, **3**	R^1	R^2
a	HCO	H
b	MeCO	H
c	EtCO	H

2, **4**	R^1	R^2
a	H	HCO
b	H	MeCO
c	H	EtCO

Py = 1*H*-pyrrol-1-yl

Scheme 1. Preparation of hexapyrrolylbenzenes **3** and **4**.

Mono α-derivatives **1a–c** of hexapyrrolylbenzene afforded of requested products **3a–c** only in low yields. In our opinion this is due to steric hindrance by the substituent in α-position of pyrrole. This suggestion was confirmed by S_NAr of mono β-derivative **2a–c,** which gave the corresponding **4a–c** in much higher yields. In both of cases the products were separated by column chromatography. Physical and chemical properties of **3a–c** and **4a–c** compounds are collected in Table 1.

Table 1. Selected physical data and yields of **3a–c** and **4a–c**

Product	R	Eluant[a]	R_f	mp [°C]	color	Yield[b] [%]
3a	H	toluene	0.07	300–303	colorless	7
3b	Me	toluene	0.11	253–254	yellow	6
3c	Et	toluene	0.11	208–212	yellow	8
4a	H	toluene/EtOAc 20:1	0.31	209–215	light yellow	39
4b	Me	toluene/EtOAc 20:1	0.13	271–272	light yellow	55
4c	Et	toluene/EtOAc 20:1	0.21	239–240	light yellow	47

[a] Eluant used for column chromatography. [b] Isolated yield after column chromatography.

We were not able to identify any by-products due to the difficult separation of the crude S_NAr reaction mixtures. For confirmation of any atom of fluorine appears in desired products **3a–c** and **4a–c**, ^{19}F NMR spectroscopy was utilized.

Conclusions

We have presented a facile and convenient synthetic method for the synthesis of monosubstituted hexapyrrolylbenzenes. Due to their sterically congested structures they may be regarded as building blocks for larger π-conjugated systems possessing propeller-shaped molecules with interesting optoelectronic properties.

Products **3a–c** and **4a–c** were synthesized in order to study their conductive properties. We observed interesting results which will published as part of a full paper.

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Experimental Section

General Procedures. Derivatives **1a–c** and **2a–c** were prepared according to the literature.[11] A 60% dispersion of sodium hydride in mineral oil was used after removal of mineral oils with hexane. DMF was distilled at reduced pressure and kept in a dark bottle over 4 Å molecular sieves. Pyrrole was used after distillation under reduced pressure and kept in a freezer. Thin layer chromatography (TLC) was carried out on silica gel 60 F_{254} (Merck) and ALUGRAM® SIL UV (Macherey-Nagel). All products were separated by column chromatography packed with silica gel 60 (0.040–0.063 mm, Merck). The ^{1}H and ^{13}C NMR spectra (DMSO-d_6 solutions) were recorded either with a Varian VXR-300 spectrometer (operating frequencies 295.0 MHz for ^{1}H and 75.12 MHz for ^{13}C) or with a Bruker DRX-500 instrument (operating frequencies 500.13 MHz for ^{1}H and 125.76 MHz for ^{13}C). Mass spectra (AEI) were measured with a GC/MS 25 RFA instrument (Kratos Analytical, Manchester) equipped with a direct inlet system at 70 eV, trap current 100 μA at temperature of the ion source 200 °C. IR spectra (KBr pellets) were measured on spectrometer PU 9800 FTIR and Impact 400 (Nicolet). Melting points were measured on a Kofler block.

