## Synthesis of Substituted Linear Ter- and Quaterphenyls via Dewar Benzenes

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Abstract: Tetramethylcyclobutadiene–AlCl<sub>3</sub> complex reacted with bisalkynes possessing phenylene and biphenylene spacer giving rise to mono- and bis-Dewar benzenes. The rearrangement of the bis-Dewar benzene derivatives under thermal conditions (150 °C) yielded the corresponding linear ter- and quaterphenyl compounds possessing substituted terminal benzene rings. A mixture of an alkynylbiphenyl and a terphenyl was also obtained by the reaction of tetramethylzirconacyclopentadiene with bisalkynylbenzene in 13% combined yield.

Key words: Dewar benzene, alkynes, cyclobutadiene, polycycles, metallacycles

Substituted Dewar benzenes (DB) and their synthesis<sup>1</sup> have been known since 1960s; however, their application in organic synthesis is rather scarce. Although several methods for preparation of DB have been developed, probably the most versatile and simple procedure is based on the reaction of aluminum trichloride with two equivalents of an alkyne (e.g., 2-butyne)<sup>2</sup> and an activated alkyne. The initial step gives rise to a complex compound that could be formally described as tetramethylcyclobuta-diene–AlCl<sub>3</sub> complex<sup>3</sup> that reacts with the activated alkyne to yield the corresponding DB. This method was used for the synthesis of DB polymers and permethylated ladderanes,<sup>4</sup> chiral DB,<sup>5</sup> phenyl-substituted DB,<sup>6</sup> conjugates with ferrocene,<sup>7</sup> and finally the method could also be used as a protecting group.<sup>8</sup>

The above-mentioned easy access to substituted Dewar benzenes and their facile quantitative rearrangement under thermal or photochemical conditions into substituted benzene rings provided strong impetus to apply this chemistry for the synthesis of polyaryl compounds. We envisioned that an alternative and hitherto unexplored methodology for the synthesis of polyaryls such as *p*-terand *p*-quaterphenyls bearing substituted terminal benzenes rings could be based on the use of the corresponding Dewar benzenes, which in turn could be prepared by the AlCl<sub>3</sub>-mediated reaction of internal alkynes with activated bisalkynylarenes.

SYNLETT 2011, No. 3, pp 0396–0398 Advanced online publication: 13.01.2011 DOI: 10.1055/s-0030-1259321; Art ID: G32010ST © Georg Thieme Verlag Stuttgart · New York The starting model bisalkynes **3a** and **3b** were prepared in two steps from the corresponding 1,4-diiodoaromatics 1 (Scheme 1) by two pathways. Pathway A started with the Sonogashira reaction under standard conditions with trimethylsilylethyne to give bis(trimethylsilylethynyl)arenes 2. After isolation and purification, their treatment with *n*-BuLi resulted in the formation of lithioderivatives, which were reacted with chloroformate to yield the corresponding bisalkynylarenes 3. 1,4-Bis(carboxymethylalkynyl)benzene (3a) and and 1,1'-bis(carboxymethylakynyl)biphenyl (**3b**) were isolated in 17% and 25% yields, respectively. Although both products were formed in reasonable yields (ca. 50-60%), as judged by the analyses of the reaction mixtures, low isolated yields can be attributed to difficult separation of the products from the starting material and intractable side products. A more direct synthesis of **3a** and **3b** (pathway **B**) relied on the Negishi coupling of iodobenzenes 1a or 1b with zinc acetylides formed in situ from methyl propynoate, zinc bromide, and a base.9 This method was shorter and more successful furnishing the desired target compounds 3aand 3b in higher isolated yields of 53% and 48%, respectively.