1-[2,3,4,5,6-Penta(1*H*-pyrrol-1-yl)phenyl]-*1H*-pyrrole-2-carbaldehyde (3a). Typical procedure

In a 25 mL two-necked flask under an argon atmosphere the mixture of NaH (1.03 g, 27.0 mmol) and DMF (30 mL) was stirred, and pyrrole (1.80 g, 27.0 mmol) was added through a dropping funnel. After the liberation of H_2 had ceased the reaction mixture was stirred for l 30 min. and the solution of 1-penta(1*H*-pyrrol-1-yl)phenyl-1*H*-pyrrol-2-carbaldehyde (**1a**; 1.0 g, 3.83 mmol) in DMF (10 mL) was added dropwise within 15 min. The reaction mixture was stirred for 24 h before it was poured into iced water (100 mL). The colorless precipitate formed was filtered off, washed with water (5x30 mL) and air dried overnight. Separation by column chromatography on silica gel (toluene) afforded the colorless product **3a**. ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.23 (1H, s), 7.04 (1H, s), 6.89 (1H, s), 6.31–6.21 (10H, m), 5.90–5.86 (11H, m). ^{13}C NMR (75 MHz, DMSO-d_6): δ 178.8, 135.2, 135.0, 134.6, 134.1, 132.8, 132.6, 123.4, 121.4, 121.3, 111.1, 109.6, 109.5, 109.2. MS: *m*/*z* (%) 496 (100) [M^+], 469 (17) [M–CHO], 404 (11) [M–C_4H_3NCHO], 77 (6) [C_6H_5]. IR (KBr): $\tilde{\nu}$ 3150, 3100, 1670, 1550, 1530, 1510, 1450 cm^{-1}. Anal. Calcd for $C_{31}H_{24}N_6O$ (496.20): C, 74.98; H, 4.87; N, 16.92. Found: C, 74.81; H, 4.85; N, 16.77;

Products **3b–c** and **4a–c** were prepared according to this procedure.

Selected physical data and yields: Table 1.

1-[2,3,4,5,6-Penta(1*H*-pyrrol-1-yl)phenyl)-*1H*-pyrrol-2-yl]ethanone (3b). ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.90–6.88 (2H, m), 6.32 (2H, m), 6.26 (4H, m), 6.19 (4H, m), 6.10 (1H, dd, *J* = 3.6, 3.0 Hz), 5.92–5.89 (6H, m), 5.86 (4H, m), 2.07 (3H, s). ^{13}C NMR (75 MHz, DMSO-d_6): δ 178.2, 135.5, 134.7, 134.5, 134.4, 132.2, 130.9, 121.4, 121.3, 121.2, 119.7, 110.1, 109.5, 109.1, 26.4. MS: *m*/*z* (%) 510 (100) [M^+], 494 (7) [M–CH_4], 466 (26) [M–$COCH_3$], 77 (7) [C_6H_5]. IR

(KBr): $\tilde{\nu}$ 3150, 3100, 2950, 2810, 1660, 1550, 1540, 1510, 1440 cm^{-1}. Anal. Calcd. for $C_{32}H_{26}N_6O$ (510.20): C, 75.27; H, 5.13; N, 16.46. Found: C, 75.20; H, 5.10; N, 16.66.

1-[1-(2,3,4,5,6-Penta(1*H*-pyrrol-1-yl)phenyl)-*1H*-pyrrol-2-yl]propan-1-one (3c). ^{1}H NMR: (300 MHz, DMSO-d_6): δ 6.75–6.76 (2H, m), 6.20 (2H, t, J = 2.1 Hz, J=1.8 Hz), 6.14 (4H, m), 6.04–6.05 (4H, m), 5.96 (1H, dd, J = 3.6 Hz, 3.0 Hz), 5.79–5.77 (10H, m), 2.32 (2H, q, J = 7.2 Hz), 0.76 (3H, t, J = 7.2 Hz). ^{13}C NMR (75 MHz, DMSO-d_6): δ 190.7, 135.6, 134.8, 134.5, 134.4, 131.9, 130.7, 121.5, 121.4, 121.3, 119.5, 118.8, 110.1, 109.6, 109.2, 31.1, 8.2. MS: *m*/*z* (%) 524 (100) [M^+], 495 (13) [M–CH_2CH_3], 467 (37) [M–$COCH_2CH_3$], 77 (4) [C_6H_5]. IR (KBr): $\tilde{\nu}$ 3130, 3110, 2980, 2890, 1665, 1540, 1520, 1530, 1440 cm^{-1}. Anal. Calcd. for $C_{33}H_{28}N_6O$ (524.20): C, 75.55; H, 5.38; N, 16.02. Found: C, 75.30; H, 5.18; N, 16.12.

1-[2,3,4,5,6-Penta(1*H*-pyrrol-1-yl)phenyl]-*1H*-pyrrol-3-carbaldehyde (4a). ^{1}H NMR (500 MHz, DMSO-d_6): δ 9.47 (1H, s), 7.17 (1H, broad s), 6.34–6.37 (5H, m), 6.26–6.29 (7H, m), 5.88–5.95 (10H, m). ^{13}C NMR (125 MHz, DMSO-d_6): δ 185.2, 135.3, 135.0, 134.8, 133.9, 131.8, 127.0, 125.3, 121.8, 121.5, 121.4, 110.2, 109.8, 109.7, 107.4. MS: *m*/*z* (%) 496 (100) [M^+], 469 (10) [M–CHO], 401 (50) [M–C_4H_3NCHO], 77 (10) [C_6H_5]. IR (KBr): $\tilde{\nu}$ 3150, 3100, 1650, 1550, 1480, 1520, 1500 cm^{-1}. Anal. Calcd. for $C_{31}H_{24}N_6O$ (496.20): C, 74.98; H, 4.87; N, 16.92. Found: C, 74.83; H, 4.83; N, 16.80.

1-[1-(2,3,4,5,6-Penta(1*H*-pyrrol-1-yl)phenyl)-*1H*-pyrrol-3-yl]ethanone (4b). ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.01 (1H, dd, J = 1.7, 1.7 Hz), 6.35–6.38 (5H, m), 6.26–6.30 (7H, m), 5,94–5.96 (4H, m), 5.92–5.94 (6H, m,), 2.07 (3H, s). ^{13}C NMR (125 MHz, DMSO-d_6): δ 191.8, 135.0, 134.9, 134.5, 134.0, 127.8, 126.3, 123.7, 121.7, 121.4, 121.3, 109.74, 109.69, 109.63, 108.8, 26.8. MS: *m*/*z* (%) 510 (100) [M^+], 495 (15) [M–CH_3], 466 (8) [M–$COCH_3$], 77 (7) [C_6H_5]. IR (KBr): $\tilde{\nu}$ 3160, 3150, 2950, 2810, 1650, 1600, 1530, 1500, 1450 cm^{-1}. Anal. Calcd. for $C_{32}H_{26}N_6O$ (510.20): C, 75.27; H, 5.13; N, 16.46. Found: C, 75.22; H, 5.15; N, 16.70.

1-[1-(2,3,4,5,6-Penta(1*H*-pyrrol-1-yl)phenyl)-*1H*-pyrrol-3-yl]propan-1-one (4c). ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.01 (1H, dd, J = 1.9, 1.9 Hz), 6.33–6.36 (5H, m), 6.25–6.29 (7H, m), 5.92–5.95 (4H, m), 5.90–5.92 (6H, m) 2.45 (2H, q, J = 7.2 Hz), 0.99 (3H, t, J = 7.2 Hz). ^{13}C NMR (125 MHz, DMSO-d_6): δ 195.2, 135.1, 134.9, 134.5, 134.0, 127.3, 125.6, 123.7, 121.7, 121.5, 121.4, 109.74, 109.68, 108.8, 31.9, 8.7. MS: *m*/*z* (%) 524 (100) [M^+], 495 (44) [M–CH_2CH_3], 467 (8) [M–$COCH_2CH_3$], 77 (5) [C_6H_5]. IR (KBr): $\tilde{\nu}$ 3130, 3100, 3000, 2950, 1670, 1530, 1520, 1500, 1420 cm^{-1}. Anal. Calcd. for $C_{33}H_{28}N_6O$ (524.20): C, 75.55; H, 5.38; N, 16.02. Found: C, 75.33; H, 5.20; N, 16.10.

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