Scheme 1 Preparation of bisalkynylarenes 3

In the next step both bisalkynylarenes 3a and 3b reacted with tetramethylcyclobutadiene–AlCl<sub>3</sub> complex under standard conditions (Scheme 2). In both cases the products were obtained as mixtures of mono- and bis-Dewar benzenes 4 and 5 that were difficult to separate not only from each other but also from the unreacted starting material. Their low solubility in various solvents should be mentioned as well. Pure compounds were obtained only after tedious chromatography of the reactions mixture by using preparative TLC. Although conversions were at least 50%, the difficulties regarding the product separation resulted in rather low isolated yields. Thus in the case of the reaction of **3a** was isolated mono-DB derivatives **4a** and bis-DB derivative **5a** in 17 and 10% yields, respectively. In a similar fashion, workup of the reaction mixture with **3b** furnished mono-DB derivatives **4b** and bis-DB derivative **5b** in 28% and 17% yields, respectively.



Scheme 2 Synthesis of Dewar benzene derivatives 4 and 5

Next the prepared compounds **4** and **5** were subjected to thermal rearrangement to the corresponding linear polyarenes. The neat compounds **4** and **5** were heated at 150 °C for six hours (Scheme 3). In all cases the reaction proceeded uneventfully to give the expected products in quantitative yields. The rearrangement of mono-BDs **4a** and **4b** gave rise the corresponding alkynylbiphenyl **6a** (95%) and alkynylterphenyl **6b** (97%). The bis-DB **5a** and **5b** yielded the corresponding terphenyl **7a** (95%)<sup>10a</sup> and quaterphenyl **7b** (97%).<sup>10b</sup> As far as physical properties of these compounds are concerned, low solubility of the formed compounds in all spectrum of solvents was noticed again.

The starting bisalkynes **3a** and **3b** also constitute an interesting starting material for potential cyclotrimerization with 2-butyne. In this regard the cyclotrimerization of either **3a** or **3b** with 2-butyne under catalytic conditions in the presence of Ni(cod)<sub>2</sub>/2PPh<sub>3</sub> or RhCl(PPh<sub>3</sub>)<sub>3</sub> did not



Scheme 3 Rearrangement of DB 4 and 5 into polyaryls 6 and 7

yield any reasonable amounts of **4** or **5**, only trace amount of these compounds were observed by TLC analysis. The major product was hexamethylbenzene formed by the homocyclotrimerization of 2-butyne. Partial success was obtained using the stoichiometric process based on the reaction of tetramethylzirconacyclopentadiene (**8**), prepared from Cp<sub>2</sub>ZrBu<sub>2</sub> and 2-butyne, with **3a** in the presence of CuCl.<sup>11</sup> After two days reaction time, which is typical for alkynes bearing just one activating group,<sup>11b,d</sup> <sup>1</sup>H NMR analysis indicated that **4a** was formed in 21% and **5a** in 28% yields (Scheme 4). Workup of the reaction mixture furnished 2:3 mixture of **4a** and **5a** in 13% isolated yield.



Scheme 4 Reaction of zirconacyclopentadiene 8 with 3a

An interesting issue is the stereochemistry of the prepared DB **5** and polyarenes **7**. It is reasonable to expect **5a** and **7a** to exist as diastereomers (with axially chirality) due to the hindered rotation along the C–C bond connecting the DB and substituted aryl frameworks with the benzene ring (as observed before<sup>11d</sup>). On the other hand, free rotation along the bond connecting the middle benzene rings in **5b** and **7b** precludes the formation of any stereoisomers under usual conditions (20 °C). In the case of **5a** only one set of signals was observed in <sup>1</sup>H NMR spectrum at 400 MHz. However, when the spectrum was recorded at higher operational frequency (600 MHz) the measured data indicated the presence of two stereoisomers (*cis* and *trans* with respect to the position of the methyl ester groups to the

plane of the benzene ring), albeit the difference in shift values was rather marginal (the ester Me groups appeared at  $\delta$  = 3.791 and 3.793 ppm, 25 °C, CDCl<sub>3</sub>). By using dynamic NMR spectroscopy the rotation barrier was calculated ( $\Delta G^{\#}$  = ca. 70 kJ/mol),<sup>12</sup> which is too low for a potential isomer separation.<sup>13</sup>

An analogous picture was also observed in the case of the polyarene **7a**: at 400 MHz the measured data indicated the presence of two diastereomers, albeit the difference in shift values was rather marginal (the H atoms of the central benzene ring appeared at  $\delta = 7.076$  and 7.085 ppm, 25 °C, DMSO-*d*<sub>6</sub>). Using dynamic NMR spectroscopy the rotational barrier for **7a** was calculated to be  $\Delta G^{\#} = ca. 77$  kJ/mol.

In conclusion, Dewar benzenes may serve as intermediates in the preparation of ter- and quaterphenyls with substituted terminal benzene rings. Namely, the whole reaction sequence is based on the reaction of tetramethylcyclobutadiene–AlCl<sub>3</sub> complex with bisalkynes bearing ester groups giving rise to bis-Dewar benzenes, thermal rearrangement of which then yields the corresponding polyaryl compounds.

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- (10)(a) Dimethyl 3,3",4,4",5,5",6,6"-octamethyl-1,1':4',1"terphenyl-2,2"-dicarboxylate (7a) <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>, Me<sub>4</sub>Si):  $\delta$  = 2.02 (s, 6 H), 2.25– 2.29 (m, 18 H), 3.43 (s, 3 H), 3.56 (s, 3 H), 7.17-7.18 (m, 4 H). <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>, Me<sub>4</sub>Si):  $\delta$  = 16.22, 16.25, 16.75, 17.50, 17.53, 17.55, 17.78, 51.38, 51.59, 129.07, 129.13, 129.42, 132.04, 132.10, 132.76, 133.00, 134.59, 134.69, 136.12, 136.32, 136.55, 136.69, 138.79, 138.96, 170.82, 170.91. IR (CHCl<sub>3</sub>): v = 2962, 2923, 2852, 1725, 1263, 1099, 1018, 801 cm<sup>-1</sup>. MS (EI): m/z (%) = 459 (12) [M<sup>+</sup>], 458 (41), 427 (30), 426 (100), 395 (23), 379 (22), 351 (12), 295 (22). HRMS: *m/z* calcd for C<sub>30</sub>H<sub>34</sub>O<sub>4</sub>: 458.2457; found: 458.2439.  $R_f = 0.65$  (hexane-EtOAc = 1:1). (b) Dimethyl 3,3",4,4",5,5",6,6"-octamethyl-1,1':4',1":4",1"'-quaterphenyl-2,2"-dicarboxylate (7b) Mp 228-230 °C (CH<sub>2</sub>Cl<sub>2</sub>). <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>,  $Me_4Si$ ):  $\delta = 2.07 (s, 3 H), 2.26-2.29 (m, 18 H), 3.47 (s, 6 H),$ 7.26–7.27 (m, 4 H), 7.64–7.66 (m, 4 H). <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>, Me<sub>4</sub>Si): δ = 16.28, 16.79, 17.59, 17.82, 51.57, 126.28, 129.37, 129.71, 130.07, 132.18, 132.83, 134.71, 136.05, 136.72, 139.08, 139.34. IR (CHCl<sub>3</sub>): v = 3077, 3029, 2984, 2950, 2222, 1727, 1605, 1434, 1378, 1292, 1201, 1174, 1004, 819, 732 cm<sup>-1</sup>. MS (EI): m/z (%) = 535 (14) [M<sup>+</sup>], 534 (43), 319 (17), 318 (100), 288 (12), 287 (71), 260 (33), 229 (24), 202 (22), 200(11), 149 (13). HRMS: m/z calcd for  $C_{36}H_{38}O_4$ : 534.2770; found: 534.2764.  $R_f = 0.43$ (hexane-EtOAc = 1:1).
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